Mobile Devices and Systems

Lesson 02

Handheld Pocket Computers and Mobile System Operating Systems

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Handheld Pocket Computers

- Come in many manifestations
- For example, the smart phone
- Pocket-sized PCs
- Differ from smart phones and multimedia phones in that that they can be programmed for customized applications

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Handheld Pocket Computers

- Offer a variety of application and programming tools not included in new generation mobile phones
- Unlike smart phones, which usually use the text-on-nine-keys format, handheld computers have full text keypad or a touch screen keypad.
- Stylus generally used to enter data into handheld devices such as PDAs and palmtops.

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Handheld Pocket Computers

- Some allow the user to write on the screen using a stylus and incorporate special software for handwriting recognition

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Palm Top

- Programmable pocket computers
- Include word processors and spread sheet software as well as PIM software
- QWERTY keyboards or touch screens with stylus for data inputs

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Handheld Pocket Computers differences with Laptop

- Pocket PCs no CD drives and hard disks
- Use flash memory
- Allow the insertion of a memory stick (A memory stick is a removable flash memory card.)
- Clock speeds of pocket computer processors are limited up to 200 MHz due to considerations about battery life

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Handheld Pocket Computers differences with Laptop

- Unlike laptops and notebooks, which use regular microcomputer operating systems, pocket computers have specially designed operating systems
- OS scaled to the requirements of the software, hardware, and peripherals used in handheld computers

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Windows CE

- An operating system from Microsoft
- Support multitasking on handheld devices
- Real-time operating system meant for handheld computers and embedded systems

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Windows CE

- Kernel different from the kernel of the desktop versions of Windows
- Computing devices with low storage and can be run in about 1 MB of memory.
- But the Windows CE OS memory needs are larger as compared to Palm OS
- Support a wider range of hardware than Palm OS.
- Support different CPUs such as NEC MIPS, Intel StrongARM, AMD X86, etc.

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Features in Windows CE devices

- High resolution colour/ display, touch screen and stylus keypad
- Complex APIs
- Gives the user a PC like feel and Windows like GUIs

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Features in Windows CE devices

- PIM, MS Office, Internet Explorer features on handheld mobile system
- The CompactFlash card slots to extend memory and extension card slots
- OS memory requirement is large but scales to the requirement of the device peripherals

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Features in Windows CE devices

- Digital camera card
- Games
- Microsoft Windows Media player and other media players

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Active Sync Feature in Windows CE devices

- Synchronizing mobile data with PC using a USB, serial port, PC infrared port, or Ethernet LAN for interfacing

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Windows Mobile (formerly known as PocketPC)

- A suite of basic applications for handheld devices along with a compact operating system
- Based on the Windows CE platform
- Application software suite includes the pocket (small screen display) versions of Excel, MSWord, PIM, Internet Explorer, and Outlook

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Windows Mobile (formerly known as PocketPC)

- Supports JavaScript and ActiveX programs
- Includes the Windows Media Player for playing files of various audio and video formats
- Bluetooth communication with PCs and neighbouring devices

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Palm OS

- An operating system from Palm Inc
- Used in smart phones and handheld computing devices
- Optimized to support a very specific range of hardware — CPU, controller chips

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Palm OS

- Screens of Palm OS based devices cannot be much different from the hardware reference platform designed by Palm Computing without major changes in the operating system itself

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Palm OS

- Advantageous in that that, because it is compiled for a specific set of hardware, its performance is very finely tuned
- Inability to adapt to different sorts of hardware

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Palm OS

- Does not support multitasking
- Is definitely not a great platform for running multimedia applications
- Works efficiently when running small productivity programs but doesn't offer much expandability.
- Palm OS devices usually have wide screens and input of data is facilitated by a touch screen

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Highlighting features of Palm OS devices

- Simple APIs compared to Windows CE
- OS memory requirement is low (16MB memory in the system suffices)
- Needs lesser processor clock speed and, therefore, has lesser energy requirements

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Highlighting features of Palm OS devices

- PIM, address book, data book for task-to-do and organizing, memo pad,
- SMTP (simple mail transfer protocol) e-mail download, offline creating and sending POP3 (post office protocol 3) e-mail,
- Internet browsing functions,
- Windows organizer, and PDA (personal digital assistant)

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Highlighting features of Palm OS devices

- Wireless communications including email, messaging, and browsing the web and multimedia applications such as playing music
- A cradle connects to PCs

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Highlighting features of Palm OS devices

- HotSync software for synchronizing with PCs through a serial port or infrared port
- HotSync resolves conflicts in different versions of files during data exchange

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Highlighting features of Palm OS devices

- Infrared port for communication with mobile phones and external modems
- Extension card slots
- Most compatible with the Dragonball processor from Motorola

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Highlighting features of Palm OS devices

- Most Palm OS devices offer a display resolution 160 × 160 and 256 colour touch screen
- Palm OS devices can be integrated with GSM/CDMA cellular phones
- Devices easily serve as platforms for third party games, travel and flight planner, calculators, graphic drawings, preparing slide shows, etc.

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The PalmOne Tungsten T5 handheld

- Uses the Palm OS
- Includes Palm desktop software for Windows and Mac both and other essential software
- 256 MB internal flash memory

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Highlighting features of Palm OS devices

- Expansion slot support to MMC (multimedia card), SD (secure digital) memory card, and SDIO (secure digital input/output) memory card
- Doubles as a flash drive that enables quick drag and drop of files from a PC to the handheld

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Symbian OS

1. Most widely used operating system for smart phones
2. Runs exclusively on ARM processors
3. Structure much like that of some desktop operating systems

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Symbian OS

4. Offers pre-emptive multitasking, multithreading
5. Memory protection
6. Initially designed for handheld devices with limited resources, strongly emphasizes on memory conservation

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Symbian OS

7. Embodies event-based programming and when applications are not directly concerned with events, the CPU is switched off
8. Such techniques are very useful in conserving battery life

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Features of a recent version of Symbian OS

- Support for WLAN Hindi and Vietnamese language support to serve a larger range of consumers
- Native support for Wi-Fi
- Support for FOTA (firmware over-the-air)

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Features of a recent version of Symbian OS

- Improved memory management
- Low boot-time
- Native support for Push-to-talk

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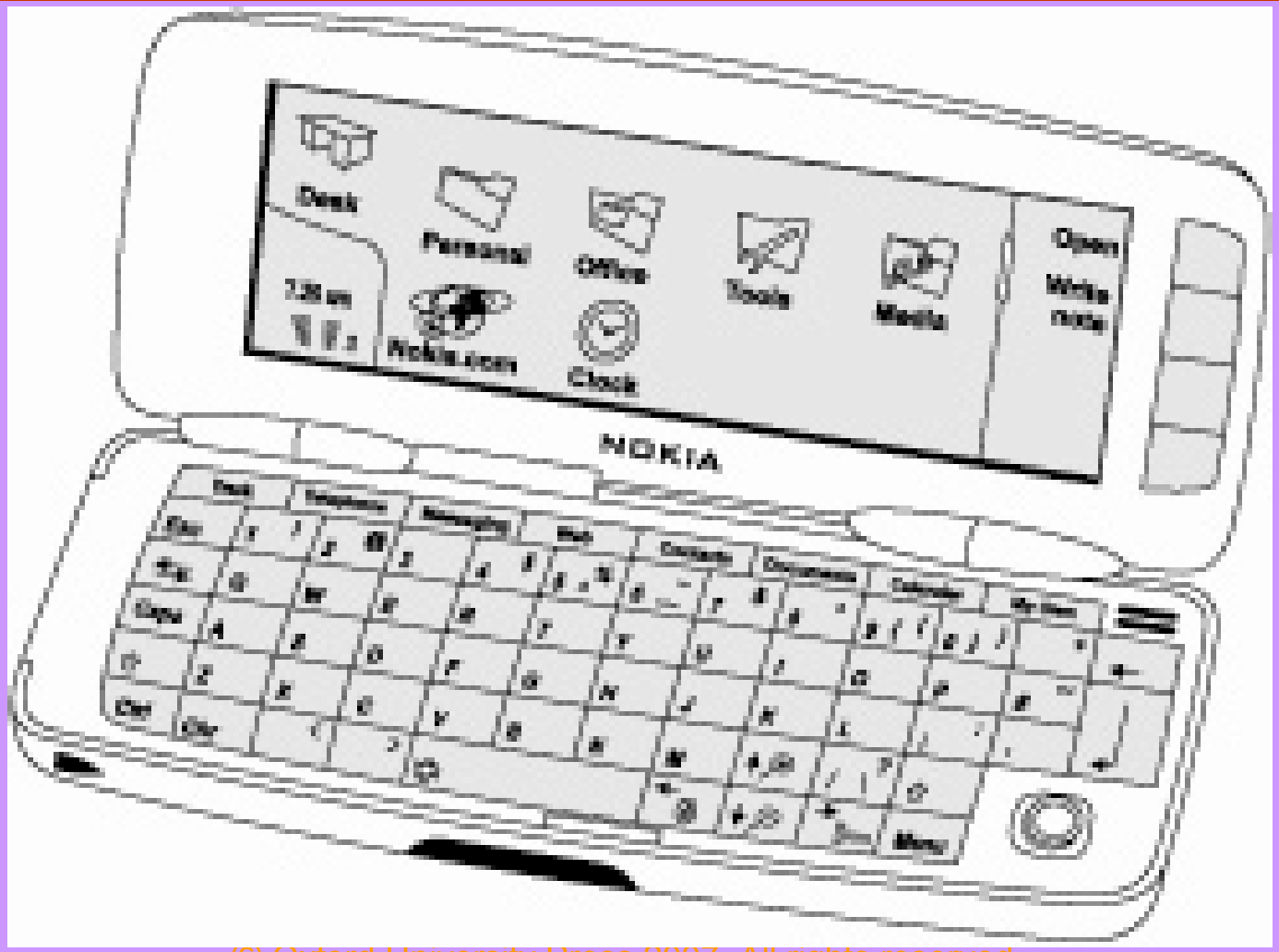
Symbian OS Based Nokia 9300



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N9300

- Provides high-speed data-connectivity using EGPRS (EDGE)
- Advanced voice features such as a hands-free speakerphone and conference calling capability.
- A large storage memory which includes 80 MB of built-in memory plus a multimedia card (MMC) slot

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N9300

- Compatible with most Lotus and Windows programs.
- Supports Microsoft Office formats (MS Office 97 onwards)
- Supports viewing of slide shows
- PIM interfaces for applications such as calendar, contacts,

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N9300

- Microsoft Outlook 98, 2000, 2002, 2003, Microsoft Outlook Express/Windows' Address Book, IntelliSync Wireless e-Mail, Lotus Notes (5.x and 6.x), and Lotus Organizer (5.x, and 6.x)
- Internet connectivity for Web browsing

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N9300

- PC synchronization feature
- Synchronizes and chains to a PC in the vicinity
- Integrates corporate solutions IBM WebSphere EveryPlace Access, BlackBerry Connect, Oracle Collaboration Suite
- Secure Mobile Connection using NVPN Client

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N9300

- Symantec Client Security 3.0
- Fujitsu Business Process Mobilizer
- Includes the Adobe Reader
- Sports the HP Mobile Printing software which enables Bluetooth connectivity with compatible printers for wireless printing

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Linux for Mobile Devices

- Linux can be modified easily to suit different sorts of hardware and software applications
- Being an open source OS, it enables the user to customize their device to suit their specific needs

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Linux

- Considered to be more secure than most other operating systems.
- Linux support is easily available from the many forums and associations that promote this OS
- Many international mobile phone manufacturers turning to Linux for their OS requirements

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Summary

- Handheld Pocket Computers
- Pocket-sized Differ from smart phones and multimedia phones in that that they can be programmed for customized applications
- Windows CE
- Active Sync for synchronization

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Summary

- Palm OS
- HotSync
- Symbian OS
- Linux

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End of Lesson 02

Handheld Pocket Computers and Mobile System Operating Systems

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Mobile Devices and Systems

Lesson 05
Sensors, Actuators, Robots, Smart Appliances and Set-top box

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Sensors

- Electronic devices that sense the physical environment
- For example, sensors for temperature, pressure, light, metal, smoke, and proximity to an object
- Sensor sends the signals to a computer or controller
- Facilitate interaction of the mobile device with the surroundings

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Sensors

- A CCD (charge-coupled device) camera to identify various objects or a microphone to recognize voices
- Sensor for background noise to control voice amplification during a call.
- Sensor for surrounding light used to control the brightness of the LCD screen.

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Sensors

- A microphone senses voice
- Sends the voice signals to a speech processing system (SPS)
- The SPS authenticates the mobile owner. Then, the SPS can also be used to dial a spoken number and interpret and execute spoken commands.

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Sensors

- A sensor for measuring the strength of the signal received controls the amplifications of received signals

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Smart sensors computational, communication, networking capabilities

- Deployed to communicate information to a network, a central computer, or a controller
- A robotic system or an industrial automation system– multiple smart sensors embedded in it.

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Smart sensors

- Consists of the sensing device, processor, memory, analog to digital converter (ADC), signal processing element, wireless or infrared receiver and transmitter

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Smart Sensor

- Performs communicational as well as computational functions
- Generally programmed using assembly language or C

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Actuators

- Actuator receives the signals from a controller or central computer and accordingly activates a physical device, appliance, or system

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Actuator Examples

- Servomotor in a robot's hand, loudspeaker, power transistor supply current to an oven, solenoid-valve actuator, a transmitting device in a sensor network, etc.

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Smart actuator

- Receives the commands or signals from a network, mobile device, computer, or controller and accordingly activates the physical device or system

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Smart Label Sensor-actuator pairs

- Used in control systems
- For example, a temperature sensor and current actuator pair controls the oven temperature
- A light sensor and bulb current actuator pair controls the light levels
- A pressure sensor and valve actuator pair controls the pressure

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Smart Label Sensor-actuator pairs

- Industrial plants have large numbers of pairs of sensors and actuators.
- A set of smart sensors and actuators networked using a control area network bus (CAN bus), for example, in an automobile or industrial plant.
- Smart sensors programmed in assembly language or C using development tools.

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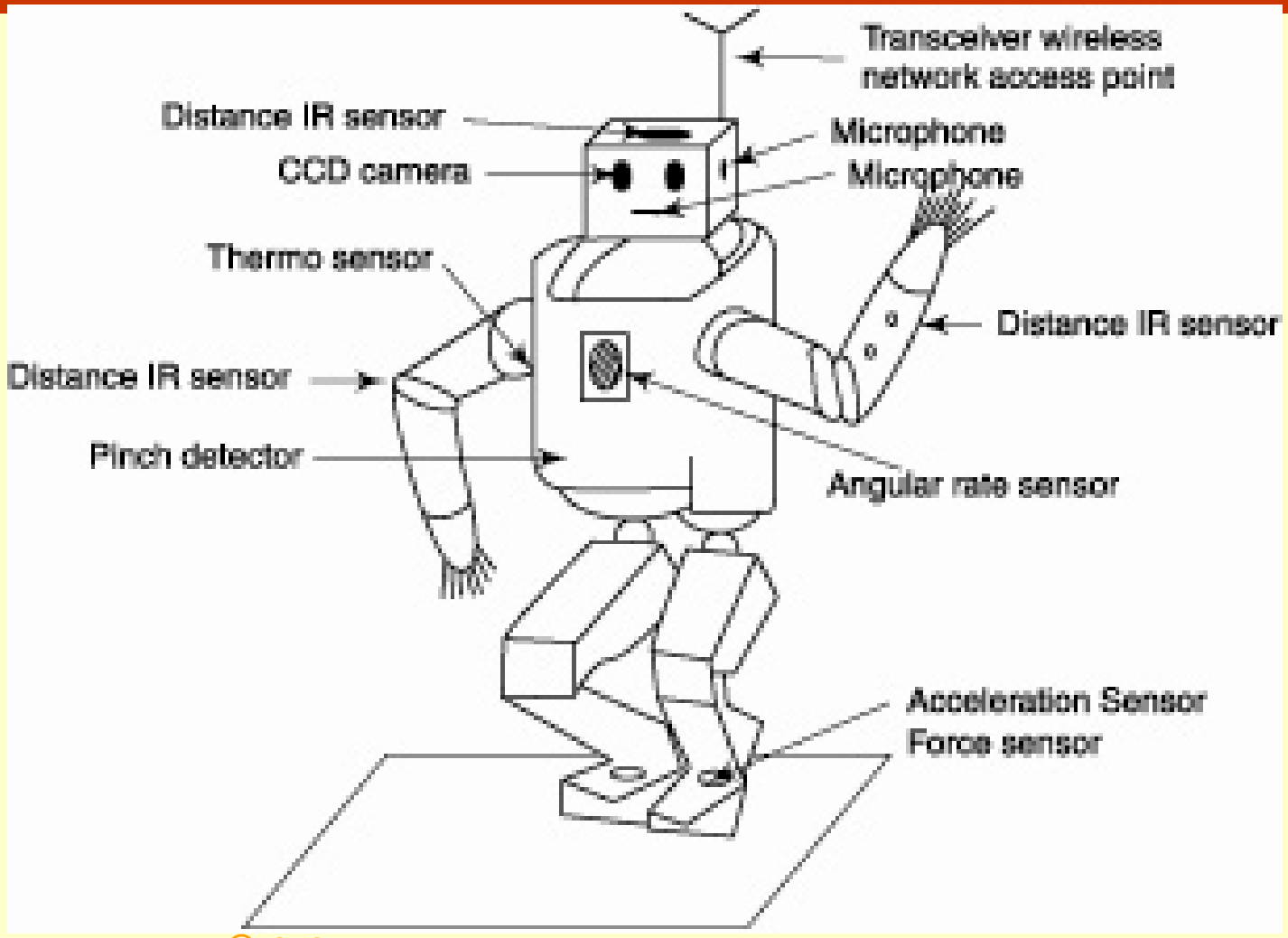
Robotic Systems



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Robotic Systems

- Robotic systems incorporate a variety of overlapping technologies from the fields of artificial intelligence and mechanical engineering.
- Robotic systems essentially programmable devices consisting of mechanical actuators and sensory organs— linked to a computer embedded in them

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Robotic System mechanical structure

- Might involve manipulators
- or might concern the movement of the robot as a vehicle

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Sensors in Robots

- Acceleration and force sensors in the right and left feet
- Infrared distance sensors at the head and hands
- CCD camera in eyes
- Angular rate sensor at the middle
- Microphones at mouth
- Pinch detection at the belly
- Thermo sensors and touch sensors at shoulders, hands, and head

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Actuators in Robots

- At the mouth, there can be speaker to let a robot issue commands to other robots or relay sensed information via spoken messages
- At each moving joint—feet, knee, waist, neck, shoulder, hand, and gripper palm, there are actuators and motors

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Smart Appliances

- Possible to control home appliances and security systems using a cell phone or computer.
- Home appliances networked using power lines.
- Signals of frequencies up to 525 kHz can be induced in such lines communicate from one appliance to another, thus forming a network

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Smart Appliances

- The devices also communicate though a central server.
- Home appliances be also networked using very short-range wireless protocols, such as Bluetooth or ZigBee

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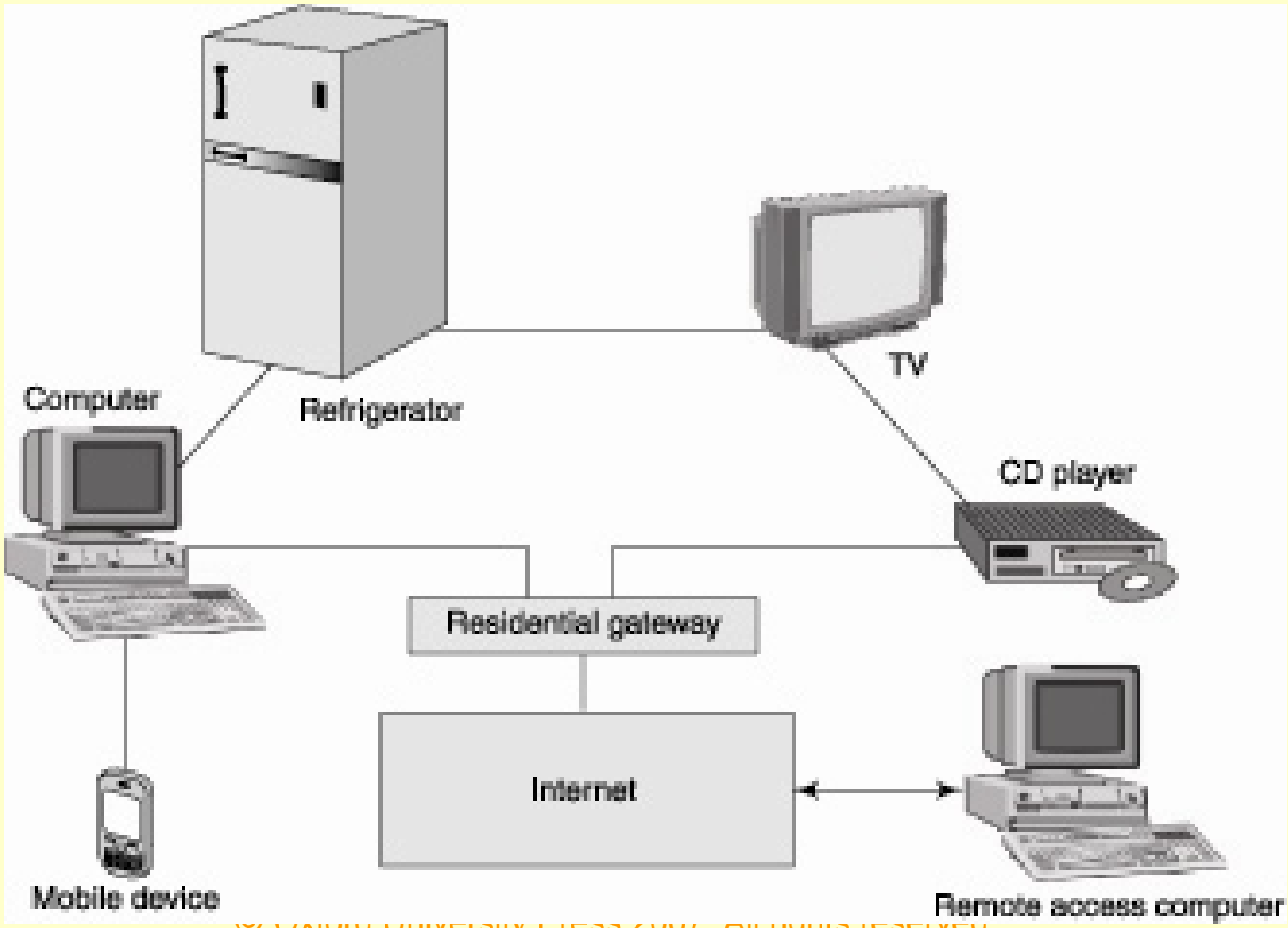
Smart Appliances



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Set-top Box

- A sophisticated computer-based device
- Data, media, and network processing capabilities
- Interconnects the home TV and the broadcasting service network

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Programming language in a setup box

- Java most commonly used.
- Set top boxes run deciphering and encrypting software
- Software component, called a device agent, which administers the device on behalf of the service provider.

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Software component in a setup box

- Mechanism of operation is similar to that of a mobile phone device, where the server of mobile service provider manages and administers the operation of the device.

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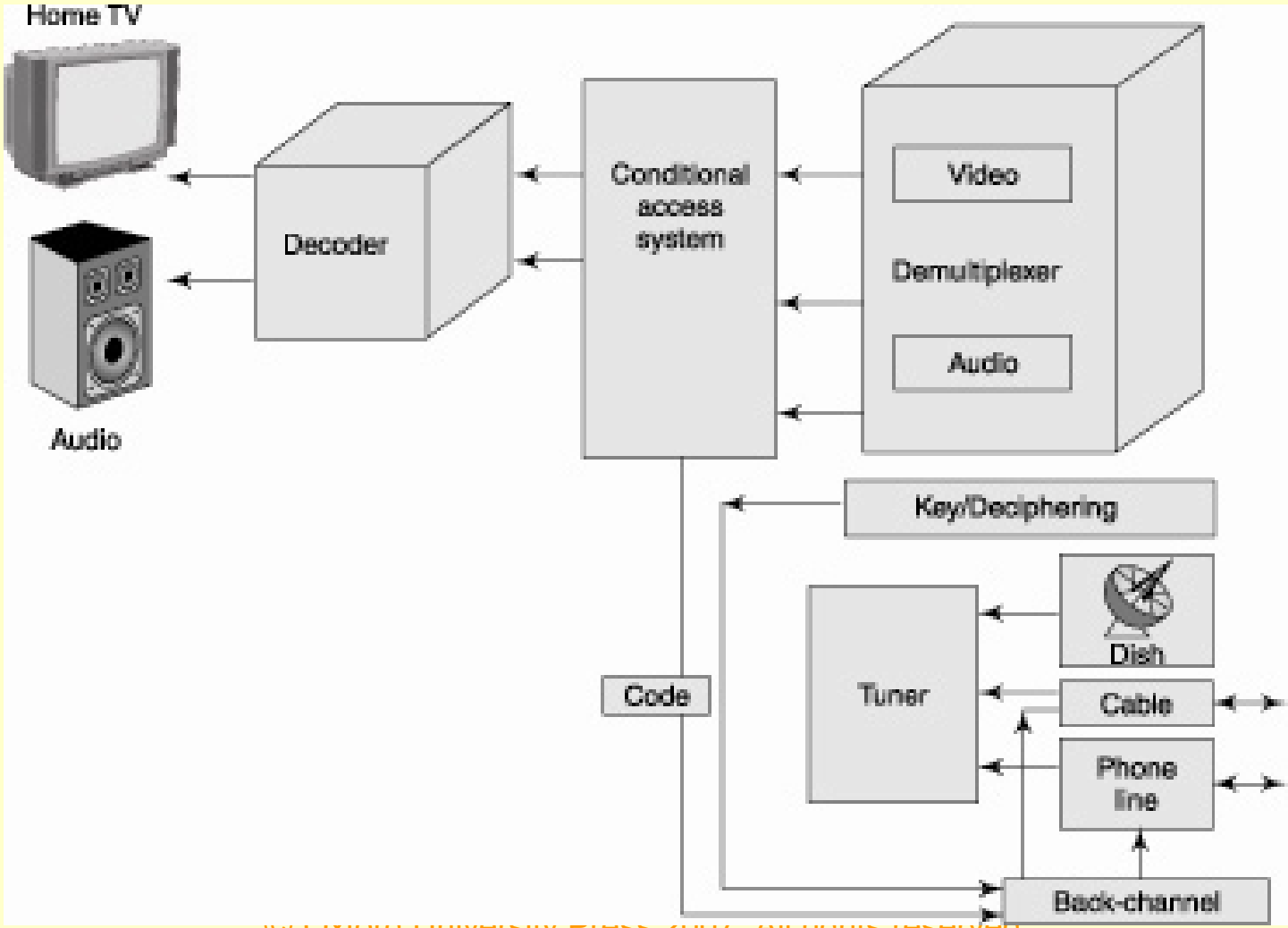
Set top Box



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Summary

- Sensors
- Actuators
- Sensor-actuator pairs
- Mobile Robots
- Smart Application controlled by mobile device
- Set-top box for video, audio reception from cable, phone line, satellite and Internet

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End of Lesson 05

Sensors, Actuators, Robots, Smart Appliances and Set-top box

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Mobile Communication – An overview

Lesson 01

Guided Transmission and Unguided Wireless Transmission

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Communication

- Communication– a two-way transmission and reception of data streams
- Signals for Voice, data, or multimedia streams transmitted
- Signals received by a receiver.

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Signals

- Signals from a system transmit through a fibre, wire, or wireless medium.
- According to defined regulations, recommended standards, and protocols

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Mobile Communication

- Entails transmission of data to and from handheld devices
- Two or more communicating devices
- At least one is handheld or mobile
- Location of the device can vary either locally or globally
- Communication takes place through a wireless, distributed, or diversified network

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Guided Transmission

- Metal wires and optical fibres guided or wired transmission of data
- Guided transmission of electrical signals takes place using four types of cables

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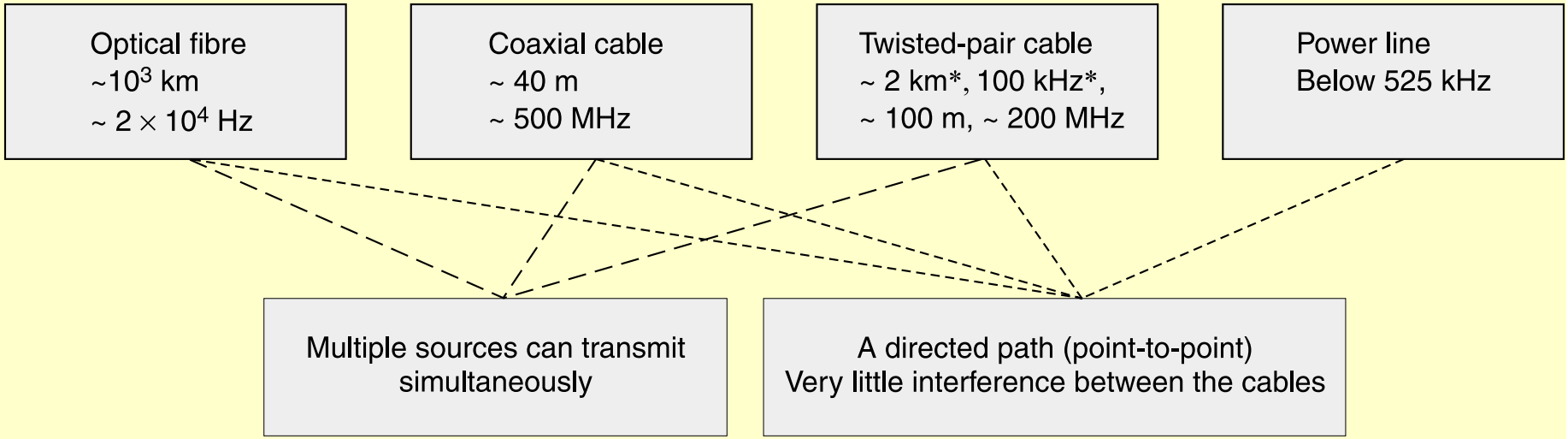
Fibre- and wire- based transmission and their ranges



*Without coding (traditional)

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Four types of cables for Guided Transmission

1. Optical fibre for pulses of wavelength 1.35–1.5 μm
2. Coaxial cable for electrical signals of frequencies up to 500 MHz and up to a range of about 40 m

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Four types of cables for Guided Transmission

3. Twisted wire pairs — for conventional (without coding) electrical signals of up to 100 kHz and up to a range of 2 km, or for coded signals of frequencies up to 200 MHz and a range of about 100 m
4. Power lines, a relatively recent advent in communication technology— used for long-range transmission of frequencies between 10 kHz and 525 kHz

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Guided Transmission Advantages

- Transmission along a directed path from one point to another
- Practically no interference in transmission from any external source or path
- Using multiplexing and coding, a large number of signal-sources simultaneously transmitted along an optical fibre, a coaxial cable, or a twisted-pair cable

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Guided Transmission Disadvantages

- Signal transmitter and receiver fixed (immobile).
- No mobility of transmission and reception points.
- Number of transmitter and receiver systems limits the total number of interconnections possible

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Unguided– Wireless Transmission

- Electrical signals transmitted by converting them into electromagnetic radiation
- Radiation transmitted via antennae that radiate electromagnetic signals

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Unguided– Wireless Transmission

- Various frequency bands within the electromagnetic spectrum
- Different transmission requirements
- $f = c/\lambda = (300/\lambda)$ MHz [λ in meter]

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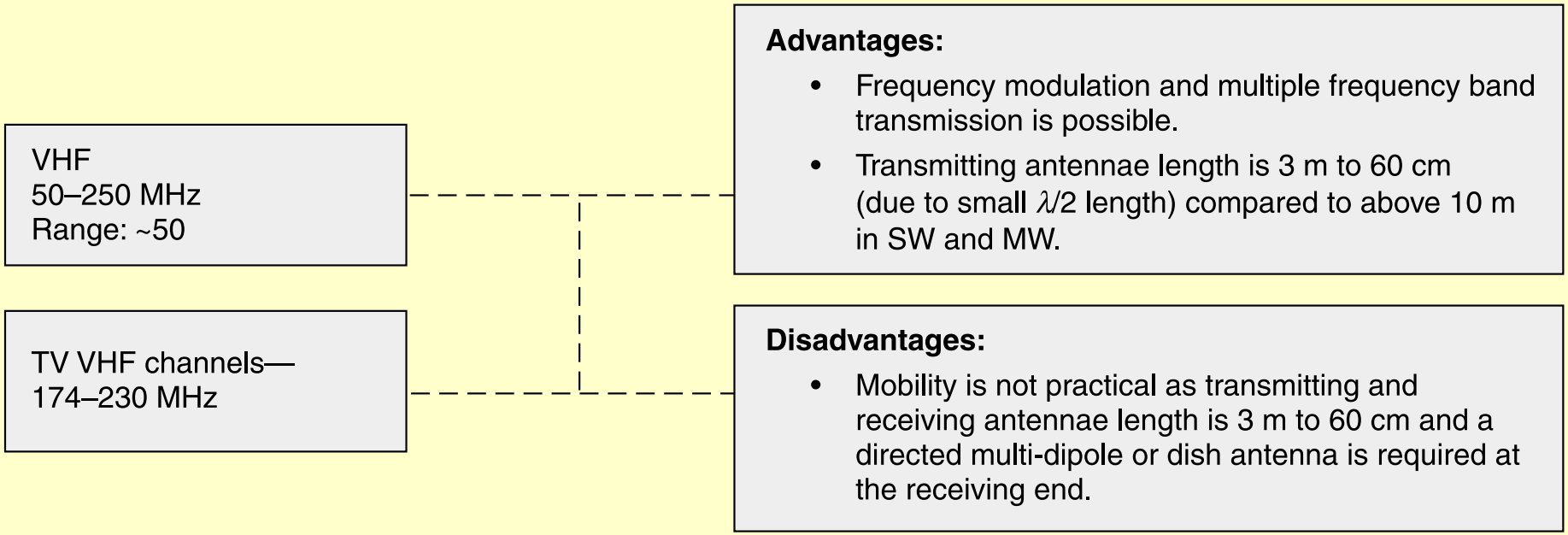
VHF and TV-VHF



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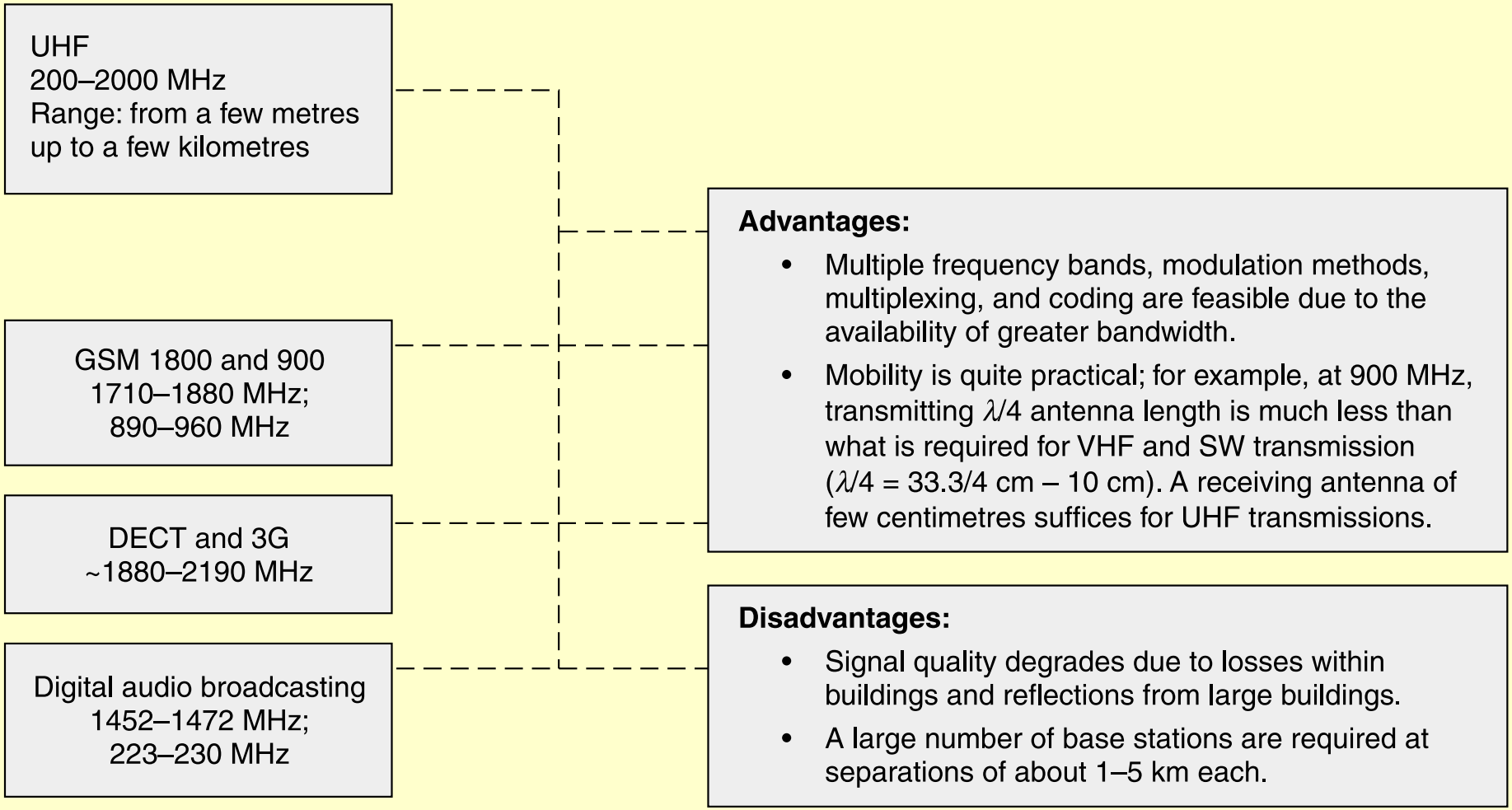
UHF, GSM, DECT, 3G and DAD



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Super high Microwave and Extreme High

- 2 GHz to 40 GHz (~15 cm to 0.75 cm) [Microwave bands and satellite signal bands]
- Extreme high frequency (EHF): Above 40 GHz to 10^{14} Hz (0.75 cm to 3 μm)

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Infrared

- Far Infrared: Optical wavelengths between 1.0 <m>m to 2.0 <m>m and [(1.5 to 3) <x> 1014 Hz (0.15-0.3 THz)]
- Infrared: 0.90 <m>m to 0.85 <m>m in wavelength and ~ (3.3 to 3.5) <x> 1014 Hz [<@> 350 to 330 THz]

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Antennae

- Devices that transmit and receive electromagnetic signals
- Most function efficiently for relatively narrow frequency ranges
- If not properly tuned to the frequency band in which the transmitting system connected to it operates, the transmitted or received signals may be impaired. The forms of antennae are chiefly determined by the frequency ranges they operate in and can vary from a single piece of wire to a parabolic dish

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Antennae forms

- Chiefly determined by the frequency ranges they operate in
- Vary from a single piece of wire to a parabolic dish

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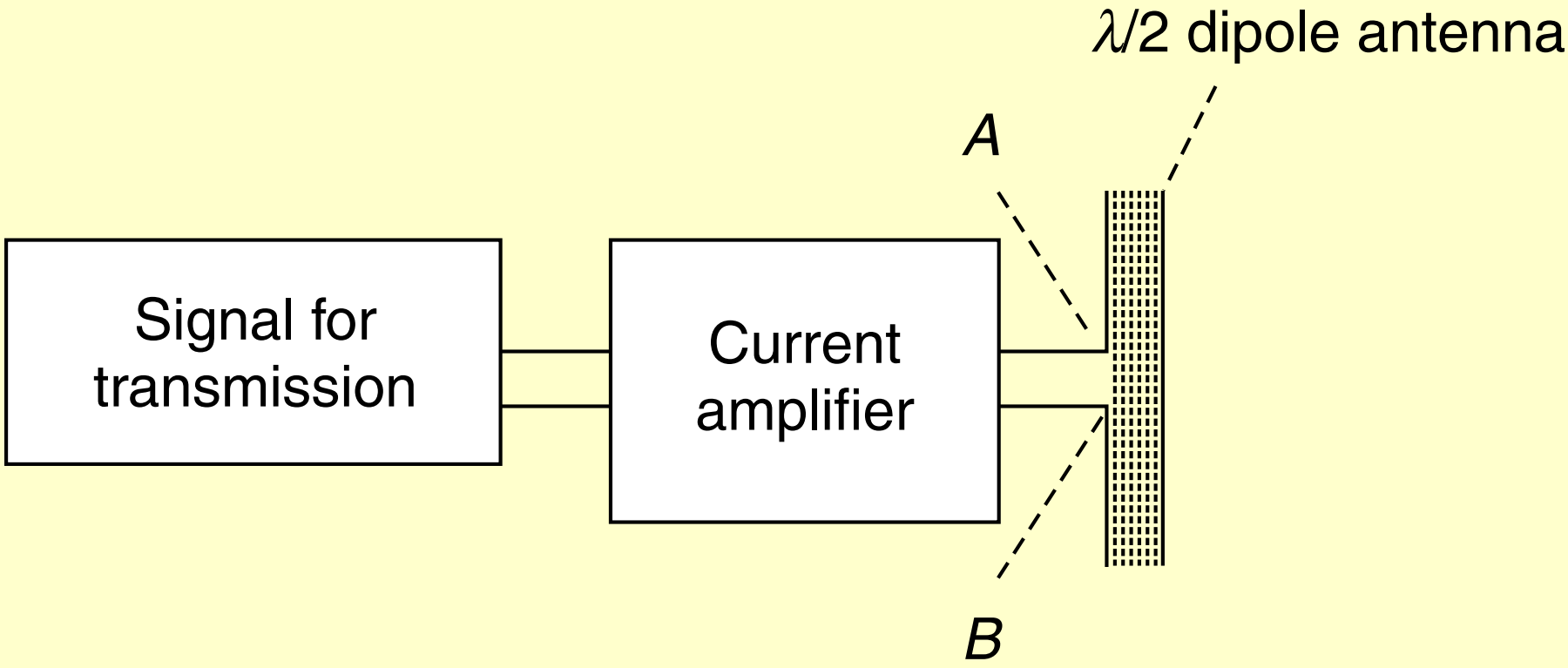
λ/2 Dipole Antenna



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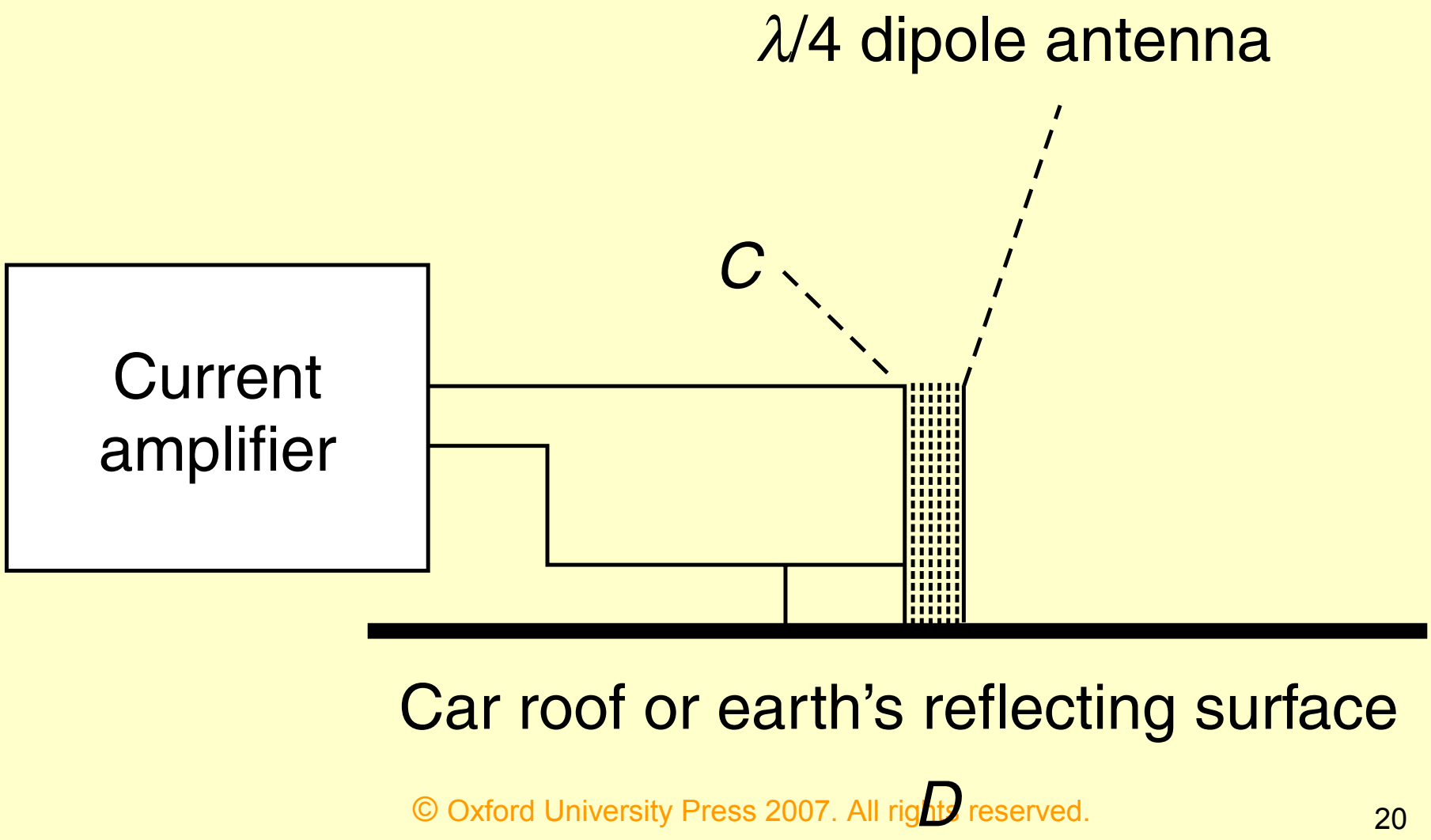
λ/4 Dipole Antenna



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Radiation pattern

- Important feature— signal amplitude at an instant is identical along the pattern
- Circular pattern means that radiated energy, and thus signal strength, is equally distributed in all directions in the plane
- A pattern in which the signal strength is directed along a specific direction in the plane

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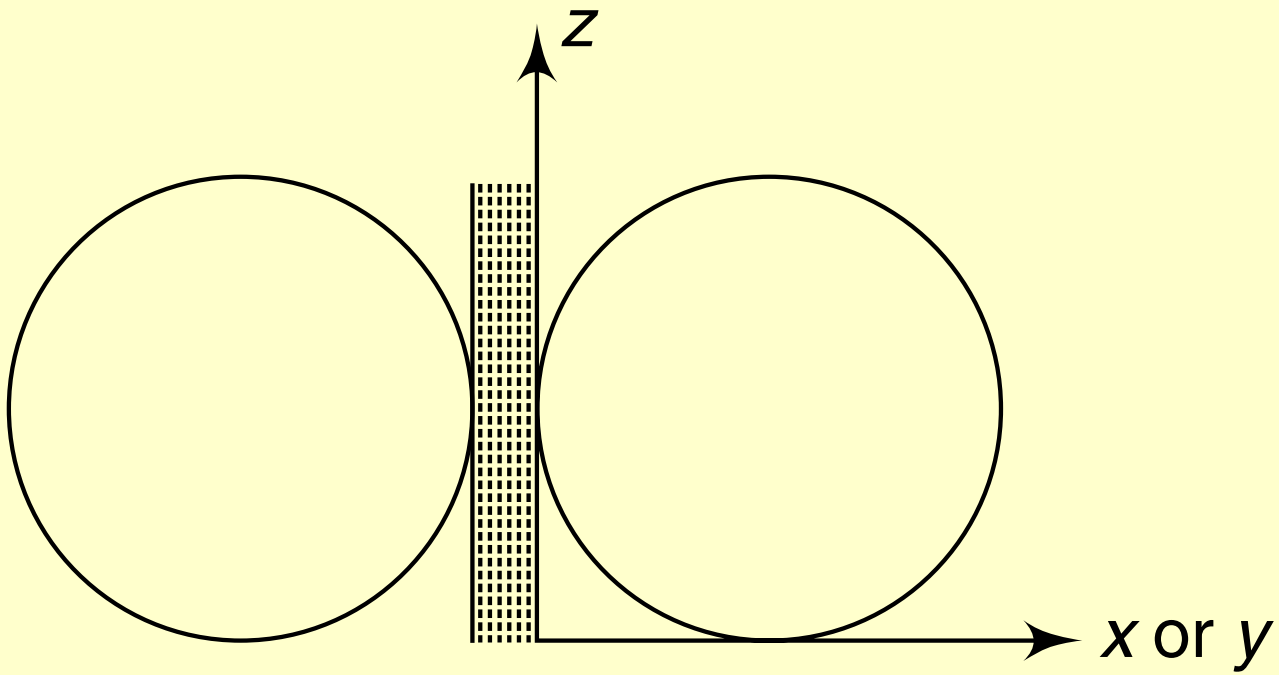
λ/2 Radiation pattern in z-y and x-z planes- Identical signal amplitude along circle



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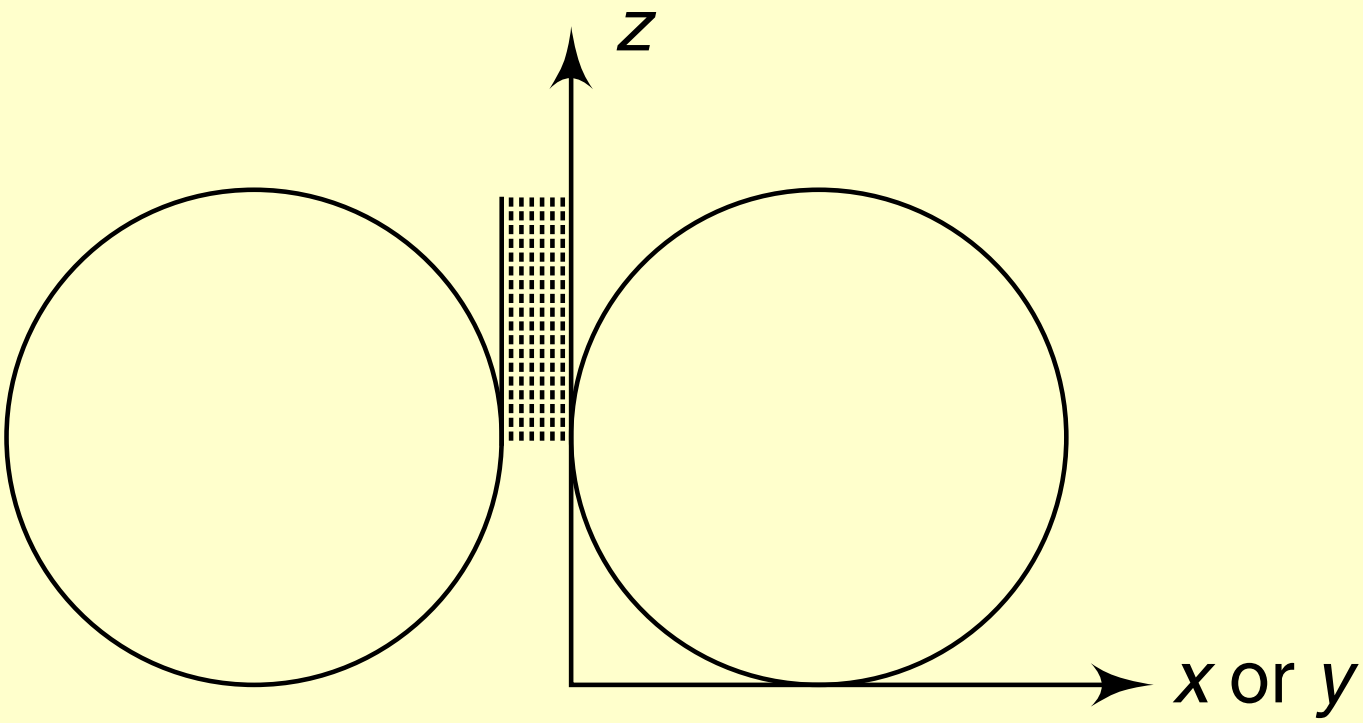
λ/4 Radiation pattern in y-z and x-z planes Radiation Pattern



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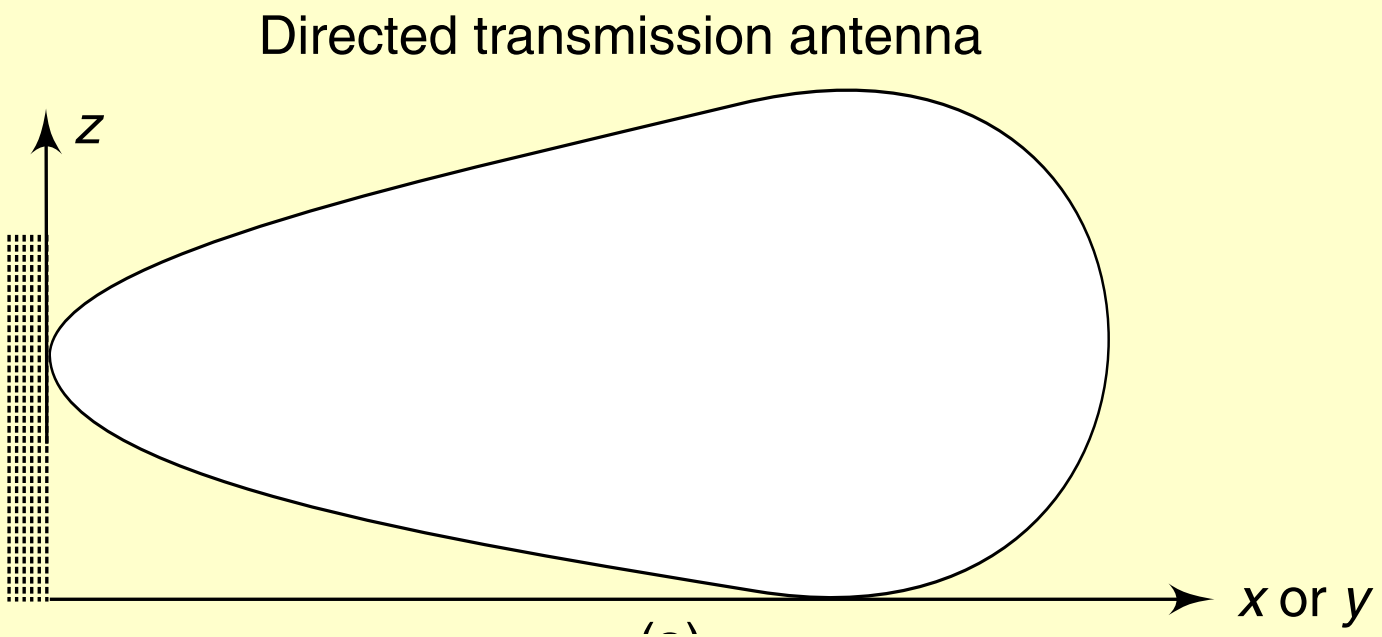
Directed Transmission Antenna Radiation pattern in z-y and z-z planes Radiation Pattern



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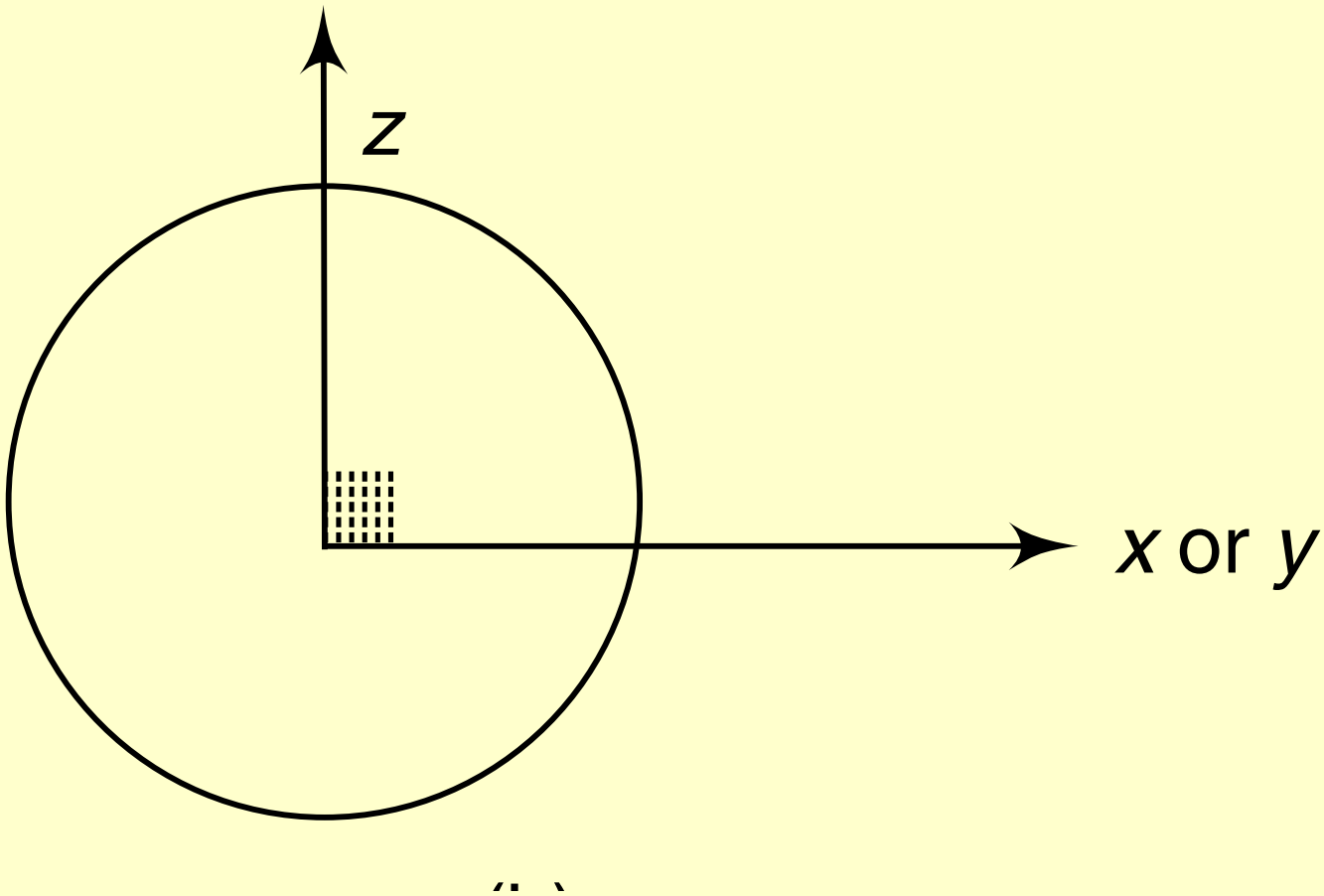
Same Antenna Radiation pattern in x-y planes Radiation Pattern



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Summary

- Mobile communication– location of the device can vary either locally or globally and communication takes place through a wireless, distributed, or diversified network
- Two ways of signals transmission

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… Summary

- Guided through wires and optical-fibres
- Unguided through wireless
- VHF and UHF Frequency bands
- Microwave and Infrared bands
- Antenna
- Undirected and directed antennae

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End of Lesson 01

Guided Transmission and Unguided Wireless Transmission

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Mobile Communication – An overview

Lesson 02

Propagation of Signals and Requirement of Modulating the Signals

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Wireless propagation of signals

- Faces many complications
- Mobility renders reliable wireless transmission much more difficult
- Antenna height and size at mobile terminals generally quite small

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Propagation properties

- Obstacles in the vicinity of the antenna a significant influence on the propagated signal
- Vary with place and, for a mobile terminal, with time

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Line-of-sight propagation

- Between the transmitter and the receiver
- Transmission of signals without refraction, diffraction, or scattering

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Spherical radiation pattern and Line of sight Signal strength

- Decreases as the square of the distance from the transmitter in free space
- Larger distances the radiated power is distributed over a larger spherical surface area

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Signal strength

1. **Decrease due to attenuation**
2. When obstacles in the path of the signal greater in size than the wavelength

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Signal strength Attenuation

1. FM band signal transmitter 90 MHz (λ = 3.3 m)– faces attenuation of in objects of size 10 m and above
2. GSM 900 MHz (λ > = 33 cm) signal– then it will face attenuation in objects of size > 1 m (>> λ ~ 33 cm)

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Scattering of signal

- From an obstacle of size equal to or less than the wavelength
- GSM signal, about 33 cm in wavelength, scattered by an object of 30 cm or less
- Decreases signal strength greatly

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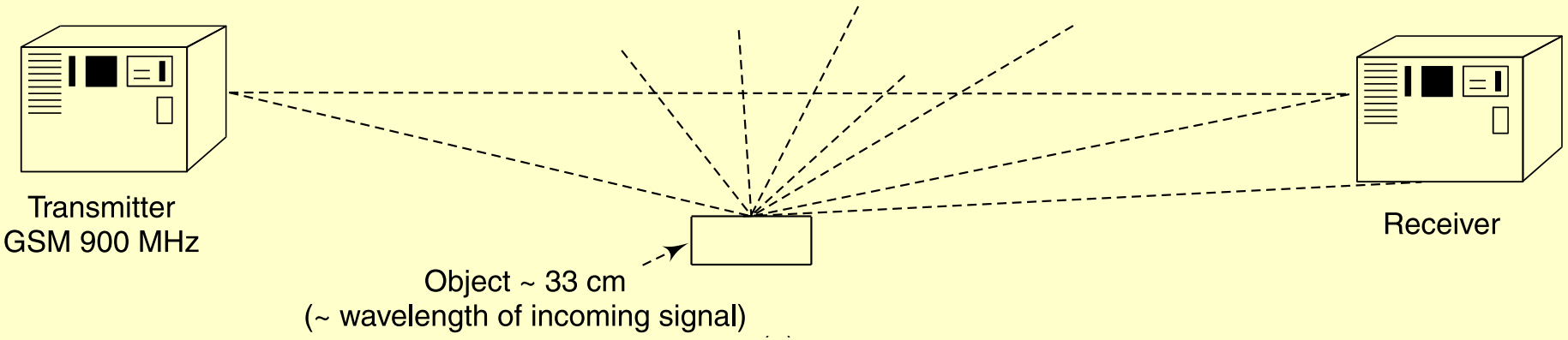
Scattering of signals



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Diffraction of signals

- Signal bends as a result of **diffraction** from the edges of an obstacle of size equal to or less than the wavelength.
- GSM signal of wavelength 33 cm will diffract from an object of 33 cm or less.

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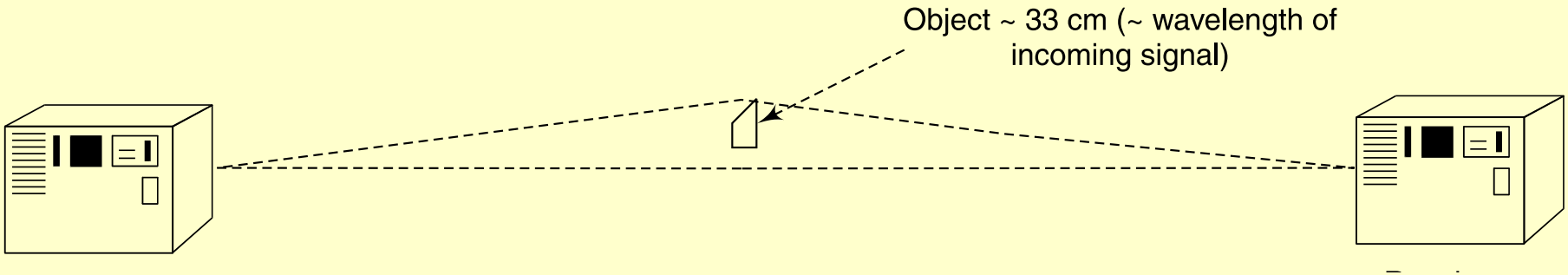
Diffraction of signals



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Reflection of signals

- Signal ***reflected*** from the surface of an obstacle, the earth's surface, or a water body of size greater than the wavelength of the signal.
- GSM 900 MHz (λ = 33 cm) signal the transmitter signal reflects from an object of size 10 m and above (much greater than λ)

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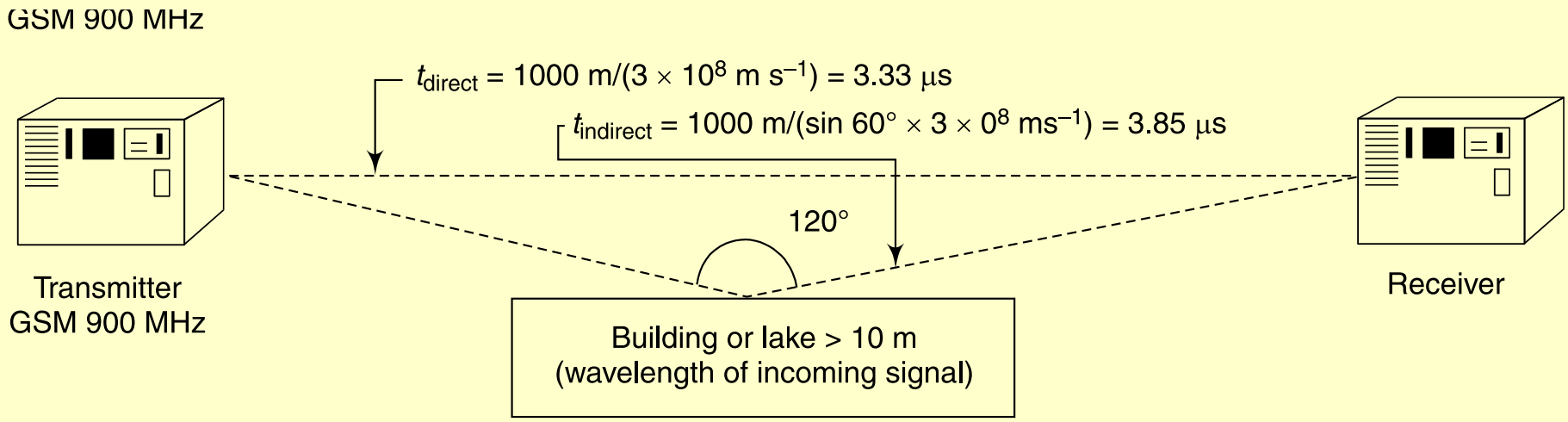
Reflection of signals



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Delayed Reach of Reflected signals

- Delay more pronounced in case of multi-hop paths.
- Distorts waveforms
- Causes misrepresentation of information encoded in the signal

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Elimination of signal distortions due to delays

- By Digital signal processing techniques the distortions due to delays from direct and multiple paths
- Recovers original signal

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Modulation of Wireless Signals

- Sizes of antennae required for wireless transmission inversely proportional to the frequencies
- Voice signals frequencies between 0.1 kHz to 8 kHz and Music-signal frequencies lie between 0.1 kHz to 16 kHz.
- Ranges unsuitable for wireless transmission

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Modulation of Low frequency range wireless signals

- Requirement of abnormally large sized antennae
- Moreover, properties medium (air or vacuum)— such that ultra low frequency signals can't be transmitted across long distances without significant loss of signal strength

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Modulation

- Makes wireless transmission practical
- Increases the compatibility of transmitted signal and transmission medium

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Summary

- Propagation of signals
- Line of sight
- Attenuation in obstacles in the path of the signal greater in size than the wavelength
- Scattering from an obstacle of size equal to or less than the wavelength

...

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… Summary

- Diffraction from the edges of an obstacle of size equal to or less than the wavelength
- Reflection from the surface of an obstacle, the earth's surface, or a water body of size greater than the wavelength of the signal

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… Summary

- Need for Modulation Signals with a carrier
- Properties medium (air or vacuum)—such that ultra low frequency signals can’t be transmitted across long distances without significant loss of signal strength

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End of Lesson 02

Propagation of Signals and Requirement of Modulating the signals

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Mobile Communication – An overview

Lesson 03

Introduction to Modulation Methods

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Modulation

- The process of varying one signal, called *carrier*, according to the pattern provided by another signal (modulating signal)
- The carrier usually an analog signal selected to match the characteristics of a particular transmission system.

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…Modulation

- The amplitude, frequency, or phase angle of a carrier wave is varied in proportion to the variation in the amplitude variation of the modulating wave (message signal).

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Equation for signal amplitude at an instant t, $s(t)$

$s(t) = s0 \sin [(2\pi \times c/\lambda \times t) + \Phi_{t0}]$

$= s0 \sin [(2\pi \times f \times t) + \Phi_{t0}]$

- $s0$ — the peak amplitude (amplitude varies between $s0$ and $-s0$)
- c — the velocity of the transmitted wave
- Φ_{t0} — the phase angle of the signal at t = 0 (a reference point with respect to which t is considered)
- f — the signal frequency

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Modulation of the voice or data signal

A technique by which f_c or a set of carrier frequencies used for wireless transmission such that

- peak amplitude, s_{c0},
- frequency, f_c,
- Phase angle Φ_{ct0} varies with t in proportion to the peak amplitude of the modulating signal $s_m(t)$

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Modulation

- Amplitude modulation (AM) if amplitude of carrier varied
- Frequency modulation (FM) if frequency varied
- Phase modulation if phase angle varied

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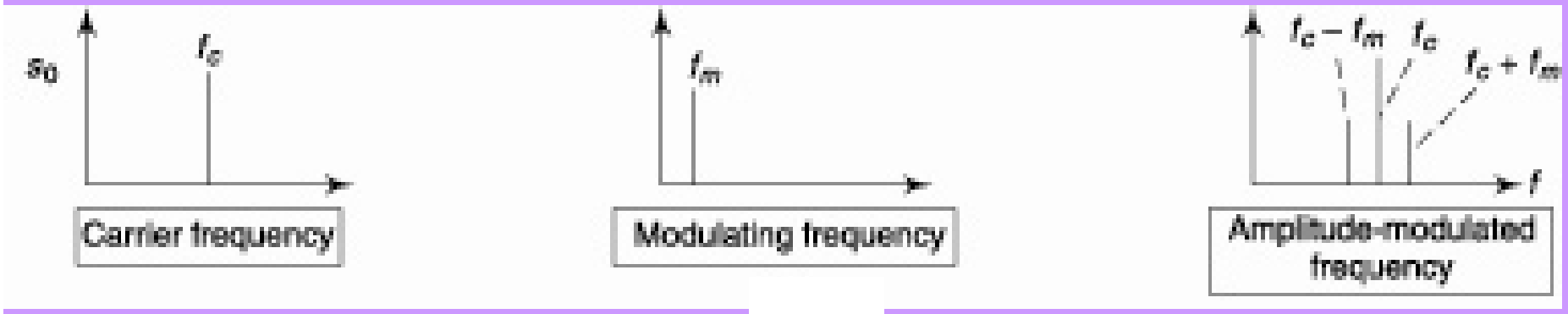
Amplitude Modulation (AM)



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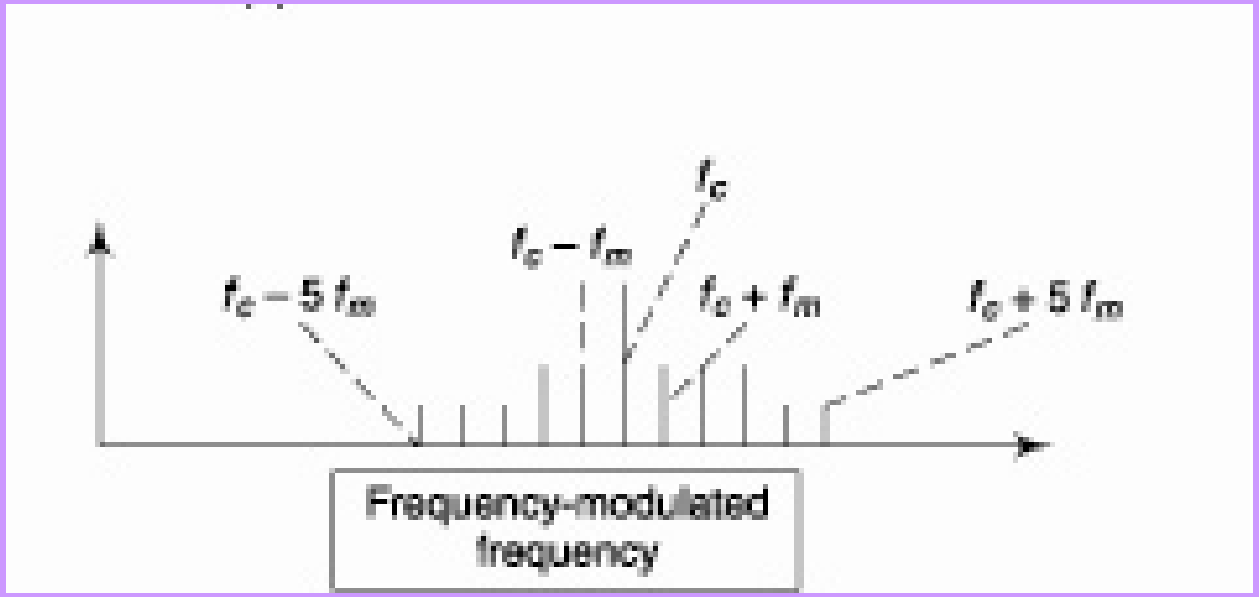
Frequency Modulation (FM)



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Digital Modulation

A technique by which amplitude, frequency, or phase angle parameters of carrier or sub-carrier frequencies varied according to the variation in the

- modulating signal bit 1 or 0 the or
- modulating bit-pair 00, 01, 10 or 11
- or set of 4 or more bits

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Digital Modulation of 1s and 0s

- Amplitude Shifted Keying (ASK) if as per 1 or 0 amplitude of carrier varied
- Frequency Shifted Keying (FSK) if as per 1 or 0 frequency varied

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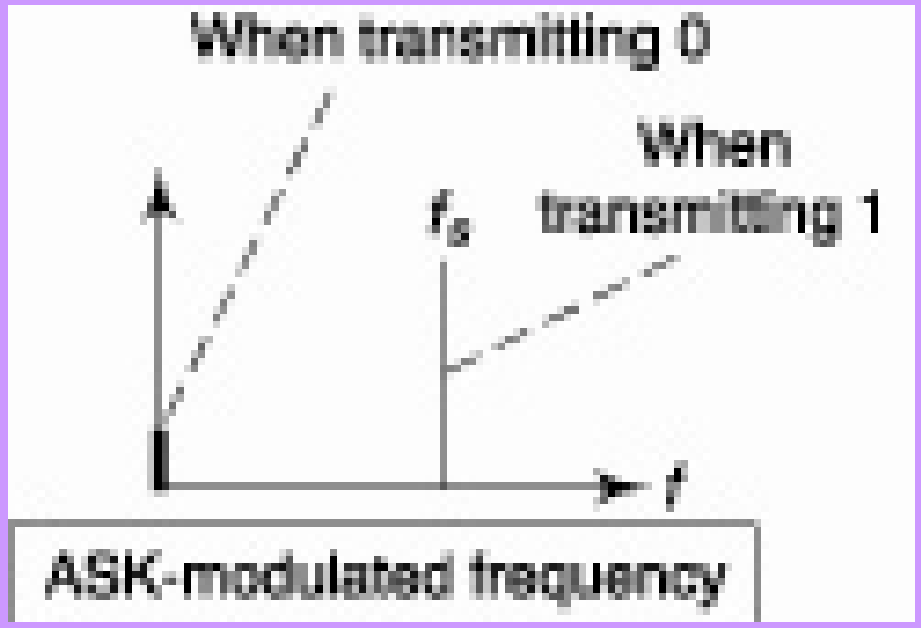
Amplitude Shifted Keying Modulation (ASK)



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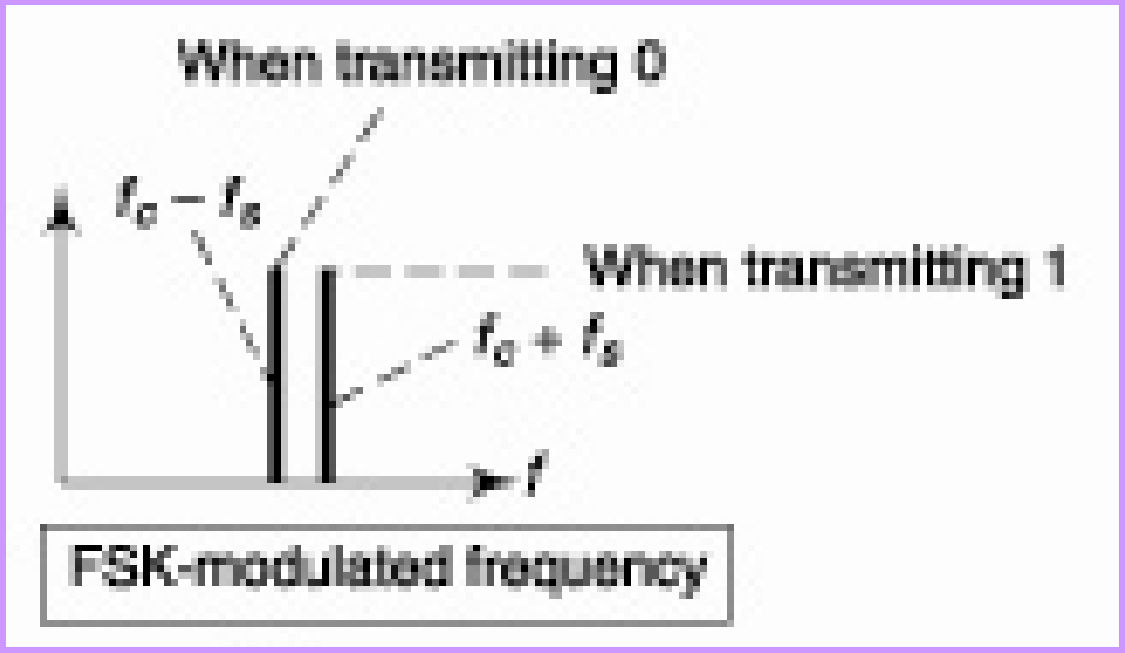
Frequency Shifted Keying Modulation (FSK)



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Phase Modulation of 1s and 0s

- Binary Phase Shifted Keying (PSK or BPSK) 0° or 180° if as per 1 or 0 phase angle varied
- Gaussian Minimum-phase Shifted Keying (GMSK) 0° if change from 1 to 0 and 180° varied if change from 0 to 1 and then using minimizing technique for filtering introduced high frequency components on PSK

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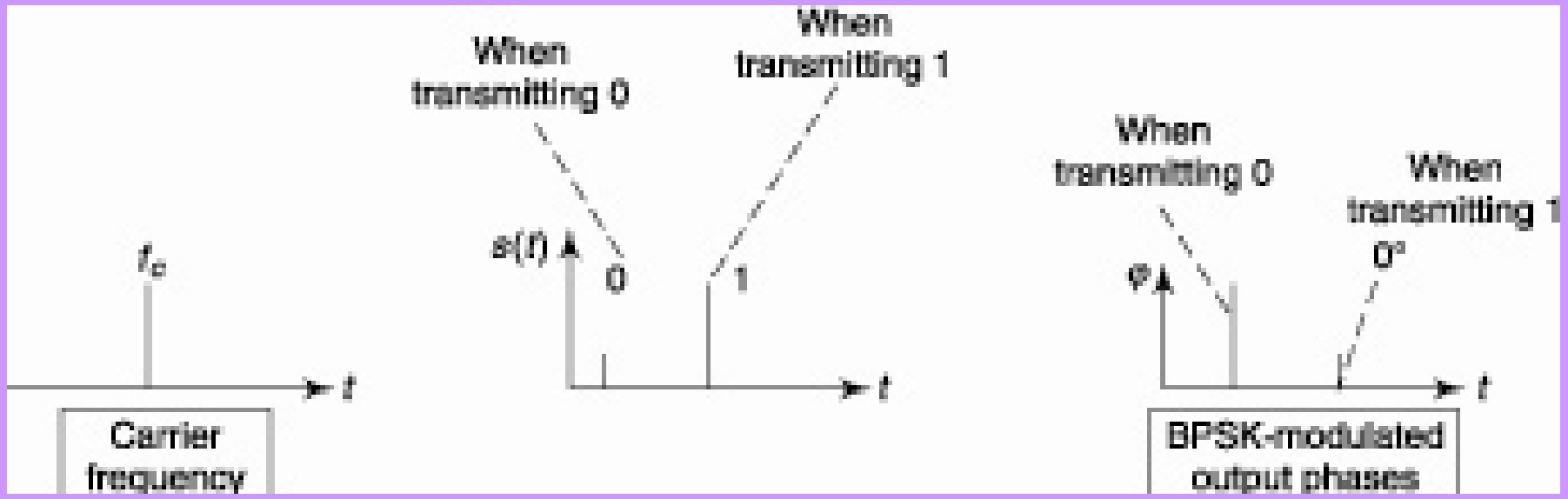
BPSK



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Phase Modulation of 1s and 0s

- Quadrature Phase Shifted Keying (QPSK or BPSK) as per 00, 01, 10 or 11
- QPSK Phase angle shift = Φ of the transmitted signal s(t) will be $3\pi/4$, $-3\pi/4$, $-\pi/4$, $+\pi/4$ ($\equiv 135^\circ, 225^\circ, 315^\circ$, 45° after each successive time interval T when bit pattern is 10 00 11 01. [T = 1/f]

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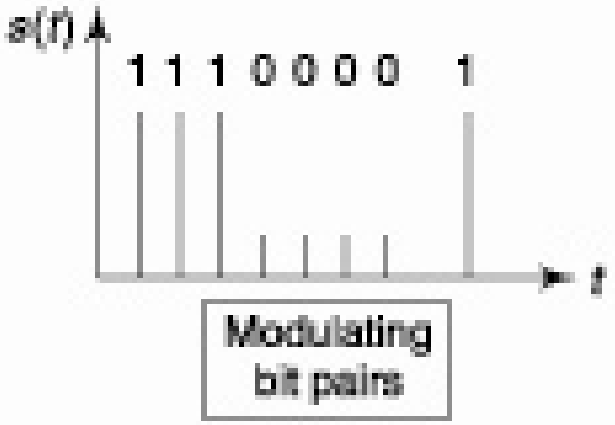
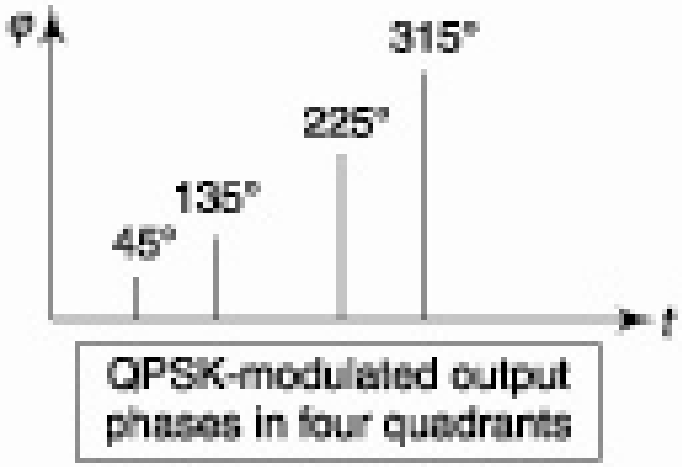
QPSK





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8-PSK modulation

- Bit pattern is 101 000 110 011 100 111. The phase angle of the transmitted signal $s(t)$ will be $-5\pi/8$, $\pi/8$, $-3\pi/8$, $7\pi/8$, $-7\pi/8$, and $-\pi/8$, after each successive time interval of T. [T = 1/f]

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Quadrature Amplitude Modulation (QAM) modulation

- Quadrature amplitude modulation quadrature phase shift keying
- 16-QAM– The 16 PSK, 3-stage amplitude modulation

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Summary

- Amplitude, frequency and phase modulations
- AM of analog signals
- FM of analog signals

...

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…Summary

- Digital modulation

I. BPSK

II. GMSK digital modulation

III. QPSK digital modulation

IV. ASK and FSK digital modulation

V. 8-PSK

VI. 16-QAM

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Introduction to Modulation Methods

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Mobile Communication – An overview

Lesson 04

Introduction to SDMA, TDMA, FDMA, CDMA and OFDAM

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Multiplexing

- Means that different channels, users, or sources can share a common space, time, frequency, or code for transmitting data

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Multiplexing

- Space division multiple access (SDMA)
- Time division multiple access (TDMA)
- Frequency division multiple access (FDMA)
- Code division multiple access (CDMA)
- Code Orthogonal frequency division multiple access (COFDM) also called OFDM

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SDMA– A division of the available space

- Multiple sources can access the medium at the same time
- Wireless transmitter transmits the modulated signals and accesses a space slot and another transmitter accesses another space slot such that signals from both can propagate in two separate spaces in the medium without affecting each other

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SDMA Example

- Four groups *A*, *B*, *C*, and *D* of mobile users and four different regional space slots, *R*1, *R*2, *R*3, and *R*4
- Group *A* uses *R*1, *B* uses *R*2, *C* uses *R*3, and *D* uses *R*4 for transmitting and receiving signals to and from a base station

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TDMA– different sources using different time-slices for transmission of signals

- **A**n access method in which multiple users, data services, or sources allotted different time-slices to access the same channel.
- Available time-slice divided among multiple modulated-signal sources. These sources use the same medium, set of frequencies, and same channel for transmission of data.

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TDMA Example

- GSM Eight radio-carriers (e.g., mobile phones) *C*1, *C*2, *C*3, *C*4, *C*5, *C*6, *C*7, and *C*8 in eight TDMA time-slices, one for each radio carrier.
- Eight phones GSM devices simultaneously transmit in the same frequency band (channel)
- Time-slice allotted to each 577 μs

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FDMA– different sources using different frequency for transmission of signals

- **A**n access method in which multiple users, data services, or sources allotted different frequency-slices (bands) to access in same space and time-slice
- Available frequency range is divided into bands which are used by multiple sources or channels at the same time
- Various channels allotted distinct frequency bands for transmission

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FDMA Example

- GSM 900 at 890–915 MHz uplink from user to the base station and 935–960 MHz downlink
- Each channel 200 kHz bandwidth.
- 124-channel uplink needs 200 kHz $\times$ 124 = 24.8 MHz
- Similarly, 124-channel downlink requires 24.8 MHz

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CDMA– different sources using different Codes for transmission of signals

- An access method in which multiple users are allotted different codes (sequences of symbols) to access the same channel (set of frequencies)
- A *symbol* is a bit (0 or 1) which is transmitted after encoding and processing bits of data such as text, voice, pictures, or video

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CDMA Example– Each code is uniquely made up of *n* symbols

- Used for transmitting a signal of frequencies $fc0$, $fc0 + fs$, $fc0 + 2fs$, …, $fc0 + (n - 2)\ fs$, $fc0 + (n - 1)\ fs$ by the same channel.
- Frequencies are also called chipping frequencies in scheme called DSSS (Direct Sequence Spread Spectrum) and hopping frequencies in FHSS (Frequency hopping Sequence Spread Spectrum

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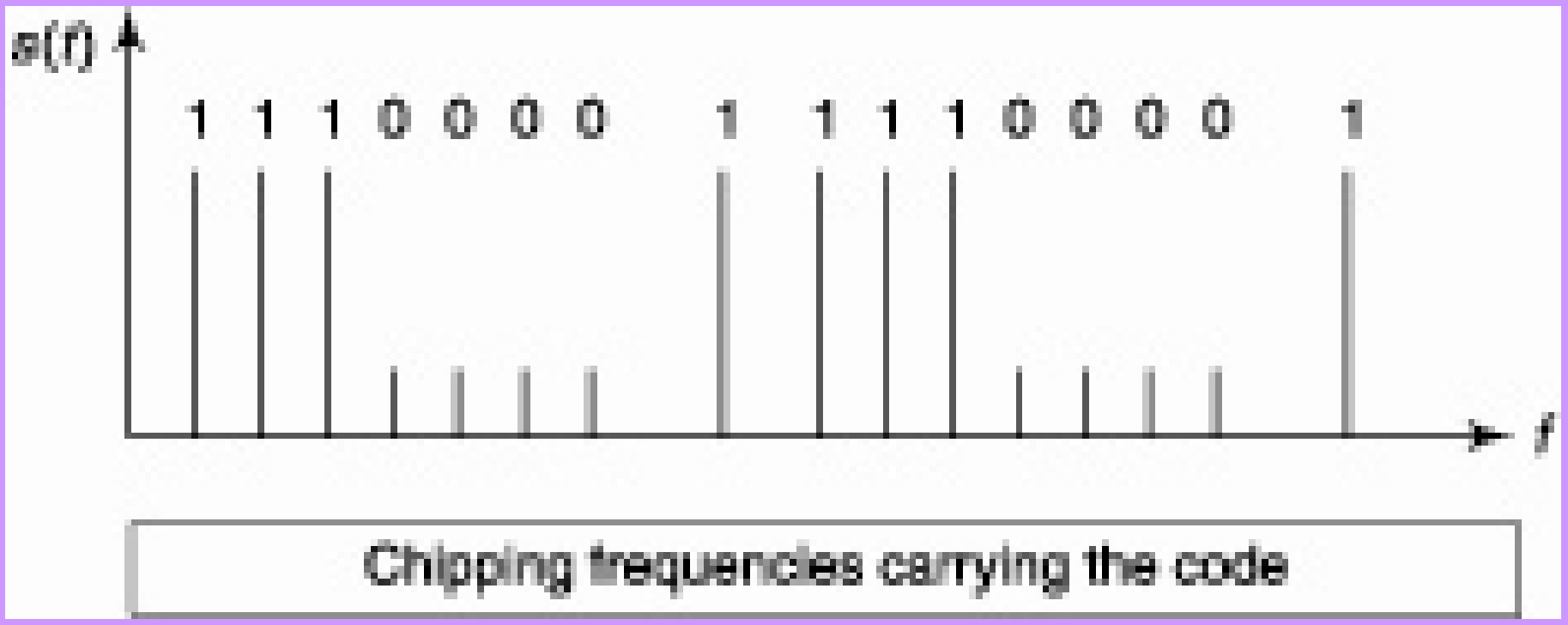
CDMA Chipping frequencies when an exemplary code 1110000111100001



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OFDMA

- **An** access method in which **multi-carrier, multi-tone transmitting for a set of symbols**
- Mmultiple users, data services, or sources allotted different frequency-slices (bands) to access in same space and time-slice but orthogonal codes

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OFDMA

- Each carrier transmits a distinct set of sub-carriers and each set of sub-carriers is assigned a code which is orthogonal to another
- Two frequency signals *s*1(*t*) and *s*2(*t*) are said to be orthogonal if *s*1(*t*) has maximum amplitude at the instant when *s*2(*t*) has zero amplitude and vice versa

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OFDAM

- An access method in which the adjacent sets of sub-carriers {[$f_{c0}/n_{sc}\ f_g + (f_{c0}\ n_{sc}^{-1} + n_{sc}^{-1} f_s)$, …], [$f'_{c0}/n_{sc}\ f_g + (f'_{c0} n_{sc}^{-1} + n_{sc}^{-1} f'_s)$, …], [$f'_{c0}/n_{sc}\ f''_g + (f''_{c0} n_{sc}^{-1} + n_{sc}^{-1} f''_s)$, …] that are carrying a subset of symbols are orthogonal

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Summary

- Space division multiple access (SDMA)
- Time division multiple access (TDMA)
- Frequency division multiple access (FDMA)
- Code division multiple access (CDMA)
- Code Orthogonal frequency division multiple access (COFDM) also called OFDM

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Introduction to SDMA, TDMA, FDMA, CDMA and OFDAM

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Mobile Communication – An overview

Lesson 05

Introduction to 2G and 3G Data Communication Standards

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First and Second Generations (1G and 2G)

- First generation wireless devices only voice signals
- Second generation (2G) devices communicate voice as well as data signals have data rates of up to 14.4 kbps
- The 2.5G and 2.5G+ are enhancements of the second generation and sport data rates up to 100 kbps

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Third generation (3G) mobile devices communication

- Higher data rates than 2G and support voice, data, and multimedia streams
- Facilitates data rates of 2 Mbps
- Higher for short distances
- 384 kbps for long distance transmissions.
- Enable transfer of video clips and faster multimedia communication

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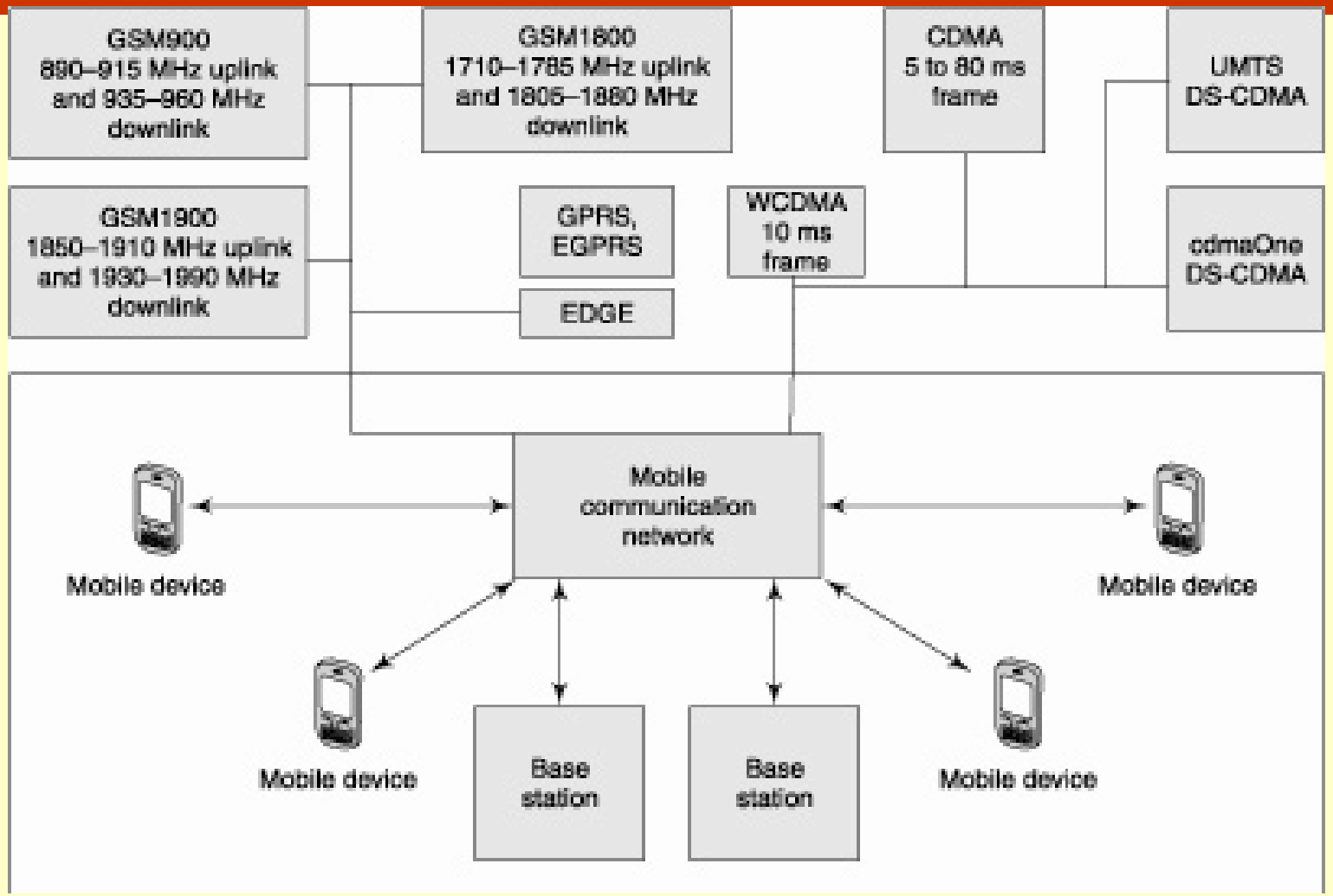
GSM and CDMA based standards



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GSM standards

- A set of standards and protocols for mobile telecommunication

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GSM Standard

- A global system for mobile (GSM) was developed by the Groupe Spéciale Mobile (GSM)
- Founded in Europe in 1982
- Support cellular networks

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GSM 900

- GMSK modulation
- FDMA for 124 up channels and 124 down channels
- 890-915 MHz for uplink and 935-960 MHz
- Channel of bandwidth 200 kHz
- 8 radio-carrier analog-signals TDMA for user access in each deployed channel

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GSM 900

- Users time-slices of 577 μs each
- Maximum 14.4 kbps

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EGSM (extended global system for mobile communication)

- An additional spectrum of 10 MHz on both uplink and downlink channels

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EGSM 900/1800/1900 MHz tri-band

- An additional spectrum of 10 MHz on both uplink and downlink channels
- GSM 1800 1710–1785 MHz for uplink and 1805–1880 MHz for downlink
- GSM 1900 1850–1910 MHz for uplink and 1930–1990 MHz for downlink

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GPRS (general packet radio service) — GSM 2G+ (2.5G)

- Packet-oriented service for data communication of mobile devices
- Utilises the unused channels in the TDMA mode in a GSM network

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EDGE (enhanced data rates for GSM evolution)

- An enhancement GSM Phase 2.5G+]
- 8PSK communication to achieve higher rates of up to 48 kbps per 200 kHz channel
- High compares to up to 14.4 kbps in GSM.
- Using coding techniques the rate can be enhanced to 384 kbps for the same 200 kHz channel

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EGPRS and HSCSD

- (enhanced general packet radio service) is an extension of GPRS using 8PSK (phase shift keying) modulation
- Enhances the data rate EGPRS based on EDGE
- Used for HSCSD (high speed circuit switched data)

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CDMA

- Evolution of CDMA from 2.5G in 1991 as cdmaOne (IS-95)
- CDMA supports high data rates
- 3G.
- Voice as well as data and multimedia streams.
- CDMA 2000, IMT-2000, WCDMA and UMTS
- Support cellular networks

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CdmaOne

- Founded in 1991
- QUALCOM, USA
- Belongs to 2G+
- IS-95 (interim standards 95)
- Operates at 824–849 MHz and 869–894 MHz.
- CDMA channel transmits analog signals from multiple sources and users

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WCDMA

- Supports asynchronous operations
- 10 ms frame length with 15 slices.
- Smaller end-to-end delay in the 10 ms frame as compared to 20, 40, or 80 ms frames
- Each frame length is modulated by QPSK— both for uplink and downlink

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WCDMA

- DSSS CDMA
- Supports a 3.84 Mbps chipping rate
- Both short and long scrambling codes are supported, but for uplink only
- 3G partnership project (3GPP)

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CDMA2000 and CDMA 2000 1x (3GPP2)

- For voice communication
- Circuit as well as packet switched communication
- Internet protocol (IP) packet transmission
- Multimedia and real time multimedia applications
- 3G partnership project 2

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UMTS (universal mobile telecommunication system)

- Supports both 3GPP (3G partnership project) and 3GPP2
- Communicates at data rates of 100 kbps to 2 Mbps

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CDMA2000 and CDMA 2000 1x

- Chipping rates are in multiples of f_s = 1.2288 Mbps
- 3G IMT 2000 carrier frequency f_{c0} = 2 GHz
- Included in UMTS
- CDMA 2000 1x f_s = 1.2288 Mbps
- Also backward compatible to 2.5G cdmaOne IS-95

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Summary

- Mobile voice, data and multimedia communication standards
- GSM 900/1800/1900
- 2.5G+
- GPRS
- CdmaOne
- WCDMA
- CDAM 2000

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Introduction to 2G and 3G Data Communication Standards

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Mobile Communication – An overview

Lesson 06

Introduction to WPANs and WLANs

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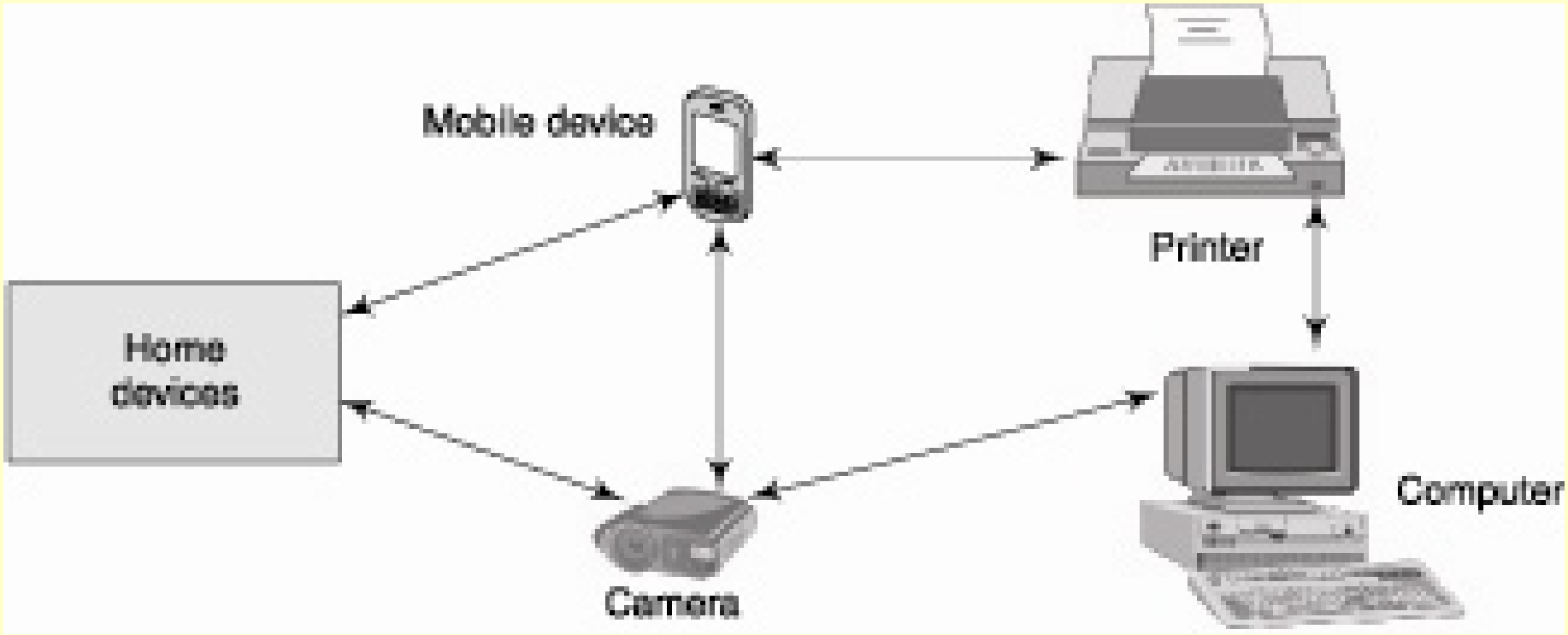
Wireless personal area network using Bluetooth, ZigBee, or IrDA protocols



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Bluetooth IEEE 802.15.1

- WPAN standard
- Operates at a frequency of 2.4 GHz radio spectrum which is identical to that of the IEEE 802.11b WLAN standard
- Bluetooth provides short distance (1 m to 100 m range as per the radio spectrum) mobile communication
- Data rates between the wireless electronic devices are up to 1 Mbps

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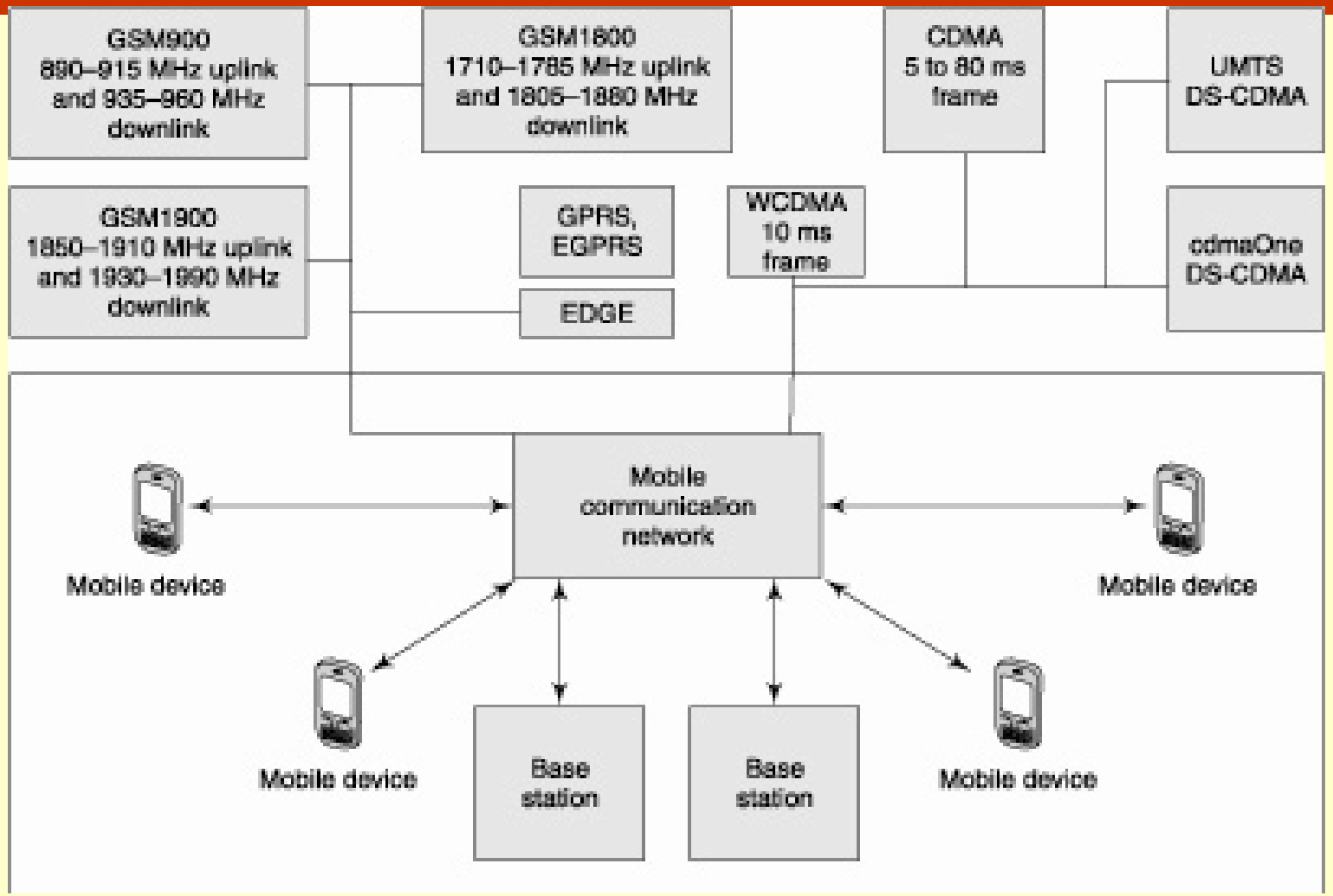
GSM and CDMA based standards



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Bluetooth

- Between the mobile phone handset and headset for hands-free talking
- Between the computer and printer, or
- Computer and mobile phone handset.
- Enables user mobility in a short space with other Bluetooth enabled devices or computers in the vicinity
- Uses FHSS (frequency hopping spread spectrum)

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Bluetooth

- Facilitates object exchanges
- Object can be a file, address book, or presentation

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ZigBee WPAN standard that is IEEE 802.15.4

- Lower stack size (28 KB) in the protocol
- Lower network-joining latency when compared to Bluetooth (250 KB).
- For Low transmitting power systems
- Interoperable standard based on RF wireless communication

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ZigBee

- Expected to provide large-scale automation and the remote controls up to a range of 70 m
- Data rates of 250 kbps, 40 kbps, and 20 kbps at the spectra of 2.4 GHz, 902 MHz to 928 MHz, and 868 MHz to 870 MHz, respectively
- Uses DSSS

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ZigBee

- Designed for robotic control,
- industrial,
- home, and
- monitoring applications.

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ZigBee Applications

- ZigBee enabled electric meter communicates electricity consumption data to the mobile meter reader
- A ZigBee enabled home security system alerts the mobile user of any security breach at the home

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IrDA (infrared data association) 1.0

- Protocol for data rates up to 115 kbps
- **IrDA** 1.1 supports data rates of 1.152 Mbps to 4 Mbps

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WLAN and Internet Access

- IEEE 802.11a, 802.11b, and 802.11g standards
- WLAN also called WiFi (Wireless Fidelity).

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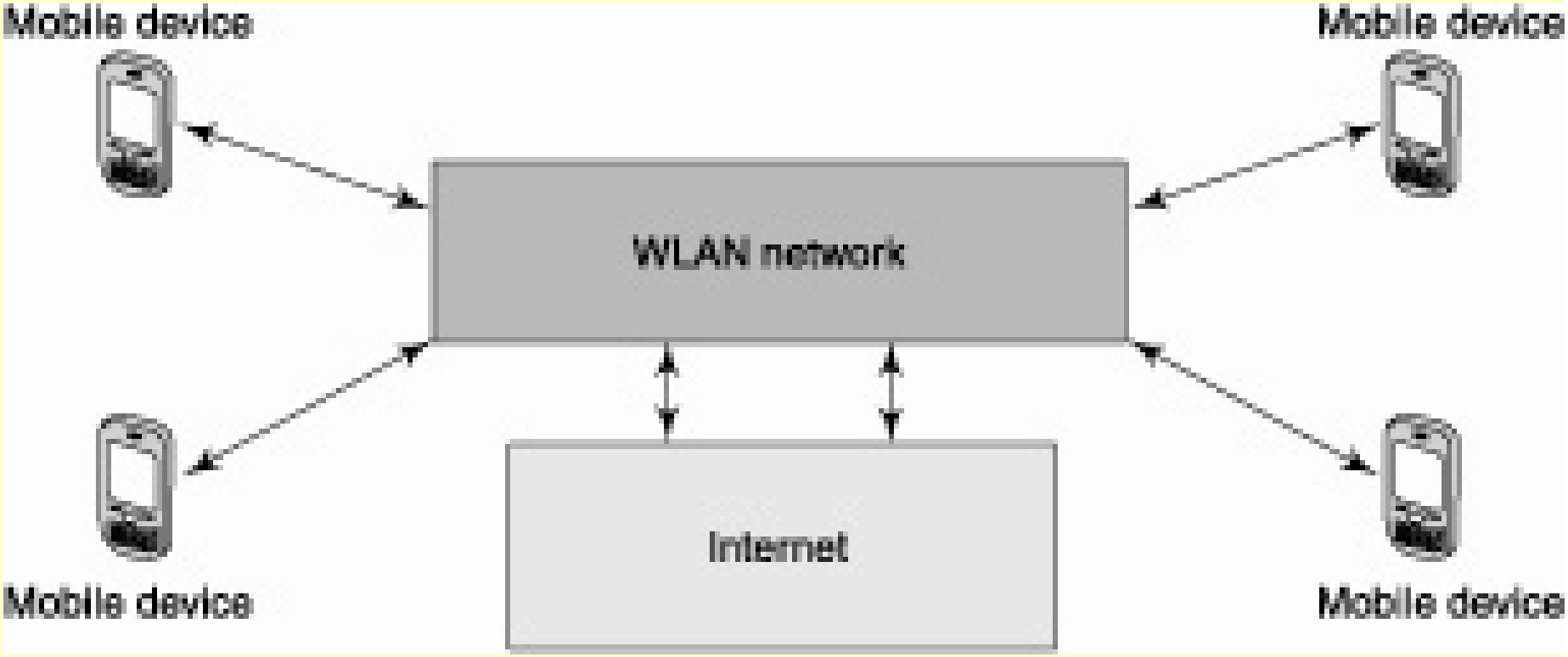
Mobile communication using an 802.11 WLAN standard



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IEEE 802.11 based standards for WLANs

- 802.11a– MAC layer operations such that multiple physical layers in 5 GHz (infrared, two 2.4 GHz physical layers)
- Infrastructure based architecture as well as Mobile ad hoc network (MANET) based architecture. [Refer to Chapter 12 for a description of the MANET.] Modulation is OFDM [Section 1.1.2(5)] at data rates of 6 Mbps, 9 Mbps,… Data rates supported are from 54 kbps to a few Mbps.

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IEEE 802.11 based standards for WLANs

- 802.11a– MAC layer operations such that multiple physical layers in 5 GHz (infrared, two 2.4 GHz physical layers)
- Infrastructure based architecture as well as Mobile ad hoc network (MANET) based architecture.

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802.11a

- OFDM at data rates of 6 Mbps, 9 Mbps,…
- Data rates supported are from 54 kbps to a few Mbps

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802.11b

- 54 Mbps and at 2.4 GHz.
- Modulation DSSS /FHSS
- Supports short-distance wireless networks using Bluetooth (IEEE 802.15.1) based applications and the HIPERLAN2 (HIPERformance LAN 2)

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802.11b

- OFDMA physical layer
- Provides protected Wi-Fi access.
- The data rates are 1 Mbps (Bluetooth), 2 Mbps, 5.5 Mbps, 11 Mbps, and 54 Mbps (HIPERLAN 2).

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802.11g

- Operates at 54 Mbps and at 2.4 GHz
- Used for many new Bluetooth applications
- Compatible to 802.11b
- Uses DSSS in place of OFDMA

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802.11i

- Provides the AES and DES security standards

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WiMax (worldwide interoperability for microwave access) IEEE 802.16

- New generation innovative technology
- Delivers high-speed, broadband, fixed, and mobile services wirelessly to large areas with much less infrastructure

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WAP (wireless application protocol)

- provides the web contents to small-area-display devices in mobile phones
- Service providers format contents in the WAP format

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I-Mode (internet in mobile mode)

- Developed by NTT DoCoMo, Japan
- Very popular wireless Internet service for mobile phones

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Summary

- Wireless personal area standards
- Blue tooth
- ZigBee
- IrDA
- Wireless LAN 802.11 standards
- Wi-Fi
- WiMax

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End of Lesson 06
Introduction to WPANs and WLANs

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Mobile Communication – An overview

Lesson 07

Introduction to Mobile Computing

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Mobile computing– A Definition

- The process of computation on a mobile-device
- In mobile computing, a set of distributed computing systems or service provider servers participate, connect, and synchronise through mobile communication protocols

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Wikipedia Definition

- Mobile computing as a generic term describing ability to use the technology to wirelessly connect to and use centrally located information and/or application software through the application of small, portable, and wireless computing and communication devices

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Mobile computing

- Provides decentralized (distributed) computations on diversified devices, systems, and networks, which are mobile, synchronized, and interconnected via mobile communication standards and protocols.
- Mobile device does not restrict itself to just one application, such as, voice communication

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Mobile computing

- Offers mobility with computing power
- Facilitates a large number of applications on a single device

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Ubiquitous computing

- Refers to the blending of computing devices with environmental objects
- A term that describes integration of computers into practically all objects in our everyday environment, endowing them with computing abilities
- Based on pervasive computing

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Pervasive Computing

- Pervasive means ‘existing in all parts of a place or thing’.
- Pervasive computing– The next generation of computing which takes into account the environment in which information and communication technology is used everywhere, by everyone, and at all times.

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Pervasive computing

- Assumes information and communication technology to be an integrated part of all facets of our environment, such as toys, computers, cars, homes, factories, and work-areas

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Pervasive computing

- Takes into account the use of the integrated processors, sensors, and actuators connected through high-speed networks and combined with new devices for viewing and display

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Mobile computing

- Also called **pervasive computing** *when a set of computing devices*, systems, or networks have the characteristics of *transparency*, application-aware *adaptation*, and have an *environment* sensing ability

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Pervasive computing devices

- Are not PCs
- Are handheld, very tiny, or even invisible devices which are either mobile or embedded in almost any type of object

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Mobile Computing

- Novel applications
- A large number of applications
- Very recently made mobile TV realizable

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SmartPhone Feature Example

- A mobile phone with additional computing functions so as to enable multiple applications
- SMS (short message service), MMS (multimedia messaging service), phone, e-mail, addres book, web browsing, calender, task-to-do list, pad for memos.
- Compatibility with popular Personal Information Management (PIM) software

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SmartPhone Example

- Integrated attachment viewing.
- SureType keyboard technology with QWERTY-style layout.
- Dedicated Send and End keys.
- Bluetooth® capability for hands-free talking via headset, ear buds, and car kits.

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SmartPhone Example

- EvDO* support enabling the device as a wireless modem use for laptop or PC.
- Speaker phone
- Polyphonic ring tones
- 64 MB memory
- Bright, high-resolution display, supporting over 65,000 colors

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Enterprise Solutions

- Enterprises or large business networks
- Huge database and documentation requirements
- Business solutions for corporations or enterprises

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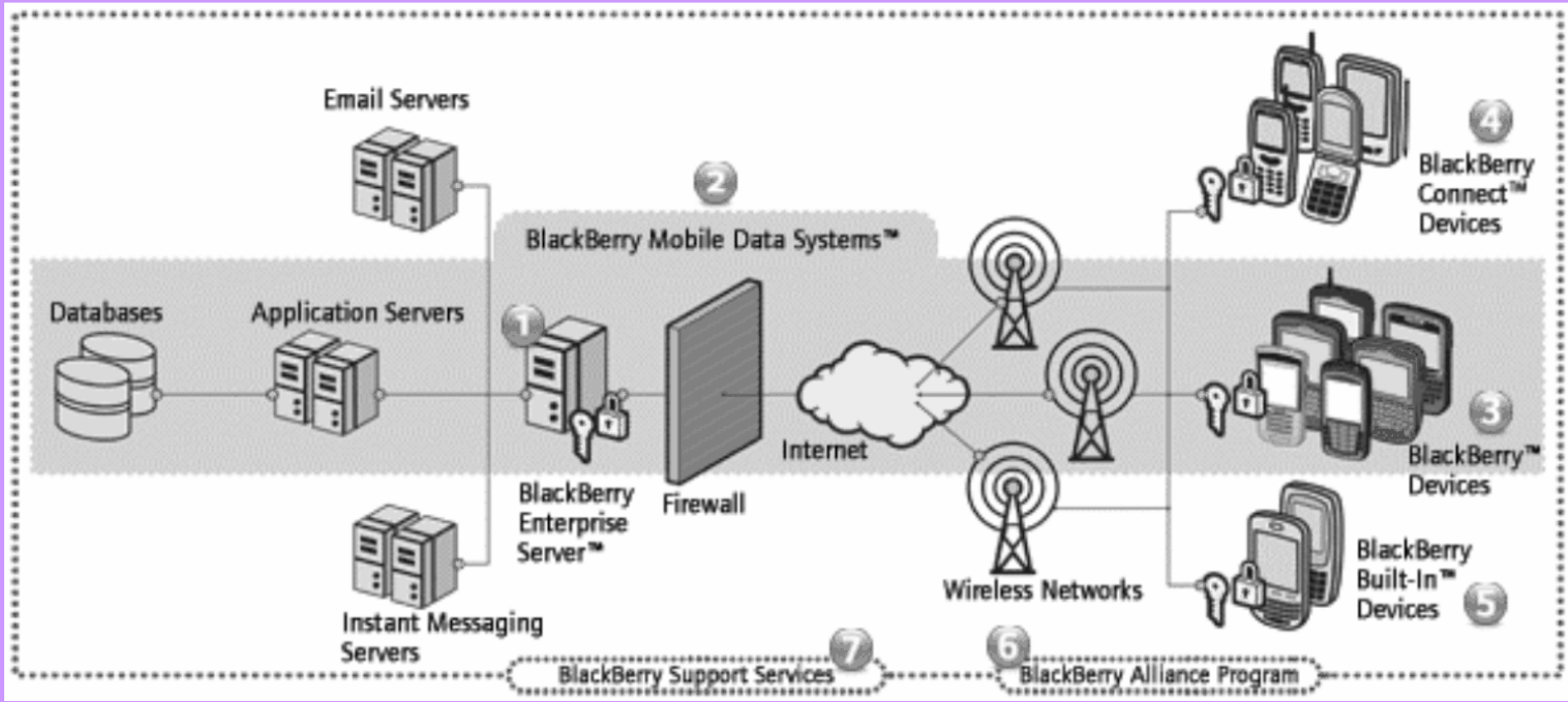
An enterprise solution architecture for a BlackBerry device



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Mobile Computing application to Music and Video

- Example– Apple iPods enables listening to one's favourite tunes anytime and anywhere
- View photo albums
- Slide shows
- Video clips

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Mobile Commerce

- Stock quotes in real time or on demand.
- The stock purchases or selling
- Bank transactions
- Retail purchases
- Supply chain management
- e-Ticketing– booking cinema, train, flight, and bus tickets

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Limitations to mobile computing

- Resource constraints: Battery
- Interference: the quality of service (QoS)
- Bandwidth: connection latency
- Dynamic changes in communication environment: variations in signal power within a region, thus link delays and connection losses

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Limitations to mobile computing

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…Limitations to mobile computing

- Network Issues: discovery of the connection-service to destination and connection stability
- Interoperability issues: the varying protocol standards
- Security constraints: Protocols conserving privacy of communication

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Summary

- Mobile computing — ability to use the technology to wirelessly connect to and use centrally located information and/or application software through the application of small, portable, and wireless computing and communication devices voice, data and multimedia communication standards …

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…Summary

- Ubiquitous and pervasive computing
- SmartPhone
- Enterprise solotions
- Music and video
- M-commerce
- Constraints of Mobile Computing

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End of Lesson 07

Introduction to Mobile Computing

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Mobile Communication – An overview

Lesson 08

Mobile Computing Architecture

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Mobile computing Architecture

- Programming languages used for mobile system software
- Operating system functions to run the software components onto the hardware
- Middleware components deployment

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Mobile computing Architecture

- Layered structure arrangement of mobile computing components
- Protocols and layers used for transmission and reception

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Programming Languages

- Java— J2SE.
- J2ME (Java2 Micro edition)
- JavaCard (Java for smart card
- The Java enterprise edition (J2EE) used for web and enterprise server based applications of mobile services

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Programming Languages

- C and C++
- Visual C++
- Visual Basic.

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Operating System

- Symbian OS, Window CE, Mac OS…
- Offers the user to run an application without considering the hardware specifications and functionalities
- Provides functions which are used for scheduling the multiple tasks in a system

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Operating System

- Provides the functions required for the synchronization of multiple tasks in the system
- Multiple threads synchronization and priority allocation
- Management functions (such as creation, activation, deletion, suspension, and delay) for tasks and memory

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Operating System

- Provides Interfaces for communication between software components at the application layer, middleware layers, and hardware devices
- Facilitates execution of software components on diversified hardware.
- Provides Configurable libraries for the GUI (graphic user interface) in the device.

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Operating System

- Provides User application's GUIs, VUI (voice user interface) components, and phone API
- Provides the device drivers for the keyboard, display, USB, and other devices

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Middleware for Mobile Systems

- Software components that link the application components with the network-distributed components
- To discover the nearby device such as Bluetooth
- To discover the nearby hot spot

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Middleware for Mobile Systems

- For achieving device synchronization with the server or an enterprise server
- For retrieving data (which may be in Oracle or DB2) from a network database
- For service discovery at network
- For adaptation of the application to the platform and service availability

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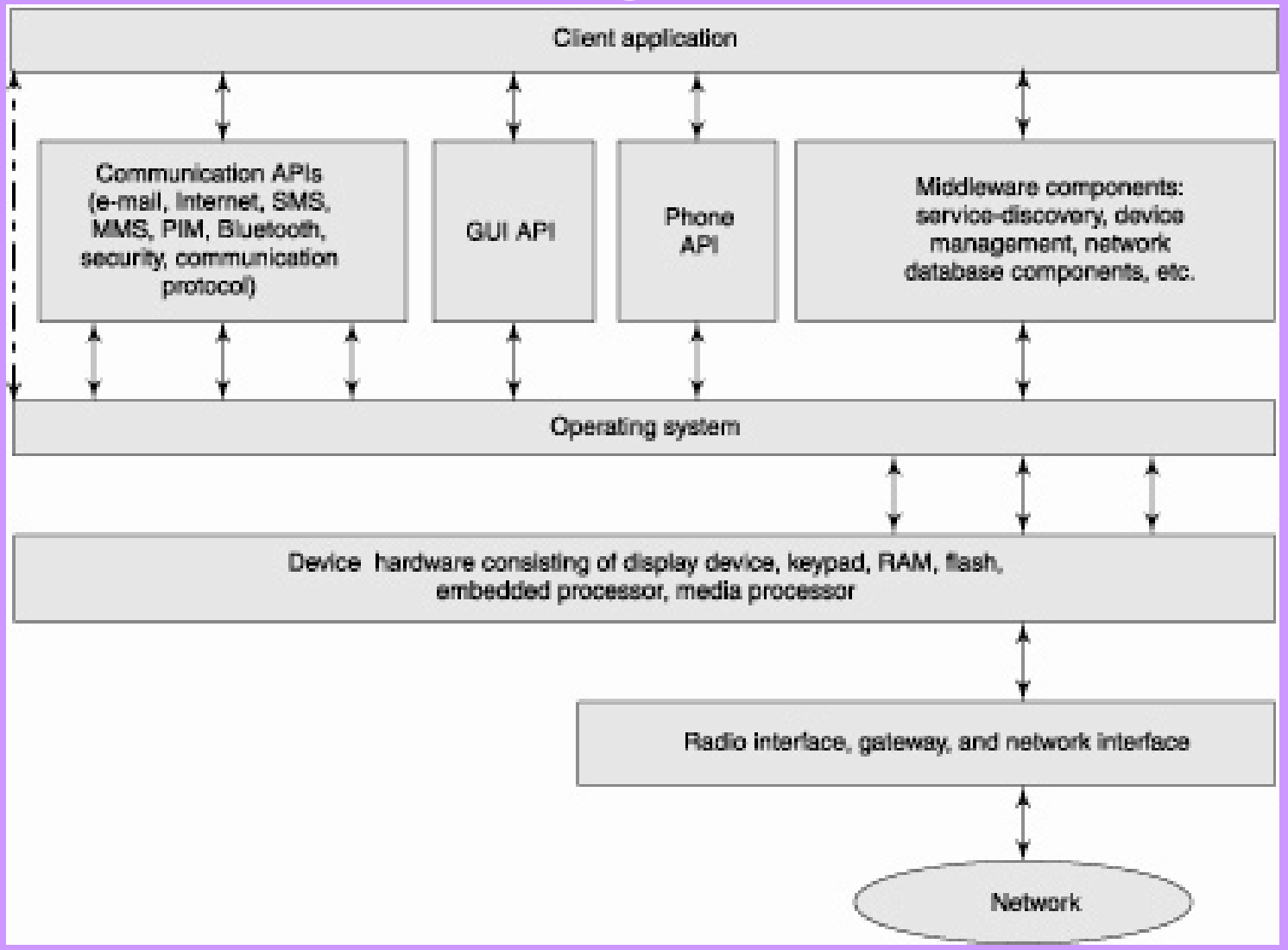
Mobile Computing Architectural Layers



Mobile computing services Protocols

- Such as GSM 900, GSM900/1800/1900, UMTS, and I-Mode
- WPAN protocols— Bluetooth, IrDA, and Zigbee)
- WLAN protocols —for example, 802.11a and 802.11b)
- WAP

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Mobile Computing system Layers

1. Physical for sending and receiving signals (for example, TDMA or CDMA coding)
2. Data-link (for example, multiplexing)
3. Networking (for linking to the destination)

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…Mobile Computing system Layers

4. Wireless transport layer security (for establishing end-to-end connectivity)
5. Wireless transaction protocol
6. Wireless session protocol
7. Wireless application environment (for running a web application, for example, mobile e-business)

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Summary

- Mobile Computing Programming languages– Java, J2ME, C/C++, Visual Basic, visual C++
- OS– Symbian OS, Window CE, Mac OS
- Middleware components
- Architecture software layers
- Protocols layers
- Network Layers

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End of Lesson 08

Mobile Computing Architecture

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Mobile Communication – An overview

Lesson 09

Mobile System Networks

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Mobile System Networks

- Cellular networks
- WLAN networks
- Ad Hoc Networks

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Cellular Networks

- A cell is the coverage area of a base station, connected to other stations via wire or fibre or wirelessly through switching centres
- The coverage area defines a cell and its boundaries.

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Cellular Networks

- Each cell base station functions as an access point for the mobile service.
- Each mobile device connects to the base station of the cell which covers the current location of the device
- All the mobile devices within the range of a given base station communicate with each other through that base station only.

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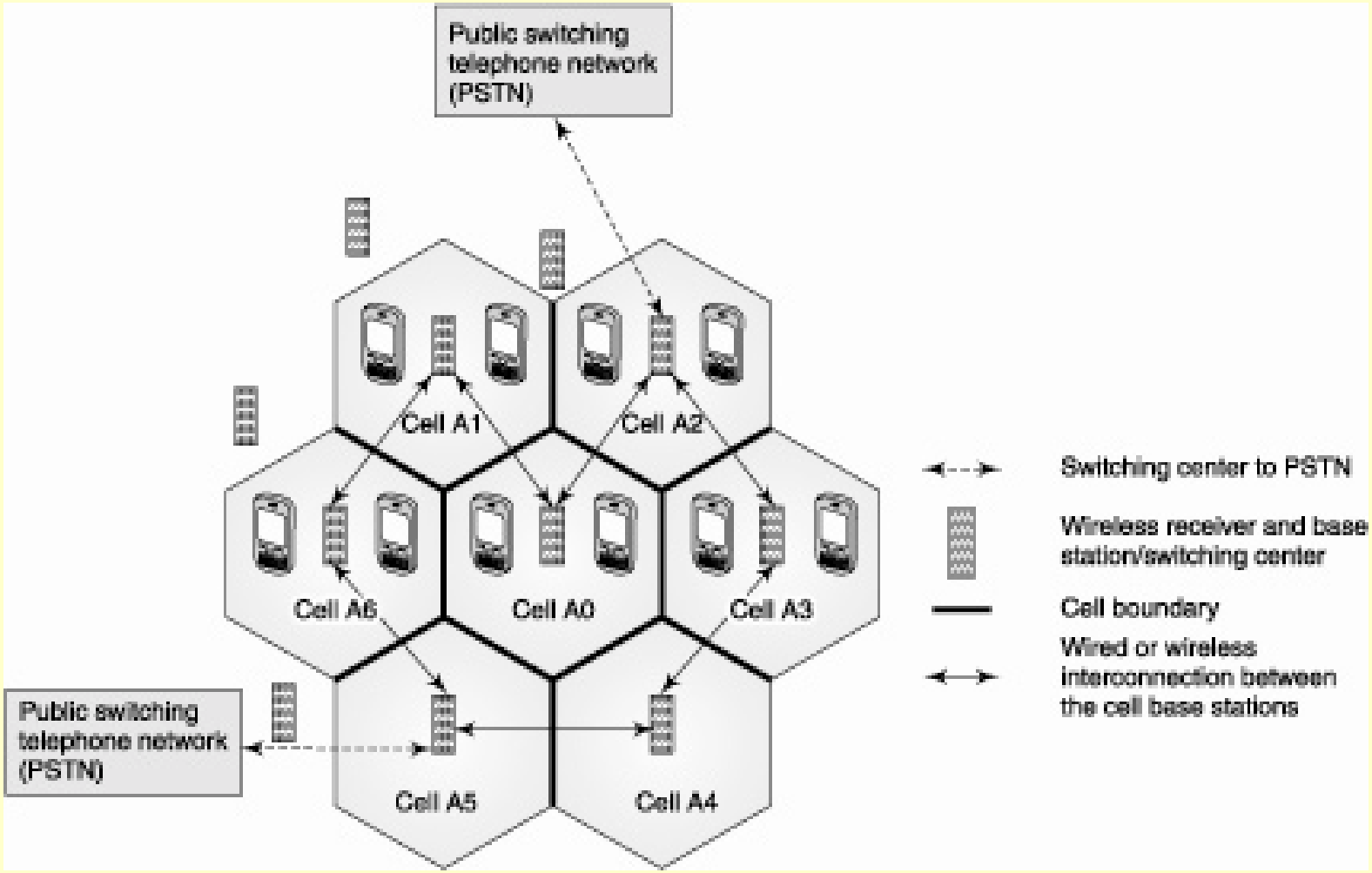
Cellular Network



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WLAN Network and Mobile IP

- For connectivity between the Internet, two LANs, mobile devices, and computers
- Mobile device connects to an access point, called a hot spot
- The access point, in turn, connects to a host LAN which links up to the Internet through a router

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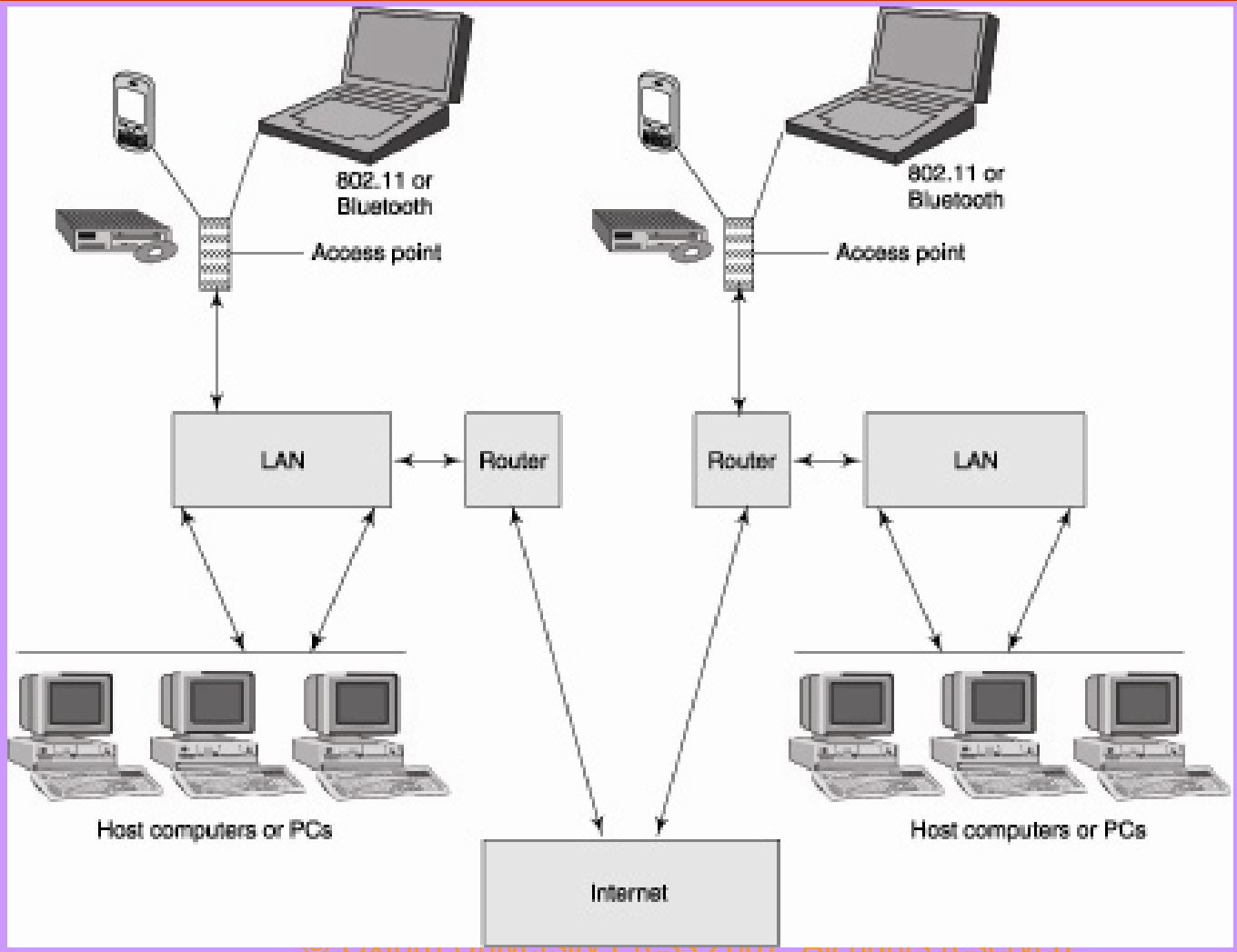
Communication between mobile devices using a WLAN network through hot-spots



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Mobile IP

- An open standard based on the IP (internet protocol)
- Mobile IP network provides the mobile IP service using home agents and foreign agents.

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Ad hoc Networks

- The nodes, mobile nodes, and sensor nodes communicate among themselves using a base station
- The base stations function as gateways
- The ad hoc networks deployed for routing, target detection, service discovery, and other needs in a mobile environment

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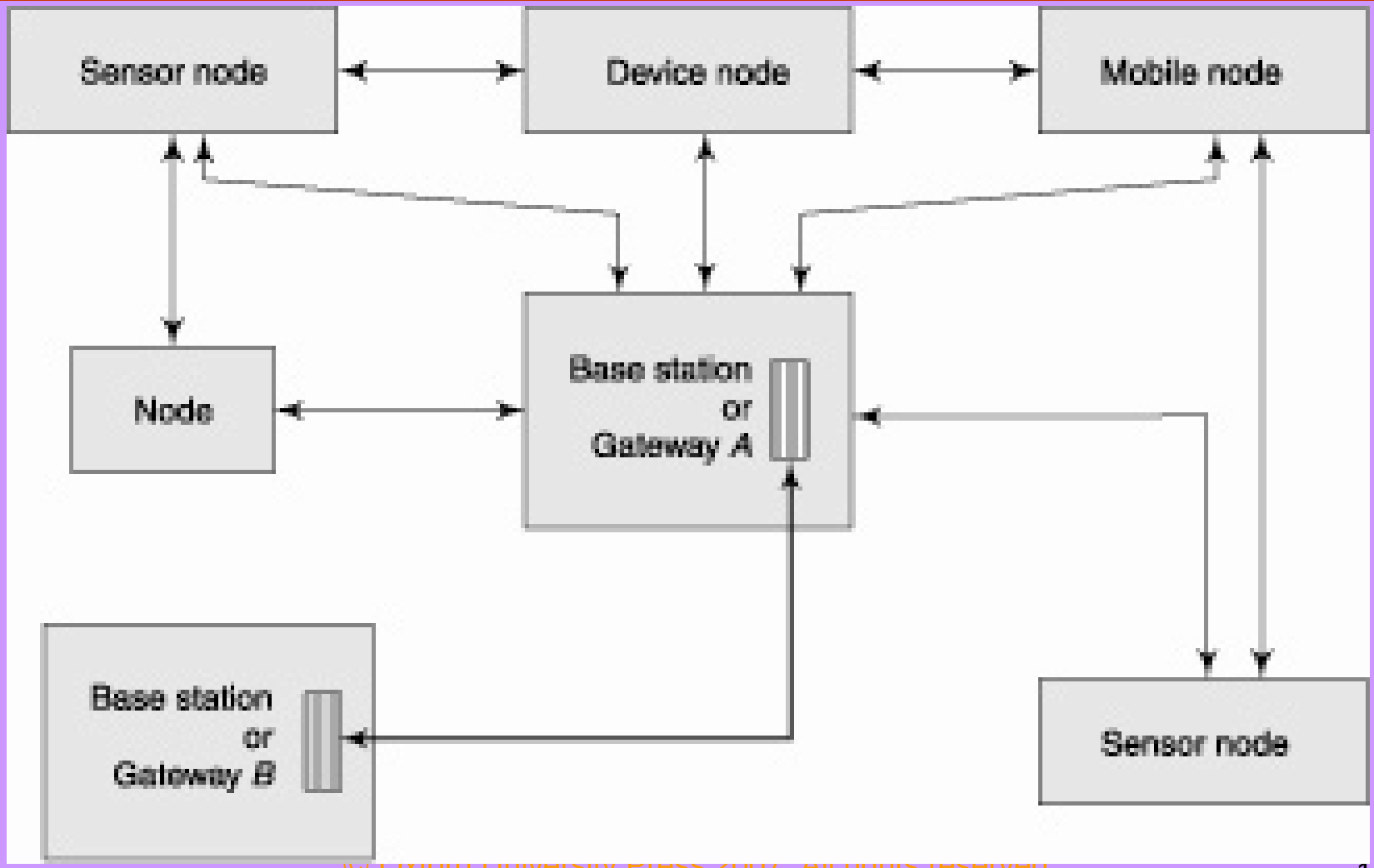
Communication of mobile nodes and Sensor nodes using a base station as a gateway



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Summary

- Mobile Computing Systems Networks
- Cellular networks
- WLANs
- Mobile IP network
- Access points
- Ad hoc
- Sensor networks

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End of Lesson 09

Mobile System Networks

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Mobile Communication – An overview

Lesson 10

Data Dissemination, Synchronization and Mobility management

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Data Dissemination

- Mobile phone also acts as a data access device for obtaining information from the service provider's server
- Smartphones in enterprise networks work as enterprise data access devices
- An enterprise server disseminating the data to the enterprise mobile device

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Data Dissemination

- iPhone a data access device for accessing music or video
- Links up to download files which can then be saved and played
- Students also use the iPhone for replaying faculty lectures and retrieving e-learning material disseminated from University server

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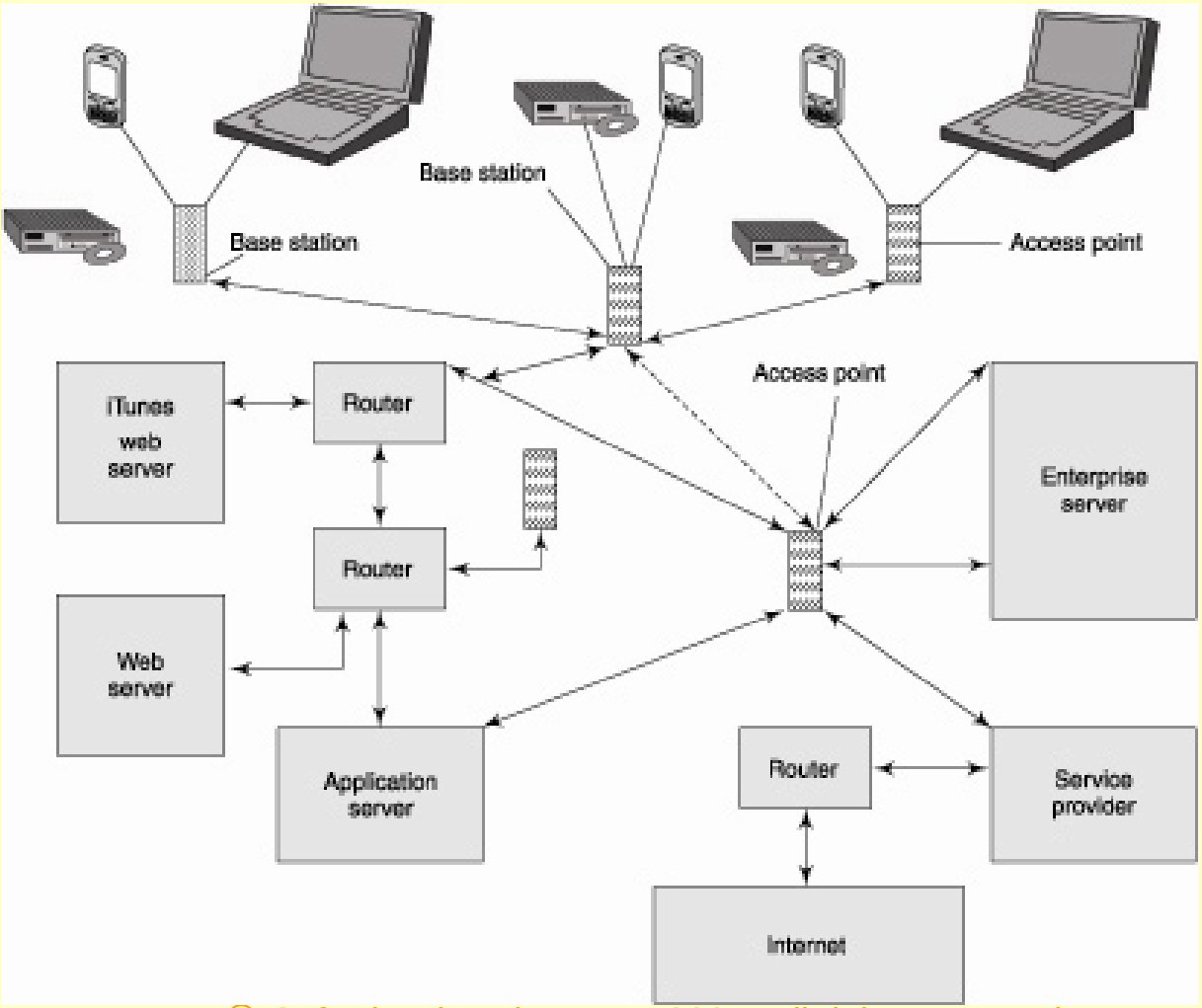
Data dissemination by servers through base stations and access points



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Data Synchronization Example

- A new popular ringtone added to one of the servers of a mobile service provider
- D*ata synchronization* means that all the servers of the service provider get identical sets of ringtones
- tone

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Data Synchronization Example

- All the devices connected to the server should be updated about the availability of any new data
- Ringtone databases available to all the mobile phones include a copy of the title of that tone

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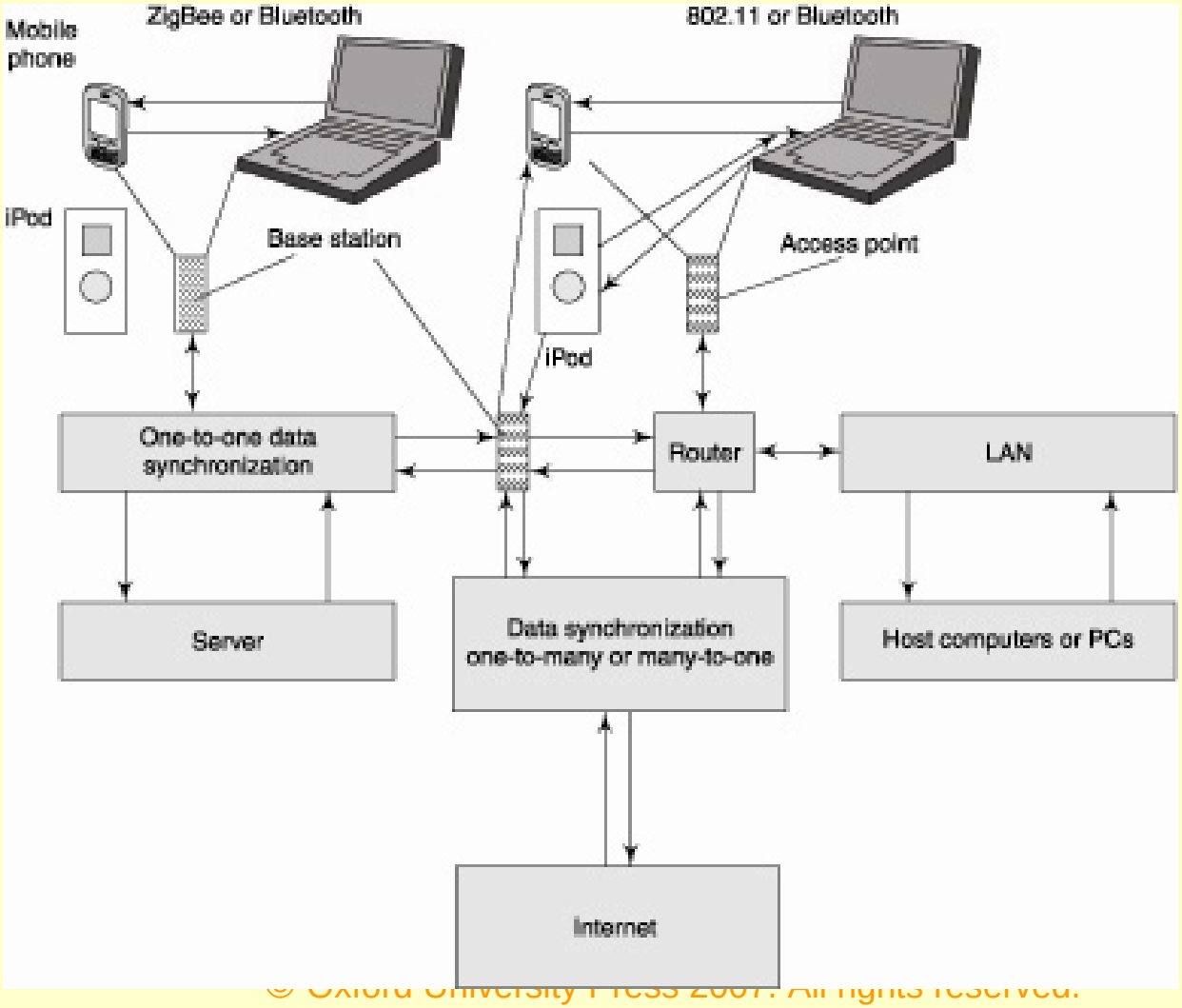
Data synchronization paths in a mobile network



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Data Synchronization

- One to One Synchronization
- One to Many Synchronization
- Many to Many Synchronization

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Mobility Management

- Means maintaining uninterrupted (seamless) signal connectivity when a mobile device changes location from within a cell Ci or network Ni to a cell Cj or network Nj
- Infrastructure management for installation and maintenance of the infrastructure that connects cell Ci to Cj or network Ni to Nj.

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Mobility Management

- Location management and registration management *by handoff* for cell transfer when a mobile device's connection with the *i*th cell is transferred

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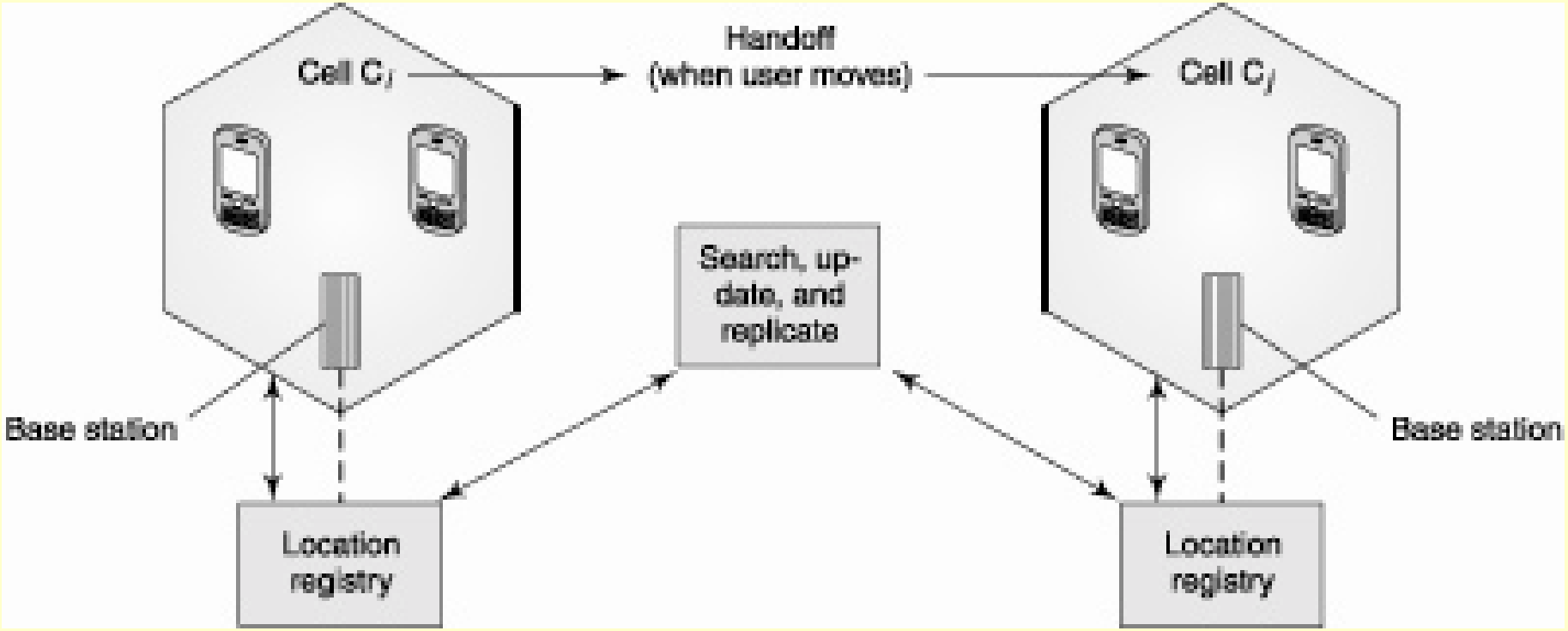
Mobility Management



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Summary

- Data dissemination from server to mobile systems
- Data synchronization between one to one or one to many or many to many
- Mobility Management

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End of Lesson 10

Data Dissemination, Synchronization and Mobility management

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Mobile Communication – An overview

Lesson 11

Mobile systems Security

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Security

- Important for maintaining privacy and for mobile e-business transactions
- Wireless security mechanisms for providing security of the data transmitted from one end point to another

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Security

- Provides for wire-equivalent privacy and non-repudiation when some data i sent to an end-point
- No denial of service to authenticated object(s)

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Security

- A serving station authenticated before it can provide service to mobile devices

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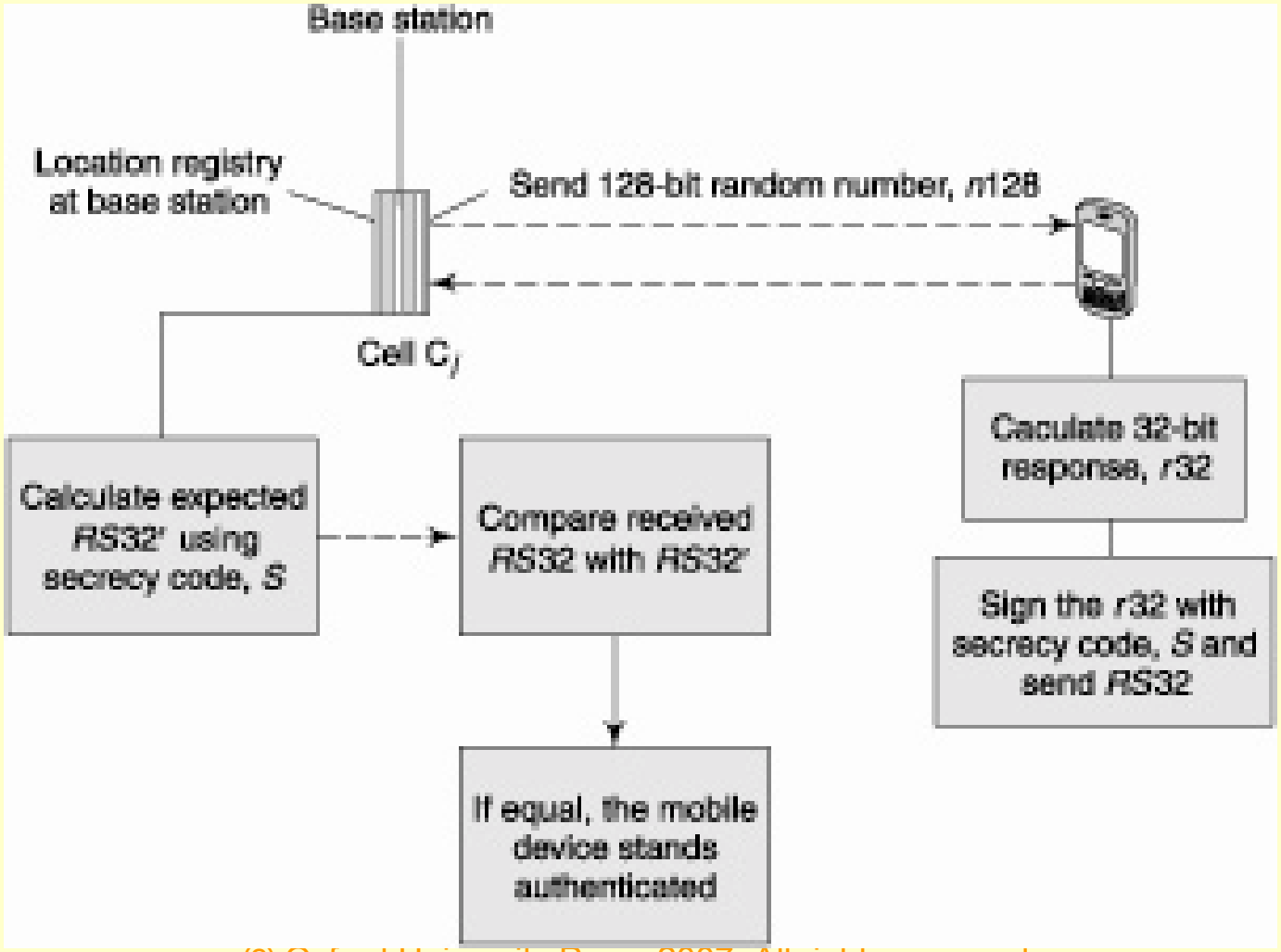
The authentication method of security in case of GSM



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Cryptography

- to keep private information from getting into the hands of unauthorized agents
- Encryption– the transformation of data into coded formats
- Encrypted data decrypted (transformed back to an intelligible form) at its destination

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Cryptography Algorithms

- Used for encryption and decryption of transmitted data
- Enable the receiver and the sender to authenticate data
- Discover if data security has been compromised during transmission

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Cryptography Algorithms

- Use a secret key, to encrypt data into secret codes for transmission
- RSA (Rivest, Shamir, Adleman) algorithm is a cryptography algorithm used for private key generation.

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Cryptography algorithms

- Classified into two categories; symmetric and asymmetric
- Used to create a *hash* of the message or a MAC (message authentication code)

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Hash function

- Used to create a small digital fingerprint of the data to be transmitted
- Fingerprint is called the hash value, hash sum, or, simply, hash.
- Hash of the message is a set of bits obtained after applying the hash algorithm (or function).
- This set of bits alters in case the data is modifies during transmission

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Message authentication codes (MAC)

- Also used to authenticate messages during transmission
- The MAC of a message created using a cryptographic MAC function which is similar to the hash function but has different security requirements

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Message authentication codes (MAC)

- The receiver reviews the hash or the MAC of the received message and returns it to the sender
- Exchange enables the sender and the receiver to find out if the message has been tampered with and thus helps verify message integrity and authenticity.

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Data encryption standard (DES)

- Uses 56-bits for a key plus 8 bits for parity.
- Block length 64 bit. [Maximum block size = 2^{64} bits

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Triple DES

- Triple DES an enhance version of DES
- Multiple encryptions or encryption-decryption-encryption steps in the cryptic message– A different key at each step for cryptic message creation

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Advanced encryption standard (AES)

- 9 possible combinations of key lengths and block lengths
- The key-length can be 128, 192, or 256 bits
- The block lengths can also be 128, 192, or 256 bits
- Block length of 128 bits means maximum block length = 2^{128} bits.

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RSA– The Asymmetric key based standard

- The RSA (Rivest, Shamir, Alderman) algorithm uses 128, 256, 512, or 1024 bit prime numbers for encryption

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DSA (digital signature algorithm)

- Used to sign a record before transmitting
- Provides for a variable key length of maximum 512 or 1024 bits

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DSS (digital signature standard)

- Based on the DSA
- Signature enables identification of the sender
- identifies the origin of the message, and
- checks the message integrity

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Digital certificate

- An electronic certificate used to establish the credentials of a data set.
- Issued by a certification authority and contains the certificate holder's name, a copy of the certificate holder's public key, a serial number, and expiration dates.

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Digital certificate

- Includes the digital signature of the certificate-issuing authority for verification of the authenticity of the certificate
- The certification authority distributes a digital certificate, which binds a public key to a specific sender

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Summary

- Cryptographic algorithms
- Hash
- MAC
- DES, Triple DES
- AES
- RSA
- Digital signatures and certificates

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End of Lesson 11

Mobile systems Security

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Mobile Devices and Systems

Lesson 01

Mobile Phones and Media Players

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Mobile phones

- Communicate with other phones using a cellular service-provider network
- Packed with smart functions and are available in smaller sizes
- Applications of mobile phones no longer confined to telephonic communication
- Can synchronize and upload and download data to and from PCs

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Mobile phones

- Provides e-mail and Internet connectivity
- Even click pictures and prepare albums
- Includes a personal information manager (PIM), a handheld computer, and an entertainment device

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New generation mobile phones

- Pack in everything from a computer to an FM radio and from video recording to TV viewing

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Smart Phones

1. A GSM, CDMA, or tri-band wireless radio interface to a cellular network provided by a mobile service provider
2. Small area LCD display
3. A smart T9 keypad– (A smart keypad is one that remembers previously keyed entries.

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Smart Phones

4. T9 stands for ‘text on 9 keys’.
5. A text input system that offers an alternative to multi-tapping for entering textual characters on a numeric keypad
6. Smart T9 keypads useful for creating SMS messages and entering contact information.

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Smart Phones

7. Functions as a phone as well as a PIM—phone diary, address book, task-list, calculator, alarm, and calendar
8. Ability to send and receive SMS messages of up to 160 characters
9. Ability to send and receive MMS (multi media messaging service) messages for transmission of digital images, video clips, and animations

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Smart Phones

10. Provisions for games, e-commerce, and e-ticketing
11. Bluetooth communication with PCs and neighbouring devices
12. Integration of location information, GPS and maps

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Smart Phones

13. WAP enabled for Web page access, download, and other Web-based applications through a WAP gateway or proxy

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Multimedia Phones

1. Offers multimedia functionalities
2. Functions of a smart phone, a MultiPhone can also play MP3 format audio and MP4 format video files
3. Some phones may also support other formats such as WMA, AAC, etc.
4. N91 belongs to this series and focuses on music and media playing

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Multimedia Phones

5. Possible to watch TV on a mobile phone using EDGE/EGPRS (3G) connectivity
6. Many mobile service providers link up with various TV channels
7. Enable users to enjoy mobile TV on the LCD screens of their cell phones

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Multimedia Phones

8. Mobile phone gaming
9. Enables users to play networked multiplayer games
10. Include cameras for still pictures and video recording. Some phones also offer picture-editing software which enable the user to edit, crop, and refine pictures on their cell phone handsets

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Nokia N91

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Nokia N91

1. GSM/GPRS EDGE 900/1800/1900 MHz connectivity
2. Advanced voice calling functions such as an integrated handsfree speaker, voice dialling, voice recording, and conference calling
3. Up to 4 GB of internal dynamic memory for multimedia functions and an additional 30 MB for storing calendar, contacts, and text messages

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Nokia N91

4. A music player optimized for listening to music. It can play audio files in MP3, AAC, AAC+, eAAC+, RealAudio, WAV, WMA, M4A, True Tones, AMR-WB, and AMR-NB formats. And video files in formats such as MPEG4 and RealVideo
5. External speakers using a stereo audio jack
6. FM radio and visual radio

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Nokia N91

7. 2 Megapixel camera for video recording and still pictures
8. 176 × 208 pixel display with up to 262,144 colours
9. PIM for managing features such as calendar, contacts, task lists, and PIM printing

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Nokia N91

10. WLAN 802.11b/g for hotspot connectivity, Bluetooth version 1.2 for wireless connectivity, and XHTML browser for Internet browsing.
11. Nokia PC Suite to synchronize data with the PC using a USB port or Bluetooth
12. Battery with a digital talk time of up to 4 hours and standby time of up to 7.9 days

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Cellular Networks for Mobile Phones

- Each cell has cells adjoining it in various directions.
- Adjacent cells distinct frequencies.
- To avoid interference between the signals transmitted by different cells

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Cellular Networks for Mobile Phones

- Base stations connect among themselves through either guided (wire- or fibre-based) or wireless networking or a public switching telephone network (PSTN).
- Multi-cell cellular network entails that when the transceivers (mobile phones) move from place to place, they will also have to switch from cell to cell

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Handoff and Handover

- When a mobile device moves and reaches a cell boundary
- Switching on to next cell occurs by handover of the device connection to another neighbouring base station

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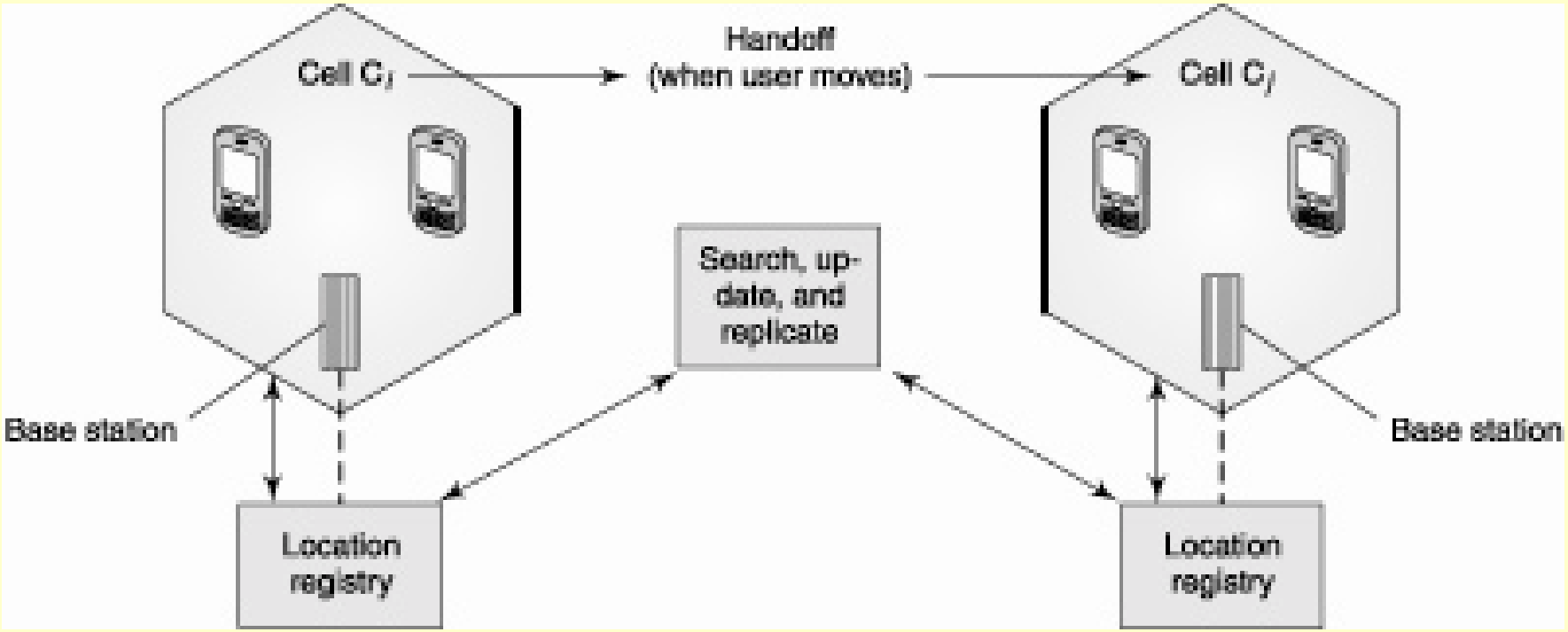
Cellular Networks for Mobile Phones



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Apple iPhone

- Commercially available from June 2007
- A multimedia and Internet enable mobile phone
- The features of an iPod, a SmartPhone, a digital camera, and a handheld computer
- Mac OS X operating system

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Apple iPhone Features

- A single physical button, '*home*'
- The user controls the iPhone by sliding a finger across its touch-sensitive 3.5-inch display.
- No stylus is needed
- Touch screen requires bare skin to operate

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Apple iPhone Features

- Various versions—4 GB and 8 GB flash memory versions
- Wide, touch-sensitive, 3.5-inch display screen, which has a resolution of 320 × 480 pixels at 160 pixels-per-inch display
- incorporates multi-touch sensing and a virtual keypad. The virtual keypad has automatic spell checking, predictive word capabilities, and a dynamic dictionary.

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Apple iPhone Multi-touch sensing Features

- A relatively new technology in the field of human–computer interaction.
- While touch sensing commonplace for single points of contact, *multi-touch* sensing enables a user to interact with a system with more than one finger at a time, as in chording and bi-manual operations.

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Apple iPhone Features

- Ambient light sensor which senses the lights in proximity and automatically adjusts screen brightness to save power
- Proximity sensor shuts down the display and touch screen when the phone is held to the ear

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Apple iPhone Features

- Phone call by simply pointing the finger at a name or number in a call log, address book or favorites list
- Innovative use of the contacts list is that, using a new technology, the iPhone automatically synchronizes all contacts from a PC, Mac, or Internet service

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Apple iPhone Features

- Special phone-call feature automatically adjusts music volume with incoming phone calls.
- An easy-to-use conference call feature lets users connect two calls with one touch of the screen
- Allows conferencing, call holding, call merging, and caller ID.

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Apple iPhone Features

- Sports the Visual Voicemail feature which allows users to skip directly to voicemails they want to hear.
- SMS text messaging on the iPhone similar to iChat, with user dialogue encased in bubbles with familiar iChat sounds, and a touch keyboard appears below for entering text.

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Apple iPhone Features

- Supports full iTunes integration
- Provides for iPod audio and photo file formats and functions, for example, shuffling of songs, repeat one or all, sound check on or off, and 20 equalizer settings

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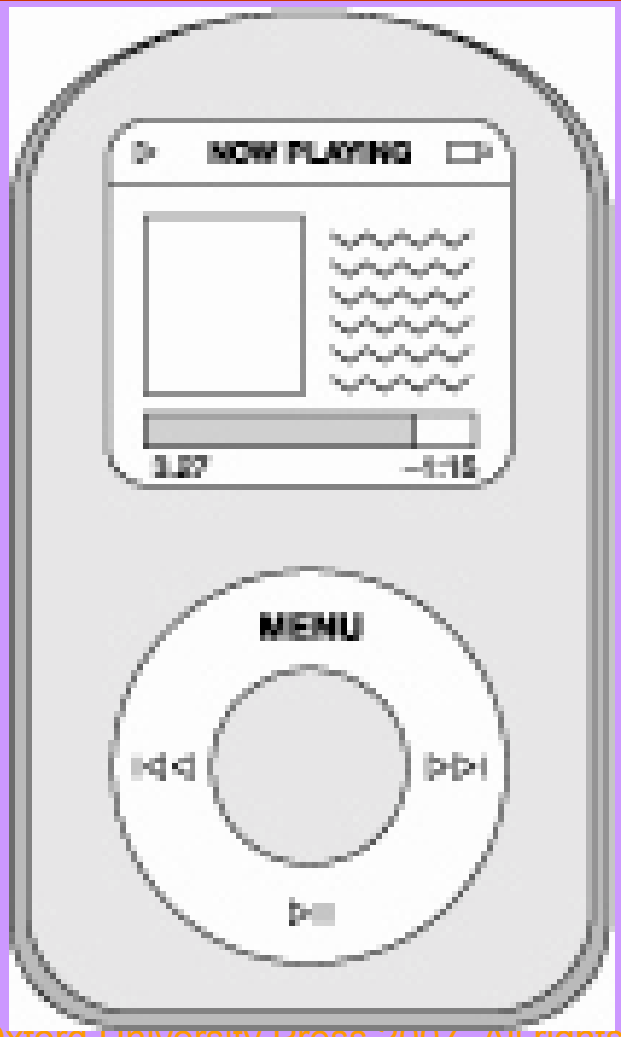
Mobile Digital Music Players— Apple iPod



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Apple iPod

- Includes flash-based players
- Simple user interfaces
- Mostly designed around a central scroll wheel
- 5th generation iPod incorporates a video player
- Use the Apple iTunes software for transferring, storing, managing, and playing music, photos, and videos

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Apple iPod MA350LL/A

- Stores 240 songs in 1 GB, 500 songs in 2 GB, and 1,000 songs in 4GB versions.
- Supports Apple audio communication by AAC files between 16 kbps to 320 kbps
- Battery life of up to 14 hours for music playback and up to 4 hours for slide shows with music

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Apple iPod MA350LL/A

- Provides customized main menu to create multiple On-the-Go playlists
- Adjust audio-book playback speed
- Clicker playback through headsets
- Rate the songs
- Shuffle the songs or albums

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Apple iPod MA350LL/A

- Repeat one or all,
- Sound check on or off
- 20 equalizer settings
- Sleep timer
- Multilingual display

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Apple iPod MA350LL/A

- Supports MP3, VBR, WAV, and AIFF file formats
- Supports JPEG file photo display and download.
- Syncs iPod-viewable photos in BMP, TIFF, PSD (Mac only), and PNG formats.

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Apple iPod MA350LL/A

- Supports protected AAC files from the iTunes Music Store
- Supports Audible (formats 2, 3, and 4).
- Supports web browsing

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Apple iPod MA350LL/A

- Supports a calendar and task-to-do lists.
- Supports ear-bud headphones and a speaker phone.
- Ports dock connector
- Stereo mini jack
- A USB through dock connector
- USB cable

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Summary

- SmartPhone
- MultiMedia Phone
- N91
- Apple iPhone
- Digital Music Player

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End of Lesson 01

Mobile Phones and Media Players

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Mobile Devices and Systems

Lesson 04
Smart Systems– Labels, RFID and tokens

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Smart systems

- Smart Labels
- Smart labels
- RFID
- Smart tokens

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Smart Labels

- Smart Labels multiple applications in our day-to-day lives in their numerous forms such as identification Labels, key Labels, etc.

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Label

- Serves the purpose of identifying the contents of a package
- A barcode label on a book packs in information about the publisher, title, author, publishing date, and reprint edition of a book
- Barcode labels also used in stores so that a reading machine can identify the product and its price.

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Label

- differs from a card in terms of thickness and visibility
- A label using wireless means for product identification can be concealed inside the product

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Smart Label

- Has a processor, memory, transceiver, and antenna similar to a contactless smart card
- Smart labels are essentially an earlier version of the now popular RFID tags
- Powered by the received signals just like smart cards
- Smart label need not be visible when implanted into a product or package.

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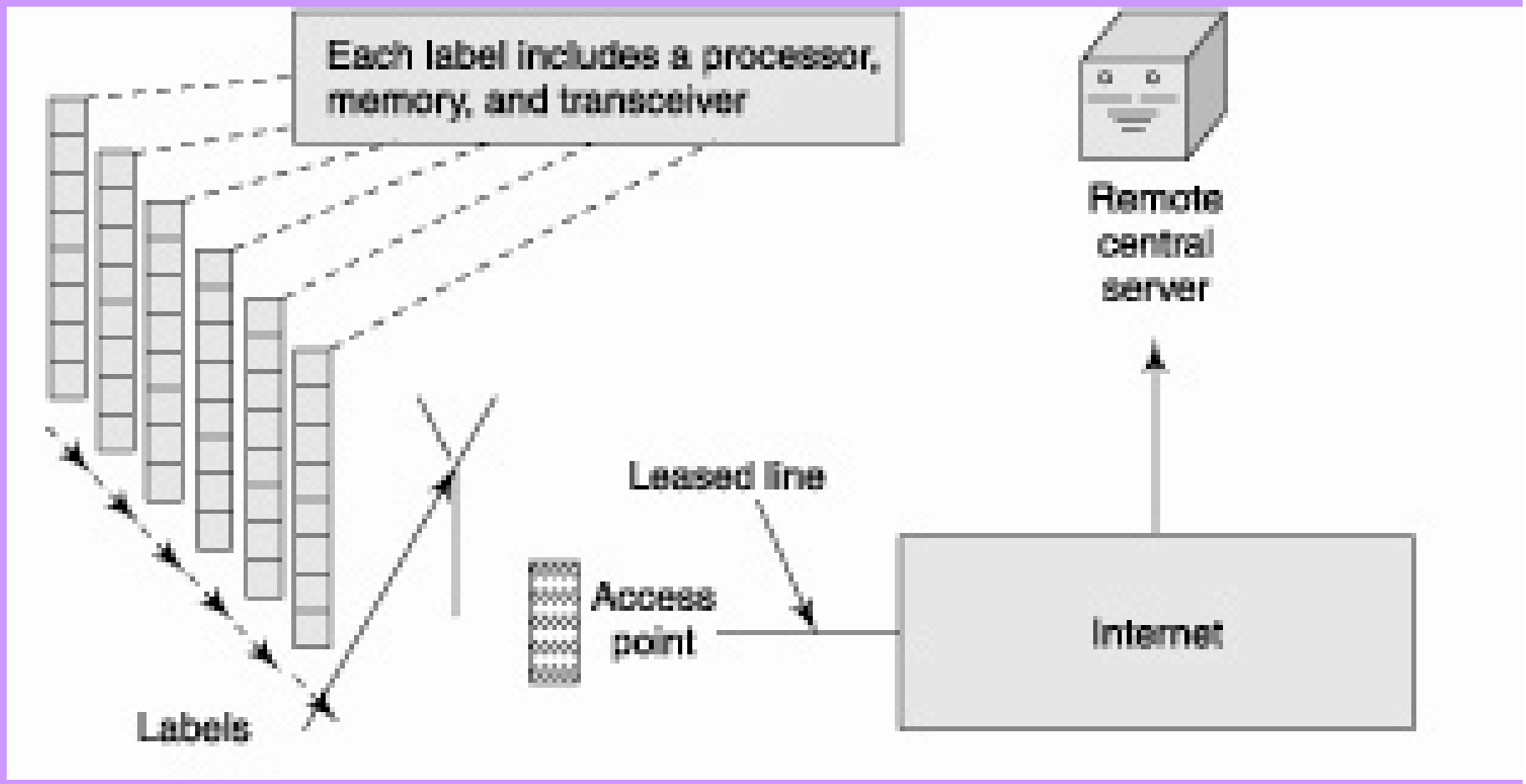
Network of labels



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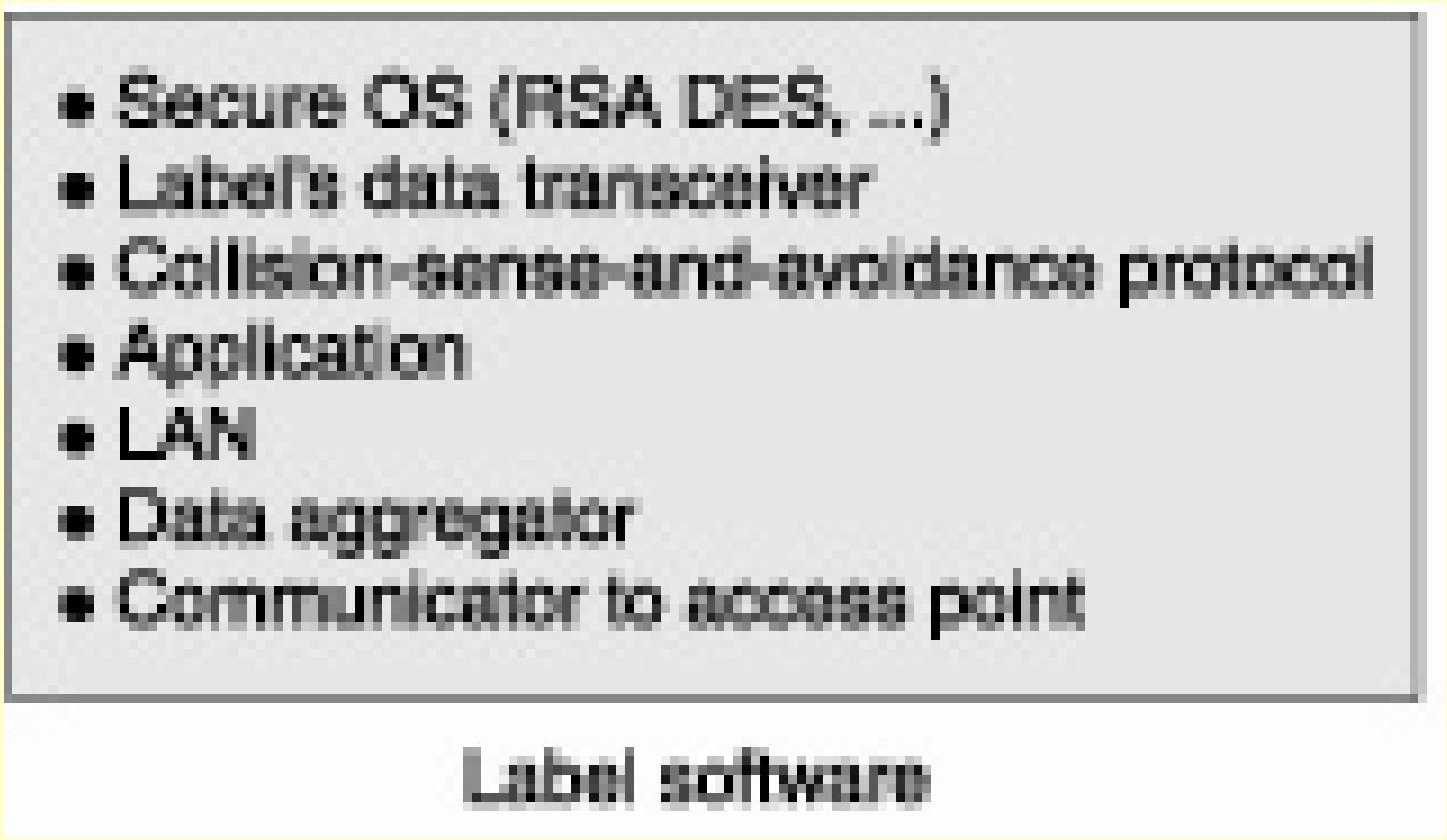
Software in label



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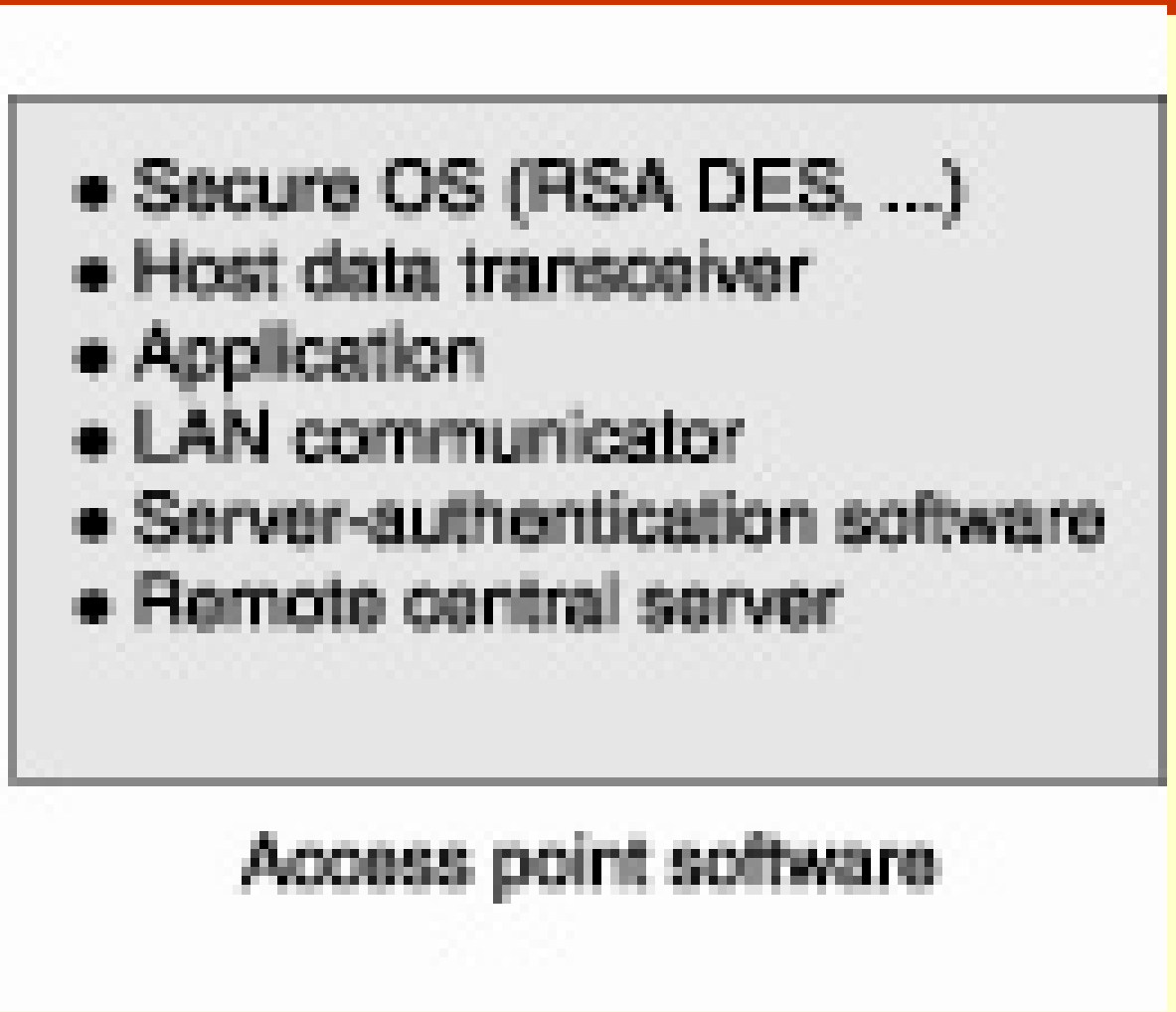
Access point software for label



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Smart Labels Network

- Networked together using a central reading and computational device (host) or PC
- Cluster of labels form a network similar to a LAN network
- Collision-sense-and-avoidance protocol used so that multiple labels are not allocated the same ID tag and the central server can uniquely identify each one

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Smart Labels

- Use secured hardware and server-authentication software
- The central server also detect the removal of a labelled product or packet from a product-shelf and raises alarm in case the product does not reach the destined point, for example the cash counter in a store

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RFID automatic identification method

- Remote storage and retrieval of data on RFID tags
- RFID tags are objects that when tagged (attached) onto people, products, or animals enable their identification using radio waves from a nearby source
- RFID tags or labels contain integrated circuit chips and antennas.

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RFID computations and Data transfer rates

- Usually limited to transmission of the tags' contents
- Data transfer rates of up to 115 kbps with signals from 915 MHz, 868 MHz (at the higher end of the spectrum to 315 MHz and 27 MHz (at the lower end of the spectrum)

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RFID tag

- Each one monitored by a hotspot in the vicinity of the tag
- A line-of-sight access
- The hotspot computer and wireless transceivers transmits and receive signals from the RFID tags

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RFID tag hotspots

- The hotspots connect to the Internet through a leased line, wireless, or mobile services.
- A mobile device or PC with a wireless interface is programmed to function as the hotspot.

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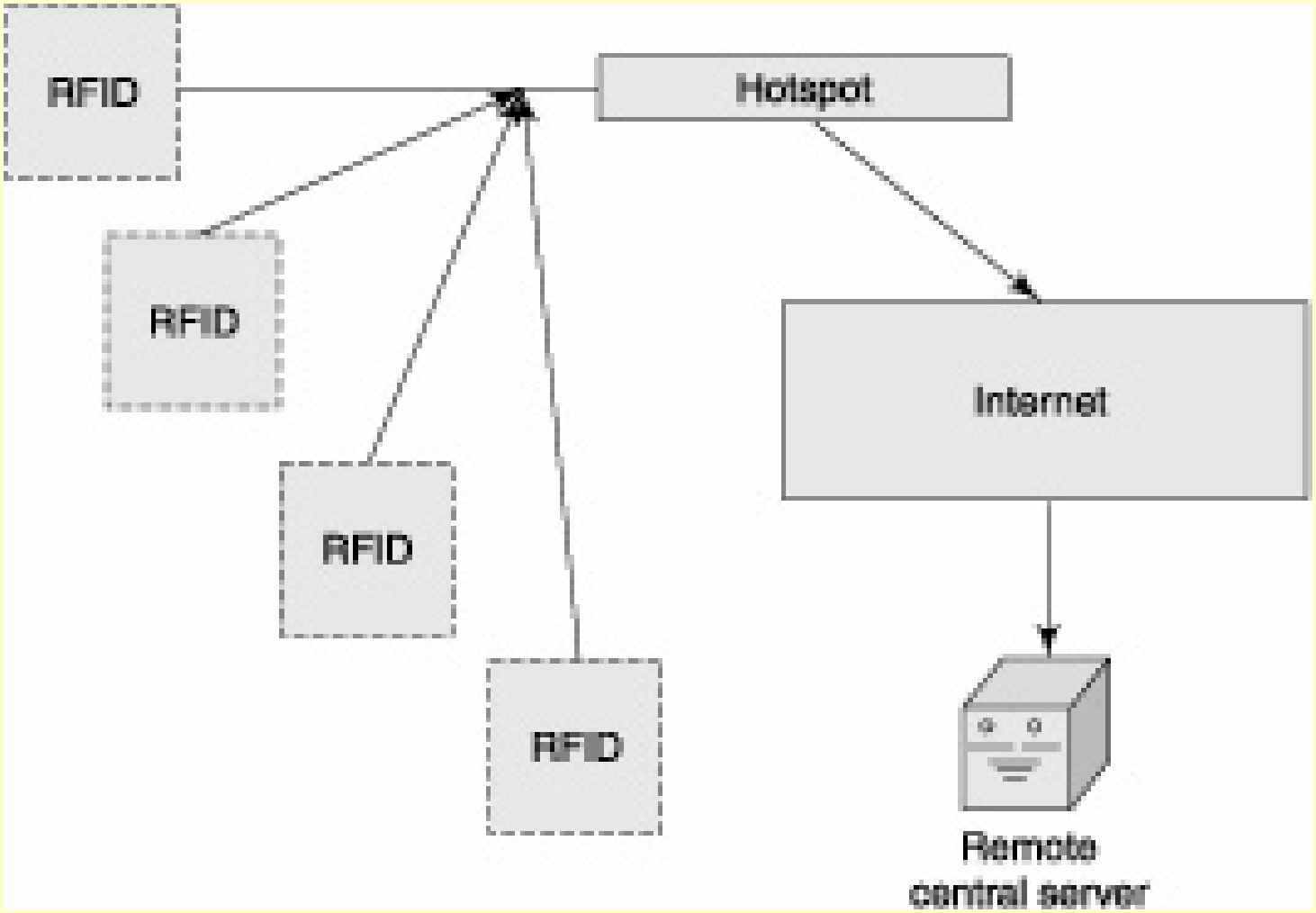
RFID and Hot spot



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Smart Token

- Used for authentication purposes before an action, such as granting entry into a restricted area, is initiated
- A smart token— an encapsulated chip including an embedded processor and a memory
- Token sizes small, usually of the order of a shirt button or a pen nib

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Smart Token Protocols

- Use either a wire-based protocol and communicate at 16 to 128 kbps or ASK 13.56 Mbps for contact-less communication.

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Token Applications

- A smart token for granting permissions to employees to enter a work place.
- A smart token to remotely open the car doors

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Token Applications

- Defence departments can accept only authenticated parcels.
- A smart token in a button form concealed within a parcel and used for authentication of supplies sent to defence departments

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Summary

- Smart Label computer , memory and transceiver
- Network of labels
- Hotspot
- RFIDs
- Tokens

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End of Lesson 04

Smart Systems– Labels, RFID and tokens

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Mobile Devices and Systems

Lesson 06
Limitations of Mobile Devices and Systems

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Quality of Service constraints

- Technical restrictions and practical considerations— difficulties in mobile device uninterrupted operations
- Maintaining quality of service along with the provisioning of seamless access to all users

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Accessibility constraints

- Smart labels on packages limited access– transmitted signals low power
- Labels can only be read from very short ranges

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Accessibility constraints

- RFID access limited to ranges within line of sight
- RFID transmissions require hotspots close by due to low transmitted signal strength. (A hotspot is an access point an interface for mobile systems, sensing systems, and embedded systems to connect to a mobile network, wireless LAN, or the Internet.)

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Range Constraint

- Signal strength inversely proportional to the square of the distance
- Degradation of signal quality due to reflection, scattering, and diffraction

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Range Constraint

- Access range limited to the range up to which the signal strength is such that it can be separated from the noise
- Up to which multi-path delays can be compensated for by digital signal processing techniques to restore signal quality

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Connectivity

- Connectivity loss or intermittent connectivity in certain situations
- The atmospheric conditions changes in environment affect signal strength
- Water attenuation of UHF and near microwave
- For example, in the event of heavy rain, there may be complete loss of connectivity

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Security Constraints

- Unsolicited advertisements and unwanted messages
- Virus attacks
- Hackers render it functionless or threaten integrity and security of the data stored on the device
- Noise signals transmitted by an attacker can jam a mobile device

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Security Constraints

- Repeated transmission of unwanted signals by an attacker can drain the resources of the device
- Energy resources depleted fast when computations are forced and authentication algorithms are run repeatedly

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Mobility constraints

- *Non-availability of an access point* or base station
- Infrastructural issues
- No base stations or Wi-Fi hotspots providing connectivity and access to the Internet to sensors, labels, automotive systems, RFID tags, and cell phones

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Mobility constraints

- Use of different standards in different regions limits the operability
- a GSM phone may not be operable in all continents hence hampering global roaming for the user
- Some service providers may not be able to provide connectivity in all parts of the country or in other continents, etc.

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Energy Constraints in Devices

- Limited energy in battery
- Battery size and power limited due to considerations such as size, weight, and bulk of mobile devices
- The devices need to be recharged after short periods of time. In this way energy availability also limits device mobility.
- Some devices such as smart cards, smart labels, remote sensors, and actuators do not even have a battery of their own. They derive their energy from the radiation received from a wireless source in vicinity. Such devices, therefore, require these sources to operate

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Energy Constraints in Devices

- Some devices such as smart cards, smart labels, remote sensors, and actuators do not have a battery of their own.
- They derive their energy from the radiation received from a wireless source in vicinity.
- Such devices require these sources

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Mobile Computing Strategy in view of constraints

- Processor circuit dissipates higher energy when its clock frequency higher
- Computational speed higher at higher clock frequency
- A device is, therefore, programmed so that only computations such as graphic image processing run at full processor speed

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Mobile Computing Strategy in view of constraints

- The clock frequency reduced for the other computations to save power.
- The clock is activated only when a device interrupts or starts processing instructions.
- Many innovative mobile computing strategies adopted to mitigate the effects of energy constraints on mobile computing

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Mobile Computing Strategy in view of constraints

- Use ZomBee protocol– a lesser stack size as compared to Bluetooth so less energy dissipation due to lesser computational requirements
- Use of a communication protocol that has less protocol stack overheads reduces the energy requirement.

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Mobile Computing Strategy in view of constraints

- When a host or hotspot seek certain data from a device frequently, program adapts itself so that the frequently required data is calculated and stored in a buffer from where it can be sent at slow clock frequencies on demand from the host
- A program can also just transmit any changes in the data with respect to previous data

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Mobile Computing Strategy in view of constraints

- Communication scheduling strategies are adopted
- Frequently required data transmitted as per a schedule
- This saves the host energy which would otherwise be required for sending commands and also saves the devices energy that would be dissipated in processing the commands

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Processor Design

- Innovative circuits of mobile device processors have been designed and are continuously improved upon so that the same program instructions process with lesser energy dissipation per unit computational speed
- Examples of energy efficient processors—ARM and TigerSharc

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Transceiver Design and Programming Strategy

- Designed such that signals of just sufficient strengths transmitted to the receiver
- Just sufficient strength means that the signal strength is low but clearly distinguishes noise and maintains message integrity

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Transceiver Design and Programming Strategy

- Control commands from the host are sent at lower signal frequencies
- Once the device is ready and gets powered up, the transceiver transmits the data for operation
- Multi-hop routing– reduce the distance up to which a signal is required to travel

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Hardware Limitations

- Constraints on memory
- Innovative forms of memory designed and are continuously improved upon.
- Internal flash drives and the card slots for external memory used

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Hardware Limitations

- Memory stick used to enhance the memory in the device
- Large memory capacity– 30GB video memory in mobile devices in a recent enhancement of the Apple iPod

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Bandwidth Constraints

- Limited by the frequency spectrum that a regulator allots to a service provider
- The service must use the frequency spectrum allotted to it in an efficient manner

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Bandwidth Constraints

- Multiplexing and coding techniques help in achieving efficient transmission.
- The technology in use also limits the spectrum efficiency
- For example, CDMA has higher spectrum efficiency as compared to GSM

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Bandwidth Constraints

- Limited bandwidth
- An obstacle to seamless connectivity and quality of signals aired, when a large number of mobile devices simultaneously demand network connectivity

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Summary

- Number of constraints in mobile devices and systems
- Quality of service
- Security
- Connectivity
- Accessibility
- Range

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Summary

- Energy dissipation and availability
- Memory
- Hardware
- Appropriate computing and communication strategy

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End of Lesson 06
Limitations of Mobile Devices and Systems

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Mobile Devices and Systems

Lesson 07
Automotive Systems

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Automotive Systems since the late 1960s

- Extensive use of computing and processing units for Car engines control, automobile stability, transmission and braking processes, driving comfort and ease

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Recently revolution in automotive systems

- Sophisticated information oriented technology
- GPS navigation
- Reverse sensing and night vision
- Communication systems

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Recently revolution in automotive systems

- Voice control
- Speech Recognition
- Traffic congestion information
- Smart card security control
- Collision avoidance sensors

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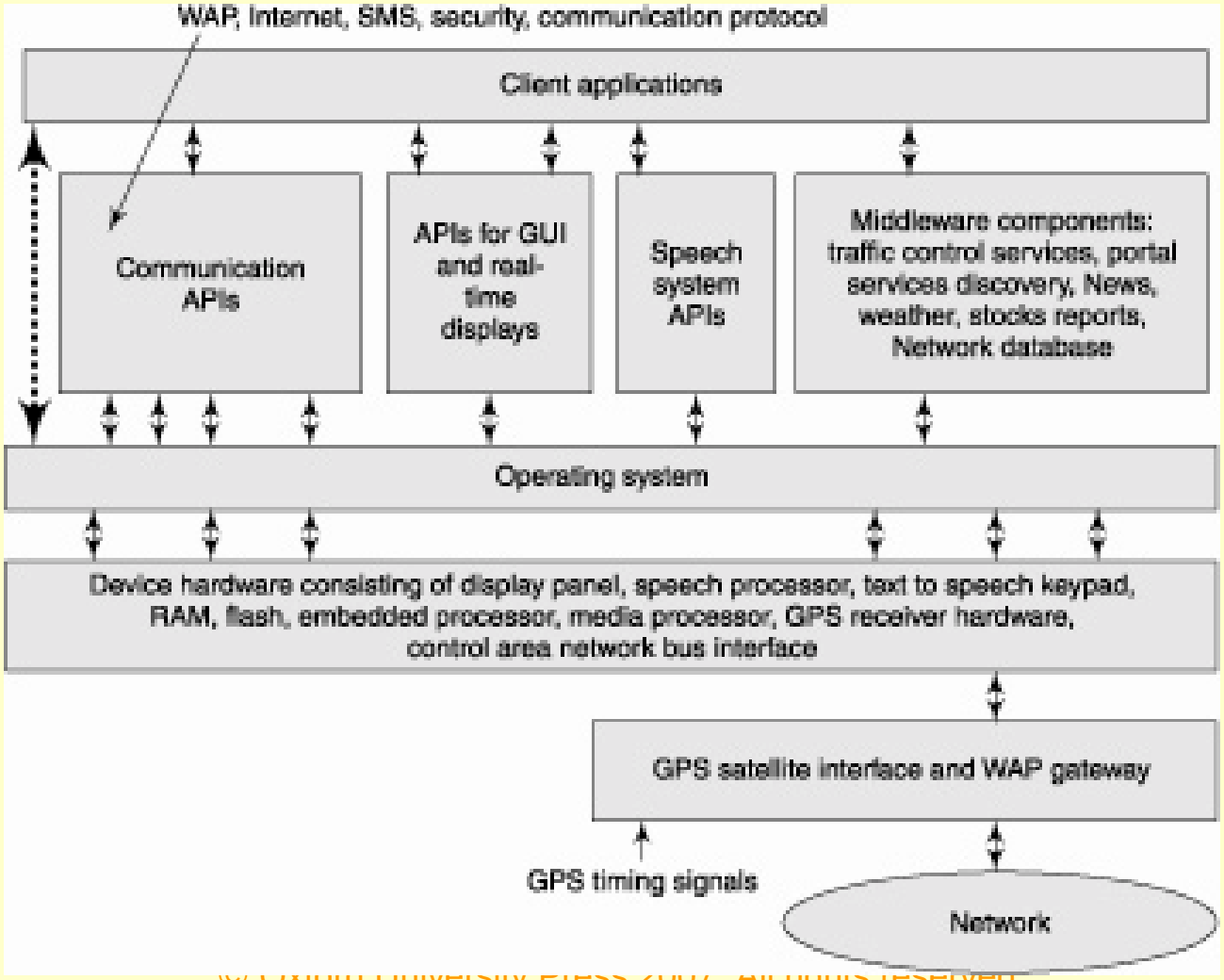
Mobile computing architecture in an automobile



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Programming Languages

- Use Java, ASP, and JSP for web based applications and retrieval of data from databases at various portals
- For example, while driving towards the airport a user can retrieve flight information from the airline's portal

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Speech Recognition System (SRS)

- Automobile start by the driver's commands after recognizing their voice through the SRS
- Application software can be programmed such that the driver can command the automobile to halt, maintain the current speed, or stay under a given speed limit
- The SRS uses a digital signal processor

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Messaging System

- WAP (wireless application protocol) device in an automobile enable connection to the Internet
- A service provider can transmit, in real time, the news, weather data, and stock reports.

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Traffic reports System

- Traffic control service sends traffic reports
- Automobile owner can subscribe to a traffic control service provider which provides SMS messages about traffic slowdowns and blockages at various points in the city

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Traffic reports system

- Traffic messages then converted to speech using a text to speech (TTS) converter software and can be heard by the driver
- It enables the driver to select roads that will provide a faster, hurdle-free passage

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Text to speech (TTS)

- Use C in Linux for converting an SMS text to speech (TTS)
- Driver need not divert their attention to read the text on the display panel
- Can, instead, listen to the received message while driving

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Anti-collision system

- Warn the driver if the automobile gets too close to another
- Also sense objects which are not visible to the driver using a laser, infrared, or RADAR system
- Collision avoidance systems take control of the vehicle to avoid colliding with other objects

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Global positioning (GPS) System

- Also called geographical positioning system)
- Automobile can be fitted with GPS receiver
- Receives signals transmitted by various GPS satellites orbiting the earth
- Timing circuits of all satellites are in synchronization
- Each signal carries this time information

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Global positioning (GPS) System

- Let us assume that the time information from the i^{th} satellite is t_{0i}
- Each satellite signal will have a different value for t_{direct}
- $t_{direct(i)}$ for the i^{th} satellite
- Receiver will receive the signal at time t = $t_{0i} + t_{direct(i)}$
- Reads t_{0i} from the time information in the signal

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Global positioning (GPS) System

- Calculates $t_{direct(i)}$ from t and t_{0i}.
- At an instant, at least three GPS satellites are in view of any location on the globe.
- The values, $t_{direct(i)}$, $t_{direct(j)}$, $t_{direct(k)}$, …, for the i, j, k, ... satellites give the present geographical position of the automobile

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Geographical position Message

- Geographical position continuously marked on a map on a display-panel
- Helps the driver in choosing the right path to the destination
- A data-to-speech converter application software can also be used to speak aloud the name of the current position

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Application programming for the position and changes in the map

- Use GTK (graphic tool kit) language or C in Linux for drawing, in real time, the road map on the display panel with the automobile's position suitably marked on the map on a real-time basis
- Changes the map on the screen in case the automobile moves into another zone
- Continuously shifts the marked position as the automobile moves

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Automobile Start and Malfunction Logins

- Smart card or smart token to start the automobile
- The card inserted into the host not only starts the car but also logs the data for the malfunctions recorded during driving.
- At the service workshop, a card reader reads the card and retrieves the logged data as well as the service history details

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Automobile Malfunction Logins

- The workshop can render a more efficient service using this information
- The service provider's PC writes the details of the service provided onto the card memory for future reference
- JavaCard used for developing the start and malfunction logging applications

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Sensor and Actuator Programming

- Number of sensors and actuators
- For example, pressure sensors
- Sensors communicate, to the display panel, warnings about tyre pressures
- Sensors and actuators connect to the CAN bus

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Entertainment Systems in Automotive

- A number of entertainment systems, for example, FM radio, media players to play Wave (WAV), RealAudio (RA), and MPEG-1 Audio Layer 3 (MP3) files
- Programs for downloading music from the Internet in formats such as WAV, RA, and MP3 using a WAP gateway

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Entertainment Systems in Automotive

- A USB port can be used to download files from another system.
- A Bluetooth device used to download data from PDAs, smart phones, and pocket PCs

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Real-time applications

- Windows CE OS functions for the multiple threads and networking and communication protocol APIs
- Real-time applications for the Java platform can also be developed using OSEK

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Summary

- Automotive systems
- Collision control
- Messaging systems
- TTS
- GPS, position and maps on screen
- Traffic reports
- Malfunction logins

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End of Lesson 07
Automotive Systems

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GSM and Similar Architectures

Lesson 01

GSM Services

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Global system for mobile communications (GSM)

- A mobile communication standard
- GSM communication– uses cellular networks
- The GSM standard operates in the frequency ranges of 900, 1800, and 1900 MHz

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Global system for mobile communications (GSM)

- Tri-band (operable in GSM 900/1800/1900) phones enable easy international roaming in GSM networks
- GSM– a second generation (2G) communication standard

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Three types of integrated services for voice and data

- Teleservices
- Supplementary services
- Bearer services

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Teleservices

Teleservices
(Point-to-point cellular broadcast)

- Telephone/fax
- Voice full 13 kbps
- SMS up to 160 characters
- Emergency number 112
- MMS—GIF, JPG, WBMP
- Teletext
- Videotext access
- Fax group 3

Half data rate speech
Enhanced full rate speech
Can be implemented differently

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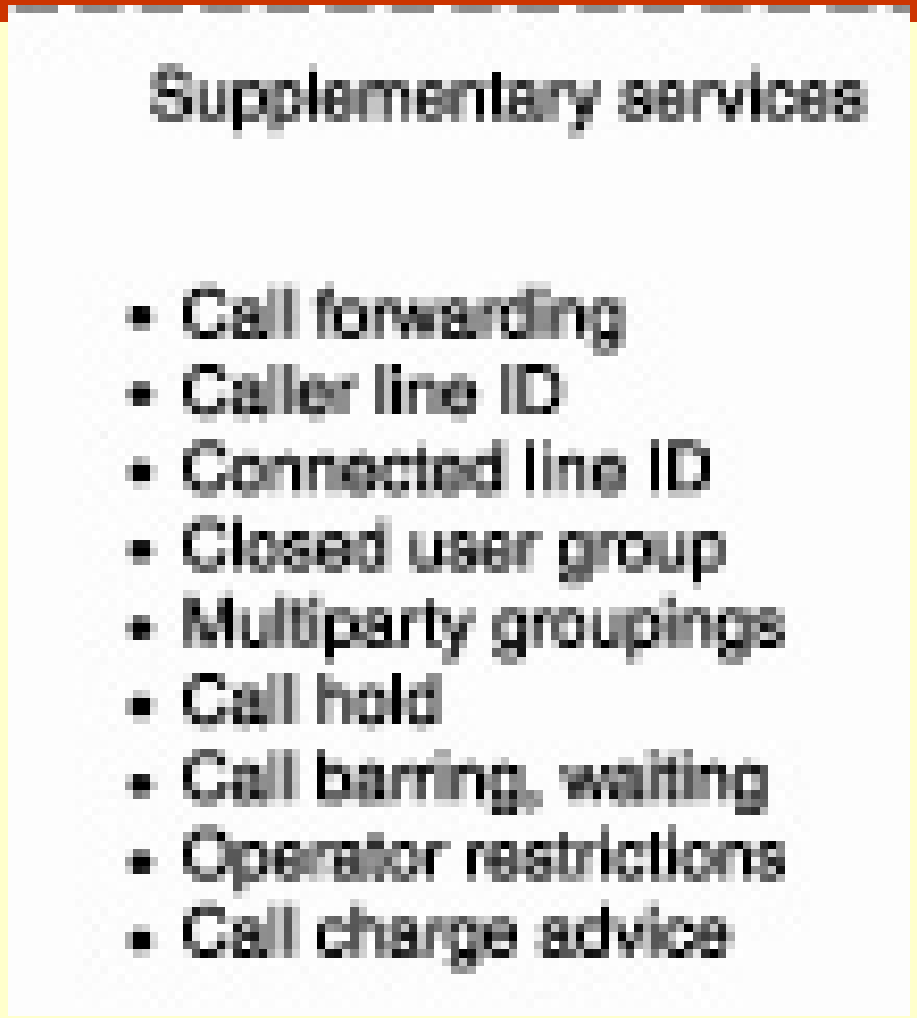
Supplementary services



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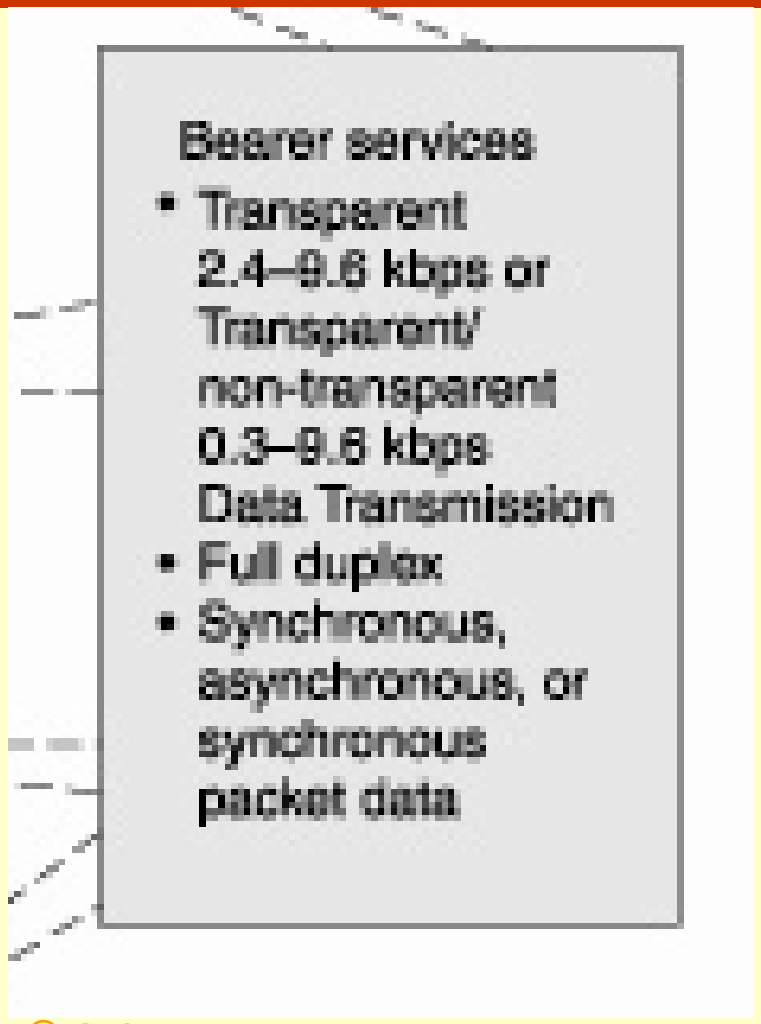
Bearer services



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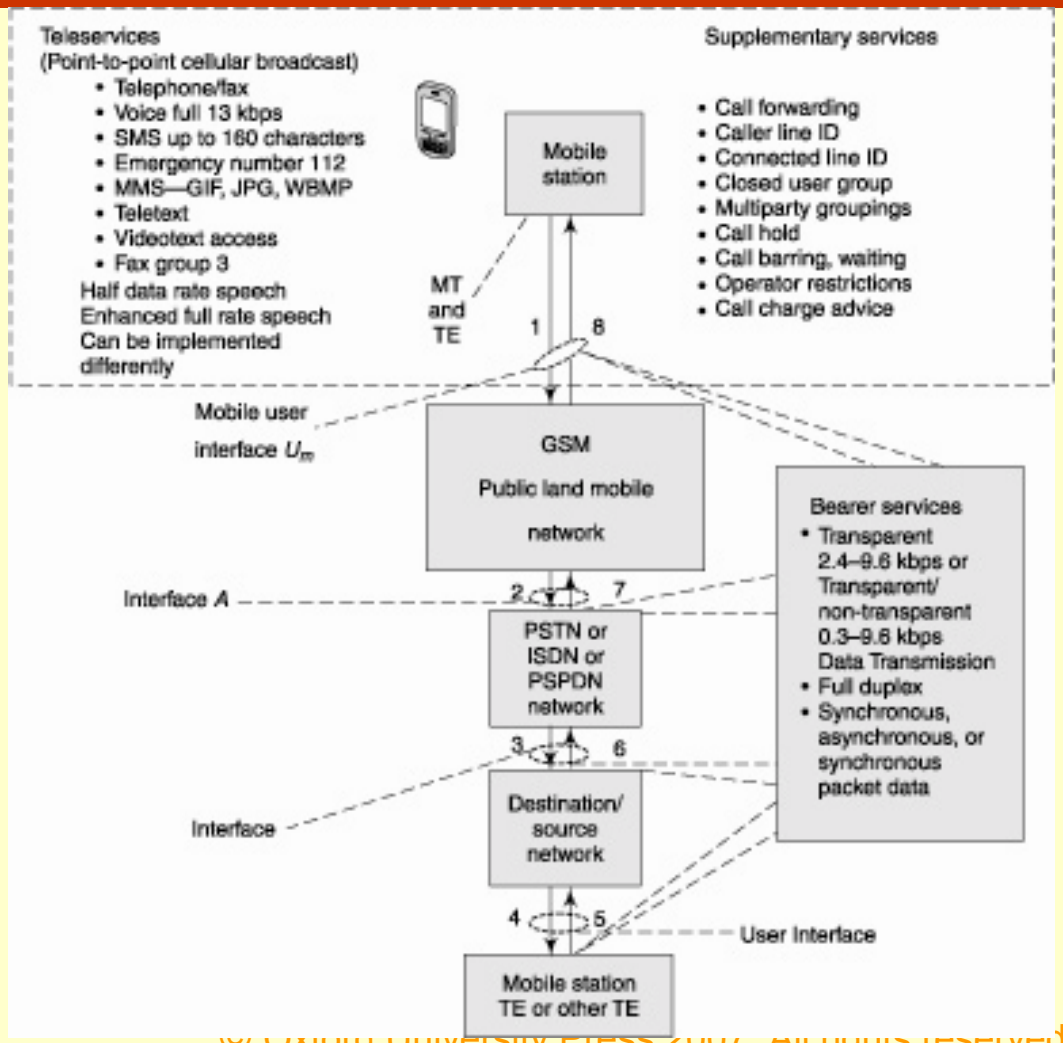
Integration of teleservices, bearer services, and supplementary services



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Connection

- Establishes between two TEs—the source and the destination
- The destination TE may or may not belong to a GSM network

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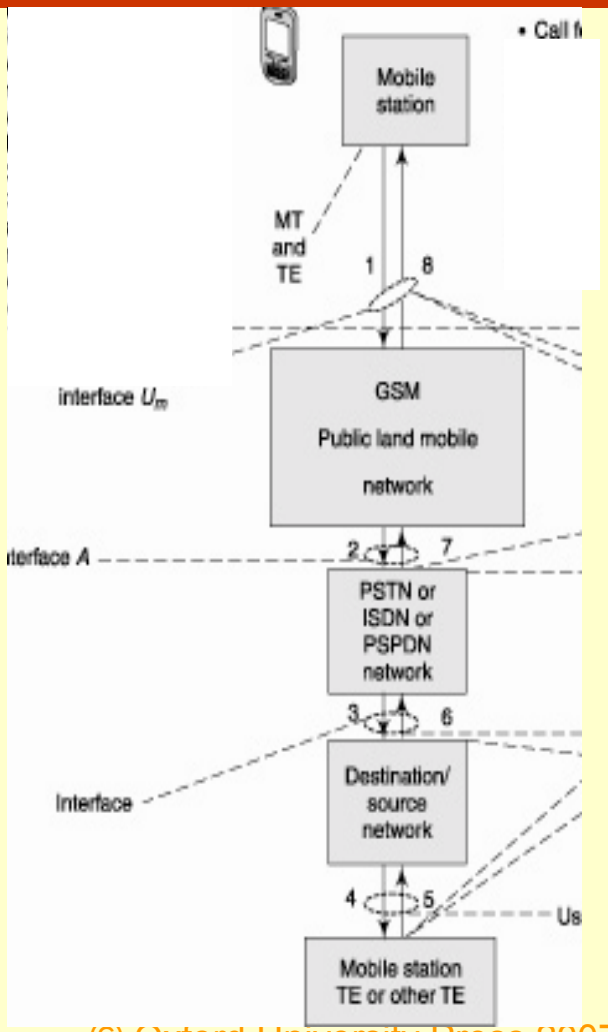
Connection between two terminal equipments or mobile terminals



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Interfaces

- A mobile terminal acts as an interface between a communications network (for example, interface between the GSM public land mobile network) and terminal, TE — the source or destination of the service
- The TE used by a caller to connect and talk (communicate) and MT for mobile communication

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Connection

- Depends on the source–destination network which may be a GSM, PSTN (public switched telephone network), ISDN (integrated services digital network), PSPDN (public switched public data network), or any other network carrying the data to the end-point TE

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Connection from caller

- A caller TE transmits through interface 1 to a GSM public land mobile network
- Through 2 to a PSTN network
- Through 3 to a source–destination network
- Through 4 to a terminal or mobile station TE
- In place of the PSTN network, there may be an ISDN or PSPDN network

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Connection from called TE to caller MT

- The connected TE communicates back by transmitting through interfaces 5, 6, 7, and 8

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Sets of the Interfaces

- Four sets of interfaces (1, 8), (2, 7), (3, 6), and (4, 5). There is a transceiver in each set
- The symbol U_m (user mobile interface) conventionally denotes the interface (1, 8)
- Symbol *A* denotes a mobile network interface (2, 7) to a PSTN or other wired network

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Four transceivers

- Transmit as well as receive in full duplex mode
- Full duplex mode means simultaneous two-way transmission
- The MT interface can also be half-duplex transmission
- Half duplex means that two-way transmission possible but not both ways at the same time

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Teleservices

- Services offered by a mobile-service network to a caller (TE)
- Ttelephonic-voice at full data rate (13.4 kbps)
- Fax
- SMS
- Emergency number 112 for emergency calls

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Teleservices

- MMS [supporting GIF, JPG, WBMP, teletext, and videotext access (GIF, JPG, and WBMP are formats of files that store pictures)]
- Point-to-point — from a TE to another TE
- A point-to-point service is implemented using cellular communication

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Additional teleservices (introduced in phase 2 of GSM)

- Half data-rate speech or enhanced full-rate speech services, and these may or may not be rendered by cellular and point-to-point access systems
- A GSM smart phone, which connects to a GSM public land mobile network

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Additional teleservices

- A number of teleservices including phone, voice data (for example, recorded message played on auto-answer of incoming calls), SMS, and MMS to another GSM or PSTN network

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Phase 2 Supplementary Services

- Caller line forwarding (redirection), caller line identification
- Line identification to the caller
- Closed user group formation
- Multiparty groupings (e.g., in an enterprise)
- Call holding, call waiting, and barring calls from specified numbers or groups

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Phase 2 Supplementary Services

- Restricted provisioning of certain services to the users
- Internet and email access granted on special requests from users)
- Providing information regarding call charges, remaining phone account balance, etc

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Bearer services

- Transmission of data (voice signals are also transmitted as data) between two user network interfaces [(1,8) and (4,5) using the intermediate interfaces [(2,7) and (3,6)] at a mobile network

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Bearer

- Means a set of data which is transmitted from or received by a TE i.e., the voice-data or data set that has been formatted in certain specified formats
- This data transmits at certain standardized rates through the interfaces

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Bearer

- Voice-data– data that is obtained after digitizing, coding, encoding, appending error detection and correction bits, and encrypting of a voice signal

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Bearer Services

- Each TE has a user interface
- The interface (1, 8) of a mobile station connects the MT to a GSM public land mobile network
- The interface (4, 5) of a PSTN phone connects to a PSTN network

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Bearer Services

- An intermediate PSTN network acts as an interface for a GSM public land mobile network
- In place of PSTN, there may be ISDN, PSPDN, or some other network

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Bearer service (service through the interfaces)

(a) transparent and uses data rates of 2.4 kbps, 4.8 kbps, or 9.6 kbps or

(b) non-transparent and uses lower data rates (300 bps to 9.6 kbps

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Bearer services classification

- Synchronous data transfer
- Asynchronous data transfer
- Synchronous data packet transfer

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Summary

- GSM 900/1800/1900 bands
- Teleservices
- Supplementary services
- Bearer services
- Connection using interfaces
- Four type of interfaces

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End of Lesson 01

GSM Services

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GSM and Similar Architectures

Lesson 02
Data transmission

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Data Transfer

- Transparent
- Non transparent

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Transparent Data transfer

- Means that the interface for the service is using only physical layer protocol
- Physical layer means the layer which transmits or receives data after formatting or multiplexing using a wired (wire or fibre) or wireless (radio or microwave) medium
- The physical layer protocol in a GSM bearer service– provides for FEC (forward error correction)

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FEC

- Entails insertion of redundant bits along with the data to be transmitted
- Redundant data allows the receiver to detect and correct errors

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No Handshaking in Transparent Data transfer

- Handshaking refers to interchange of acknowledgements between two networks or systems once the connection is established between them
- Provisioning for acknowledgement from data-link or higher layer at receiver and then appropriate action by transmitter data-link or higher layer

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FEC

- Also enables broadcast to multiple destinations from a single source
- Advantageous in situations where retransmission is not convenient though requires higher bandwidths– more bits per s
- Helps in broadcasting without handshaking though FEC transmission reduces data rate

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Reduction in data rate with *m* redundant bits appended in a data stream of *n bits*

- Total numbers of data bits transmitted from the sender's end = (*n* + *m*) bits
- At the receiving end, an algorithm employed to detect and correct transmission errors (error means 0 received as 1 or 1 received as 0)

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Reduction in data rate with *m* redundant bits appended in a data stream of *n bits*

- The algorithm extracts the original *n* bit streams from the received (*n* + *m*) bit sequences
- Therefore, for every (*n* + *m*) bits sent by the sender, the receiver receives only *n* bits of actual data
- Means that if the transmission channel offers a data rate *r*, then the actual data transmission rate with FEC is $r \times n \div (n + m)$

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Non-transparent Data transfer

- When data transmits at GSM 9.6 kbps the data error rates are high
- This is because when non-transparent data is transmitted at GSM 9.6 kbps, there is no retransmission and erroneous data just gets rejected
- Data above 9.6 kbps, non-transparent data-transfer used

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Non-transparent Data transfer

- Non-transparent means the service interface uses physical layer or special physical layer radio-link protocol or data link layer, and flow control layer protocols

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Protocols for data link and flow control layers

- Provide for (i) error detection and correction and (ii) selecting, rejecting, and re-transmitting the data, respectively

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Data link layer

- Data link layer the layer which frames the data and appends additional bits plus performing other functions
- Framing refers to combining and appending additional bits and header

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Flow control layer (Network layer)

- Flow control layer controls the flow of data by selecting or rejecting erroneous data transmitted and by re-transmitting erroneous data

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Data error rate

- Becomes negligibly small at slow data rates (300 bps)
- Because when non-transparent data transmits at 300 bps, then the erroneous data is corrected or gets retransmitted at data link and flow control layers

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Data error rate

- A special error correction facility called RLP (radio link protocol), used in GSM networks, is an example of a non-transparent communication protocol
- RLP results in more robust transmission with very small BER (bit error rate)

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Special error correction facility– RLP (radio link protocol) in GSM networks

- A non-transparent communication protocol
- Results in more robust transmission
- Very small BER

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Data transmission

- Synchronous data transfer
- Asynchronous data transfer
- Synchronous data packet transfer

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Synchronous data transmission

- Data transmitted from a transceiver at a fixed rate
- Constant phase differences (and thus time intervals) maintained between data bursts or frames
- Receiver must synchronize the clock rate according to the incoming data bit rate

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Synchronous data transmission

- Receiver also synchronize data bits coming in from multiple paths or stations and compensate for the varied delays in received signals
- Handshaking is not required in synchronous transmission of data
- Synchronous data transmission fast
- No waiting period during data transfer

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Examples of synchronous data transfer in a GSM system

- Voice converted into bits after coding in a GSM system and the bits are transferred at data rates of 13 kbps as synchronous data
- There are no in-between acknowledgements or waiting periods in this faithful transmission of bits

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Examples of synchronous data transfer in a GSM system

- An SMS is transmitted through a GSM channel as synchronous data
- There are no in-between acknowledgements and any transmission errors are corrected using FEC

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Asynchronous data transmission

- Data transmitted by the transceiver at variable rates and constant time intervals are not maintained between consecutive bursts or frames
- There is usually handshaking or acknowledgement of data in asynchronous data transfer

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Asynchronous data transmission

- But even if there is no acknowledgement, data flow maintained by using the FEC plus buffers can still be asynchronous
- Use of buffers causes variable delays in reception

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Examples of acknowledgement messages

- *receiver ready*
- *receiver not ready*
- unnumbered acknowledgement of acceptance of data at the receiver, rejects, set asynchronous balance mode, or disconnect
- Program files containing middleware for mobile devices have to be transmitted by the mobile service while maintaining full data integrity

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Examples of acknowledgement messages

- In file transfer cases the in-between acknowledgements of faithful transmission of bits and reporting of errors during transmission important
- Non-transparent Flow

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Examples of acknowledgement messages

- An acknowledgement is sent by the receiver for each data set to the effect that the data set received is identical to the one transmitted
- Time is, therefore, spent in implementing appropriate algorithms for data set integrity checks and acknowledgements
- This results in asynchronous data transmission

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Synchronous packet transmission

- After formation of packets
- Different packets transmitted through different interfaces, routes, channels, or time-slots to reach a common destination
- At the destination, various packets are arranged in their original sequence

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Synchronous packet transmission

- A sequence number transmitted along with each packet helps in sequential arrangement of packets at the receiver
- Each packet flow transmitted as synchronous data
- There is no handshaking or acknowledgement of the data during the flow of packets

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Example

- *N* bits of data are to be transmitted as packet switched data
- The packets can have a maximum of *n* bits each
- The data transmission rate is $n \div T$
- The time taken to complete the synchronous packet transmission = $(T \div n) \times n$ = T

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Example Data transmission formatted into 4 packets *A*, *B*, *C*, and *D*

- Assume three different routes are available for transmission
- 2× T [1 T for three packets by three routes at the same instance and 1 T when fourth packet transmits separately when $N > 3 \times n$
- To transmit the same data through one single path time taken = $4 \times T$

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Summary

- Transparent data in which only physical layer used, no handshaking or acknowledgement or flow control
- Non Transparent data in which physical layer or special Radio Link Protocol or data link plus higher layer used, also used handshaking or acknowledgement or flow control

...

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… Summary

- Synchronous data transfer with constant phase differences between bits and frames
- Asynchronous data transfer use varying phase differences between frames and when using handshaking or acknowledgement or controlled data flow
- Synchronous data packet transfer

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End of Lesson 06

Data transmission

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GSM and Similar Architectures

Lesson 03

GSM System Architecture

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Mobile communication using base station in cellular networks

- A mobile station, MS, communicates with a GSM public land mobile network (PLMN)
- In turn, may connect to a PSTN network
- The PSTN connects to a source–destination network which acts as an interface for the destination terminal, TE

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GSM network architecture

- Radio subsystem (RSS)
- Network subsystem (NSS)
- Operation subsystem (OSS)

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Mobile Station (MS)

- A mobile device or phone
- Connects to the GSM network
- Radio transmission system used in mobile phones)

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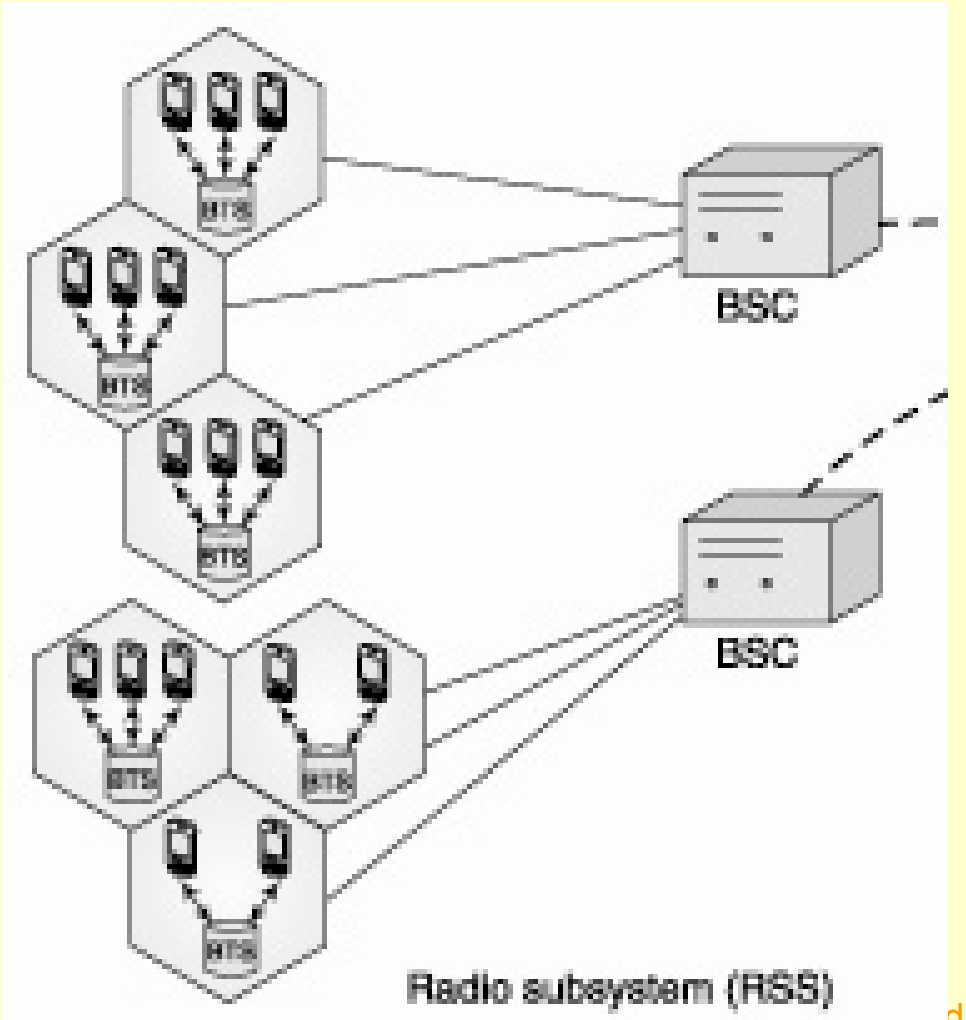
RSS



d.

Mobile Station (MS)

- Hardware and software to transmit and receive GSM data, and a user terminal (TE) through which the user receives and sends the data
- Transmits through the interface *Um* (Fig. 3.6) at a power of 1–2 W

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RSS

- Consists of a number of base station controllers (BSC)
- Each BSC connects to a number of base transceiver stations (BTS) which, in turn, provide radio interfaces for mobile devices

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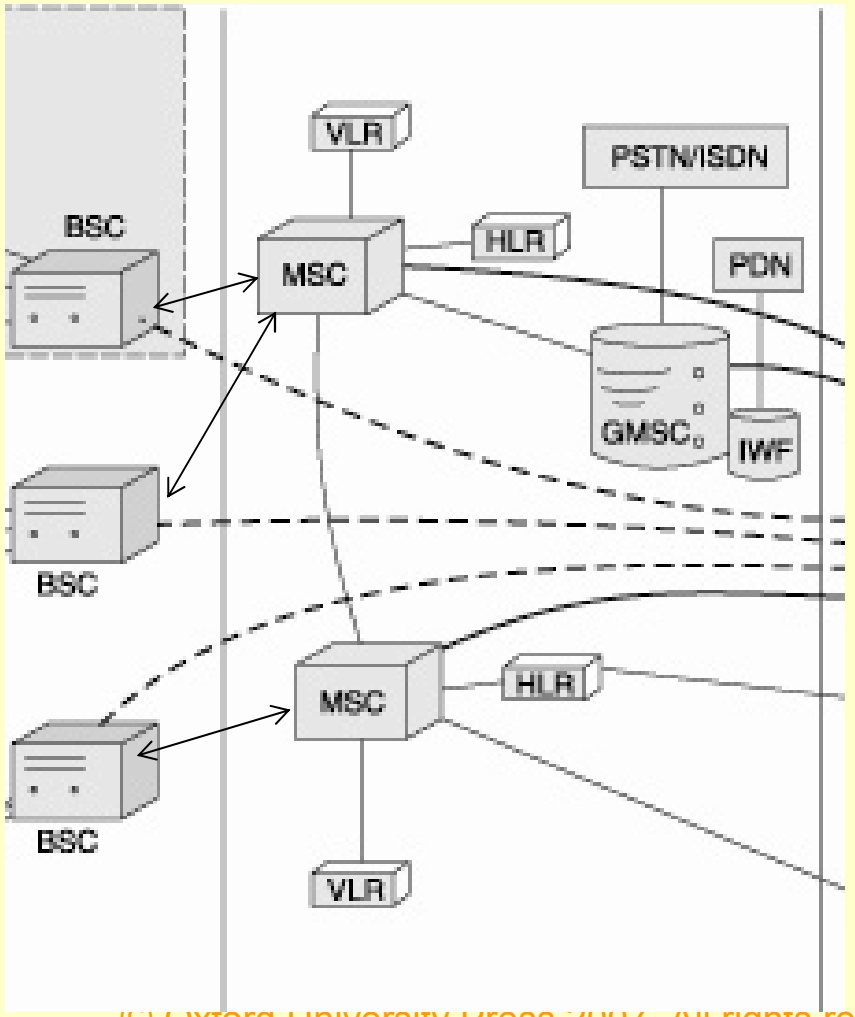
NSS



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NSS

- Consists of a number of mobile services switching centres (MSC)
- Each MSC of the NSS interfaces to a number of BSCs in the RSS
- Home location registers (HLR)
- Visitor location registers (VLR)

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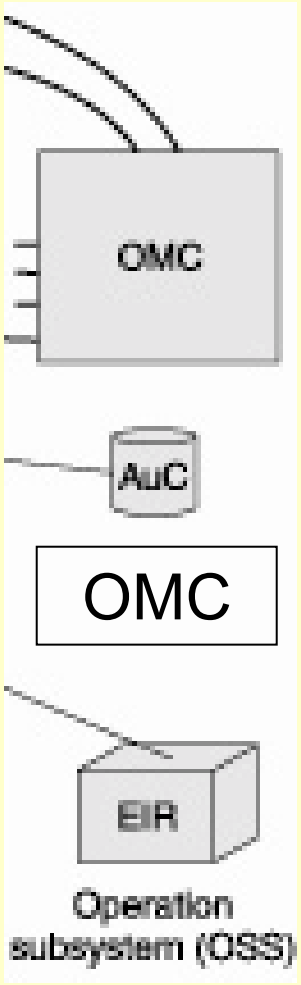
OSS



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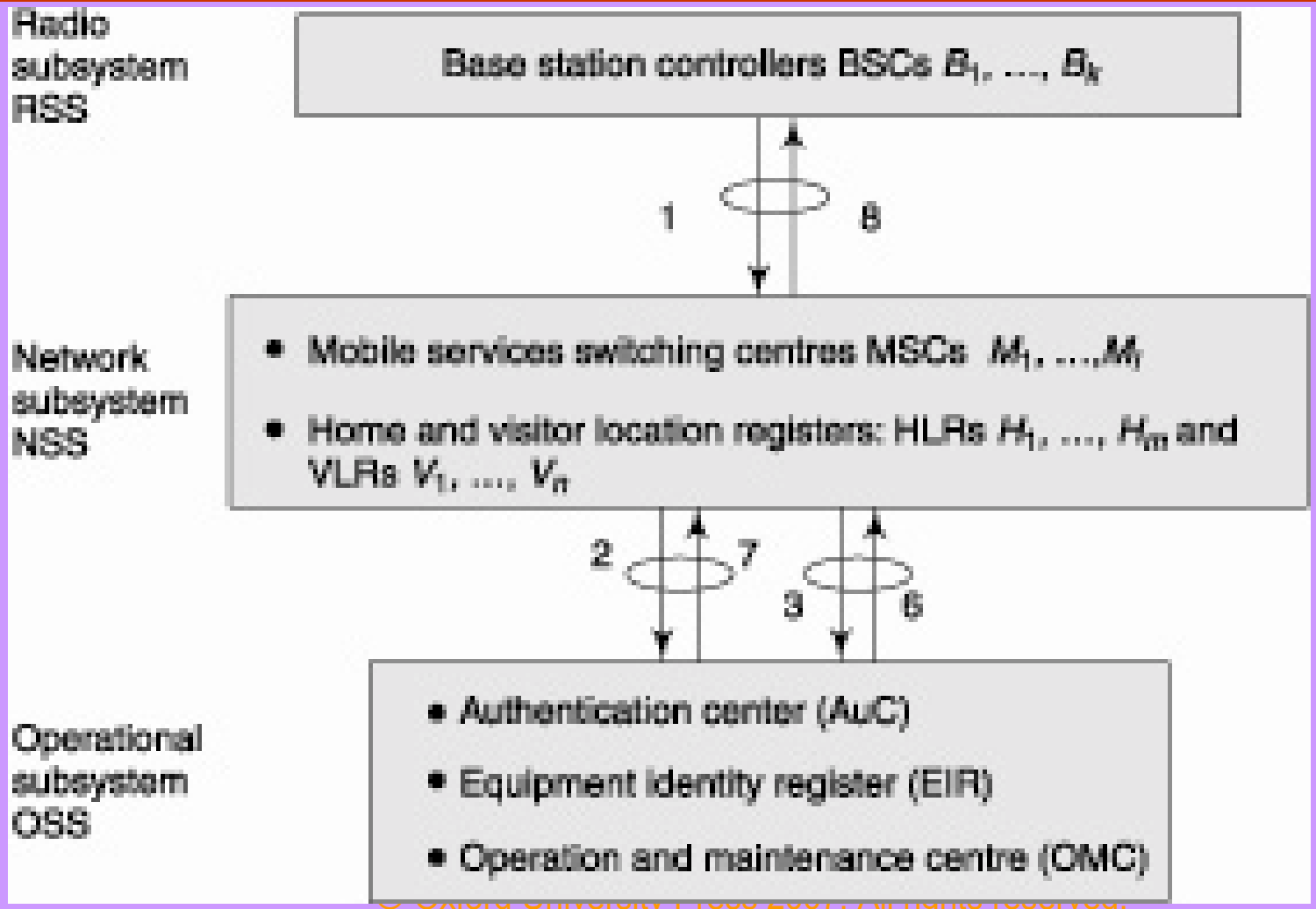
Interfacing between the three subsystems in a GSM network



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Mobile Communication from the MS

- When a mobile station MS_x communicates to another mobile station MS_y, a switching center MSC_i establishes (switches) a connection (channel) between (i) MS_x interfaced to the BTS_p, then to the BSC_q, then to MSC_r and (ii) MS_y interfaced to the BTS_u, BSC_V, and MSC_w

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GSM System communication

- RSS and NSS for communication
- MSCs must have location registries to enable the NSS to discover a path (route or channel) between MS*x* and MS*y*
- The OSS facilitates the operations of MSCs

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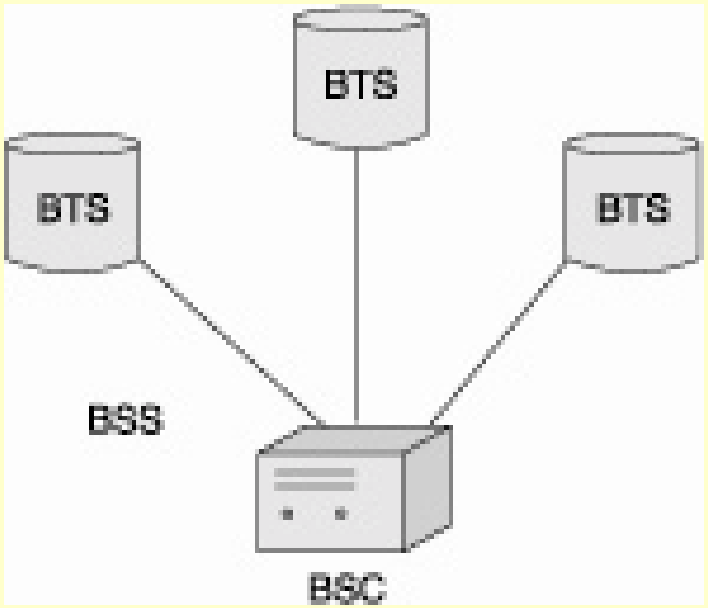
Base station system in a cellular GSM network



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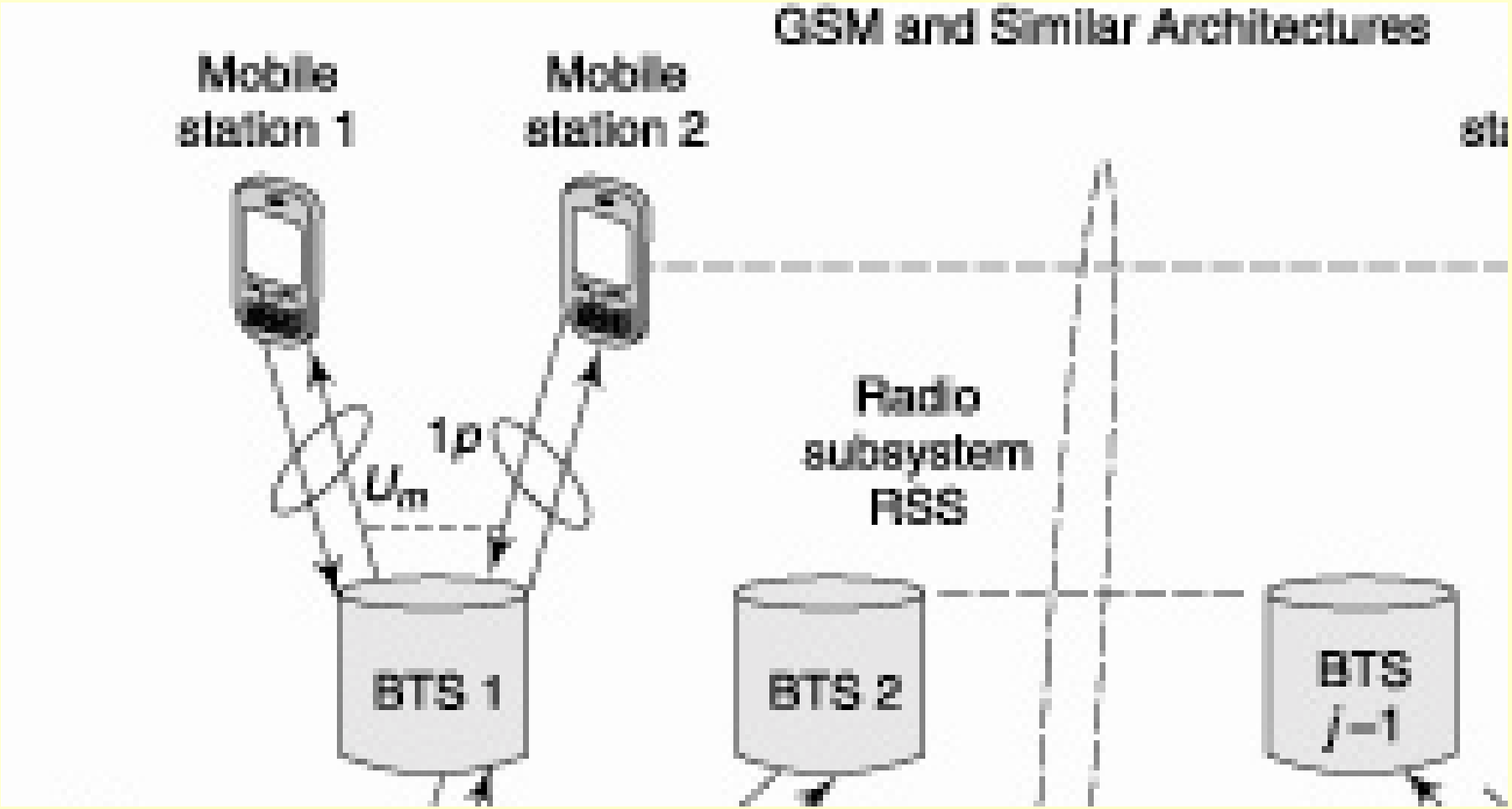
Connection interfaces in the RSS subsystem between BTS and the MSs



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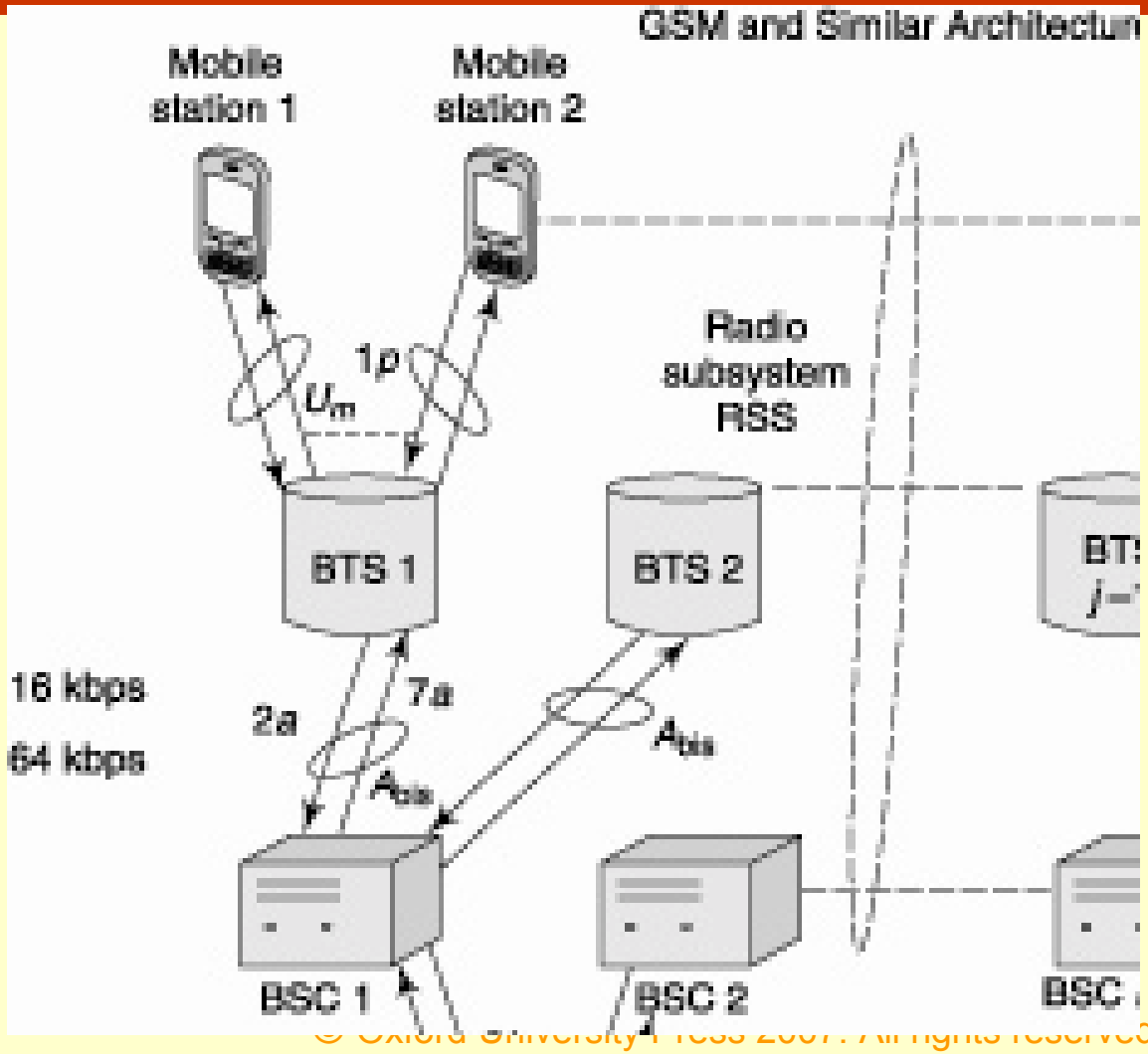
Connection interfaces in the RSS subsystem between BSC and the BTSs



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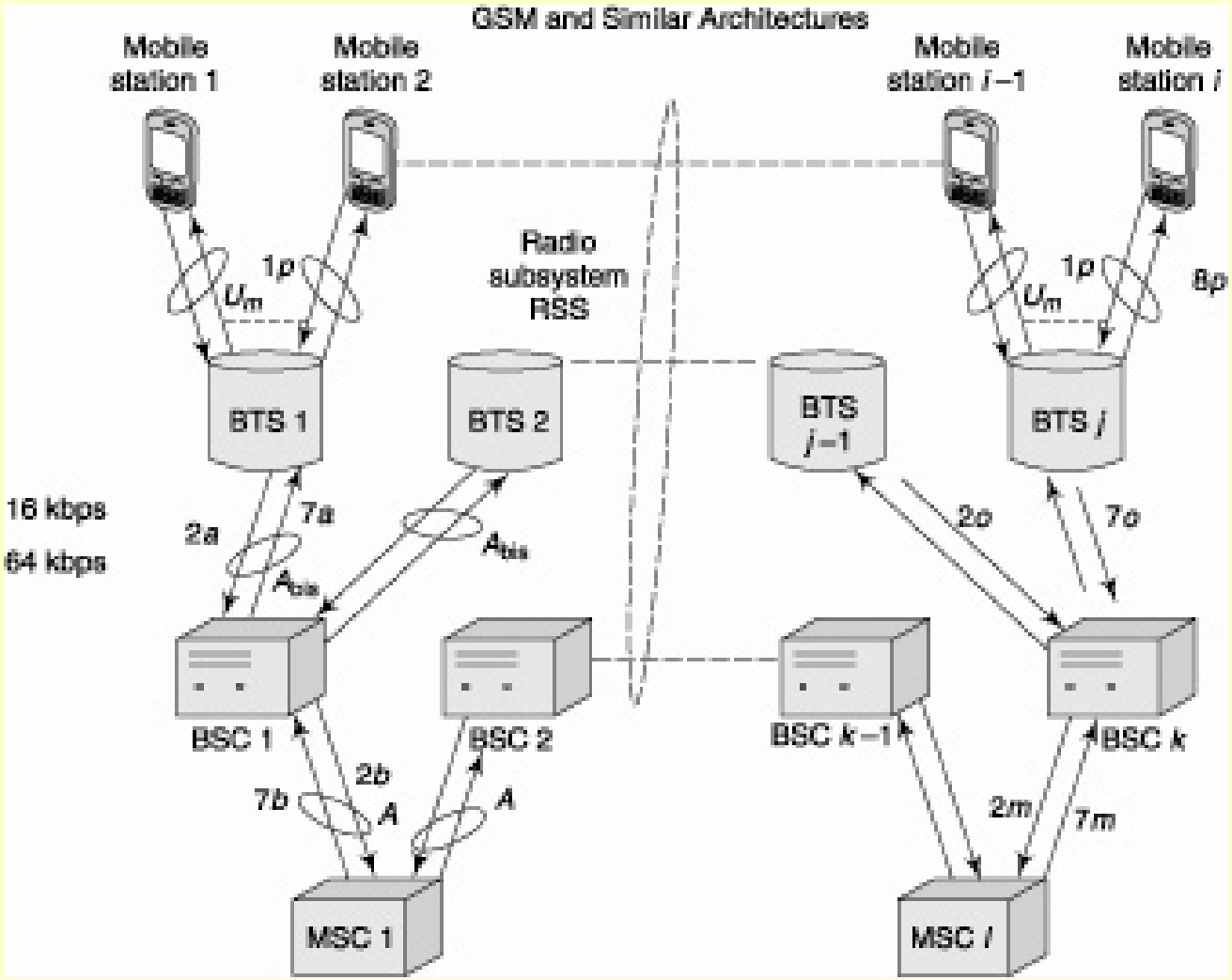
Interfaces in the RSS subsystem between MSC (in the NSS) and the BSCs



MS's subscriber identity module (SIM)

- An inserted card
- Provided by the GSM service provider

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SIM

- Uniquely identifies the user to the service
- Enables the MS to connect to the GSM network
- When the MS connects to the GSM subsystems, the SIM saves a temporary mobile (dynamic) cipher key for encryption, temporary mobile subscriber identity (TMSI), and location area identification (LAI)

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SIM

- Information which does not change when the MS moves into another location
- (i) international mobile subscriber identity (IMSI)
- (ii) card serial number and type

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SIM

- Contains a PIN (personal identification number)
- Using the PIN, the MS is unlocked when it seeks connection to another MS
- The user can use the PIN to lock or unlock the MS

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SIM Functions

- Stores the PUK (PIN unblocking key) which enables the subscriber to unlock the SIM if it is accidentally locked due to some reason
- Stores a 128-bit authentication key provided by the service provider

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SIM Functions

- The MS authenticates by a switching centre through an algorithm using this key and a 128-bit random number dynamically sent by authentication centre
- If the MS is not authenticated, the service to that number is blocked

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SIM

- Also stores the international mobile subscriber identity (IMSI)
- IMSI– a unique 15 digit number allocated to each mobile user
- IMSI three parts— a three digit mobile country code (MCC), a mobile network code (MNC) consisting of two digits, and the mobile subscriber identity number (MSIN) with up to 10 digits

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IMSI

- Same IMSI all over the globe
- Identical coding scheme
- Helps service providers in identifying and locating an MS

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IMSI

- Helps the MS in obtaining the cipher key, TMSI, and LAI from the mobile service provider during connection setup
- TMSI used to identify an MS during a connection for protecting the user ID from hackers or eavesdroppers

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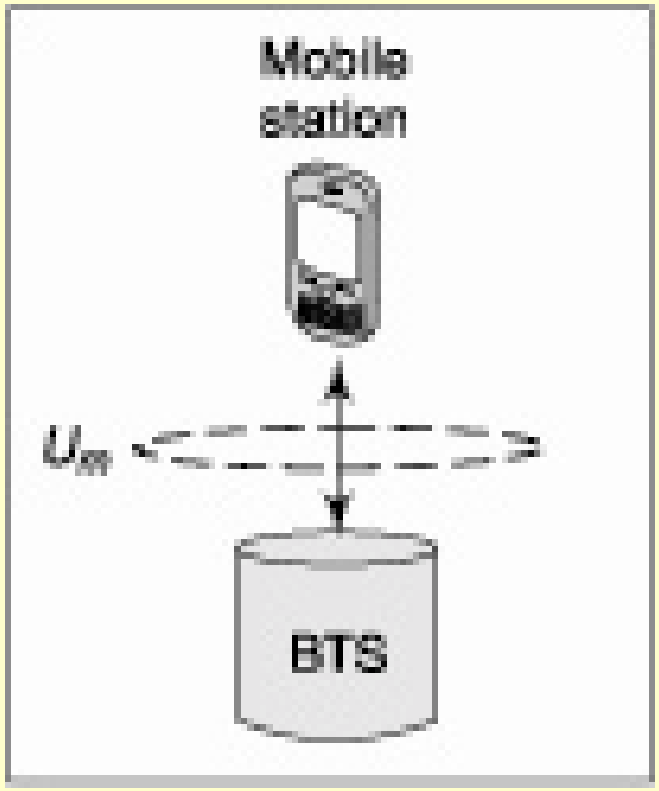
Mobile station to BTS interface in a GSM cell



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Base transceiver station (BTS)

- Connects to a number of mobile stations (MSs)
- Each MS establishes connection through the user interface *Um* [(1,8)]
- *Um* is the ISDN *U* interface for mobile
- The BTS to MS connection through *Um*
- A BTS is also connected to a BSC at through the A_{bis} interface

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Main functions performed by the BTS

- Formation of cells using appropriately directed antennae
- Processing of signals
- Amplification of signals to acceptable strength so that they can be transmitted without loss of data

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Main functions performed by the BTS

- Channel coding and decoding (for example, coding voice into bits so that it can be transmitted at 13 kbps and decoding received coded signals back to voice)

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Main functions performed by the BTS

- Frequency hopping so that multiple channels for various mobile stations can operate simultaneously using different channel band frequencies
- Encryption and decryption of data
- Paging

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Main functions performed by the BTS

- Adapting to the rate of data synchronous data transmission
- The receiver clock of the transceiver at one end of an interface adapts itself according to transmitter clock of the transceiver at the other end)

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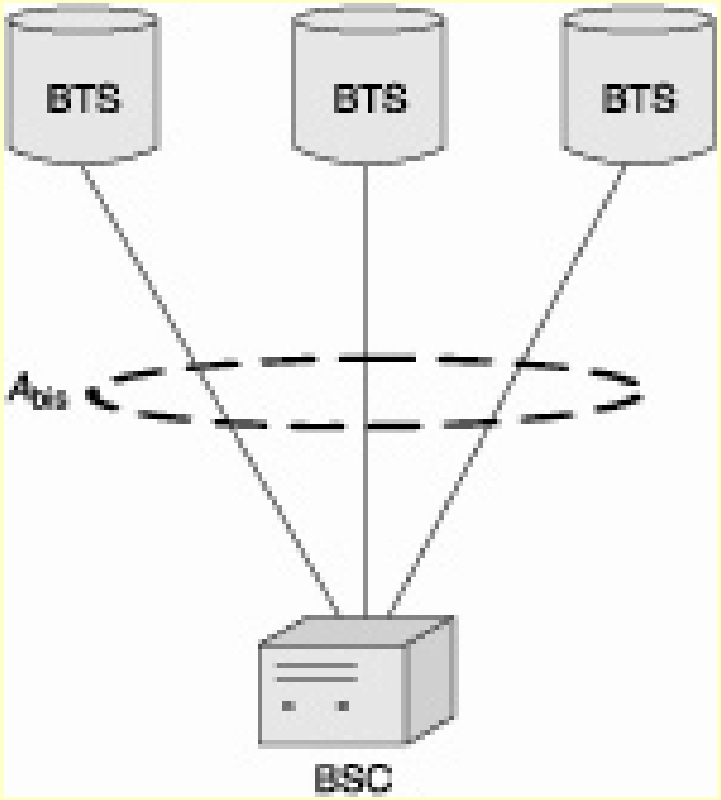
BTS to BSC interface in a GSM network



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A_{bis} transceiver

- Transmits and receives data with four multiplexed channels of 16 kbps or with a 64 kbps channel
- Usually a BTS is used to manage one cell in the GSM cellular network, but using a sectorized antenna, a single BTS can be used to manage many cells

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Base station controller (BSC)

- Manages a number of BTSs
- Uses the A_{bis} interface to connect to BTSs
- BSCs reserve radio frequencies for communication and manage handovers between BTSs

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Base station controller (BSC)

- A BSC along with the BTSs connected to it and the mobile stations managed through it forms a base station system (BSS)
- Also connected to an MSC in the networking and switching layer using an interface *A*

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Important functions performed by the BSC

- Processing of signals
- Controlling signals to the connected BTSs and control of handover of signals from one BTS to another within a BSS
- Control and handover of the signals from BSC to MSC

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Important functions performed by the BSC

- Mapping the signals of a channel– at given instant receives signals from a BTS at 16 kbps through A_{bis} and interfaces them to an MSC at 16 kbps
- Alternatively, may have to interface to a PSTN switching centre at 64 kbps through a fixed line network– mapped by assigning a 16 kbps channel for 64 kbps signals and vice versa

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Important functions performed by the BSC

- Reserving radio frequencies
- Frequency hopping (For example, multiple BTSs operate simultaneously by using the different frequencies at a given instant

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Important functions performed by the BSC

- Traffic control by continuous measurement of the frequency channel spectrum being used at a given instant
- Authentication, encryption, and decryption of data
- Updating location registry for the MSs
- Paging

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Network subsystem (NSS)

- Acts as an interface between wireless and fixed networks
- Mainly consists of switches and databases and manages functions such as handovers between BSS's, worldwide user localization, maintenance of user accounts and call charges, and management of roaming
- The interface between the NSS components and the AuC and the OMC in the OSS

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NSS

- Consists of *l* mobile services switching centres (MSC), *m* and *n* home and visitor location registers, gateway MSCs (GMSC), and inter-working functions (IWFs) with the mobile switching centres
- GMSCs and IWFs connect to the other networks (for example, PSTN, ISDN, or PSPDN)

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Basic connections and components in the NSS

- Each MSC in the NSS can manage several base station systems
- Every MSC has a home location register (HLR) and a visitor location register (VLR)
- An MSC can connect to another MSC, GMSC, and IWF

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Basic connections and components in the NSS

- An HLR connects to an AUC in the OSS.
- A GMSC can connect to an OMC in the OSS.
- GMSCs– also used to connect to a PSTN, ISDN, or PSPDN network

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Mobile services switching centre (MSC)

- Consists mainly of high-performance digital ISDN switches
- Connects to a number of BSCs over the *A* interface
- Connect to other MSCs and to fixed-line networks through GMSCs
- Used to manage BSCs in a geographical area

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Functions performed by an MSC

- Processing of signals
- Establishing and terminating the connection between various mobile stations via BSCs
- The mobile stations to be connected may fall in a given MSCs own area or in the area assigned to another MSC, in which case the communication path has to be via the other MSC

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Functions performed by an MSC

- Establishing and terminating the connection between an MS and a fixed line phone via a GMSC or IWF
- Monitoring of calls made to and from an MS
- Call charging, multi-way calling, call forwarding, and other supplementary services

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Gateway Mobile Services Switching Centre

- A special node which handles connections to other fixed networks
- These other networks may be ISDN, PSTN, PSPDN, or other PLMN networks
- Special IWFs may be used by a GMSC to connect to public data networks such as the X.25

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Visitor Location Register at Each MSC

- A dynamic real-time database that stores both permanent and temporary subscriber data which is required for communication between the MSs in the coverage area of the MSC associated with that VLR. The VLR is an integral part of the MSC

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Home Location Register

- Has the MT databases
- Stores all the relevant subscriber data including mobile subscriber ISDN number (MSISDN), details of subscription permissions such as call forwarding, roaming, etc., subscriber's ISMI, user's location area, user's current VLR and MSC status

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HLR

- . Each mobile user has only one HLR record worldwide, which is updated constantly on a real-time basis
- Each MS must register at a specific HLR of a specific MSC
- The HLR contacts AuC in the OSS for authentication

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HLR

- Each HLR is associated to an MSC so that when an MS registered at a certain HLR moves to another location area (LA), serviced by another MSC, the user's home MSC update the user's current VLR

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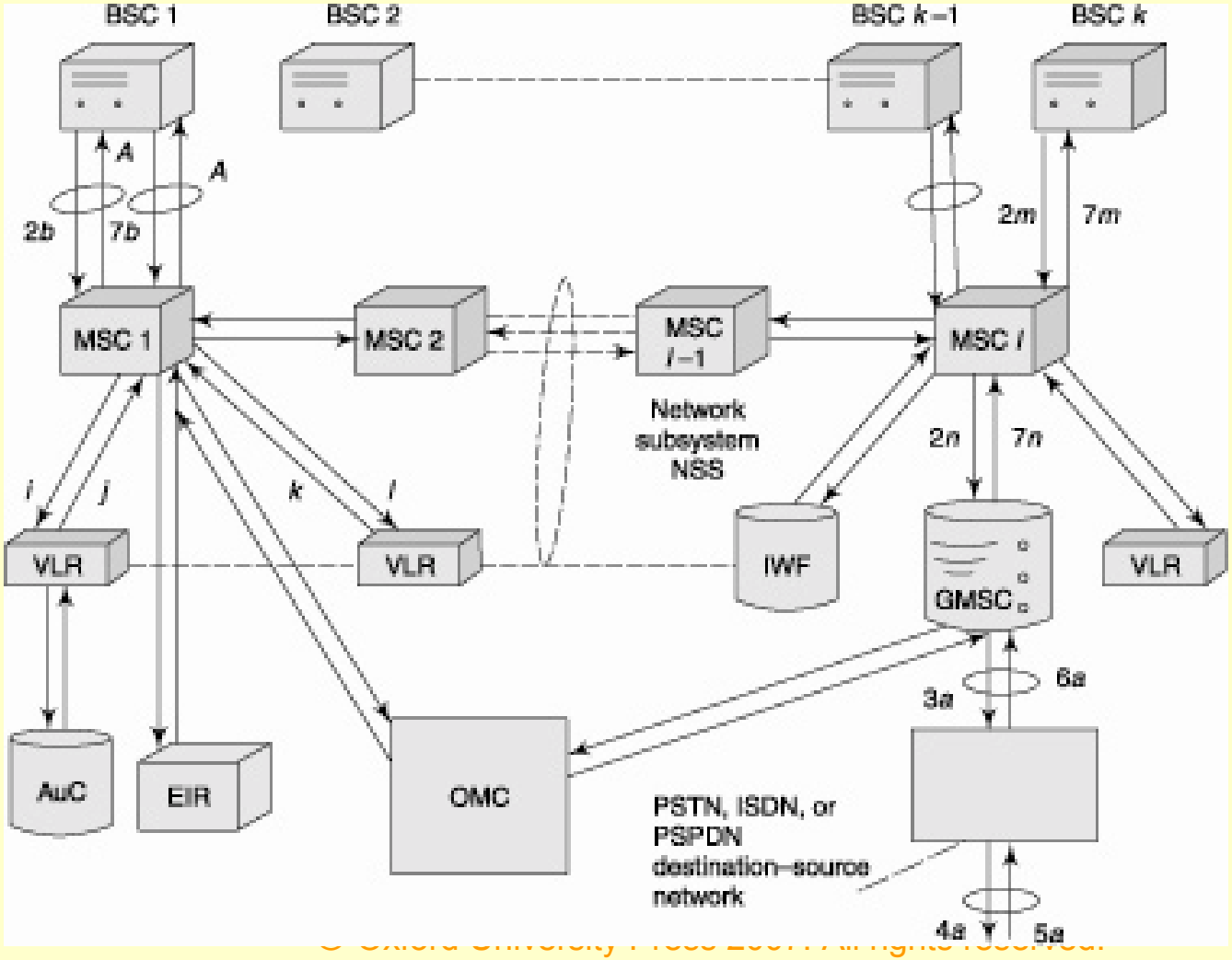
Interfaces in the NSS between MSC, BSCs, VLR, and OMC



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Operation subsystem (OSS)

- Administers the operation and maintenance of the entire network
- Each AuC associates with an HLR in the NSS and each EIR connects to an MSC
- An OMC at OSS can connect to an MSC or a GMSC in the NSS and to a BSC at RSS

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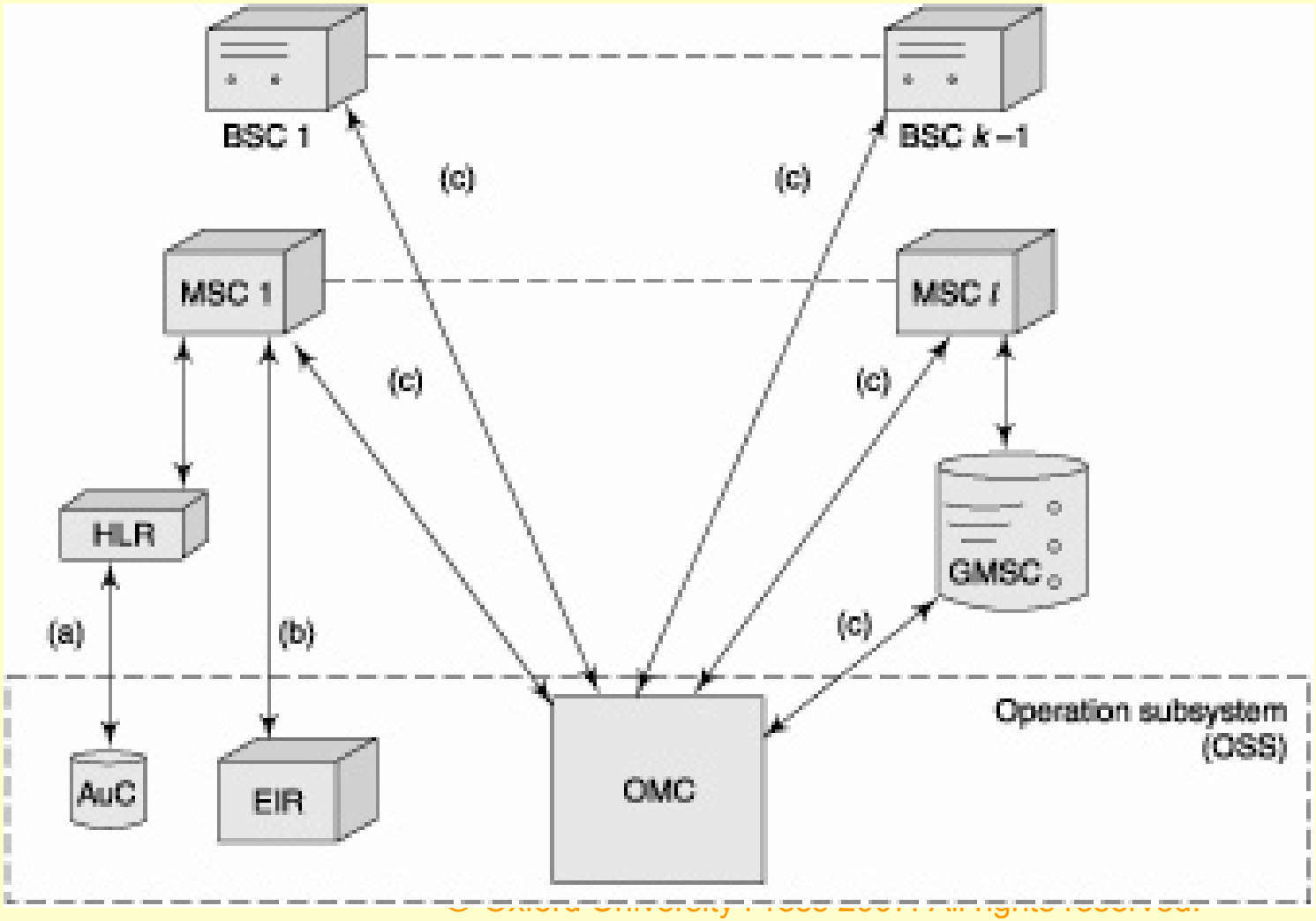
Interfaces between AuC, HLR, EIR and MSC, OMC, BSC, and GMSC



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Operation and Maintenance Centre

- Monitors and controls all other network entities through the *O* interface

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OMC functions

- Management of status reports
- Traffic monitoring
- Subscriber security management
- Accounting and billing

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Authentication Centre

- AuC calculation of authentication parameters and then conveying these to the HLR
- Used by the HLR to authenticate a user
- The AuC may also be a secured partitioned part of the HLR itself

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Authentication Centre

- Since mobile networks quite vulnerable to attacks, the GSM standard specifies that the algorithms for key generation should be separated out as an OSS network entity. This entity is the AuC

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AuC database

- Stores subscriber authentication keys

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The equipment identity register (EIR)

- Stores the international mobile equipment identity (IMEI) numbers for the entire network
- IMEI enables the MSC in identifying the type of terminal, mobile equipment manufacturer, and model and helps the network in locating the device in case it is stolen or misplaced

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EIR three lists

- A *black list* that includes mobile stations which have been reported stolen or are currently locked due to some reason.
- A *white list* which records all MSs that are valid and operating.
- A *grey list* including all those MSs that may not be functioning properly.

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Summary

- Data dissemination from server to mobile systems
- Data synchronization between one to one or one to many or many to many
- Mobility Management

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End of Lesson 03

GSM System Architecture

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GSM and Similar Architectures

Lesson 04

GSM Base station system and Base Station Controller

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GSM network architecture

- Radio subsystem (RSS)
- Network subsystem (NSS)
- Operation subsystem (OSS)

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RSS

- Consists of a number of base station controllers (BSC)
- Each BSC connects to a number of base transceiver stations (BTS) which, in turn, provide radio interfaces for mobile devices

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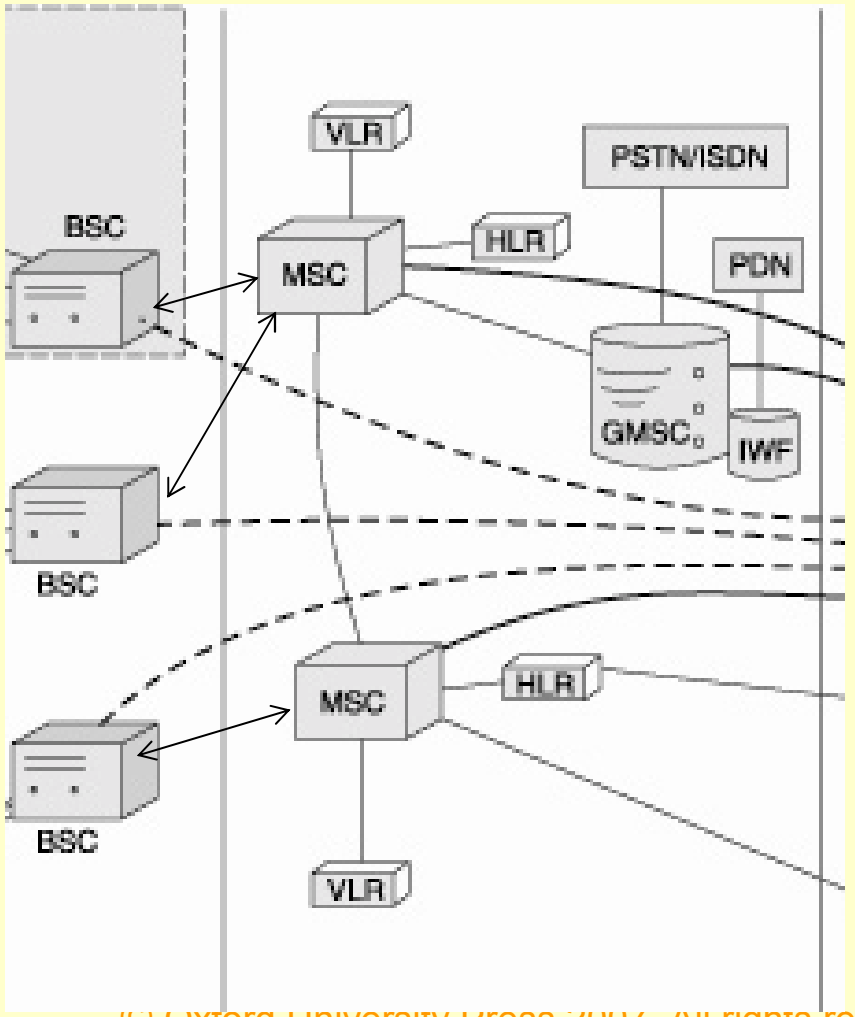
NSS



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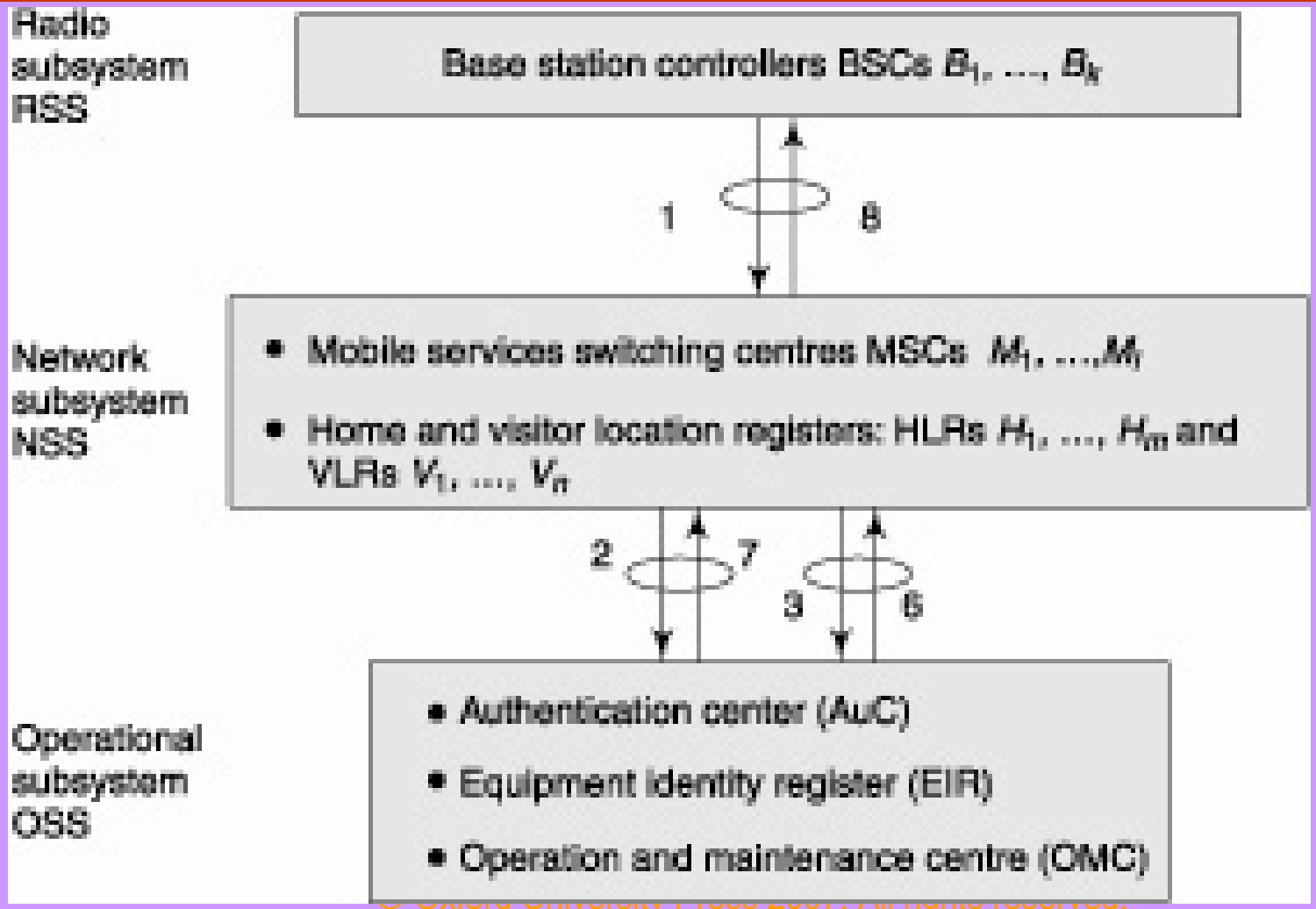
Interfacing between the three subsystems in a GSM network



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Mobile Communication from the MS

- When a mobile station MS_x communicates to another mobile station MS_y, a switching center MSC_i establishes (switches) a connection (channel) between (i) MS_x interfaced to the BTS_p, then to the BSC_q, then to MSC_r and (ii) MS_y interfaced to the BTS_u, BSC_V, and MSC_w

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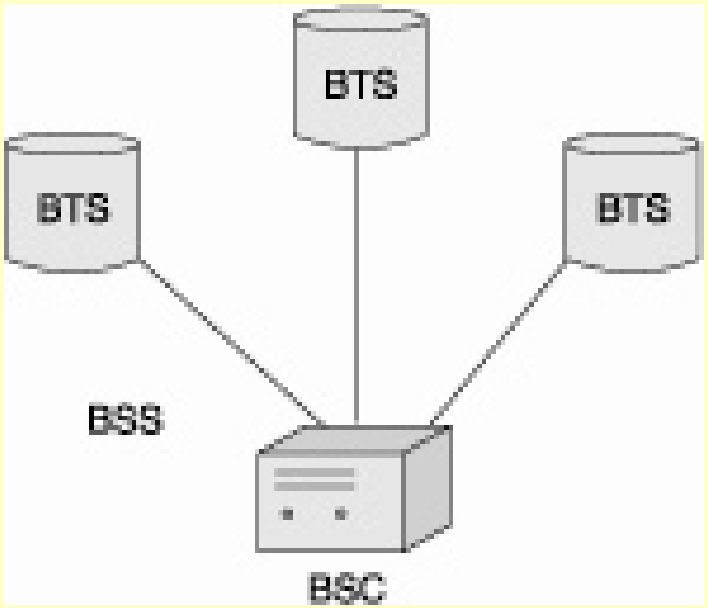
Base station system in a cellular GSM network



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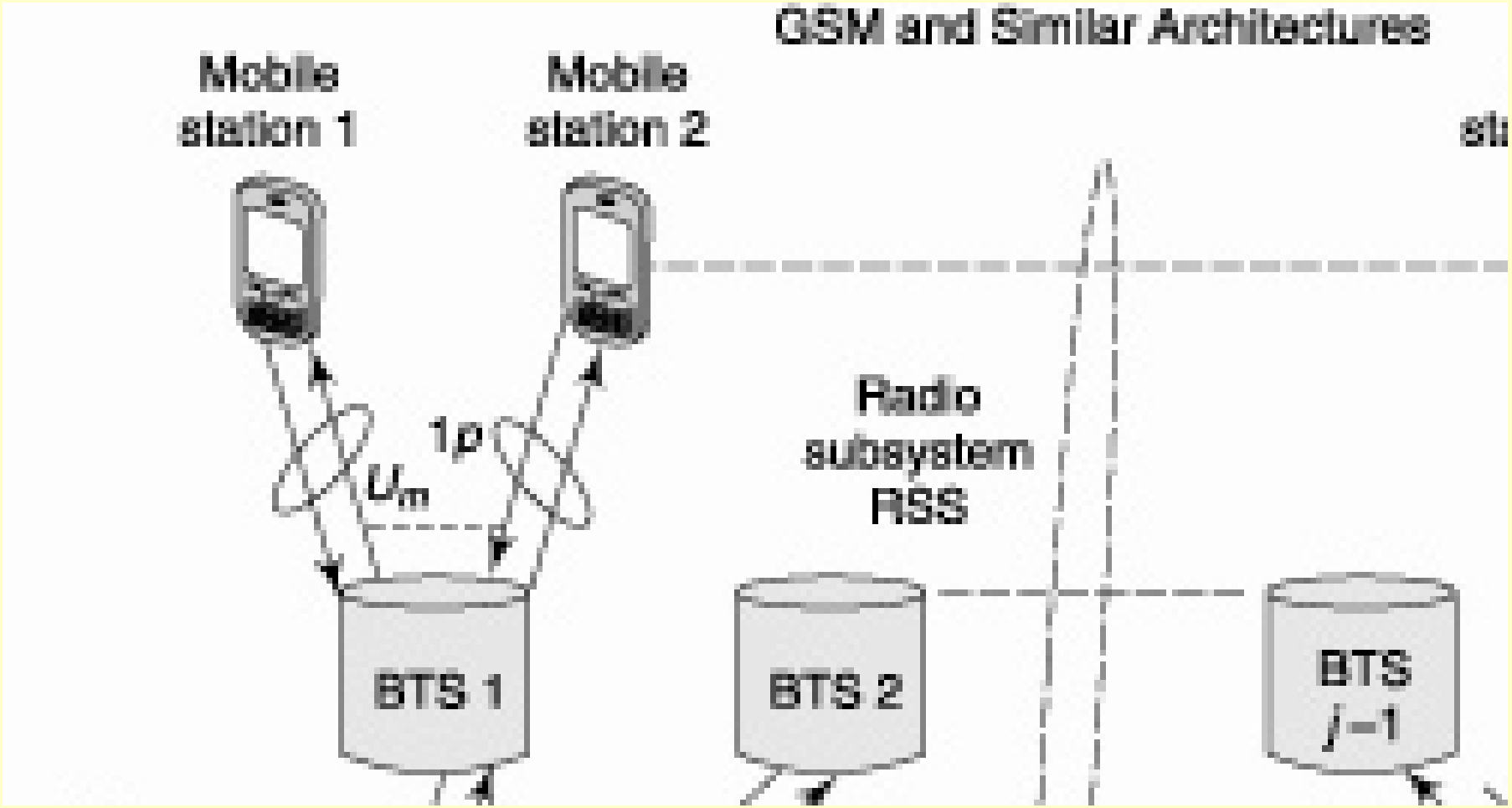
Connection interfaces in the RSS subsystem between BTS and the MSs



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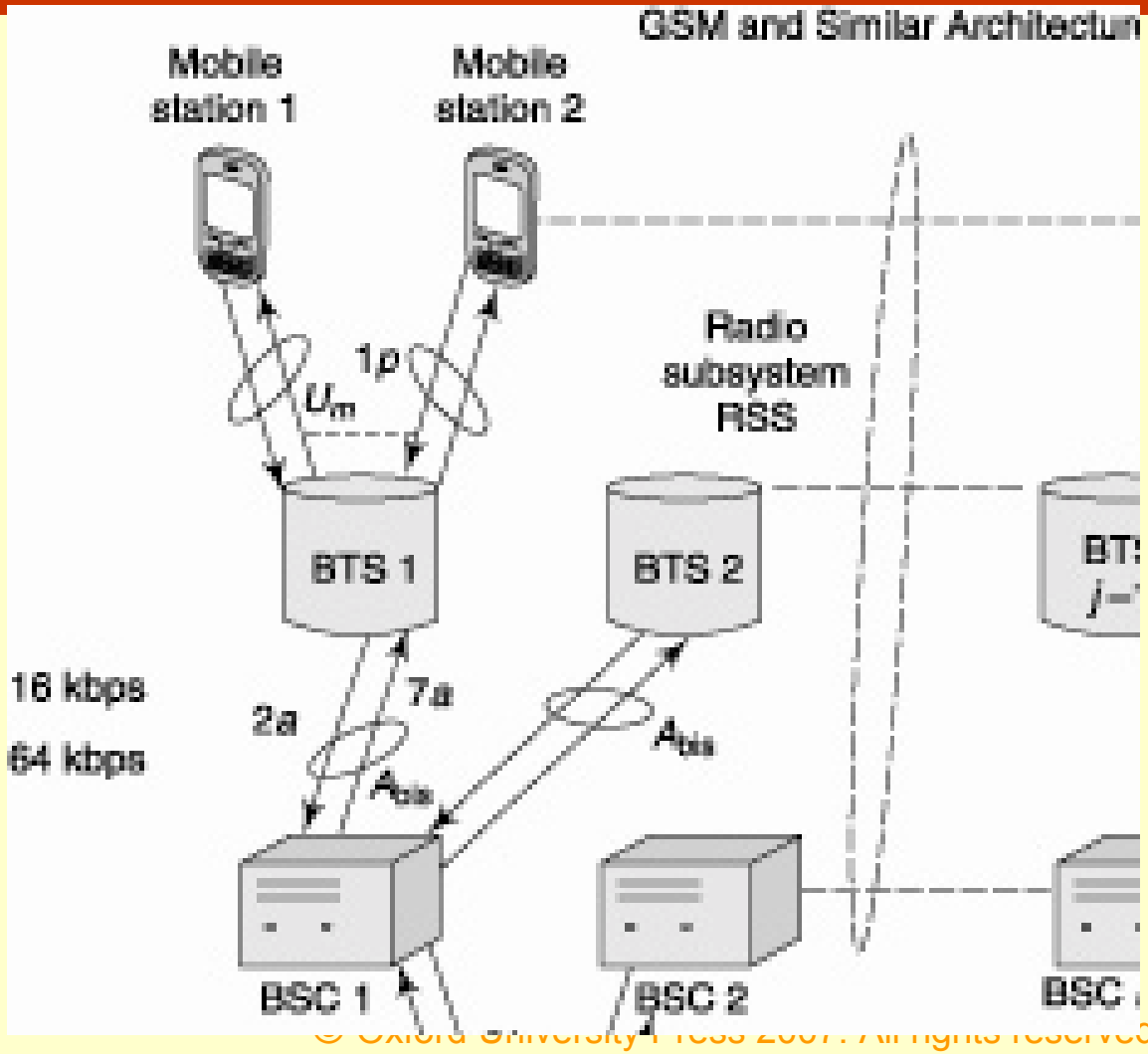
Connection interfaces in the RSS subsystem between BSC and the BTSs



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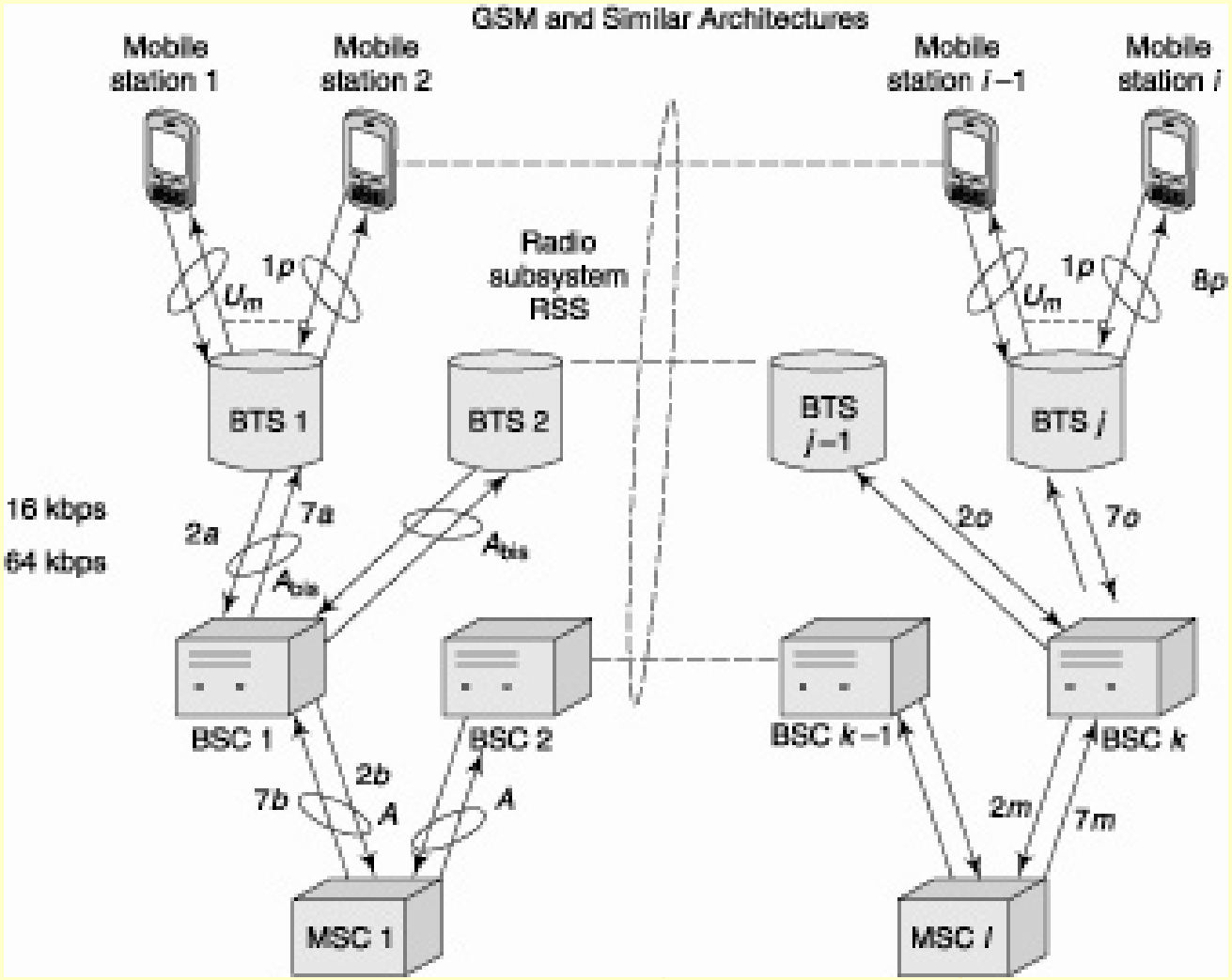
Interfaces in the RSS subsystem between MSC (in the NSS) and the BSCs



Base transceiver station (BTS)

- Connects to a number of mobile stations (MSs)
- Each MS establishes connection through the user interface *Um* [(1,8)]
- *Um* is the ISDN *U* interface for mobile
- The BTS to MS connection through *Um*
- A BTS is also connected to a BSC at through the A_{bis} interface

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Main functions performed by the BTS

- Formation of cells using appropriately directed antennae
- Processing of signals
- Amplification of signals to acceptable strength so that they can be transmitted without loss of data

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Main functions performed by the BTS

- Channel coding and decoding (for example, coding voice into bits so that it can be transmitted at 13 kbps and decoding received coded signals back to voice)

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Main functions performed by the BTS

- Frequency hopping so that multiple channels for various mobile stations can operate simultaneously using different channel band frequencies
- Encryption and decryption of data
- Paging

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Main functions performed by the BTS

- Adapting to the rate of data synchronous data transmission
- The receiver clock of the transceiver at one end of an interface adapts itself according to transmitter clock of the transceiver at the other end)

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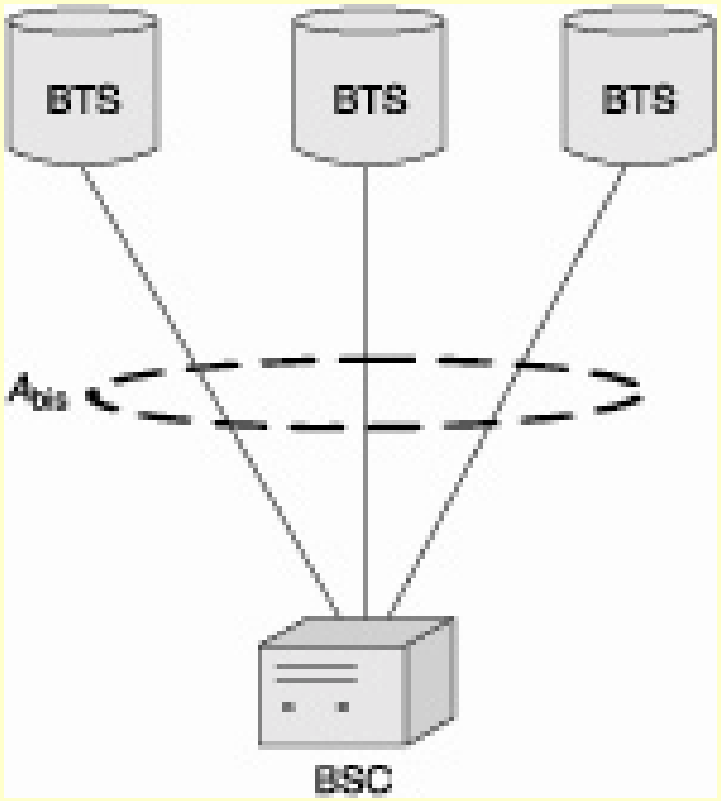
BTS to BSC interface in a GSM network



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A_{bis} transceiver

- Transmits and receives data with four multiplexed channels of 16 kbps or with a 64 kbps channel
- Usually a BTS is used to manage one cell in the GSM cellular network, but using a sectorized antenna, a single BTS can be used to manage many cells

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Base station controller (BSC)

- Manages a number of BTSs
- Uses the A_{bis} interface to connect to BTSs
- BSCs reserve radio frequencies for communication and manage handovers between BTSs

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Base station controller (BSC)

- A BSC along with the BTSs connected to it and the mobile stations managed through it forms a base station system (BSS)
- Also connected to an MSC in the networking and switching layer using an interface *A*

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Important functions performed by the BSC

- Processing of signals
- Controlling signals to the connected BTSs and control of handover of signals from one BTS to another within a BSS
- Control and handover of the signals from BSC to MSC

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Important functions performed by the BSC

- Mapping the signals of a channel– at given instant receives signals from a BTS at 16 kbps through A_{bis} and interfaces them to an MSC at 16 kbps
- Alternatively, may have to interface to a PSTN switching centre at 64 kbps through a fixed line network– mapped by assigning a 16 kbps channel for 64 kbps signals and vice versa

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Important functions performed by the BSC

- Reserving radio frequencies
- Frequency hopping (For example, multiple BTSs operate simultaneously by using the different frequencies at a given instant

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Important functions performed by the BSC

- Traffic control by continuous measurement of the frequency channel spectrum being used at a given instant
- Authentication, encryption, and decryption of data
- Updating location registry for the MSs
- Paging

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Network subsystem (NSS)

- Acts as an interface between wireless and fixed networks
- Mainly consists of switches and databases and manages functions such as handovers between BSS's, worldwide user localization, maintenance of user accounts and call charges, and management of roaming

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Summary

- BTS main functions
- Formation of cells using appropriately directed antennae
- Amplification of signals to acceptable strength so that they can be transmitted without loss of data
- Channel coding, Encryption and decryption

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… Summary

- BTS Connects to a number of mobile stations (MSs)
- BTSs connect to a BSC
- BSC functions– controlling signals to the connected BTSs and control of handover of signals from one BTS to another within a BSS

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End of Lesson 04

GSM Base station system and Base Station Controller

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GSM and Similar Architectures

Lesson 05

GSM Network Subsystems and Master Switching Centers

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GSM network architecture

- Radio subsystem (RSS)
- Network subsystem (NSS)
- Operation subsystem (OSS)

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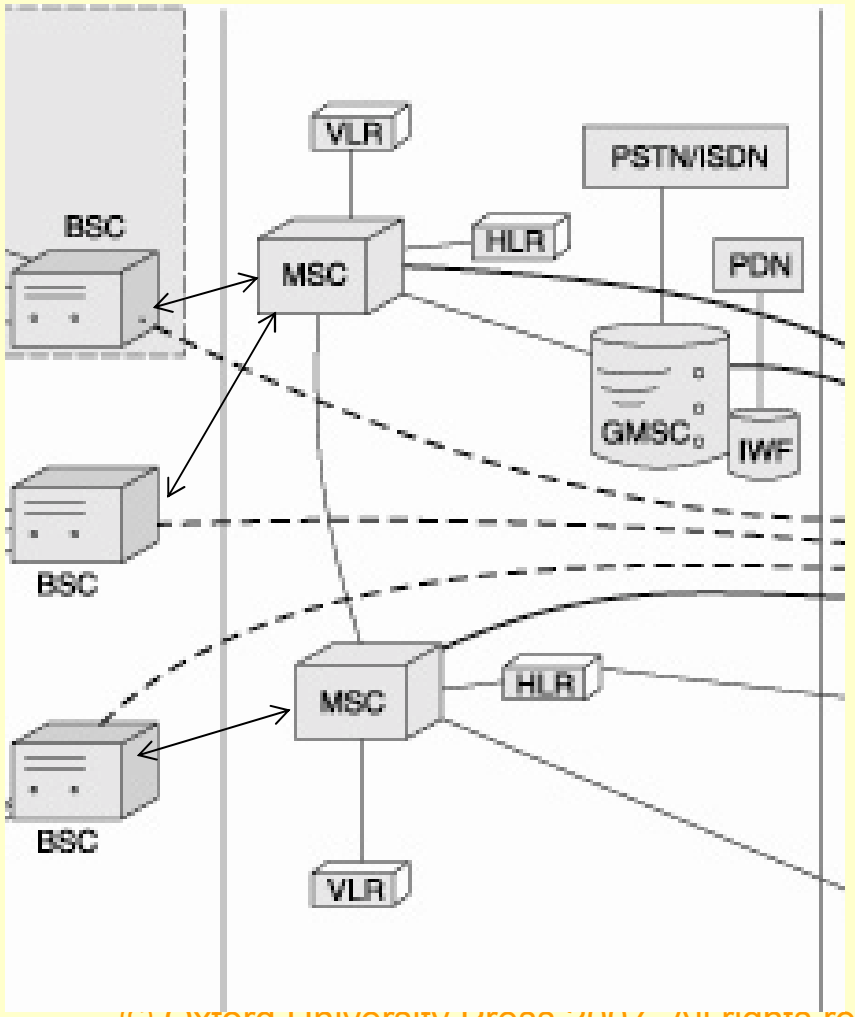
NSS



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NSS

- Consists of a number of mobile services switching centres (MSC)
- Each MSC of the NSS interfaces to a number of BSCs in the RSS
- Home location registers (HLR)
- Visitor location registers (VLR)

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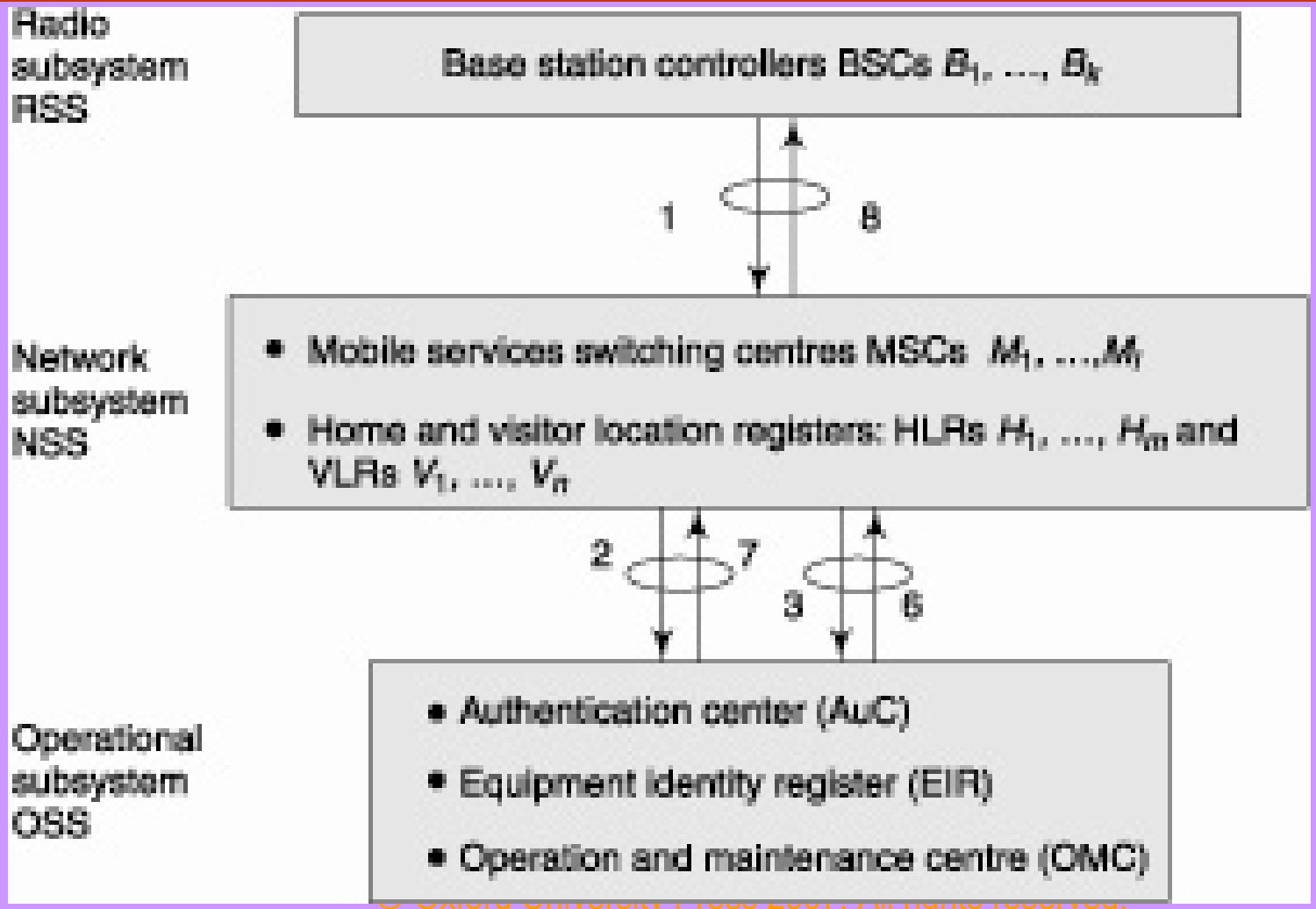
Interfacing between the three subsystems in a GSM network



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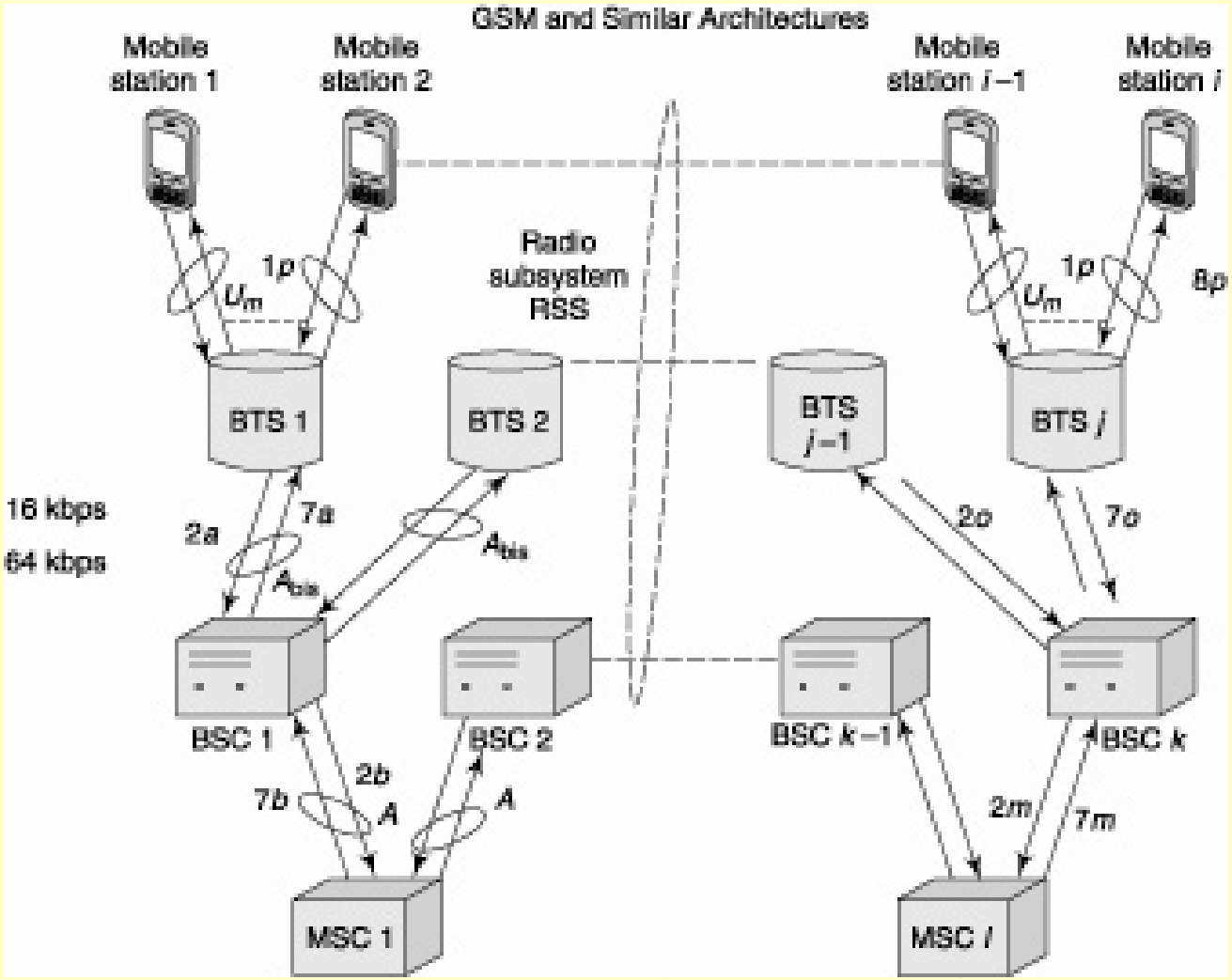
Interfaces between MSC and BSCs



NSS

- Consists of *l* mobile services switching centres (MSC), *m* and *n* home and visitor location registers, gateway MSCs (GMSC), and inter-working functions (IWFs) with the mobile switching centres
- GMSCs and IWFs connect to the other networks (for example, PSTN, ISDN, or PSPDN)

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Basic connections and components in the NSS

- Each MSC in the NSS can manage several base station systems
- Every MSC has a home location register (HLR) and a visitor location register (VLR)
- An MSC can connect to another MSC, GMSC, and IWF

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Basic connections and components in the NSS

- An HLR connects to an AUC in the OSS.
- A GMSC can connect to an OMC in the OSS.
- GMSCs– also used to connect to a PSTN, ISDN, or PSPDN network

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Mobile services switching centre (MSC)

- Consists mainly of high-performance digital ISDN switches
- Connects to a number of BSCs over the *A* interface
- Connect to other MSCs and to fixed-line networks through GMSCs
- Used to manage BSCs in a geographical area

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Functions performed by an MSC

- Processing of signals
- Establishing and terminating the connection between various mobile stations via BSCs
- The mobile stations to be connected may fall in a given MSCs own area or in the area assigned to another MSC, in which case the communication path has to be via the other MSC

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Functions performed by an MSC

- Establishing and terminating the connection between an MS and a fixed line phone via a GMSC or IWF
- Monitoring of calls made to and from an MS
- Call charging, multi-way calling, call forwarding, and other supplementary services

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Gateway Mobile Services Switching Centre

- A special node which handles connections to other fixed networks
- These other networks may be ISDN, PSTN, PSPDN, or other PLMN networks
- Special IWFs may be used by a GMSC to connect to public data networks such as the X.25

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Visitor Location Register at Each MSC

- A dynamic real-time database that stores both permanent and temporary subscriber data which is required for communication between the MSs in the coverage area of the MSC associated with that VLR. The VLR is an integral part of the MSC

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Home Location Register

- Has the MT databases
- Stores all the relevant subscriber data including mobile subscriber ISDN number (MSISDN), details of subscription permissions such as call forwarding, roaming, etc., subscriber's ISMI, user's location area, user's current VLR and MSC status

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HLR

- Each mobile user has only one HLR record worldwide, which is updated constantly on a real-time basis
- Each MS must register at a specific HLR of a specific MSC
- The HLR contacts AuC in the OSS for authentication

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HLR

- Each HLR is associated to an MSC so that when an MS registered at a certain HLR moves to another location area (LA), serviced by another MSC, the user's home MSC update the user's current VLR

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Summary

- Network subsystem
- Number of mobile services switching centres (MSC) with NSS
- Each MSC of the NSS interfaces to a number of BSCs in the RSS

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… Summary

- Consists of a number of mobile services switching centres (MSC)
- Each MSC of the NSS interfaces to a number of BSCs in the RSS
- Home location registers
- Visitor location registers
- MSC interfaces HLRs and VLRs

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End of Lesson 05

GSM Network Subsystems and Master Switching Centers

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GSM and Similar Architectures

Lesson 06

GSM Operation Subsystem

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GSM network architecture

- Radio subsystem (RSS)
- Network subsystem (NSS)
- Operation subsystem (OSS)

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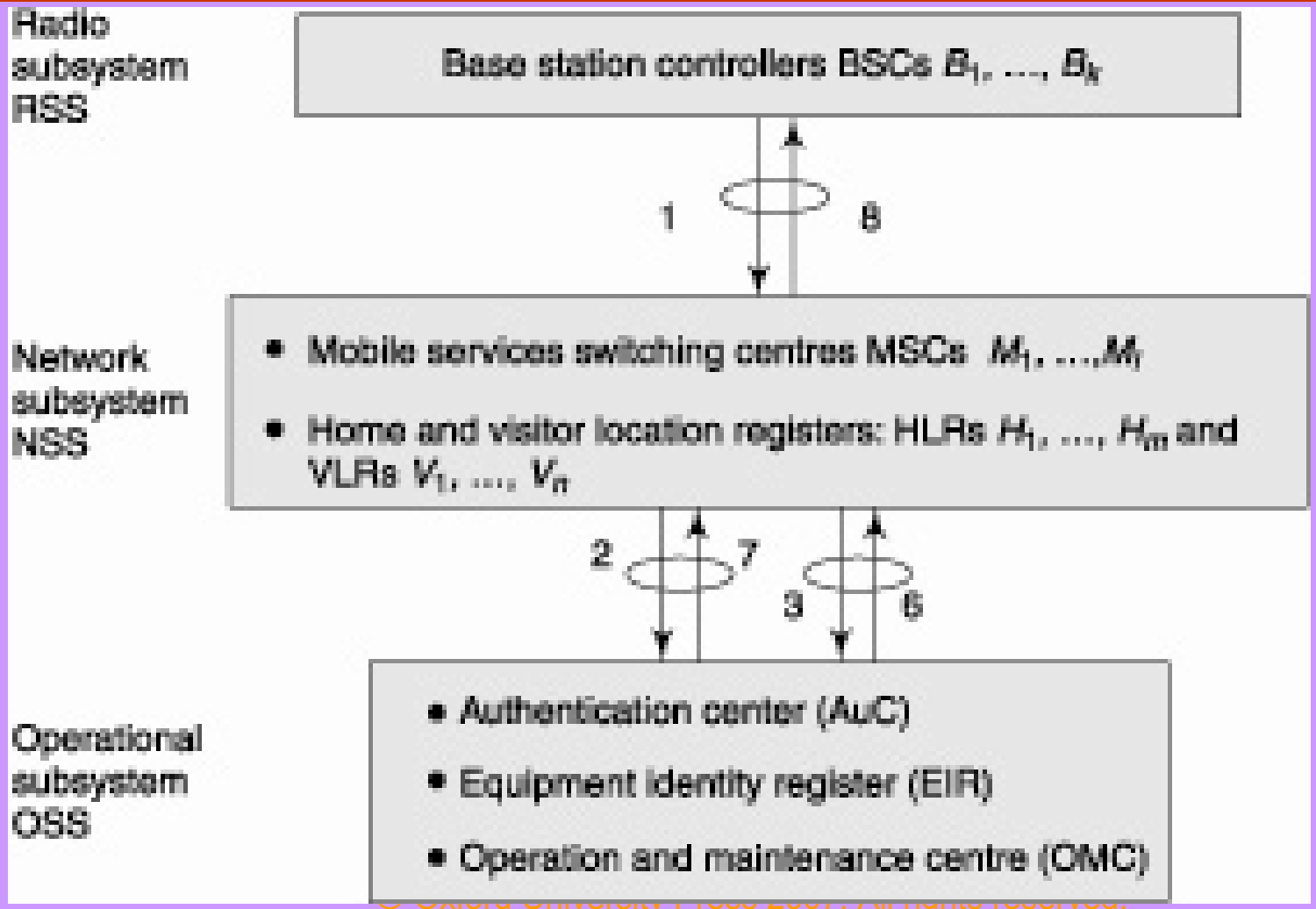
Interfacing between the three subsystems in a GSM network



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GSM System communication

- RSS and NSS for communication
- MSCs must have location registries to enable the NSS to discover a path (route or channel) between MS_x and MS*y*
- The OSS facilitates the operations of MSCs

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Operation subsystem (OSS)

- Administers the operation and maintenance of the entire network
- Each AuC associates with an HLR in the NSS and each EIR connects to an MSC
- An OMC at OSS can connect to an MSC or a GMSC in the NSS and to a BSC at RSS

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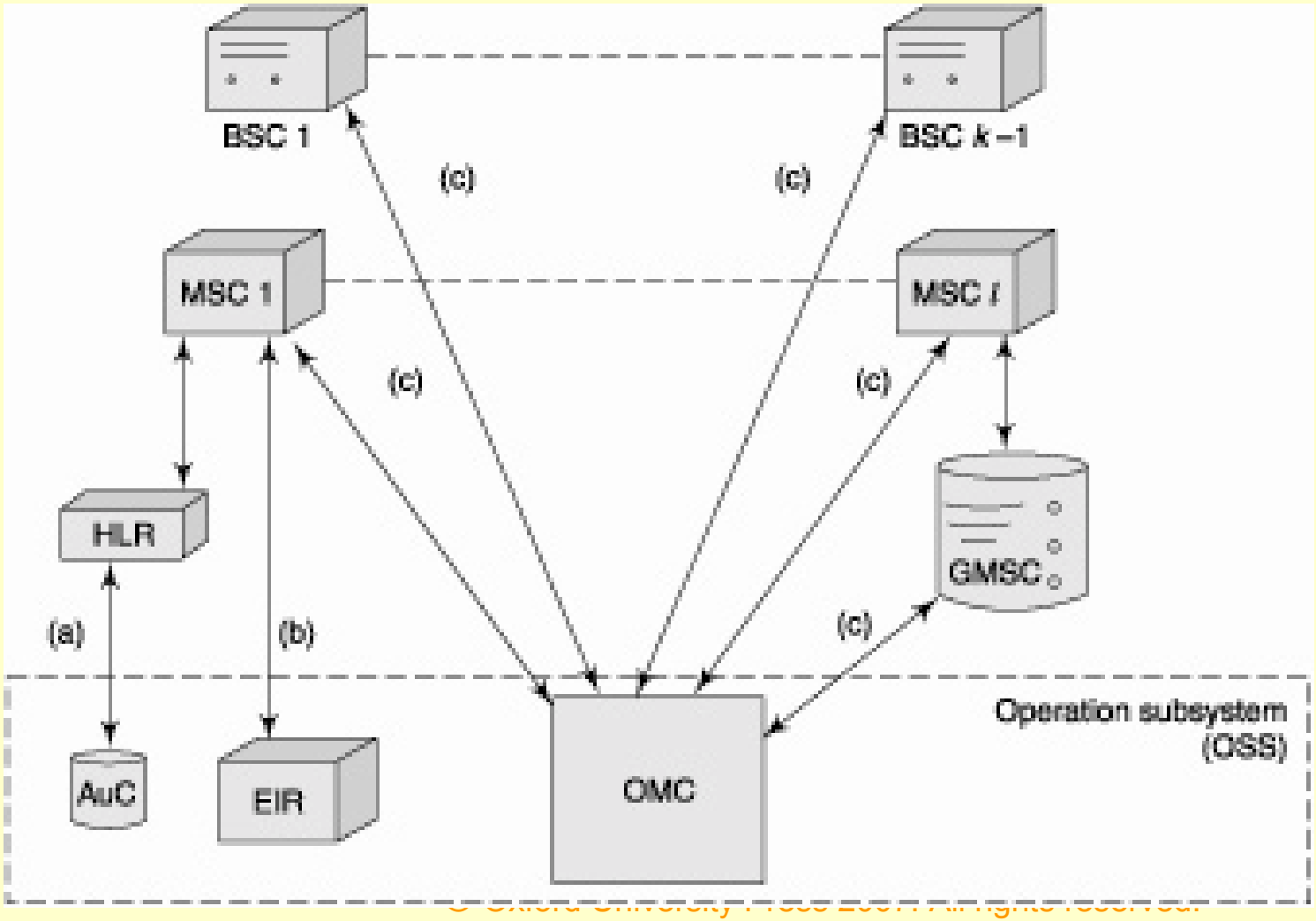
Interfaces between AuC, HLR, EIR and MSC, OMC, BSC, and GMSC



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Operation and Maintenance Centre

- Monitors and controls all other network entities through the *O* interface

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OMC functions

- Management of status reports
- Traffic monitoring
- Subscriber security management
- Accounting and billing

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Authentication Centre

- AuC calculation of authentication parameters and then conveying these to the HLR
- Used by the HLR to authenticate a user
- The AuC may also be a secured partitioned part of the HLR itself

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Authentication Centre

- Since mobile networks quite vulnerable to attacks, the GSM standard specifies that the algorithms for key generation should be separated out as an OSS network entity. This entity is the AuC
- AuC database– Stores subscriber authentication keys

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The equipment identity register (EIR)

- Stores the international mobile equipment identity (IMEI) numbers for the entire network
- IMEI enables the MSC in identifying the type of terminal, mobile equipment manufacturer, and model and helps the network in locating the device in case it is stolen or misplaced

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EIR three lists

- A *black list* that includes mobile stations which have been reported stolen or are currently locked due to some reason.
- A *white list* which records all MSs that are valid and operating.
- A *grey list* including all those MSs that may not be functioning properly.

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Summary

- OSS
- Connects to MSCs
- AuC
- EIR
- OMC

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End of Lesson 06

GSM Operation Subsystem

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GSM and Similar Architectures

Lesson 07

GSM Radio Interface, Data bursts and Interleaving

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Space Division Multiple Access of the signals from the MSs

- A BTS with *n* directed antennae– covers mobile stations in *n* cells
- Each cell defines a space

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Space Division Multiple Access of the signals from the MSs

- A given BTS_j covers the i^{th} cell and the cell is presently covering *k* mobile stations, MS1, MS2, …, MSk
- *k* can vary with time — MS can always change its location and move into another cell)

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Uplink and downlink capacities of GSM network channels

- Enhances using SDMA as this allows serving multiple users in the same frequency but in distinct time slots

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Frequency Division Multiple Access

- Dividing the allotted or available bandwidth into different frequency channels for communication by multiple sources (sets of MTs)

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Radio-carrier channels

- A set of maximum 124 radio-carrier channels each of 200 kHz can be used in GSM 900 downlink channel (MSC to BSC, BSC to BTS, and BTS to MS)
- 124 in the uplink channel (MS to BTS, BTS to BSC, and BSC to MSC)

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Radio-carrier channels

- The 124 slots in GSM 900 in the uplink frequency range —ch1: 890.1 MHz ± 100 kHz, ch2: 890.3 MHz ± 100 kHz, and so on till ch124: 914.9 MHz ± 100 kHz
- Downlink frequency slots —ch1: 935.1 MHz ± 100 kHz, ch2: 935.3 MHz ± 100 kHz … and the last frequency is ch124: 959.9 MHz ± 100 kHz

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Guard band

- GSM 900 system permits a guard band of 50 kHz at the lowest frequency end and a guard band of 50 kHz at highest frequency band
- Thus Actual frequency band for the 890.1 MHz ± 100 kHz ch1 is 890.1 MHz ± 50 kHz
- The guard bands guard against frequency drifts in radio carriers

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Channels allotted at a given instant to a BTS

- Maximum 10
- The mobile service provider reserves one channel per BTS for transmission to MS or BSC

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- Total number of channels assigned to a BTS is 11
- A GSM system station is permitted use the ch2 to ch123 only
- 122 channels are available in GSM 900
- Total number of reserve channels can be 32 for the data transmission of mobile service provider

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BTSs

- All the BTSs taken together can communicate over 90 channels (ch0, …, ch89) available in GSM band

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Data Frame in a Channel

- Each channel transmits data frames of 4.615 ms (8 time-slots) each

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Data Frame in a Channel

- The frequency-slot for each channel is 200 kHz
- A set of maximum 8 MSs (out of *I* MSs) can be assigned (by BTS_j) a radio carrier channel frequency for uplink
- Downlink frequency is greater than the uplink frequency of a radio-carrier channel by 45 MHz

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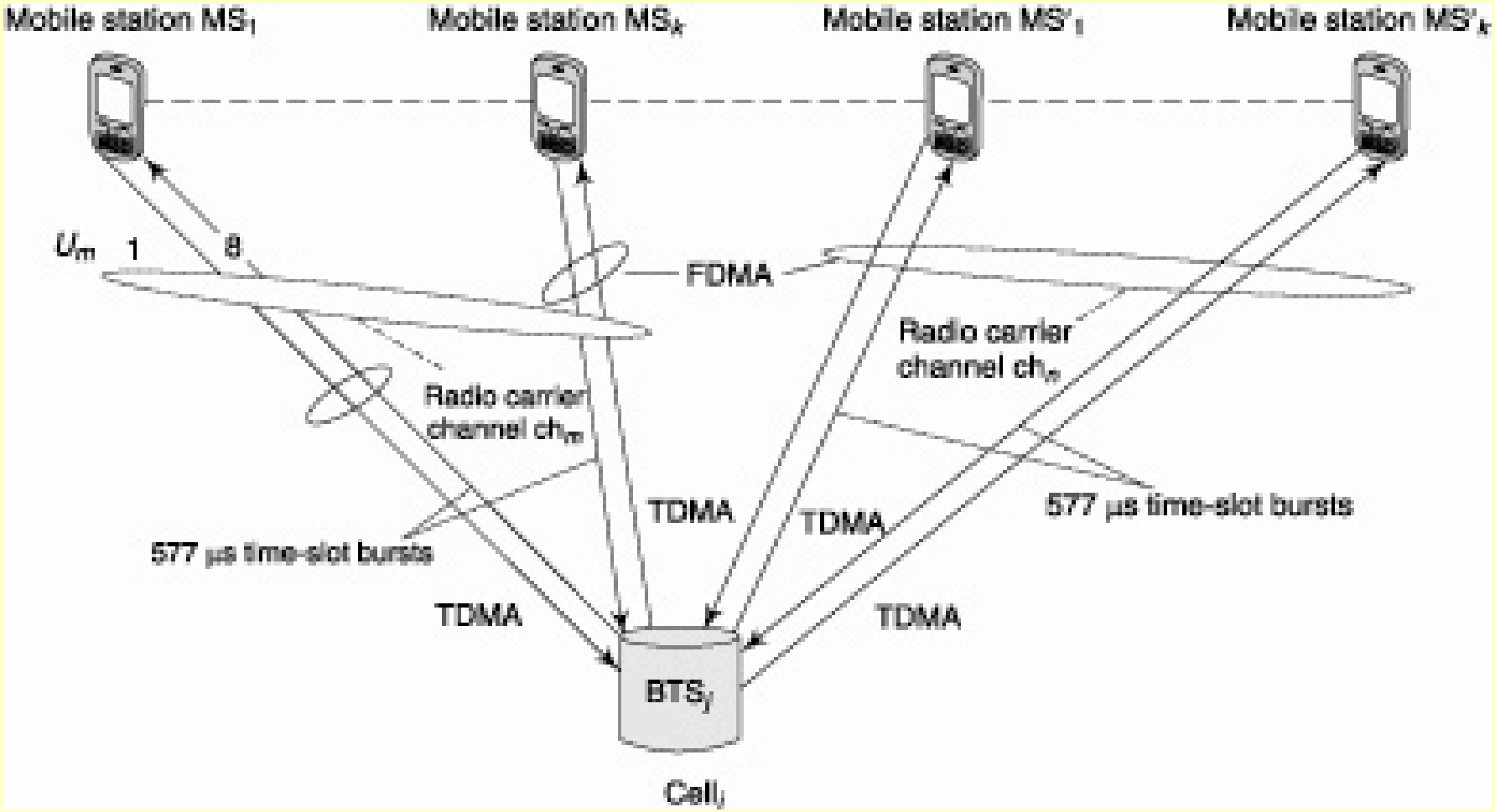
A Cell$_i$ formed by SDMA with two radio-carrier channels ch$_m$ and ch$_n$



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TDMA and FDMA both in GSM system

- $Cell_i$ with two radio-carrier channels ch_m and ch_n using FDMA (Up to 124 permitted)
- Each MS in each channel transmitting bursts in 577 μs time-slots using TDMA

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TDMA in a radio-carrier channel ch_m

- A set of maximum 8 MSs out of / MS_s can be assigned a radio carrier channel by a BTS_j using FDMA
- Transmits in distinct time slots SL0, SL1, …, SL7, each of 577 μs
- An MS uses one of the 8 distinct time slots in a given channel

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Data bursts in a data frame

- A set of data bits in an SL
- A set of 8 data bursts defines a data frame
- Each frame uses different channel (radio carrier frequency)

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Example of three mobile stations, MS1, MS2, and MS3

- Assume B1, B2, and B3 the data bursts of MS1, MS2, and MS3, respectively)
- Using the same radio-carrier channel ch_m
- Assume B1 assigned SL0
- B2 assigned SL1, SL4, and SL7
- B3 assigned SL2 and SL6

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Data frame

- At an instant, a data frame can have bursts B1, B2, B3, X, B2, B3, X, B2 transmitted in 8 time slots SL0–SL7, respectively
- X represents unassigned slots for access by either BTS_j or other MSs that are using the same radio carrier channel

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Time for data burst and frame

- Since an SL = 577 μs, data burst period = 577 μs
- Each data frame transmits in 8 ×577 μs = 4.615 ms

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Half Duplex Transmission

- The transceiver of a mobile device can function in half duplex mode when the uplink time slot t_u and downlink time slot t_d are assigned separately by a BTS
- *tu* – *td* is constant = 3×577 µs

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Frequency Hopping in Data Frames

- Specific frequency values result in signal fading at an instant
- Do not provide expected signal strengths
- A data frame frequency channel assigned to an MS by the BTS can be changed (hop) these select frequencies at a certain rate according to a predetermined sequence

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Frequency Hopping

- This helps in ensuring better signal quality for most of the period
- GSM hopping rates are 207.6 hop/s

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Delays in Data burst during transmission

- Variable delays during transmission– the reflected signals take different amounts of time
- Original signals – reconstructed using a digital signal processor (DSP)
- The DSP spends computational time in processing the signals

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Format of a Data Burst– Guard space in time slot

- At the beginning and end of every data burst of 577 μs, a guard spaces of 15.25 μs (equal to 4.125 bit transmission time interval) each reserved to account for delays in the reflected signal and computational time

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Format of a 577 μs TDMA burst

- The effective transmission time for the data bits is, therefore, [577 – (2 ×15.25)] = 546.5 μs
- 148 bits– transmitted in 546.5 μs
- Data transmission rate = (8 × 148) bits/4.615 ms = 256.555 kbps
- Transmission by GMSK modulation and at 256.555 kbps (3.898 μs/bit)

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Division among 148 bits

- Six bits, 3 at the head (*H*) and 3 at the tail (*T*) [called tail bits (TB)]
- At H, bits– 000
- At T, bits = 000

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Division among 142

- 26 bits in the middle of the burst are transmitted as training (*TR*) bits
- The TR bits enable the receiver to (a) synchronize using *H*, *TR*, and *T* bits and (b) select the strong components of the signals
- Direct path or wide reflection angle signals are the strongest ones as they travel the least distance between the transmitter and the receiver

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Division among (142 – 26)/2 = 58 bits each after H and before T

- Data in the burst can be of two kinds—MS data or mobile-service NSS control data
- On either side of the *TR* bits, an S bit can be placed to specify whether the source is the MS or NSS control data
- Meaningful data bits are 57 after H and 57 before T

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Division among 57 bits each between H and TR, and TR and T

- Assuming that only one time slot used in a data frame of 8 slots when transmitting voice and assuming that the only data bursts are voice data bursts
- Total 114 bits (57 + 57) for the user data in a data burst (timeslot)
- Total number of bits per second = 114/4.615 bit/ms = 24.7 kbps

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User and Other than user slots

- 12 slots for user data
- User data followed by one slot for control signals data
- The voice data (user data) rates ≠ 24.7 kbps but 12/13 × 24.7 kbps = 22.8 kbps

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User and Other than user slots

- Additional slots required for the frequency correction and synchronization bursts
- The control data slot is replaced by an empty slot X in every alternate set of 13 frames

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Traffic multiframe

- Total 26 data frames in one in which there are one control data, one empty, and 24 user data frames
- Traffic multiframes transmit TCH, FACCH, and SACCH data (Next lesson)

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Control channel capacity

- Within a traffic multiframe one control channel
- Capacity = $(1 \div 26) \times 24.7$ kbps = 950 bps

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Traffic multiframe

- Transmits in 26 $\times$ 4.615 ms = 120 ms interval

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Interleaving in a Traffic Multiframe

- Interleaving means inserting in-between
- The packets, each consisting of 456 bits in a 20 ms time slot, are interleaved in a traffic multiframe for voice traffic

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Example

- Assume two MSs, MS_i and MS_j multiplexed in TDMA slots
- There are 57 bits after *H* and 57 bits before *T* in the data bursts
- TCH/F (traffic channel full rate) transmission rate = 22.8 kbps
- Therefore, there are 456 (= 8×57) bits per 20 ms in voice traffic from two MSs

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Example

- When 20 ms packets of MS_i and MS_j interleave, then all the 57 bit time-slots after *H* in each data burst are used by MS_i and all the 57 bits before *T* in each data burst are used by MS_j
- Interleaving distributes the effects of channel characteristics variations with time on multiple MSs

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Summary

- Space division multiplexing to increase user capacities, FDMA to provide 124 uplink and 124 down link channels and TDMA in 8 time slots of each = 577µs
- Guard space between radio carrier channels
- Each slot carrying a data burst
- Data frame has 8 data bursts of 4.6 ms

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… Summary

- Guard interval in each time slot to account for delays in reflected signals
- 3 H bits, 3 T bits, 26 TR bits, 1 S bit and total 57 after H and 57 before T for user data
- After 12 user slots one control data slot or empty slot in traffic multiframe of 26 frames in 120 ms

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End of Lesson 07

GSM Radio Interface, Data bursts and Interleaving

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GSM and Similar Architectures

Lesson 08

GSM Traffic and Control Data Channels

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Four Types of Control Data Bursts— Access burst

- The call setup takes place when setting the initial connection using a burst
- The channel in which this burst is sent is called AGCH (access grant channel)— a part of CCCH (common control channel)

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Four Types of Control Data Bursts— Synchronization burst

- Synchronization burst— of 64 *TR* bits helps in synchronizing the transmitter and receiver time slots and in timing advance
- The data bits after header and before tail in the burst are [(142 – 64)/2] – 1 = 38 bits in place of 57 bits
- SCH (synchronization channel)— the channel used of this burst, a part of BCCH (broadcast control channel)

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Need for synchronization

- The *TR* bits help the receiver in correcting path changes
- All the MSs that are communicating with the BTS must be synchronized
- The total time durations of forward and return paths vary, as some MSs are closer than the others

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Need for synchronization

- A timing advance required for synchronization when a BTS receives a signal from a far off MS compared to a short distance MS
- The advance is of maximum 0.24 ms (63 $\times$ 3.692 μs period for 63 bits, because each bit is transmitting in a 3.692 μs interval

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Four Types of Control Data Bursts—Frequency correction burst

- Corrects the carrier frequency
- In place of the *TR*, *S*, and user data bits, a 142-bit sequence between *H* and *T* is deployed
- FCCH (frequency correction channel)—The channel for this burst sent, a part of BCCH

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Need for frequency correction

- A deviation in the frequency of a radio carrier possible
- Interference with the neighbouring channel frequency possible
- During synchronous data transmission), the receiver must synchronize the clock rate according to the incoming data bits

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Four Types of Control Data Bursts—Dummy burst

- When no useful burst being transmitted from an MS or BTS after a connection setup

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Traffic Data Channel– Voice coding

- Using a codec (coder–decoder)
- A circuit that codes analog signals into digital signals and decodes digital signals into analog according to various coding and decoding algorithms

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Traffic Data Channel — CRC and redundant bits for FEC

- The error correction bits (cycle redundancy check (CRC) and redundant bits) appended and data interleaving is performed

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Application of data interleaving

- Introducing noise in idle state to prevent user uneasiness in periods of silence

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Three type of voice traffic

- TCH/FS (traffic channel/full rate set for transmission)
- TCH/HS (traffic channel/half rate set for transmission)
- TCH/EFR (traffic channel/enhanced full rate set for transmission)

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Three type of voice traffic

- TCH/F14.4– Traffic channel/full rate at 14.4
- TCH/F9.6– Traffic channel/half rate at 9.6 kbps
- TCH/F4.8 – Traffic channel/half rate at 4.8 kbps

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Three type of voice traffic

- Due to large number of subscribers at a base station, the GSM specifications provide for the traffic rates of 14.4 kbps, 9.6 kbps and 4.8 kbps also

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TCH/FS

- Voice coded with a codec (coder–decoder) at 13 kbps
- Additional bits appended after coding, the data rate is enhanced to 22.8 kbps when transmitting at full speed

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TCH/HS

- Coded with a codec at 5.6 kbps and after the error correction bits the data rate is enhanced to 11.4 kbps and transmission takes place at half speed
- The available data rate is 22.8 kbps

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TCH/HS advantage

- Double voice signals can now be transmitted
- However this sort of voice data results in degradation of voice quality

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TCH/EFR

- Coded with another enhanced coding technique employing a codec
- EFR gives at enhanced voice quality but has limited error correction bits because the data rate is limited to 12.8 kbps

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TCH/EFR advantage

- The voice quality upgraded in those cases where the transmission error rate is small
- A codec may function in automatic mode and code the voice as TCH/FS
- TCH/EFR depending on the transmission error rate detected in the bursts

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Control Data Channels

- The 184-bit packet from data link layer
- Formatted for the data burst bits
- The 184-bits added with 40 parity bits, 4 tail bits, and 224 half-convolution coding bits
- Total result in the 456-bit packet (Multiple of 114 bit in a data burst)

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DCCH (dedicated control channels)

- An MS sends TCH traffic only after a call setup
- A bi-directional communication channel present between the BTS and MS before the TCH traffic starts
- Called standalone DCCH (SDCCH)

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SADCCH (slow associated dedicated control channel)

- Used for the registration, authentication, and other requirements
- Total 782 bits sent as dedicated control channel data in 1 s in case of slow associated standalone DCCH (SADCCH)
- 950 bps can be sent as a control data slot in a traffic multiframe

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FACCH (fast associated control channel) with TCH

- When more than 782 bits are to be sent per second, then the TCH part of the data bursts can be used
- Then DCCH is called FACCH (fast associated control channel)

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BCCH (broadcast control channel)

- A BTS needs to broadcast the frequency and cell identity
- A BTS needs to broadcast the information regarding frequencies and sequence options for hopping that can be assigned to the MSs in the cell to all the MSs
- BCCH used for that

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BCCH (broadcast control channel)

- Enables an MS to get an available radio-carrier frequency channel and transmit with different frequencies on different hops and synchronize with the BTS
- The synchronization and frequency correction bursts also use the BCCH

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CCCH (common control channel)

- A BTS (when granting access to an MS so that MS can use either SDCCH or TCH) uses a channel called AGCH (access grant channel)
- After the access is granted, the call setup or call forwarding can take place
- The control channel used for such purposes is called a CCCH

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CCCH

- When call setup requirements are transmitted from the MS, CCCH called RACH (random access channel)

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RACH

- Data burst format– during 577 μs in place of the (*H*, user data, *S*, *TR*, *S*, user data, and *T*) sequence, a 145-bit sequence is modified as 8 *H* bits, 41 synchronization bits, 36 bits user data and 3 *T* bits (total 88 bits).
- The guard-space time intervals are now equal to (68.25 × 3.692)/2 = 126 μs before *H* and after *T* bits

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PCH (paging channel)

- When call-forwarding information transmits from the BTS, the CCCH is called PCH

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Paging Example

- Transmission of information to a select target MS for example, the identity of the caller of an incoming call to the MS to which the call is to be forwarded

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AGCH (access grant channel).

- When access granting information is transmitted from the BTS, the CCCH is called AGCH

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Control Multiframes

- A control multiframe 51 data frames
- A control multiframe transmit in 51× 4.615 ms = 235.4 ms
- A traffic multiframe transmits in 120 ms

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Superframe

- After formatting, a super frame can have 51 traffic multiframes of 120 ms each or 26 control multiframes of 235.4 ms each
- A super frame, therefore, transmits in 26 × 235.4 ms or 51 × 120 ms, both equal 6.12 s

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Hyperframe

- Consists of 2048 superframes
- Transmits in 2048×6.12 s = 12533.76 s ≈ 3½ hours

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Use of sequence number *s* in Hyperframe

- *s* = 0 to (2048 × 26 × 51) – 1 slots in a *hyperframe*) to each 4.615 ms data frame
- *s* encrypted along with the data so that after decryption, the original frame number can be recovered for sequential arrangement of data

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Use of sequence number in Hyperframe

- Since the frames sequentially transmitted through the 8 TDMA time slots, the *s* also helps in identifying the original time slot of a given data burst

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Summary

- Three type of traffic data frames
- TCH/FS, TCH/HS and TCH/EFR
- Control data frame
- DCCH, SADCCH and FADCCH
- BCCH
- CCCH
- Superframe and hyperframe

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End of Lesson 08

GSM Traffic and Control Data Channels

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GSM and Similar Architectures

Lesson 09

Protocol Layers in GSM

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Layers defined in the open system interconnection (OSI) model

- physical (layer 1)
- data link (layer 2)
- network (layer 3)
- transport (layer 4)
- session (layer 5)
- presentation (layer 6)
- application (layer 7)

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Transceiver

- Receives signals
- Signals processed at the different layers arranged in order from layer 1 to layer 7

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Transceiver

- Transmits the signals
- Signals processed at the different layers arranged in order from layer 7 to layer 1

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Each layer additional headers (messages)

- In specific formats so that these layer headers for each layer can be stripped by the transceiver at the receiving end
- Various operations can be performed on the received data

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Actually used Layers

- TCP/IP or GSM, a transceiver need not define protocols for all 7 layers
- Some layers perform the functions of neighbouring layer(s)
- The MS, BTS, BSC, and MSC, for example, have just 3 layers—physical, data link, and network

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Actually used Layers

- Transport and session layer functions are taken care of by network layer protocols
- The tasks of the presentation layer are performed by other layers
- TE (user) application at either end (caller and connected ends) controls the application layer protocols

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Actually used Layers– Examples of The Mobile station, BTS, BSC, and MSC

- Have just 3 layers—physical, data link, and network
- Transport and session layer functions taken care of by network layer protocols
- The tasks of the presentation layer are performed by other layers
- TE (user) application at either end (caller and connected ends) controls the application layer protocols

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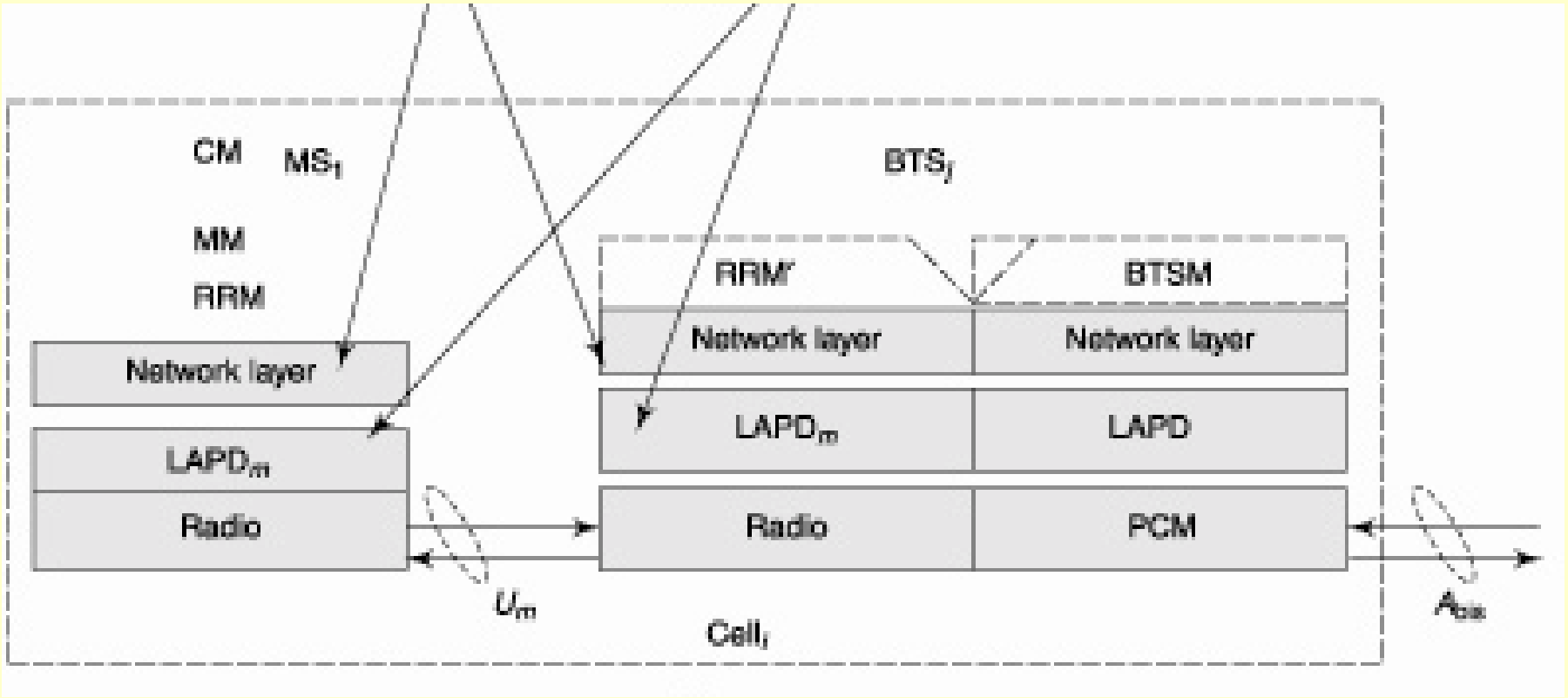
All protocol layers between the MS and BTS



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Radio protocol sublayer functions at physical layer between the MS and BTS

Radio:

- Full- or-half duplex access
- SDMA, TDMA, and FDMA
- Bursting and framing
- Synchronizing the MSs and path delays corrections
- Frequency correction
- Coding, FEC, CRC, data interleaving, and encryption
- Error detection, correction, and blocking the data not correctable
- GMSK digital modulation and transmission
- Demodulation and reception
- Decryption and decoding

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Data link layer sublayer $LAPD_m$

- Controls the flow of packets to and from the network layer and provides access to the various services
- LAPD*m* (link access protocol *D*-channel modified) for *Um*– data link layer protocol between the MS and BTS
- For accessing the *D*-channel link by GSM

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Data link layer sublayer $LAPD_m$

- A modified version of the LAPD protocol for the D-channel of ISDN (integrated services digital network)
- No need of appending and stripping of synchronization bits, *S* flag, and error correction bits to and from the layer in LAPD*m* because the radio interface (*Um*) performs these functions at the physical layer itself

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Data link layer sublayer $LAPD_m$

- Communicates by wireless across the radio interface as opposed to the guided transmission of ISDN signals in case of the LAPD

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$LAPD_m$ (Link Access D-Channel protocol for mobile) sub-layer Functions

$LAPD_m$:

- Data flow control
- Acknowledged/unacknowledged data transmission
- Address and sequence number checks
- Access point for the multiple services
- Re-sequencing of data
- Segmentation
- Data re-assembly

d.

Network layer

- Three sub layers—call (connection) management (CM), mobility management (MM), and radio resource management (RRM)

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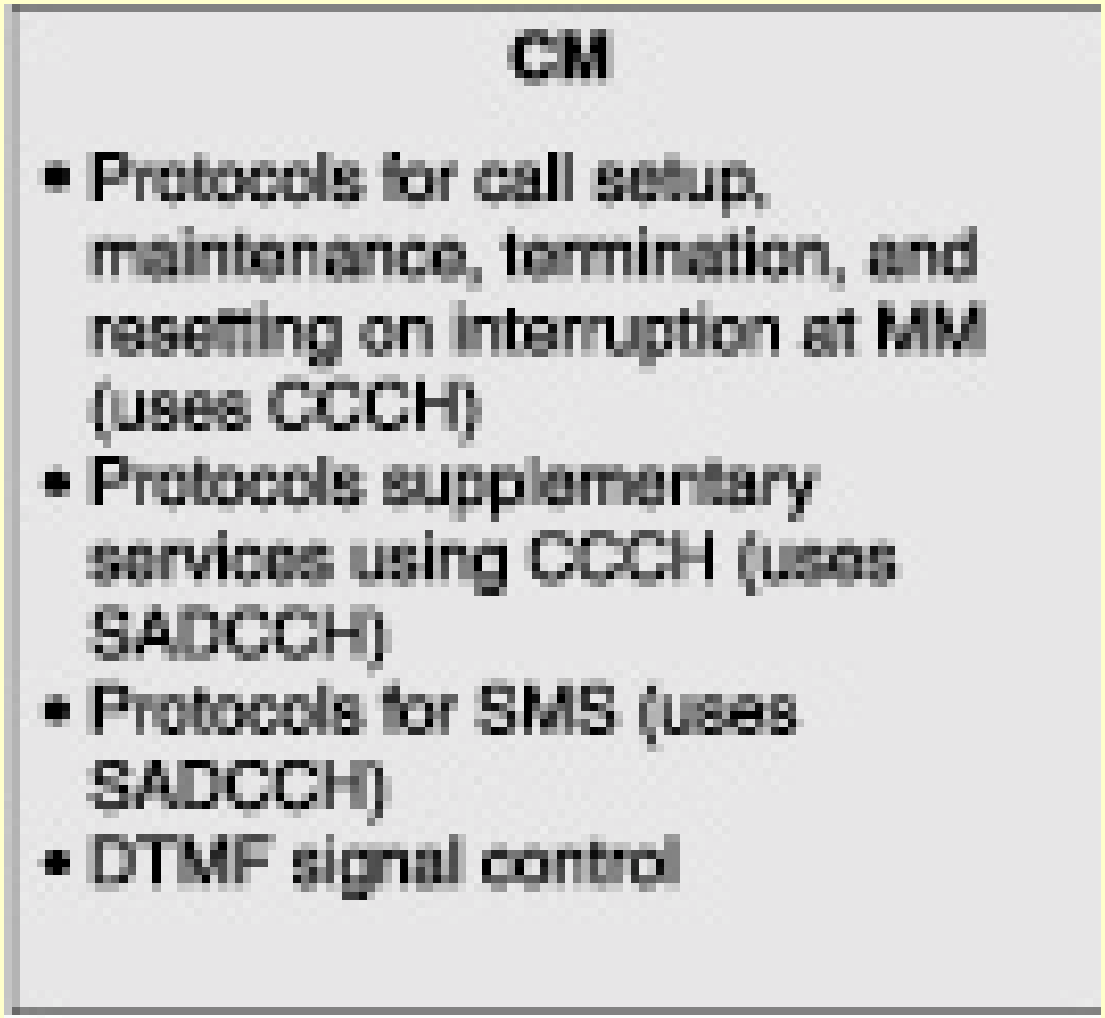
Operations in the CM sub layer



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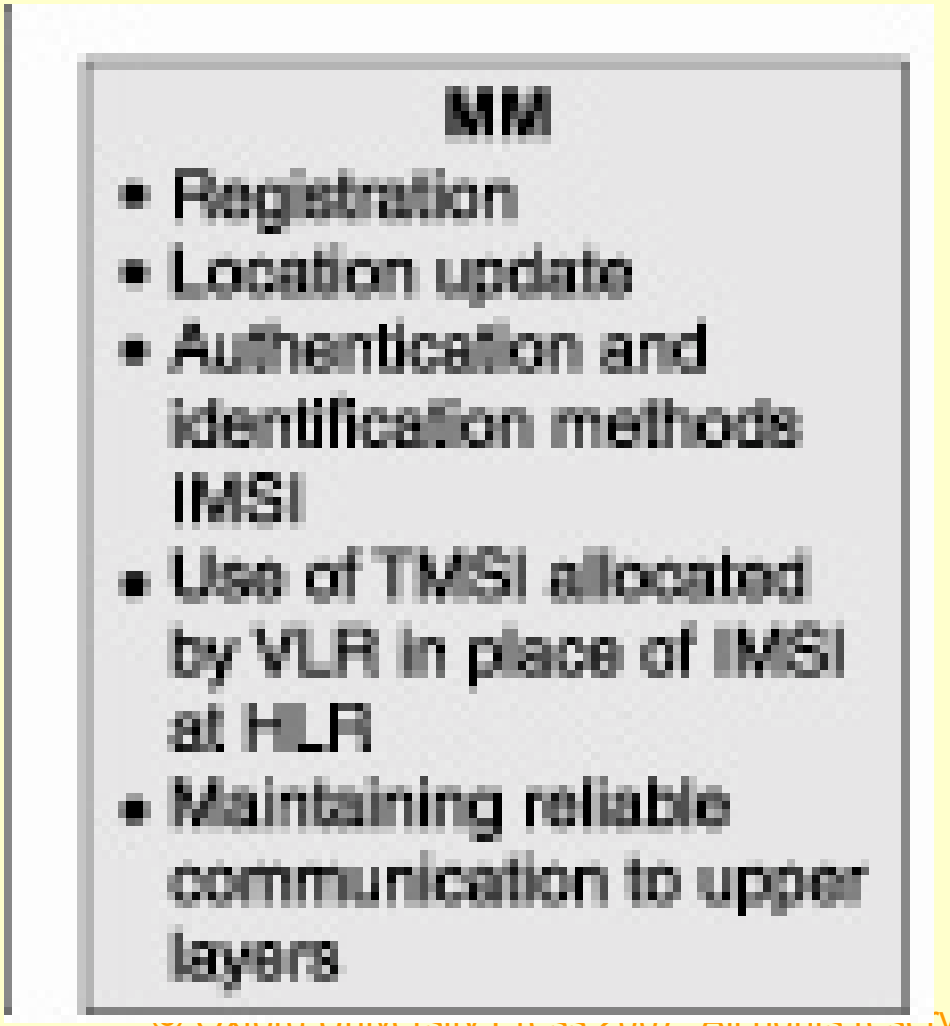
Operations in the MM sub layer



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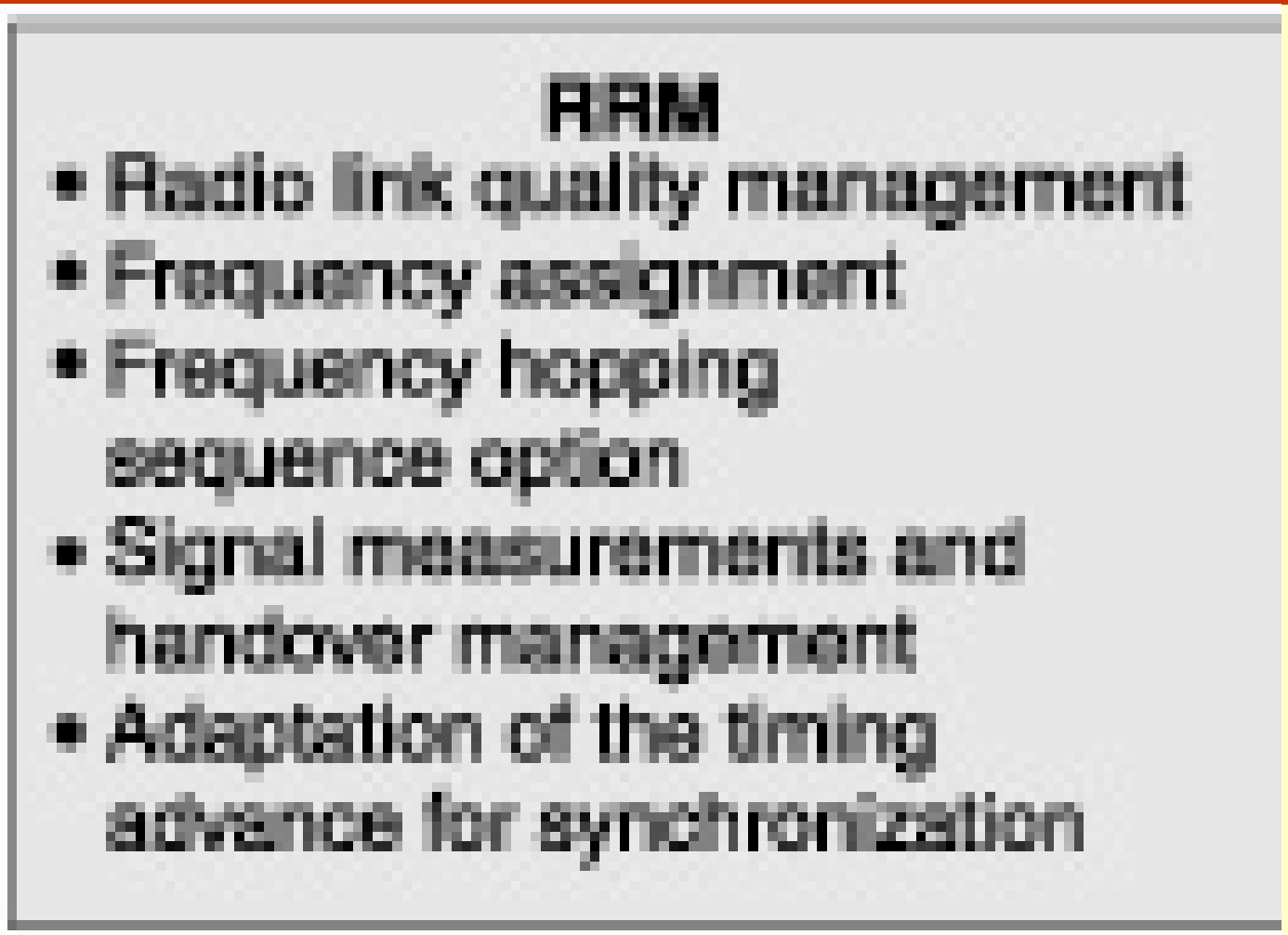
Operations in the RRM sub layer



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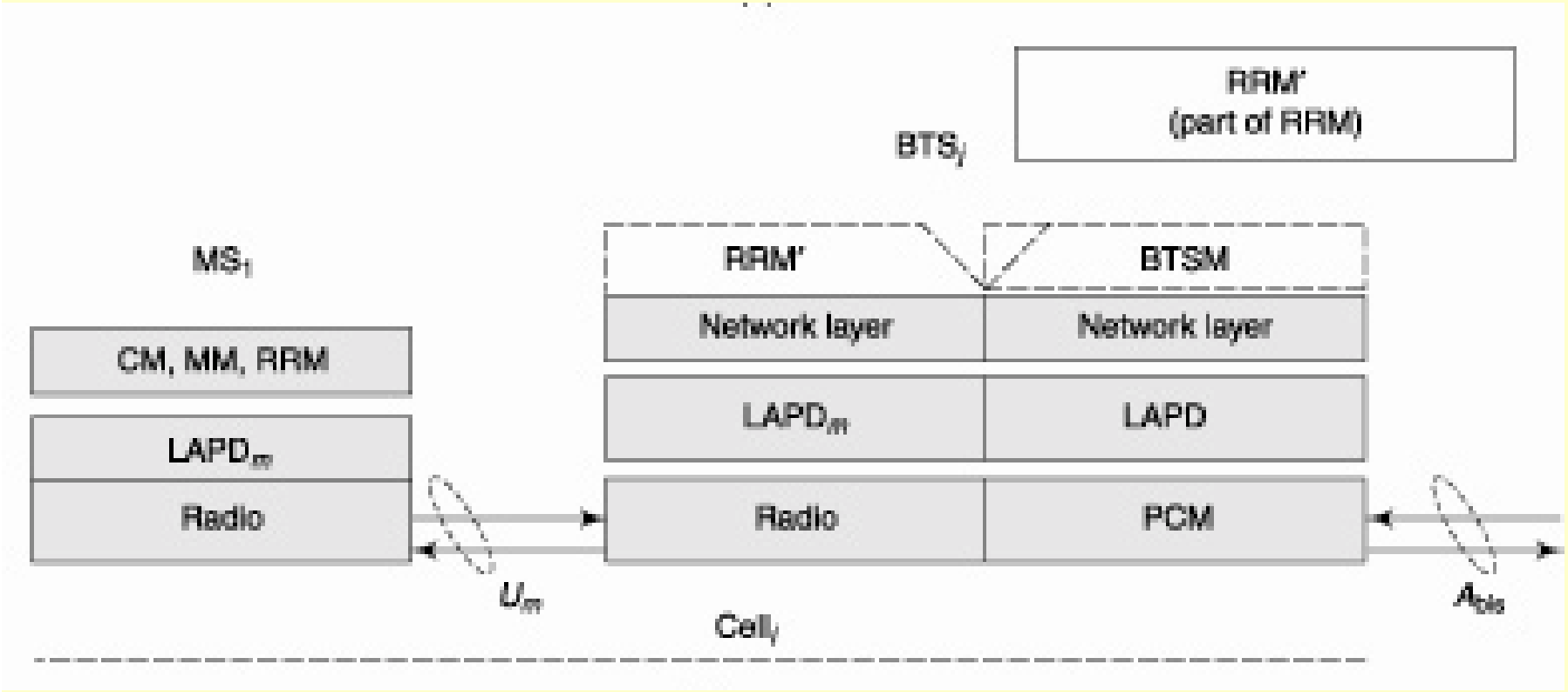
Interfaces of the Network sublayers



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CM sub layer protocol

- Supports call establishment, maintenance, and termination
- The CM sub layer also controls and supports the functioning of the SMS and supplementary services
- The CM also supports DTMF (dual tone multiple frequency) signalling

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The MM layer

- Controls issues regarding mobility management when an MS moves into another cell (location area). The RRM manages the radio resources. The BTS implements only RRM′ (a part of RRM) as the BSC handles the handover.

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Functions of the network layer

- Defines protocols for implementation of addressed messages received from the data link layer
- Defines addresses of the messages

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Functions of the network layer

- Performs the following functions:
- Defines protocols for implementation of addressed messages received from the data link layer,
- Defines addresses of the messages

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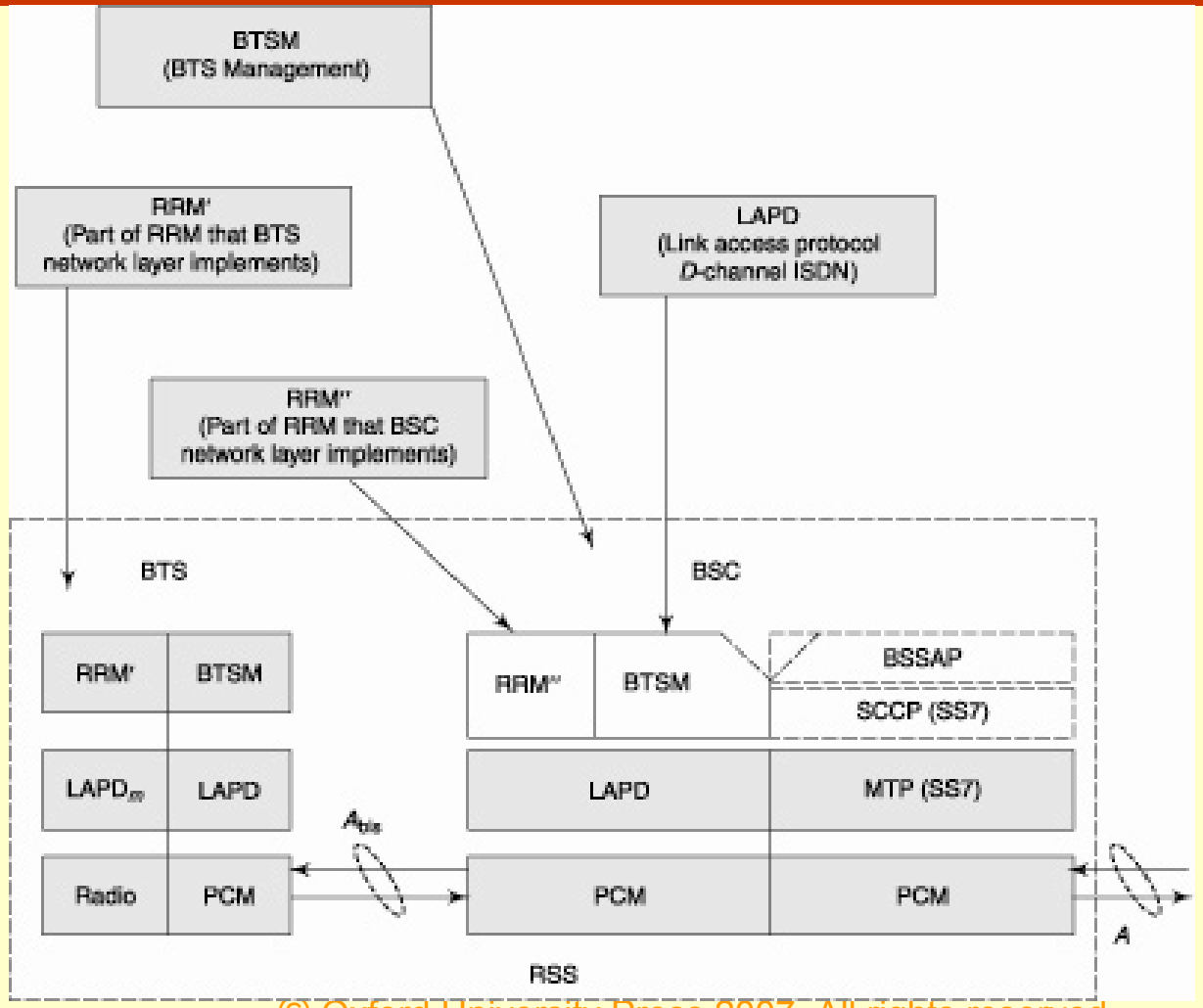
Base transceiver–Base station controller Signalling Protocols



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Physical layer between the BTS and the BSC

- A_{bis} interface (of the PSTN, ISDN, or PSPDN networks)
- The connection between the BTS and the BSC through a wired network (PSTN, ISDN, or PSPDN)

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Physical layer between the BTS and the BSC

- Voice coded in the 64 kbps PCM (pulse code modulation) format in a PSTN network
- The A_{bis} interface between BTS and BSC, therefore, uses the 64 kbps PCM (or four multiplexed 16 kbps channels) format

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PCM coding techniques

- Different from the 22.8 kbps TCH radio interface U_m (between MS and BTS)
- Translation between these coding formats performed by recoding the TCH bits received from the caller MS to 64 kbps PCM and from PCM to TCH for the receiver MS

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Effect of translations

- This translation and retranslation from one coding format to another may affect voice quality
- Therefore, a procedure called TFO (tandem free operation) adopted at the BTSs, BSCs, and MSCs
- TFO means without performing translation and back retranslation processes repeatedly

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Data link layer protocol between BTS and BSC

- LAPD (link access protocol *D*-channel) for A_{bis}
- The protocol prescribes the standard procedure for the *D*-channel of ISDN (integrated services digital network

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The network layer protocol between BTS and BSC

- BTSM (BTS management)

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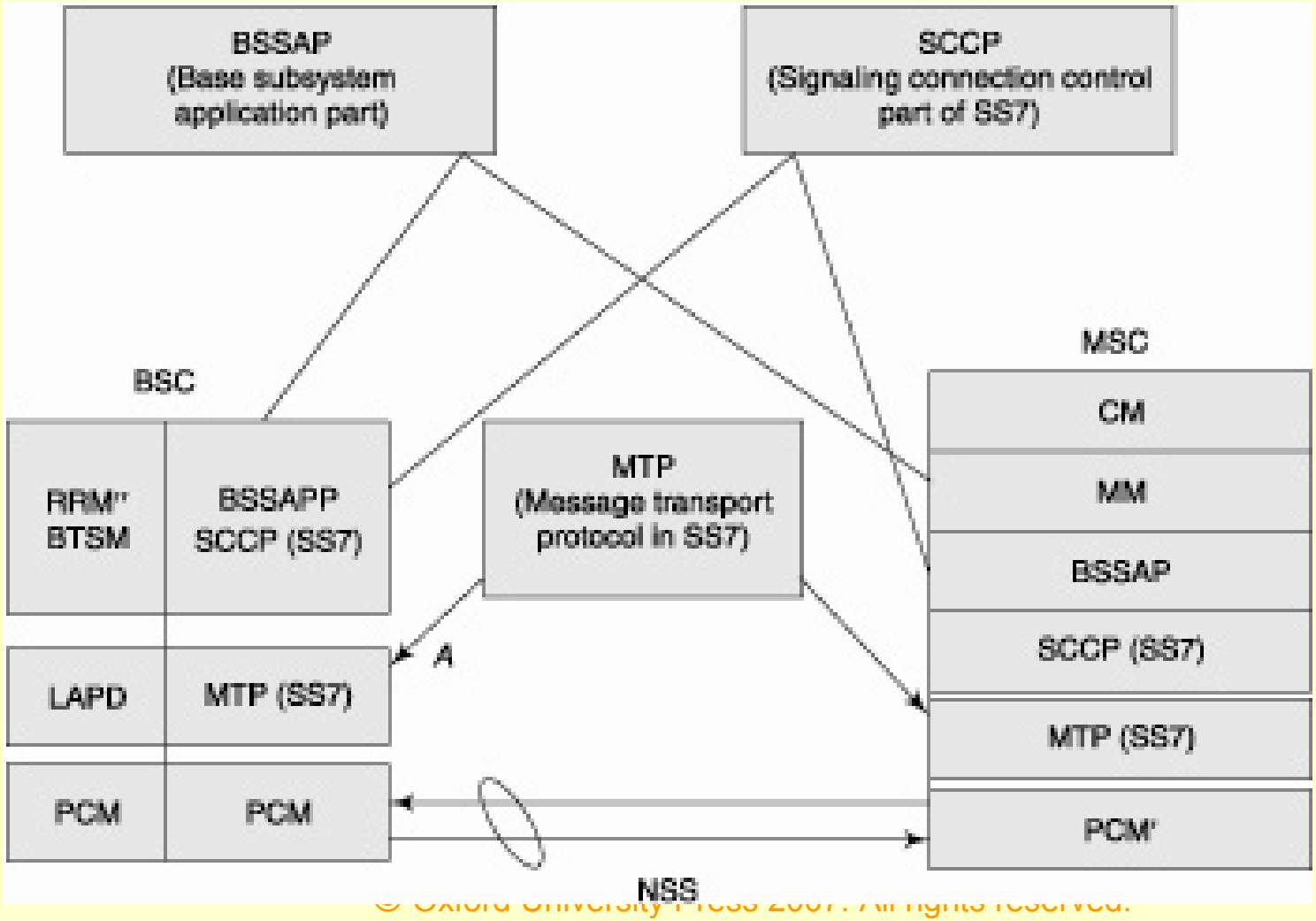
Protocols layers between the BSC and the MSC



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Data link layer protocols between the BSC and MSC

- MTP (message transfer protocol) and SCCP (signalling connection control protocol).
- MTP and SCCP are parts of the SS7 (signalling system No. 7) used by interface *A*

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Data link layer protocols between the BSC and MSC

- The layer protocol prescribes a standard procedure for the MTP and SCCP for SS7 transmission and reception in a 2 Mbps CCITT PSTN/ISDN/PSPDN network

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Network layer protocol at the BSC

- Network layer protocol sub layers at the MSC are CM, MM, and BSSAP
- BSSAP (base subsystem application part

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Summary

- The MS, BTS, BSC, and MSC, for example, have just 3 layers—physical, data link, and network
- Radio physical layer
- Data link LAPDm layer
- CM, MM and RRM at network layer

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End of Lesson 09

Protocol Layers in GSM

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GSM and Similar Architectures

Lesson 10

Localization and Calling

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Localization

- A process by which a mobile station is identified, authenticated, and provided service by a mobile switching centre through the base station controller and base transceiver either at the home location of the MS or at a visiting location

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Connection setup for a call and service on demand even while on the move

- Users want instantaneous connection setup for a call and want service on demand even while they are on the move
- The mobile service providers, on the other hand, will provide service(s) to the user only after identification of MS and verification of services subscribed

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Localization mechanism of the GSM

- Only after identifying the mobile station (MS) of the user
- Only Verifying the services subscribed

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NSS (network subsystem) of GSM architecture

- Periodically updates the location of those MSs which not switched off and are not struck off (or blocked) from the list of subscribers to the given mobile service
- The SIM in a mobile station MS_i stores location-area identification (LAI)

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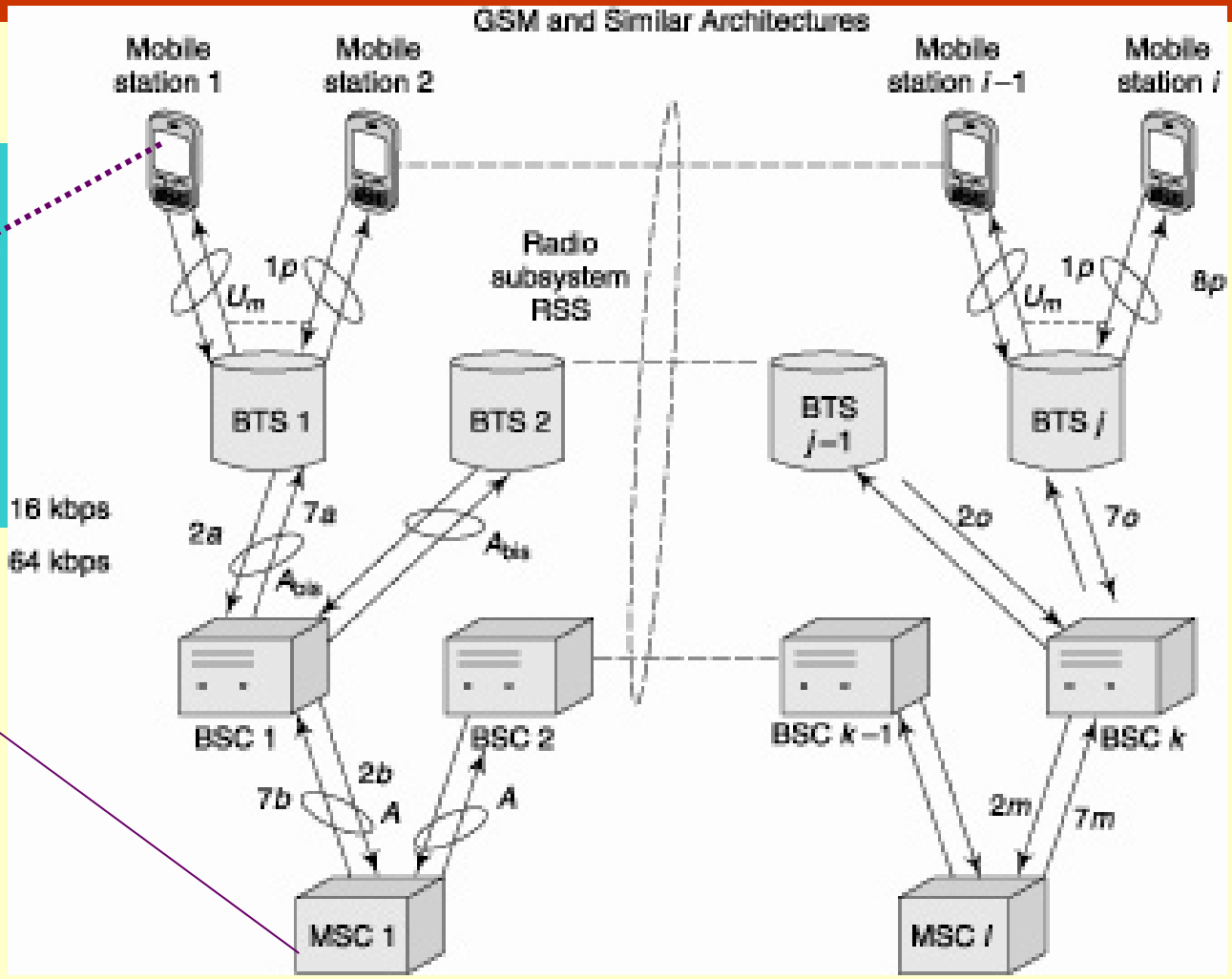
MSC sending LAI for store at SIM in mobile station

LAI updated by VLR through MSC



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LAI

- Location information which is updated by the MSC which covers the MS's current location area

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Temporary mobile subscriber identity (TMSI)

- The SIM also saves a assigned by the VLR associated to the current MSC
- The location update recorded at the VLR (visitor location register) and the LAI is updated at the SIM card in MS*i* via the MSC, BSC, and BTS covering its current location (interfaces *j*, 7*b*, 7*a*, and 8*a)*

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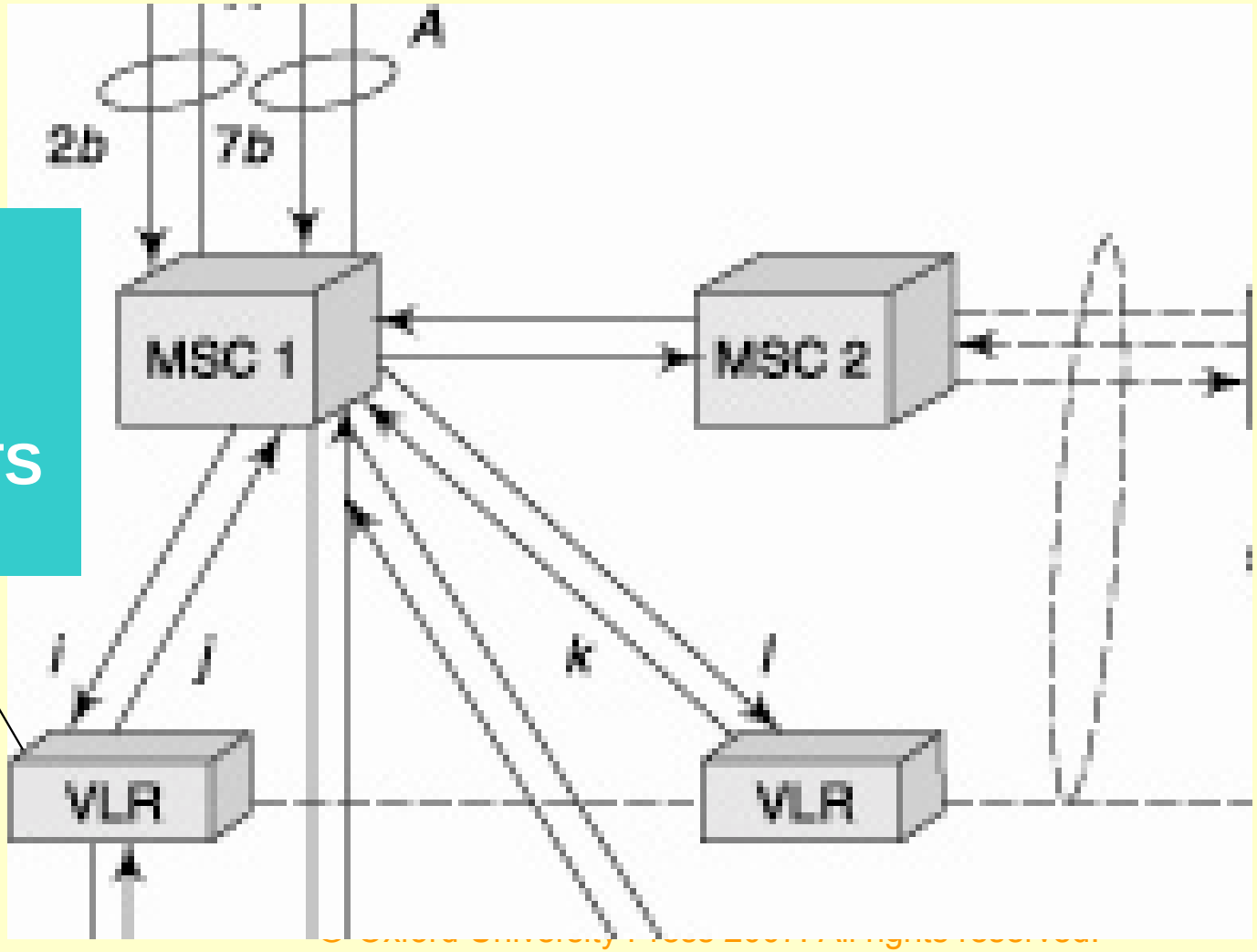
VLR for sending TMSI for BTS and Mobile station through MSC and BSC

For Mobile station and BTS a TMSI



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Main functions of an HLR

- Registration of information regarding IMSI (international mobile subscriber identity)
- MSISDN (mobile station international subscriber ISDN number)
- Roaming restrictions

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Main functions of an HLR

- Call forwarding
- Mobile subscriber roaming number (MSRN)
- Present VLR
- Present MSC

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MSISDN

- Internationally used code of the country followed destination area code in a country and subscriber number
- The identical coding scheme for address used in the ISDN network employing a fixed wire or fiber line)

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Present VLR and MSC information

- Can change when the user MS moves into another location area but the HLR which stores this information remains the same

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Main functions of VLR

- Registration of information pertaining to currently associated MSs
- The information about their HLR, IMSI, and MSISDN
- Storing information of the MSs which are in its location area and to which the MSC (associated with the given VLR) is currently network services

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Main functions of VLR

- Registration of any new MS that moves into the VLR's location area. It copies the information from the HLR of that MS
- Deregistration of an MS, if the MS dissociates from the MSC associated with the given VLR and moves out to another location area

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Communication between a mobile station TE and another TE

- The other TE could be a mobile station TE or other TE (such as a PSTN phone)
- The caller TE to be an MS communicating to the other TE via the path 1–2–3–4–5–6–7–8
- The caller TE can also be a PSTN phone

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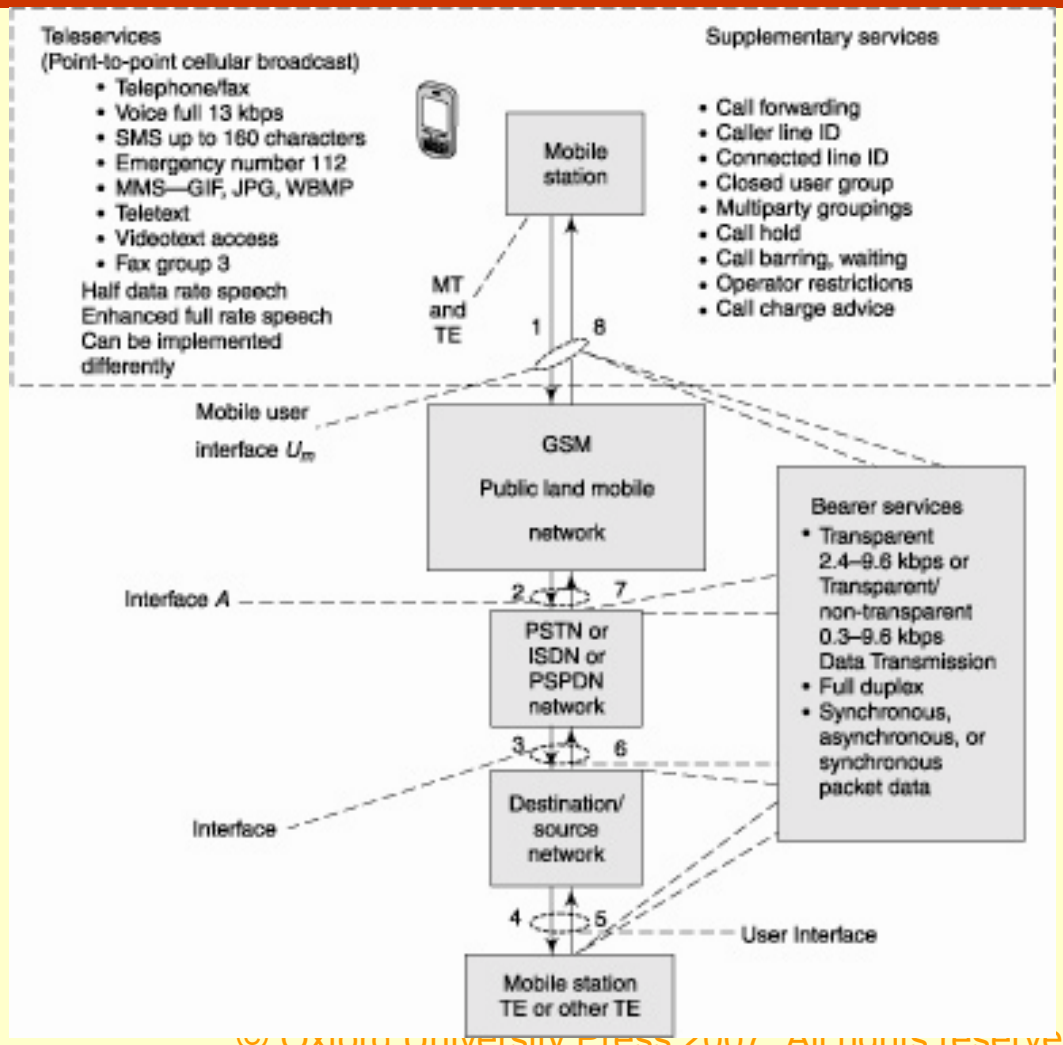
Communication between a mobile station TE and another TE



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Communication between a mobile station TE and another TE

- Different methods and protocols are used for establishing connection and maintaining communication in calling to and from mobile devices in a GSM PLMN network

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Various types of calls handled by a GSM network

- Calls originating from a mobile TE to a PSTN destination TE (Mobile→ PSTN Calls)
- Calls originating from a mobile TE to a mobile destination TE (Mobile → Mobile Calls)

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Various types of calls handled by a GSM network

- Calls originating from a PSTN TE to a mobile destination TE (PSTN → Mobile Calls)
- Message exchanges between the mobile station and the base transceiver (Mobile station ↔ Base transceiver message exchanges)
- Refer Section 3.5.1 to 3.5.4 for additional details

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Summary

- Localization process
- A mobile station identified, authenticated, and provided service by MSC
- Calling
- Use of Interfaces

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End of Lesson 10

Localization and Calling

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GSM and Similar Architectures

Lesson 11

Handover

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Handover (handoff) from one to another neighbouring cell

- Process of transferring a call (or data transfer) in progress from one channel to another
- The core network performs handovers at various levels of the system architecture or
- May handover the call to another network altogether

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Main reasons for handover in cellular networks

- If the mobile device moves out of the range of one cell (base station) and a different base station can provide it with a stronger signal
- If all channels of one base station are busy then a nearby base station can provide service to the device

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Handover process

- Important one in any cellular network
- Must be completed efficiently and without inconvenience to the user
- Different networks use different types of handover techniques

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Two main types of handover

- Hard handover– GSM systems
- Soft handover – CDMA systems

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Hard Handover

- Existing radio link must be dropped for a small period of time
- Then taken over by another base station
- A call in progress redirected not only from a base station to another base station but also from its current transmit–receive frequency pair to another frequency pair
- An ongoing call can not exchange data or voice for this duration

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Call drop in hard handover

- Break in call transmission
- Handover takes place in a few ms (at best in 60 ms)
- Interruption is hardly discernible by the user
- Handover to another cell is required when the signal strength is low and error rate is high. GSM systems perform hard handovers

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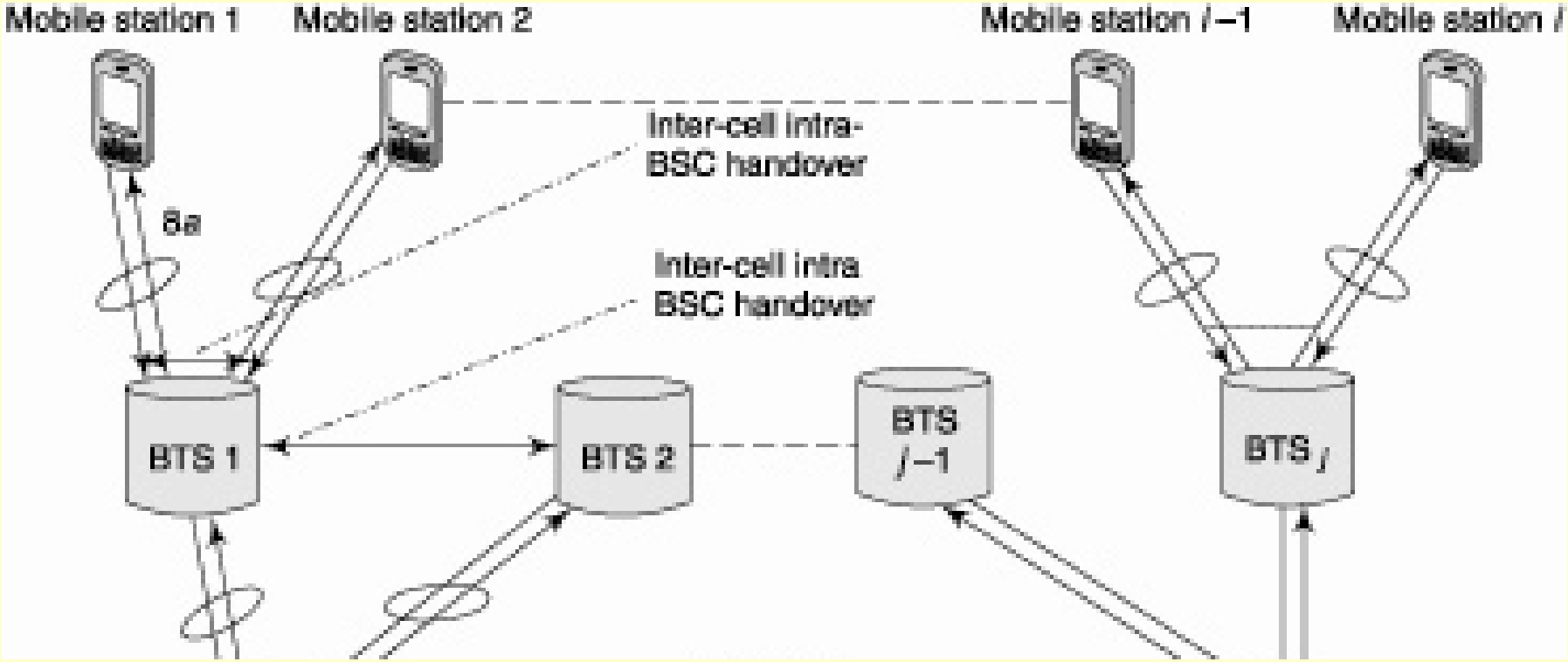
Inter-cell intra-BSC handovers when a mobile station moves from one cell to another



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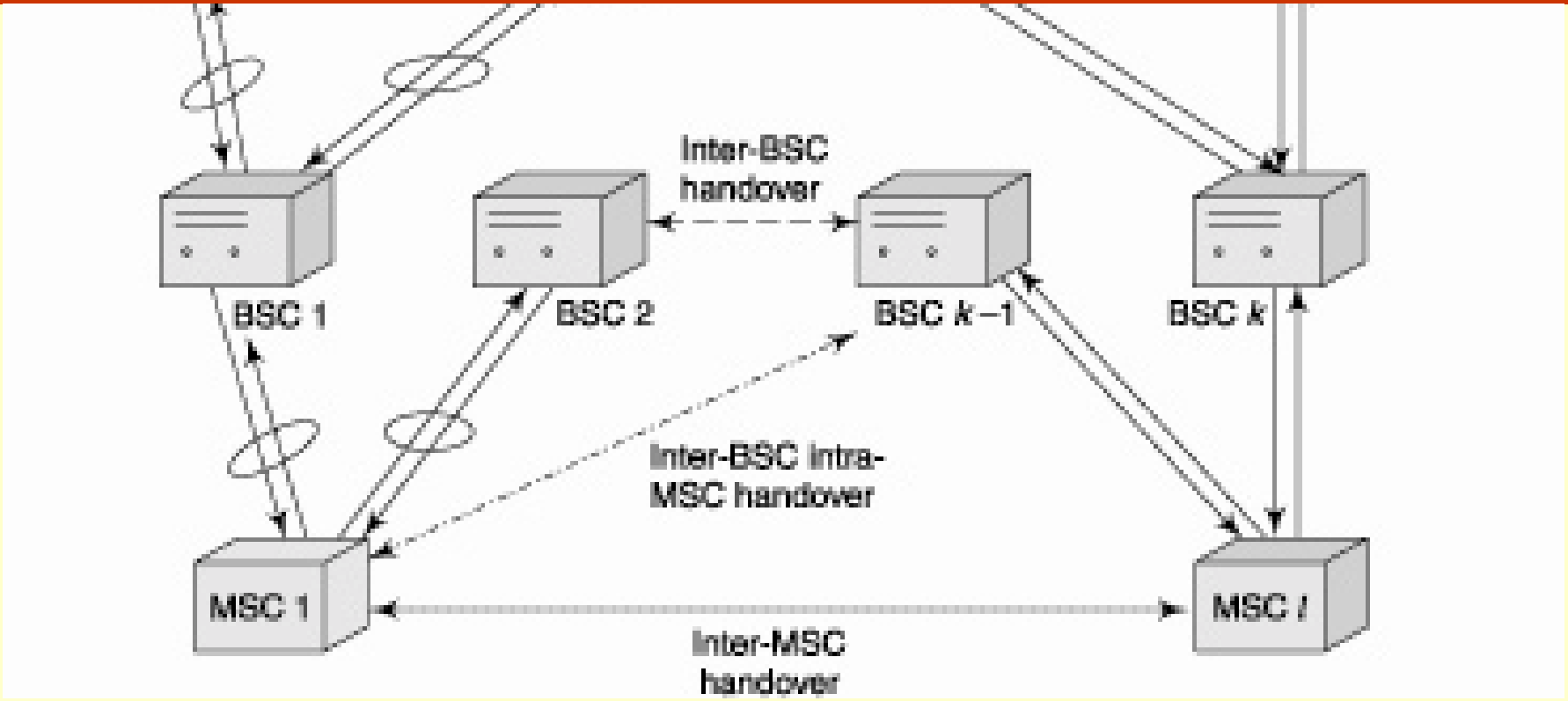
Inter-BSC intra-MSC handovers when a mobile station moves from one cell to another



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Signal strength

- Measurement continuously performed at the RRM (radio resource management) sub layers in the Mobile station, BTS, and BSC
- The RRM responsible for handover management

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Inter cell Handover

- When the signal strength goes weak due to several reasons (for example, the mobile moving away from the cell in which it is presently localized to the boundary region of another cell), there is handover from a cell to another

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Inter-MSC Handover

- Handover also takes place for load balancing when the traffic from the cells and BSCs high
- An ongoing call, which is being handled by a cell, may be handed over to another MSC
- Since the two MSCs are interfaced through PCM the handover performed over a wired line

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Inter-BSC Handover

- Handover for load balancing when the traffic from the cells and BTSs high
- The BSCs connect to an MSC
- A call, which is ongoing in a cell through a BTS, may be handed over to another BSC connected to the same MSC
- Since the BSCs connect to the MSC interfaces by PCM, the handover is over a wired line

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Inter-BSC, Inter-MSC Handover

- For load balancing when the traffic from the cells and BTSs as well as BSCs high

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Intra-cell Handover

- Due to interference at certain frequencies, the signal quality poor
- The BSC can handover the call to another frequency of the cell in such cases

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Inter-cell, Intra-BSC Handover

- When an MS moves to a neighbouring cell and suffers poor signal quality, the BSC can handover the call to a different BTS channel of the same BSC

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Inter-cell, intra-MSC handover

1. The RRM sub layer transmits a signal report from MS*i* to BTS*i* and from BTS*i* to BSC*i*. In case a handover is necessary, BSC*i* signals the handover requirement to MSC*i*.
2. MSC*i* signals the handover requirement to another BSC*j* and BSC*j* allocates radio resources and transmits the activated channel to another BTS*k*.

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Inter-cell, intra-MSC handover

3. BTS*k* sends acknowledgement of the channel to BSC*j* and BSC*j* acknowledges the handover request grant via message to MSC*i*
4. MSC*i* transmits handover command to BSC*i*, BSC*i* to BTS*i*, and BTS*i* to the MS*i*'s RRM layer

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Inter-cell, intra-MSC handover

- The RRM directs the MS radio interface to operate at another channel linked to BTS*k*

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Handoff–handover processes

- New handover methods have also evolved and are used in addition to the older techniques
- 3G standards and technology makes it possible for several mobile phones to use the same channel and for neighbouring cells to use the same frequency bands

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Soft handover

- Mobile station at the boundary of two adjacent cells— does not suffer call drops due to handover in the boundary region
- Gives seamless connectivity to a Mobile station
- An offset to pseudo noise code— method of soft handover

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Soft handover

- Soft handover does not require breaking of the radio link for cell-to-cell transfer of a call. A mobile device can be simultaneously connected to several base stations

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New generation (3G) networks

- Ensure mobility by handover not only among the BTSs, BSCs, or MSCs but also among the in-between LANs
- Ensures seamless (uninterrupted) connectivity to the user

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Summary

- Handover when the mobile device moves out of the range of one cell (base station) and a different base station can provide it with a stronger signal or when present cell traffic high
- Hard handover in GSM
- Call drop for hard handover
- Soft handover in CDMA

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End of Lesson 11

Handover

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GSM and Similar Architectures

Lesson 12

Security in GSM Services

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GSM networks various security features

- A wireless radio based network system quite sensitive to the unauthorized use of resources
- Designed to protect subscriber privacy
- Secured network against misuse of resources by unregistered users

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GSM networks various security features

- Controlled access to the network by Mobile station
- Required to use a PIN before it can access the network through U_m interface

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Authentication

- An AuC (authentication centre) for the operation and maintenance subsystem of the GSM network
- Authentication of the Mobile station
- The AuC first authenticates the subscriber Mobile station and only then does the MSC provide the switching service
- to another terminal TE, which is also authenticated in case it is a Mobile station)

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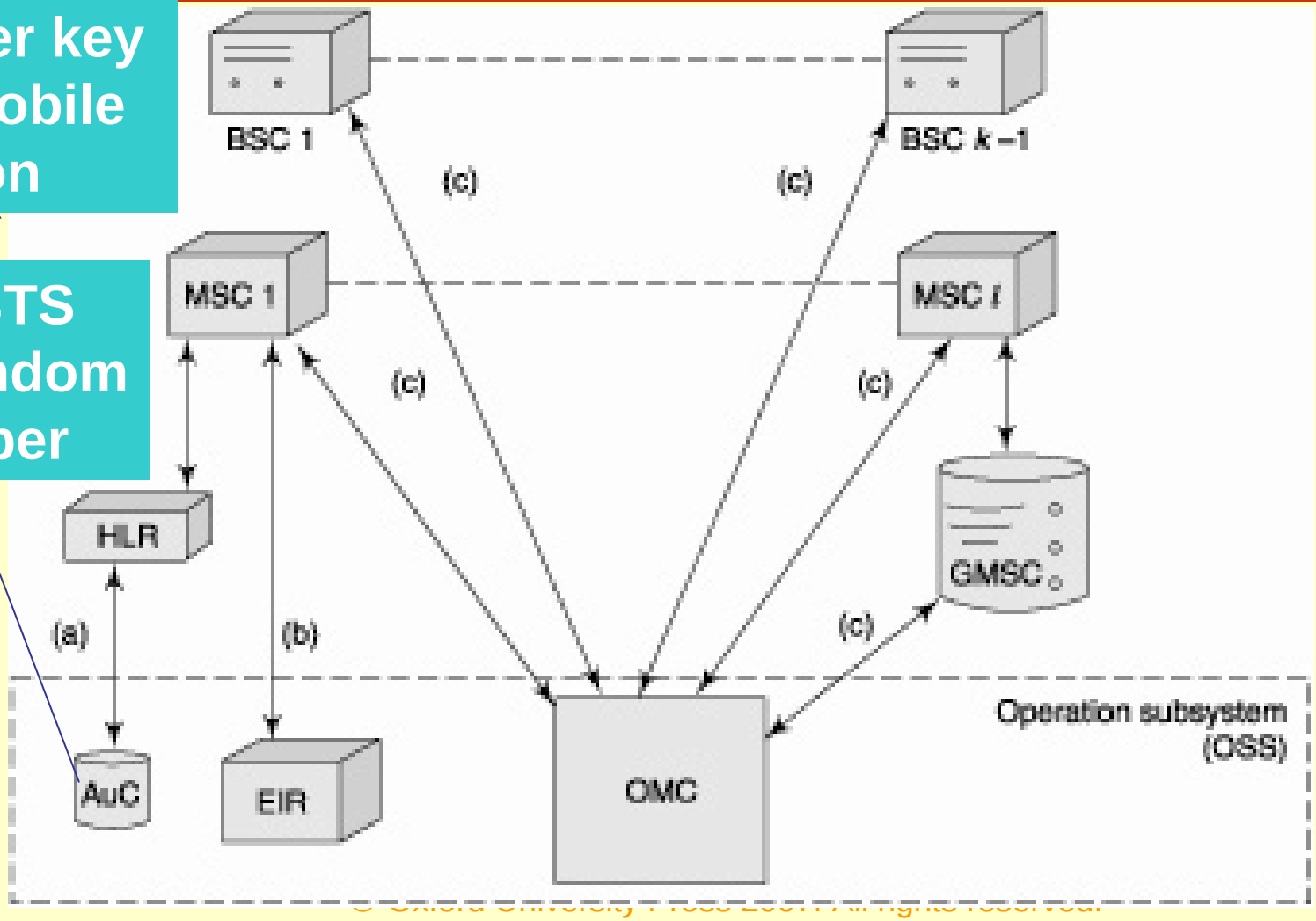
AuC sending random number for BTS and BTS sending cipher key for encryption

Cipher key for Mobile station

For BTS a Random Number



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Authentication algorithm

- Use a random number sent by the AuC during the connection set up
- An authentication key which is already saved in the SIM
- Authentication algorithm used differs for different mobile service providers

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IMSI and TMSI of the Mobile station

- Its public identity
- TMSI is the identity granted on moving to a particular location
- When a Mobile station moves to a new location area, the VLR (visitor location register) assigns a TMSI which is stored in the SIM of the Mobile station

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TMSI

- The identification of the subscriber during communication done not using the IMSI but the TMSI
- Ensures anonymous call number identity transmission over the radio channels

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Use of TMSI

- The VLR assigned TMSI generates that ID
- This protects the Mobile station against eavesdropping from external sources
- Caller line identification provision is a supplementary service

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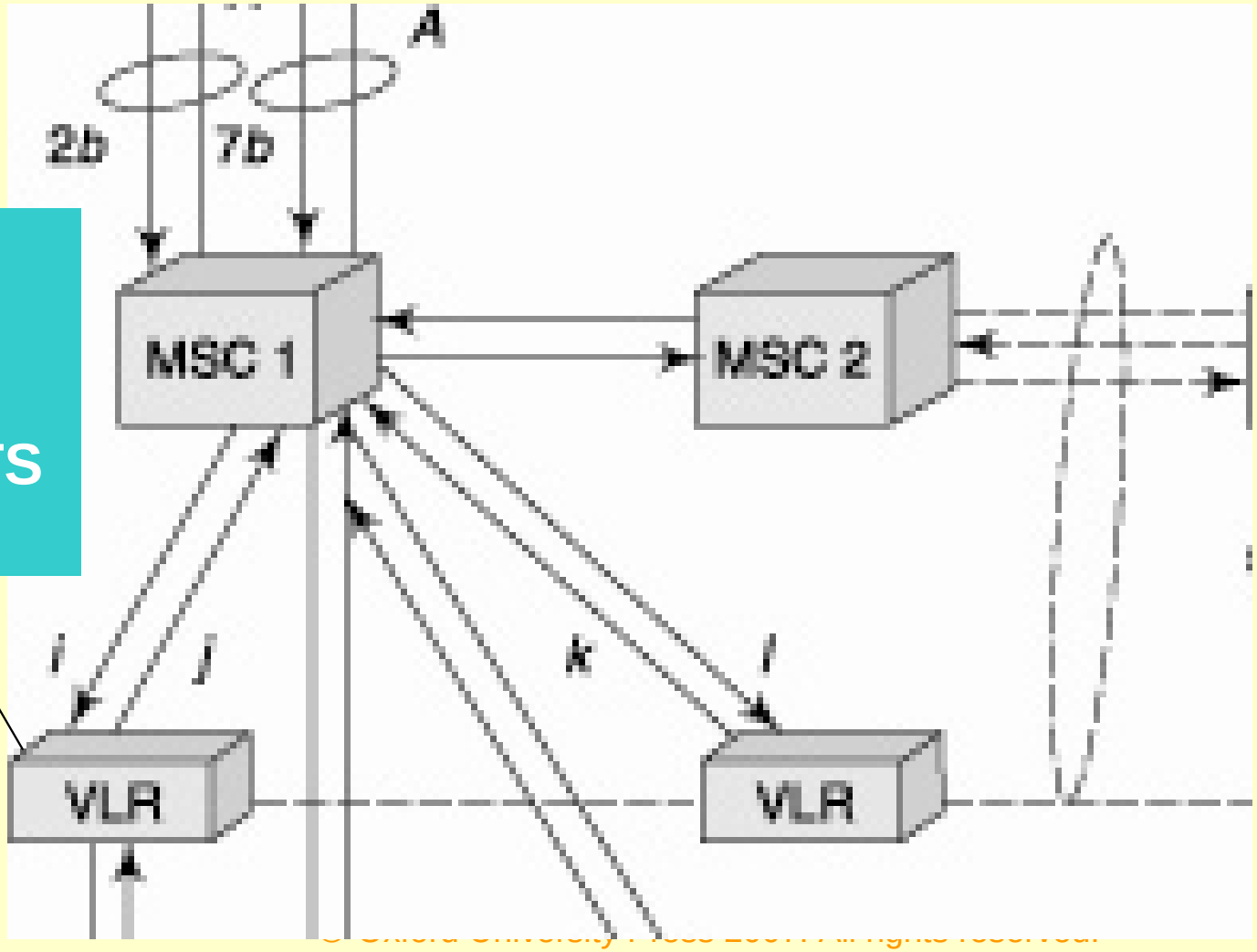
VLR for sending TMSI for BTS and Mobile station through MSC and BSC

For Mobile station and BTS a TMSI



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Encryption

- The BTS and the Mobile station perform ciphering before call initiation or before connecting for receiving a call
- The Mobile station uses a cipher (encryption key) for encryption
- Only encrypted voice and data traffic and control channel data transmit to the BTS

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The cipher

- A result of performing mathematical operations on (a) the cipher key saved in the SIM and (b) the cipher number received from the BTS when the call setup is initiated
- The BTS transmits the cipher number before a call is set up or transmitted

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Secured wireless communication between the Mobile station and BTS

- The encryption algorithm identical for all mobile service providers
- This ensures compatibility of the BTS, BSC, and MSC units made by different manufacturers
- The BTS deciphers the voice and data channel data by running a deciphering algorithm before communicating over the wired PCM (pulse code modulation) lines

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Challenge

- Random numbers used in authentication and ciphering processes
- Challenge to the mobile station to generate the results (responses) of the algorithms
- If these results are correct only then do the BTS and other units grant access to the challenged Mobile station

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Summary

- Controlled access to the network by Mobile station
- PIN before Mobile station can access the network through U_m interface
- VLR generated TMSI
- Random number generation and then encryption algorithm for cipher key generation
- Challenge

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End of Lesson 12

Security in GSM Services

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GSM and Similar Architectures

Lesson 13

GPRS

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Two switching modes

- Circuit Switching
- Packet switching

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Circuit switching

- A connection first sets up
- Then the entire data transmits through the path that has been set up during the connection

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Packet switching

- Packets of data at any given instant can take multiple (time slots or channels or paths or routes)
- Depending on the idle slots at that instant
- Receiver assembles the packets into the original sequence in the data

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General packet radio service (GPRS)

- **A** packet-oriented service for mobile stations' data transmission and their access to the Internet
- A speed enhanced data transmission service designed for GSM systems
- Speed enhanced data transmission– by packetizing data and simultaneous transmission of packets over different channels

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GPRS

- Uses the unused slots and channels in TDMA mode of a GSM network for packetized transmission from a mobile station
- Data-packets of a single mobile station transmit through a number of time slots

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GSM system– a subsystem of a GPRS system

- GPRS employing the GSM physical layer
- Connects mobile stations for voice-data transmission
- Connects the mobile stations to the Internet
- Packet data networks at higher data rates

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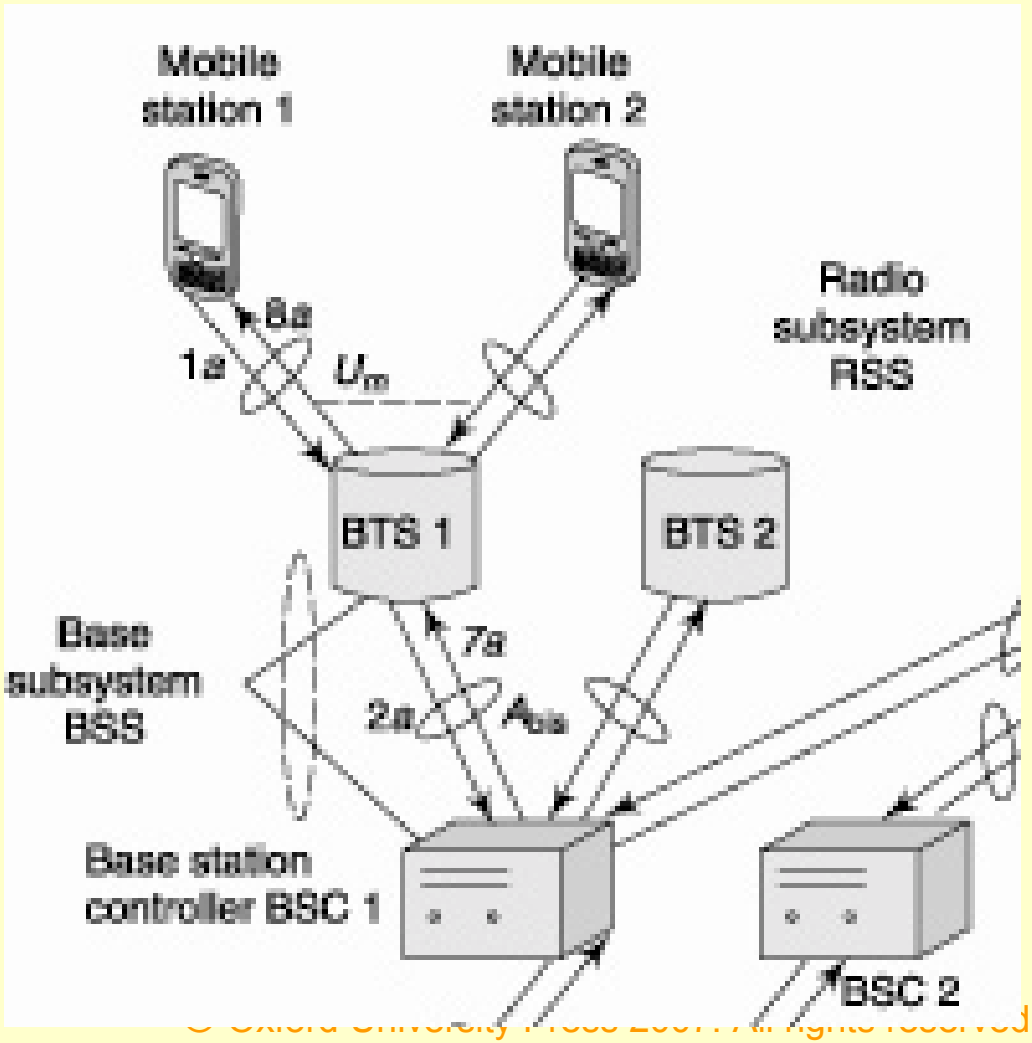
GPRS system architecture– Mobile to BSCs (Like GSM)



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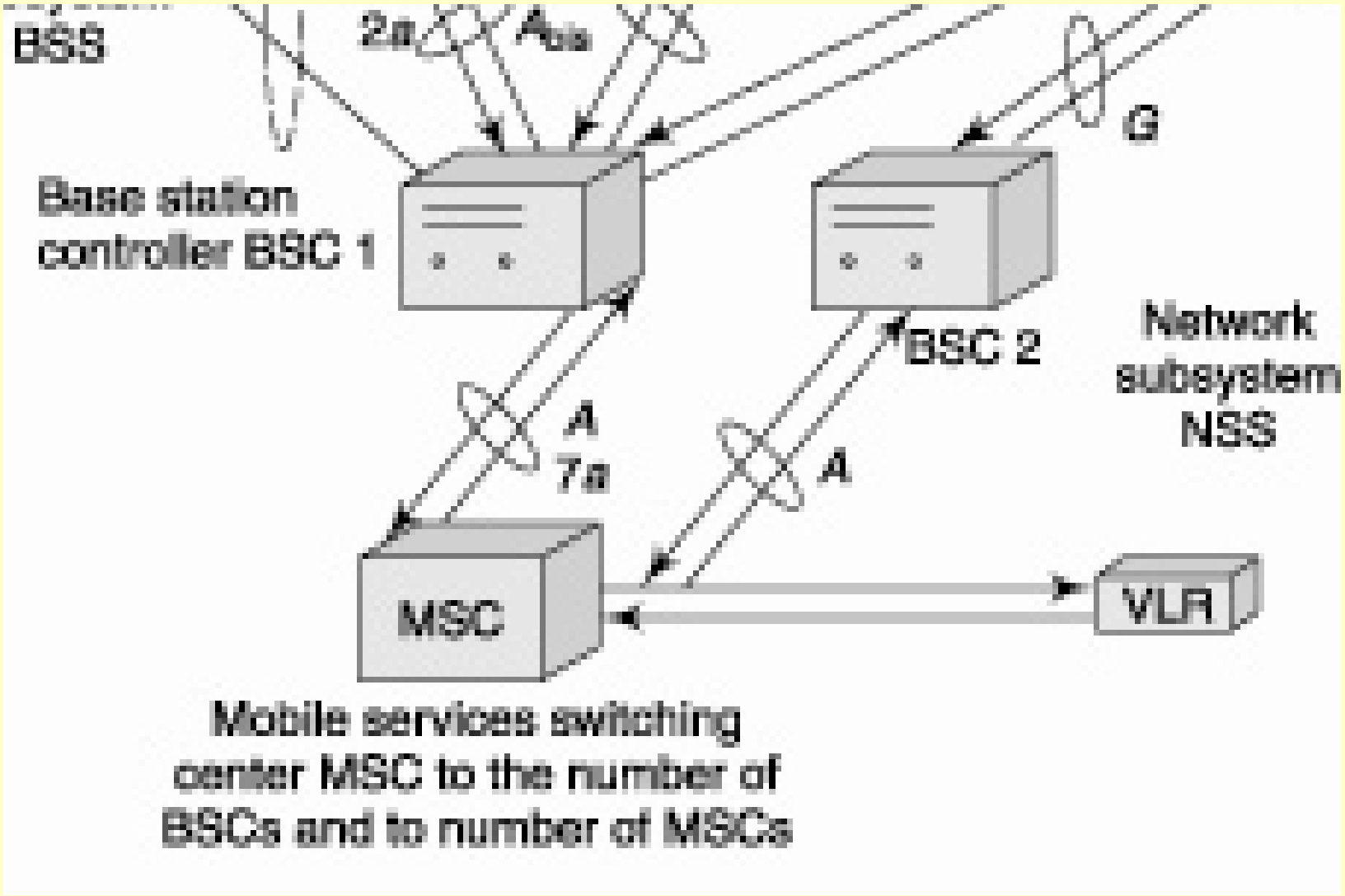
GPRS system architecture– BSCs to MSC (Like GSM)



GPRS deploying SGSNs (serving GPRS support nodes)

- SGSN interfaces to BSCs (base station controllers) on one hand and to other SGSNs on the other hand

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GPRS GGSN (gateway GPRS support nodes) interface

- To the SGSN on one hand
- A packet data network like the Internet on other hand
- The BSCs also connect to the MSCs (mobile services switching centres) as in case of the GSM system

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NSS and RSS layers

- Each SGSN and each MSC in the NSS layer connects to a number of BSCs at the RSS layer
- The SGSNs use the frame relay protocol for connection to BSCs

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GSS (GPRS subsystem)

- Consists of the SGSNs and GGSNs
- Provides GPRS connections to the Internet and other PDNs (public data networks)

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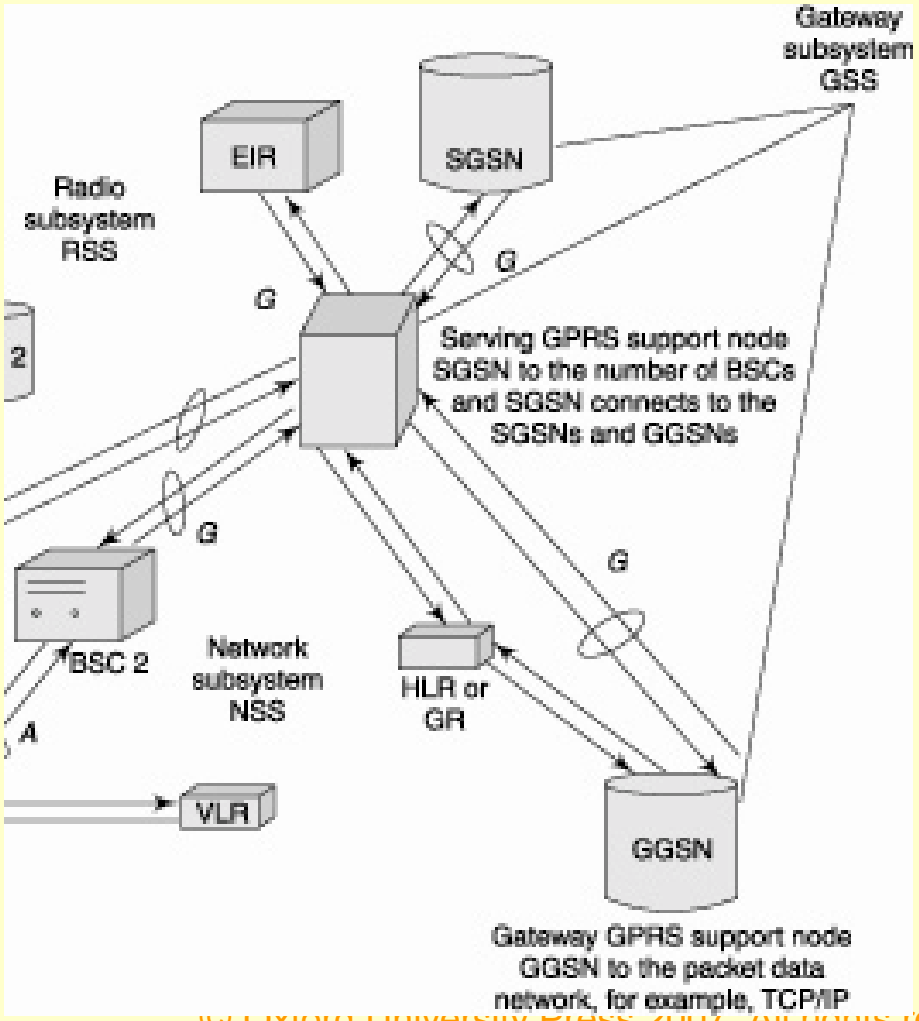
GPRS system architecture — BSCs to SGSN at GSS



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GPRS system context

- Creates and stores in the Mobile station as well as in the SGSN
- Has information of the status of Mobile station, data compression flag, identifiers for the cell and channel for the packet data and routing area information

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An EIR (GPRS equipment identity register)

- Stores the equipment data through the SGSN
- Helps the authentication, operation, and maintenance subsystems

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GPRS Protocol Mobile station (Mobile Station) Layers

- GPRS protocol layers similar to the GSM protocol layers
- The Mobile station has four layers—physical, data link, network, and application
- Session presentation and transport layer issues are taken care of by the lower layers

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BSS

- Has just three layers — physical, data link, and network
- Transport and session layer functions taken care of by network layer protocols

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The SGSN and GGSN four layers

- Physical, data link, network and transport
- Presentation layer functions are performed by the lower layers

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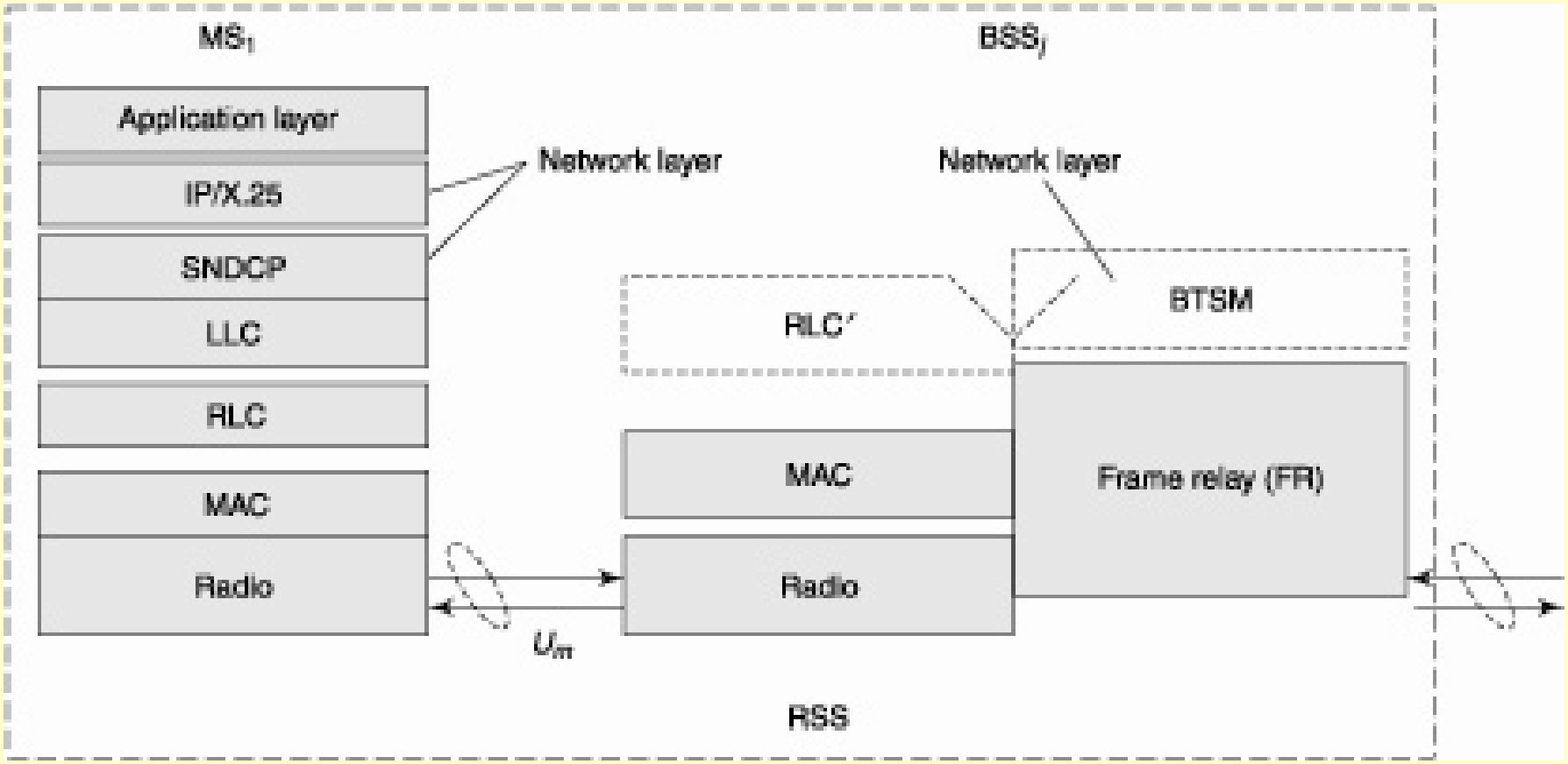
Protocol layers between the Mobile station and BSS



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Application layer at the Mobile station

- Provides end-to-end applications like voice and Internet

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FR (frame relay) Physical layer for data and network

- For transmission and reception of data and network information between the BSS
- and SGSN
- Also implements several functions for the data logical link
- Physical interface between BSS and SGSN employs a wired or fibre network

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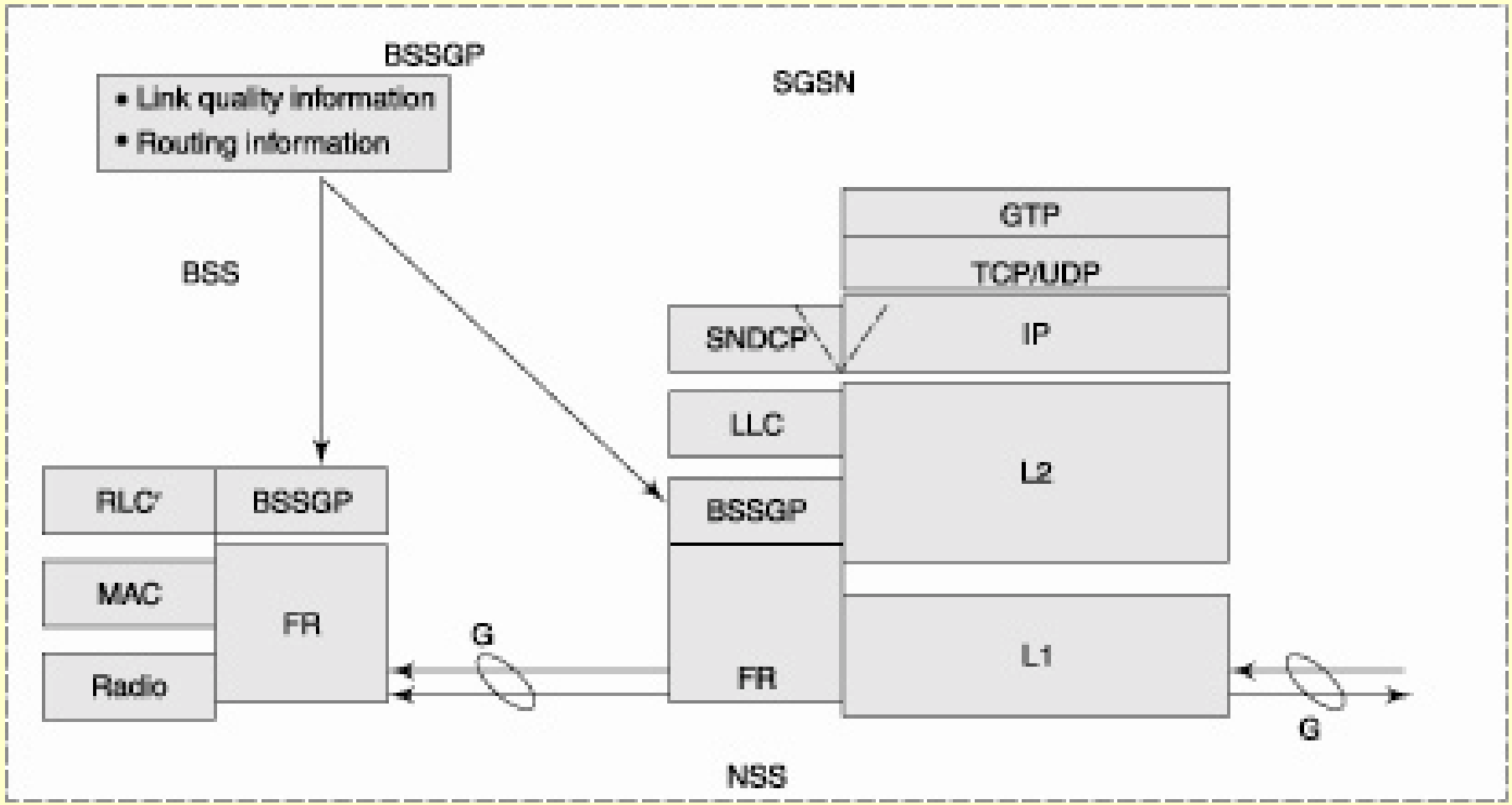
Protocol layers between the BSS and SGSN



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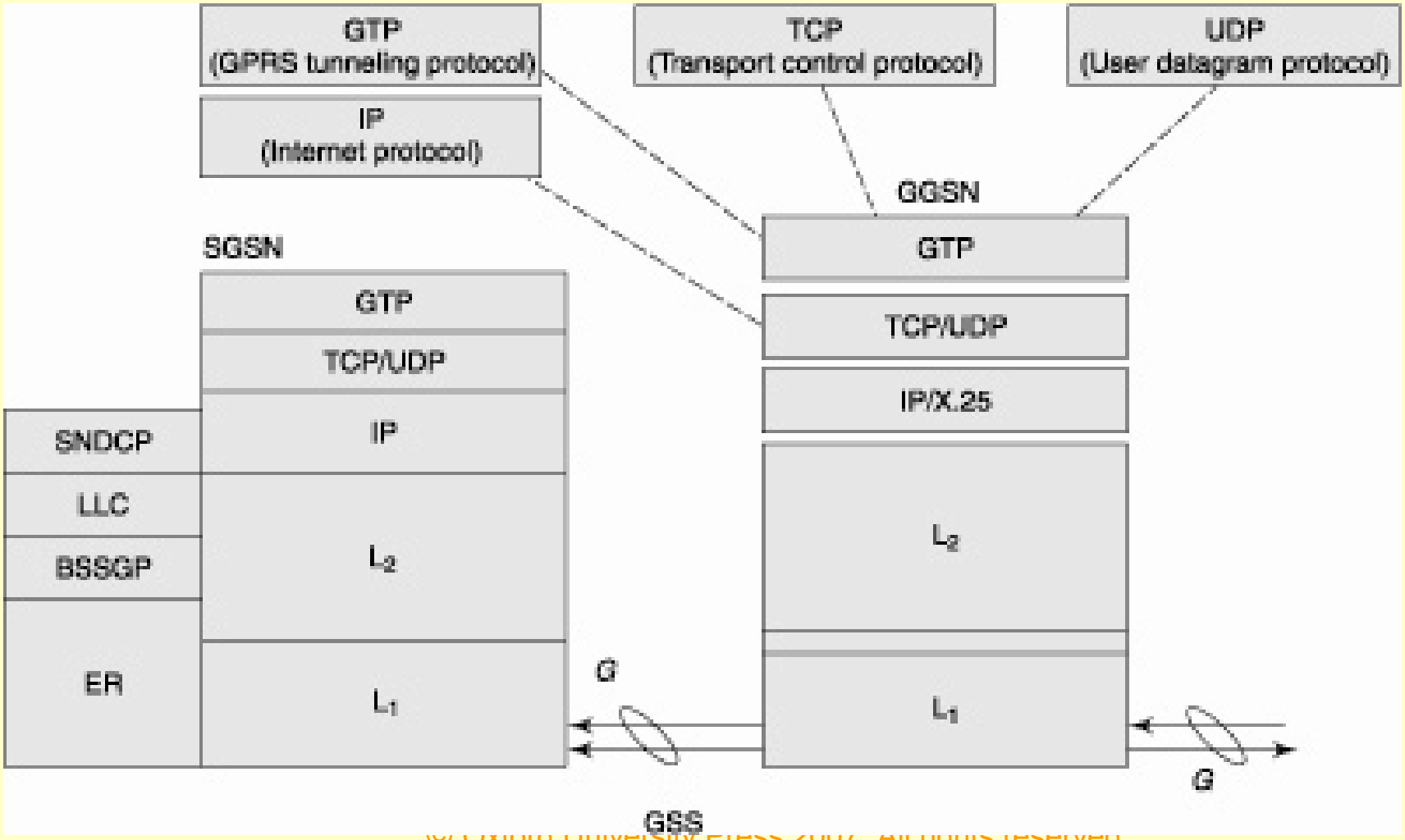
Protocol layers between the SGSN and the GGSN



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Data link layer protocol layers between SGSN and GGSN

- Layer 2 (L2) protocols of the Internet or other PDN (PSTN, ISDN, and PSPDN)

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Network layer protocol layers between SGSN and GGSN

- IP layer 3 (L3) protocols of the Internet or other PDN

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Two transport layer protocol layers at the SGSN

- TCP (or UDP) and GTP (GPRS tunnelling protocol)
- TCP for X.25 protocol at layer 3
- UDP for the IP protocol at layer 3

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Tunnelling protocol

- Uses another protocol to transmit and receive the data and information
- The information for tunnelling protocol is hidden in other protocol data

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GTP (Gateway Tunneling Protocol)

- Uses TCP and IP or UDP and IP
- The GTP facilitates flow of packets from multiple protocols
- GTP information of TID (Tunnel ID) helps in transmitting and assembling the packets for each session of the Mobile station

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Summary

- GPRS– a speed enhanced data transmission service
- Packetizing of data
- Simultaneous transmission of packets over different channels
- RSS, NSS and GSS subsystems

...

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… Summary

- SGSNs– serving GPRS support nodes
- GGSNs – gateway GPRS support nodes
- Signalling Protocol layers

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End of Lesson 13

GPRS

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GSM and Similar Architectures

Lesson 14

HSCSD, DECT and WLL

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High-speed circuit switched data (HSCSD)

- An innovation to use multiple time slots at the same time
- 2.5G GSM phase 2 standard
- An enhancement of circuit switched data (CSD)– the original data transmission mechanism in GSM systems
- Large parts of GSM transmission capacity used up by error correction codes in the original CSD transmission

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HSCSD

- HSCSD offers various levels of error correction that can be used in accordance with the quality of the radio link
- Where CSD could transmit at only 9.6 kbps, the HSCSD data rates go up to 14.4
- Several GSM traffic channels (TCHs) can join to transmit the data at high speed
- Several TDMA slots allotted to a source

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HSCSD

- A single user gets the time slots, except at call set up
- HSCSD– a high speed service for image or video transfers which are timing sensitive
- Using a maximum of 4 time slots, it can provide a maximum transfer rate of up to 57.6 kbps

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HSCSD

- If four TCH/F14.4 channels transmit together then AUR (air interface user rate) = 57.6 kbps per duplex
- In transmission of normal voice data traffic, HSCSD gives smaller latency to data as compared to GPRS

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HSCSD

- HSCSD offers better quality of service than GPRS due to the dedicated circuit-switched communication channels
- However, HSCSD less bandwidth efficient than GPRS which is packet-switched

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DECT (digital enhanced cordless telecommunications system

- An accepted standard since 2002
- DECT – for short-range communication
- Same frequency in different time slots used for the uplink and downlink radio carriers

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DECT 1900

- 1880-1990 MHz for the uplink and downlink frequencies for full duplex channels of 10 radio-carriers
- The frequencies ranges— 1890.0 MHz ± 864 kHz, 1891 MHz ± 864 kHz, 1892 MHz ± 864 kHz, …, 1898 MHz ± 864 kHz MHz, and 1899 MHz ± 864 kHz

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DECT Link

- Each link provides 120 channels for uplink and 120 channels for downlink
- Each radio carrier frequency has TDD (time division duplex) frame with 12 uplinks and 12 downlinks

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DECT TDD

- Uplink and downlink instants in separate time slots
- Each TDD time-slot– 417 μs
- TDD frame duration = (12 + 12) ×416.7 μs = 10 ms for each of the 10 radio carriers
- GMSK Like GSM

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Channel Frequency band

- 1.728 MHz each
- Each successive 4 ms– 24 TDMA channels for each radio-carrier band
- 1.152 Mbps Channel bit rates for DECT
- Speech coding– ADPCM (adaptive differential pulse code modulation)
- Voice-data traffic rate– 32 kbps.

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DECT and GSM Differences in multiple access techniques

- (a) DECT same radio carrier frequency for uplink and downlink and (b) DECT TDD-TDMA slots
- TDD of DECT differs from the half duplex transmission between Mobile station and BTS

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DECT and GSM Differences in multiple access techniques

- The carrier frequency bands different (45 MHz more for downlink) but time slot is just 3.577 μ s more for uplink (less than 1 bit interval of 3.692 μ s)

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DECT and GSM Differences in multiple access techniques

- TDD of DECT also differs from GPRS
- During transmission by class-10 Mobile station, there can be 4 receiving time slots and 2 transmitting time slots in the data frame of the same frequency-channel
- A maximum of 5 slots can be used at an instant out of 8

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DECT 1900

- Each radio carrier— 12 downlink time slots (SL0 to SL11) and 12 uplink time slots (SL12 to SL23), total 24 time slots
- Hence number of channels = (12 + 12) × 10 = 240, 120 for uplink and 120 for downlink

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Data burst

- Of 416.7 μ s. A guard space at the beginning and the end, each of interval 26 μs (equal to 30 bit transmission time interval) is reserved to account for the delays in signals and computational time
- The effective time for the data bits is, therefore, (416.7 –26 –26)≅ 364 μs

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Data burst

- 420 bits transmitted in the 364 μs interval
- The data transmission rate is 24 ×480/10 ms^{-1} = 1152 kbps
- A GMSK signal is modulated and transmitted at 1152 kbps (=0.868 μs/bit)

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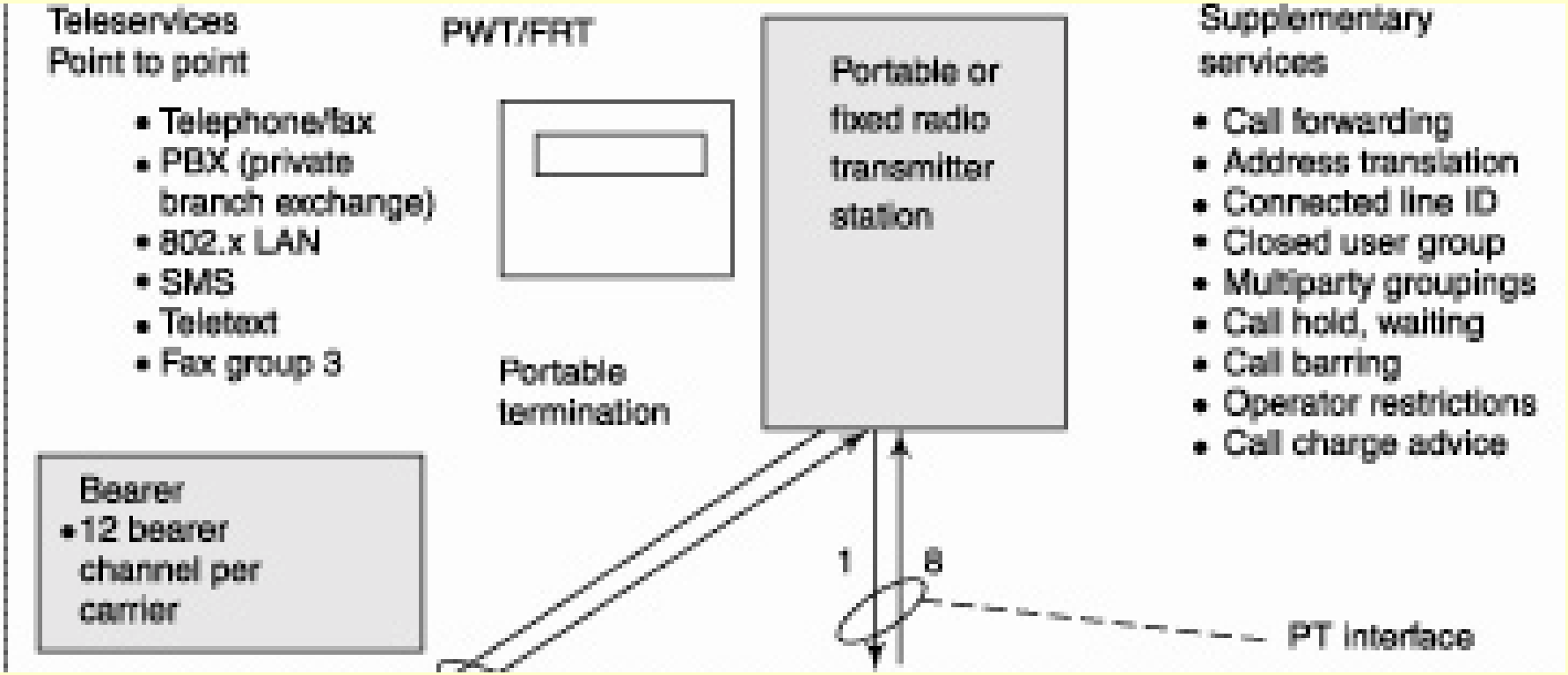
DECT teleservices and supplementary services



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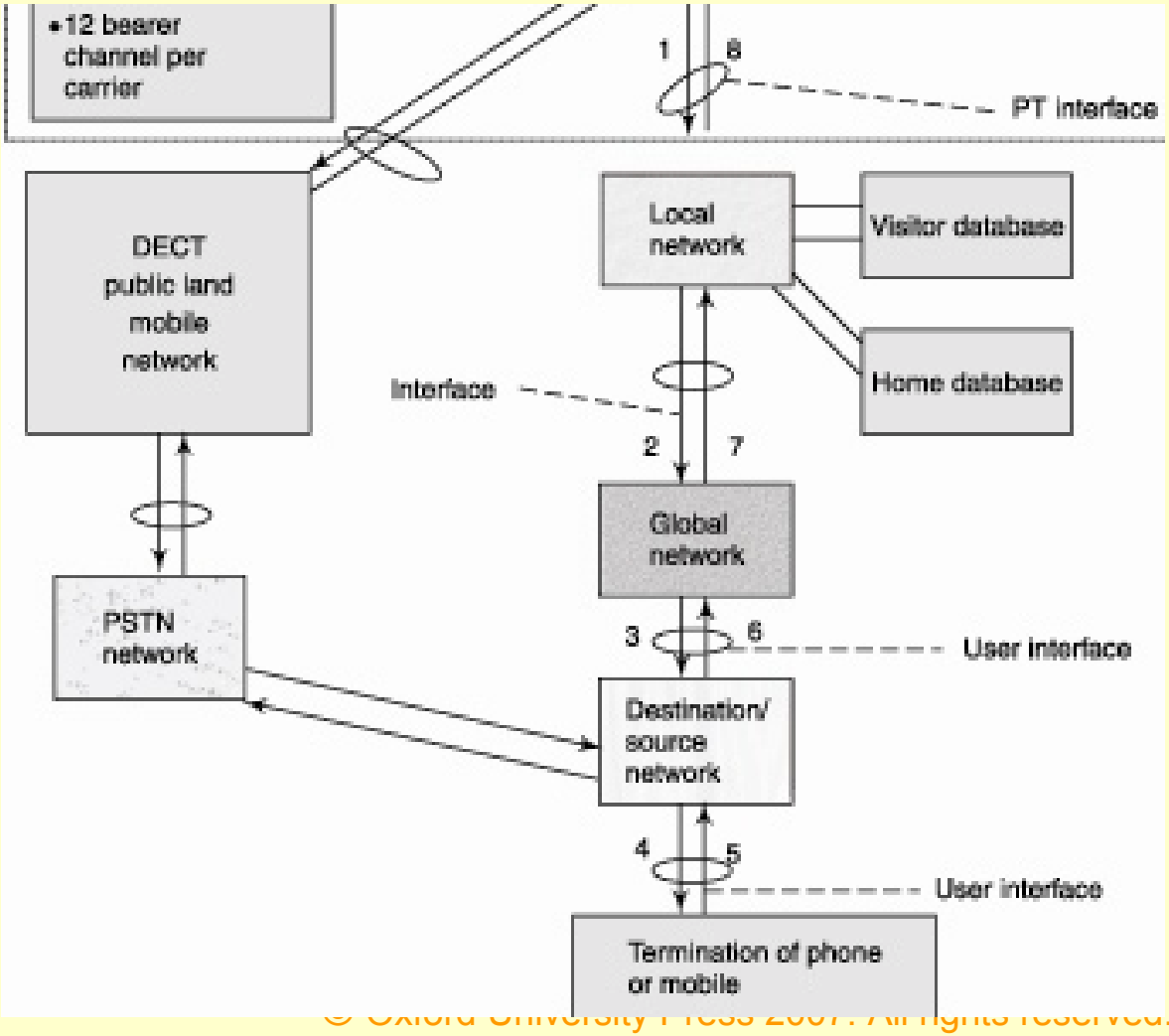
DECT architecture



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DECT architecture

- 12 bearer channels (each in one SL) per carrier
- The terminal– a portable wireless telephone (PWT) or a fixed phone with radio interface (FRT)
- The PWT or FRT connects to a public land mobile network for calling to a mobile or to a local network

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The local network

- Has a visitor database (similar to VLR in the MSC) and home database (similar to HLR in the MSC)
- Can interface to a global network or an ISDN network

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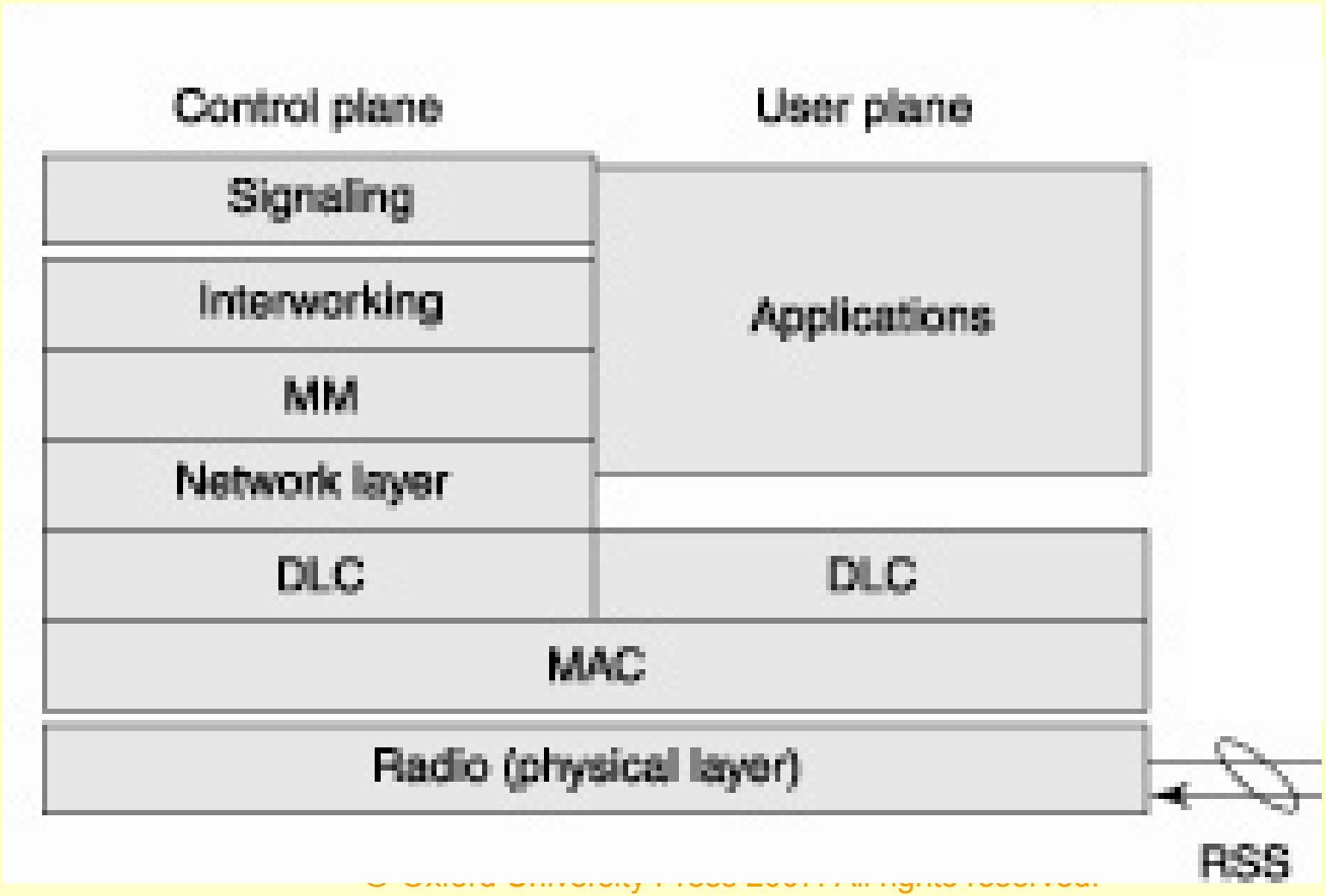
Protocol layers in DECT



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Protocol layers in DECT

- Two planes—control plane (C-plane) and user plane (U-plane)

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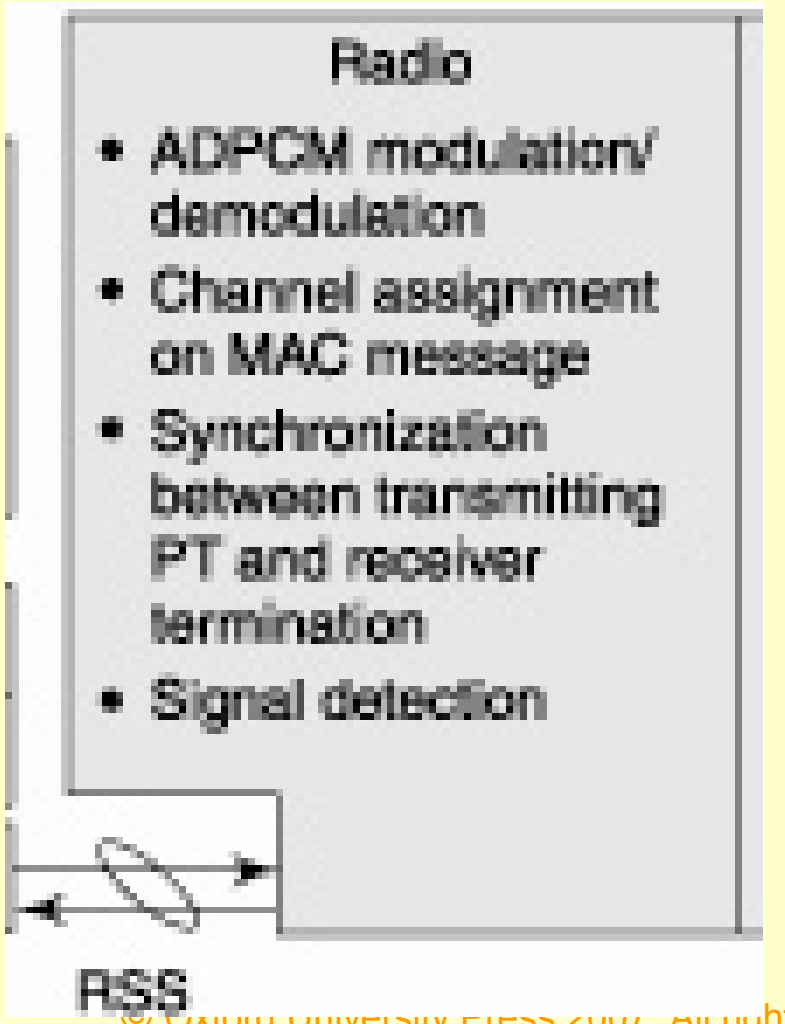
Radio in DECT



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MAC Functions

MAC (medium access control)

- Paging
- Network control, error control and correction
- Setup, maintain, and releasing channels for higher layers
- Activating/deactivating physical channels
- Broadcasting
- Segmentation
- Re-assembly
- Packet formatting

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Additional network layer

- In the control plane as compared to the user applications plane
- Transmits the DLC layer data directly to U-plane from the C-plane

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Network layer Functions

Network layer

- C-plane similar to the GSM or ISDN network layer
- Connection-less or connection-oriented message service and cell control MM (authentication, location database management)
- Release and control of resources of fixed or wireless network
- Send and receive requests
- Check resources

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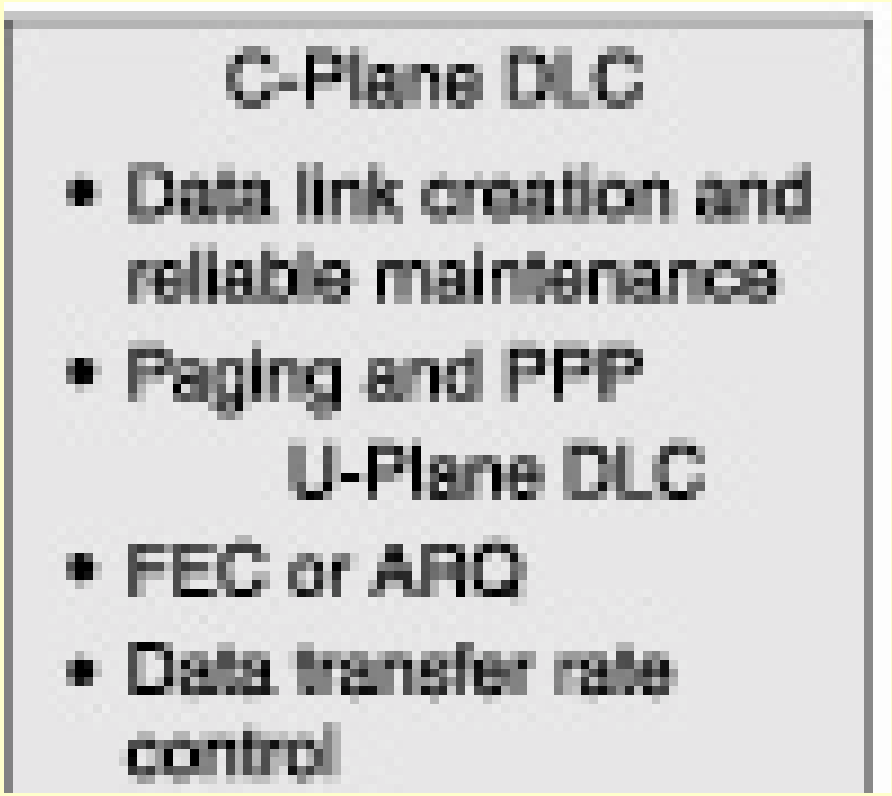
C Plane in DECT



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WLL (wireless local loop)

- FRA (fixed-radio access)
- RITL (radio in the loop)
- Connects a user to PSTN networks or broadband Internet using radio signals

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WLL

- Includes fixed and cellular systems, cordless access systems, and proprietary fixed radio access systems
- WLL implemented over DECT or other technologies to provide the link between two terminals (PWT or FRT), including CDMA, TDMA, GSM, and UMTS 3G

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WLL

- WLL, in addition to being an alternate system, helps in providing telecommunication and broadband services where wired or fibre lines do not exist

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Summary

- HDCSD
- Grouping of time slots for faster transmission
- DECT– DECT same radio carrier frequency for uplink and downlink
- DECT TDD-TDMA slots
- Protocol layers
- WLL

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End of Lesson 14

HSCSD, DECT and WLL

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Wireless Medium Access Control and CDMA-based Communication

Lesson 01

Modulation Methods for Medium-access

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Number of signal sources access to wireless medium simultaneously

- Simultaneously transmitted Signals (actually electromagnetic radiation) may interference with each other, when they travel through a medium
- Network has to receive signals from each radio carrier distinctly

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Modulation with radio carrier frequency (ies)

- Voice-data or data signals propagate through the medium after modulation
- Wireless station accesses a medium by modulation of radio carrier(s) with the signal symbols

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Symbols

- Digitized form of the analog signals
- Symbol– bit(s) prepared for transmission after encoding of data bits and insertion of the error control and other bits

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Instantaneous value of signal amplitude, *s*(*t*) at an instant *t*

- $s(t) = S \times s0 \sin(2\pi \times c/\lambda_c \times t + \phi_{t0})$
- $s(t) = S \times s0 \sin(2\pi \times f_c \times t + \phi_{t0})$

where S is the symbol to be transmitted, 1 or 0

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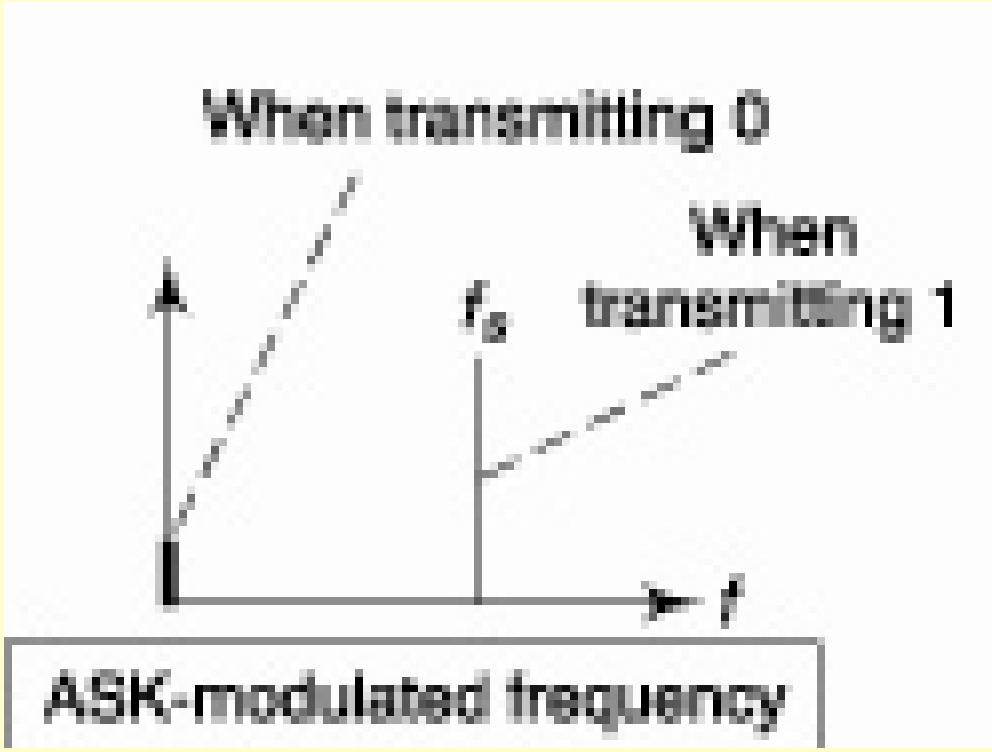
Amplitude shifted keying (ASK) modulation

s0 = *A0* when
Symbol = 0 (1)
s0 = *A1* when
Symbol = 1 (2)



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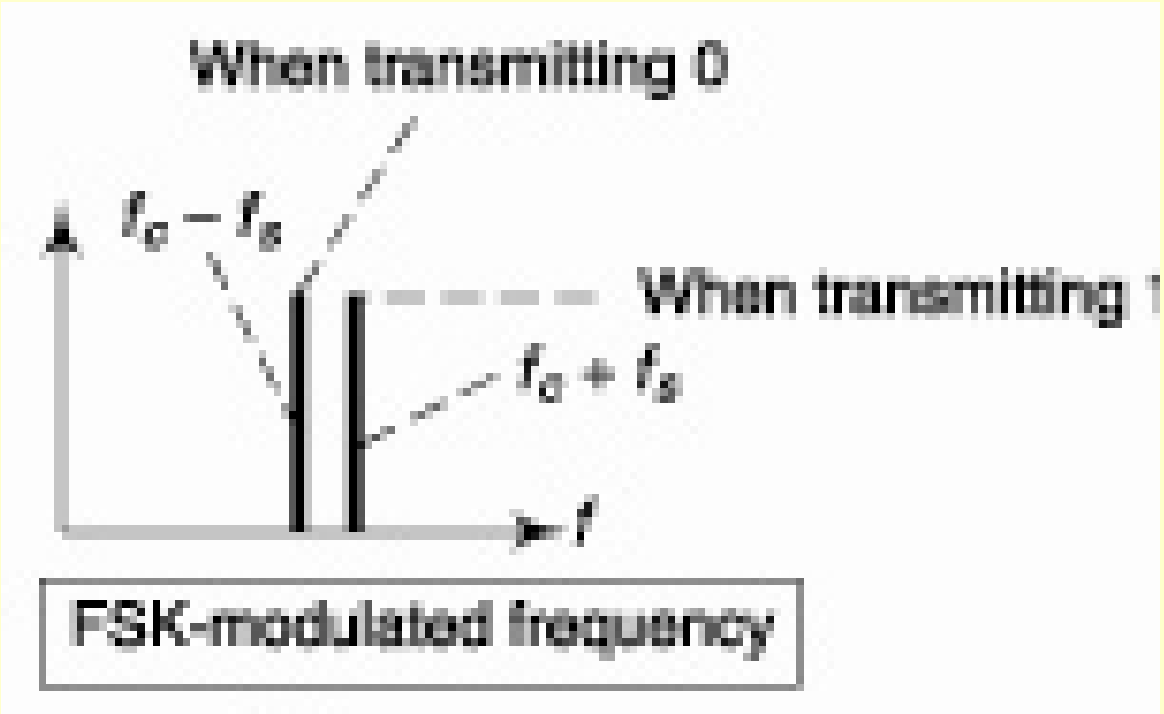
Frequency shifted keying (FSK) Modulation– BFSK

$f = f_c - f_s$ when
Symbol = 0 (1)
$f = fc + fs$ when
Symbol = 1 (2)



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BFSK (binary frequency shift keying) of f_c when S = 1

- $s_0(t) = s0/\sqrt{2} \cdot \sin(2\pi \times f_c \times t + \phi_{t0})$ when S = 0
- $s_1(t) = s0/\sqrt{2} \cdot \sin(2\pi \times (f_c + f_m) \times t + \phi_{t0})$ when S = 1
- Bandwidth > f_c
- Harmonics of $(f_c + 2 f_m)$, $(f_c + 3 f_m)$, $(f_c + 4 f_m)$ present

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GMSK (Gaussian Minimum shift keying)

- DSP based Gaussian low pass filter
- Bandwidth is 2 .f_m *plus guard band*

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QPSK

- One of the four possible distinct sequences (00, 01, 10, or 11) transmitted using a specific phase angle of the radio carrier frequency
- Symbols (00, 01, 10, or 11) represent a sequence
- Each symbol actually a sequence of 2 bits

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OQPSK

- Each alternate symbol is in the next quadrature
- 90° are added to the phase angle, the second symbol shifts to the next quadrature during transmission

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OQPSK

- An OQPSK receiver subtracts the phase angle by 90° and, therefore, receives the signal in the original quadrature and, therefore, also the original second symbol, and so on

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Advantage of OQPSK

- In-phase and quadrature signals overlap, because now they are in the same phase quadrant
- Thus, the number of sharp transitions in the signals reduces to half of its original value

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OQPSK

- Transmitted envelope smoother as compared to one transmitted through QPSK
- Utilization-efficiency of the bandwidth allotted to a mobile service improves

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π/4-QPSK

- A form of QPSK modulation in which the signal phase shifts by 45° after every two symbols

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Advantage of $\pi/4$-QPSK

- There are no sharp transitions of π in the phase angle
- The number of sharp transitions of the signals halves

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π/4-QPSK

- Lesser sharp transitions imply a lower number of significant higher harmonics, lesser bandwidth requirement per channel, and increased utilization of the allotted bandwidth to a wireless service provider
- Bandwidth utilization-efficiency improves

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Example

- Symbol sequence 10 00 11 01 to be transmitted after QPSK modulation
- After each successive time interval of T, the phase angles of the transmitted signal s(t), which are $3\pi/4$, $-3\pi/4$, $-\pi/4$, $+\pi/4$ become $3\pi/4$, $-\pi/2$, $0°$, $\pi/2$ in $\pi/4$-QPSK

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Example

- The $\pi/4$-QPSK demodulator at the receiving end subtracts $\pi/4$ after each successive bit pair, the original QPSK angles
- $3\pi/4$, $-3\pi/4$, $-\pi/4$, $+\pi/4$ found and the bits are recovered as 10 00 11 01

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Four-bit per symbol 16-QAM method

- Each symbol actually a sequence of 4 bits
- Four symbol sequences representing a 16 bits grouped and transmitted by phase shift keying
- One of the 16 possible distinct sequences transmits by a specific phase angle of the radio carrier frequency at a specific amplitude (one of the three values of amplitude s_0)

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64-QAM

- Two most significant bits for QPSK while reserving the remaining 4 for the 16-QAM signals
- 64-QAM thus transmits 6 symbols (bits) in a sequence
- When the bits are transmitted after 64-QAM, the spectrum bandwidth requirement reduces greatly

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64-QAM Example

- For example, assume that a 64-QAM modulated signal is generated and transmitted at 19.2 ksymbol/s
- One of the 64 possible distinct sequences is transmitted at a specific phase angle, frequency, and amplitude
- Six symbols represent a sequence

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64-QAM

- The bit transmission rate is 6 $\times$19.2 ksymbol/s = 115.2 kbps when 64-QAM is transmitted at 19.2 ksymbol/s
- Each symbol actually a sequence of 6 bits
- The bandwidth requirement, in this case, is thus reduced by a factor of 1/6

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Summary

- Modulation methods, ASK, FSK, GMSK
- QPSK for each symbol representing a pair of bits
- OQPSK
- $\pi/4$ QPSK
- 16 QAM for each symbol representing a set of 4 bits
- 64 QAM 16 QAM for each symbol representing a set of 4 bits

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End of Lesson 01

Modulation Methods for Medium-access

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Wireless Medium Access Control and CDMA-based Communication

Lesson 02

Medium Access using SDMA, TDMA, FDMA and CDMA

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Wireless Medium Access Control and CDMA-based Communication

Lesson 02

Medium Access using SDMA, TDMA, FDMA and CDMA

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Medium Access Problem

- Medium access so that wireless stations (WSs) transmit at any instant without interference with signals from other WSs
- WS– can be a mobile terminal (TE) at a mobile station (MS), a base transceiver system (BTS), or a wireless LAN node

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Four ways to eliminate interference between the signals at any instant *t*

- SDMA
- TDMA
- FDMA
- CDMA
- Facilitate access to the medium by multiple sources or channels of same source when each one is using a distinct set of physical space, time, frequency, and code at each instant

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SDMA (space division multiple access)

- WSs that are distantly located access the medium by transmitting at the same f_{c0} as well as in the same time-slot SL ($t' \leq t \leq t''$) *i*n different spaces (cells) only
- WSs located at suitable distances from each other are then said to transmit using SDMA

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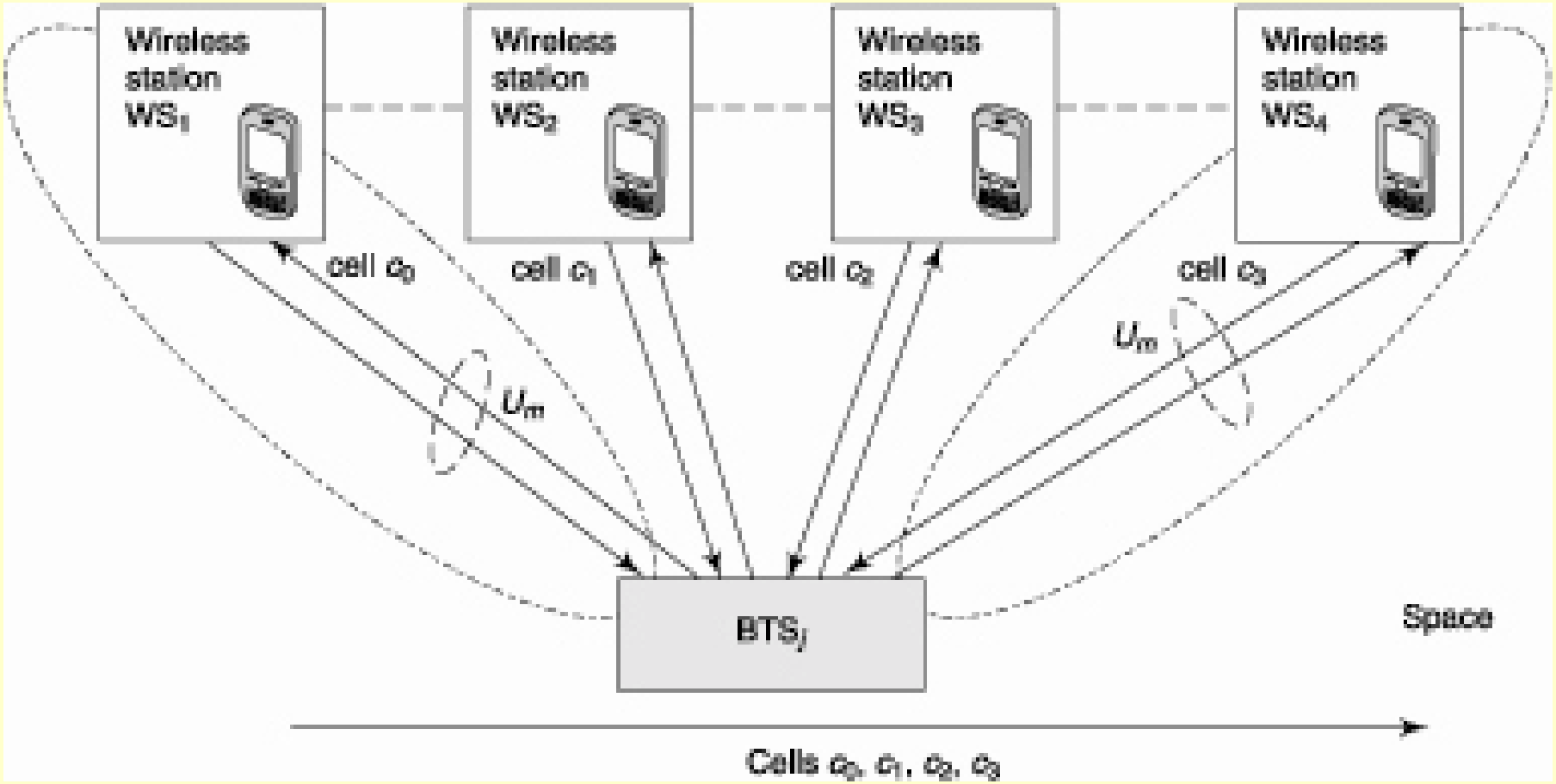
Four wireless stations, in four distinct cells, simultaneously transmitting with the same f_c



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TDMA (time division multiple access)

- *m time* slots in a communication system
- When the WSs (≤ *m*) located in the same space (cell *c*), then the WSs access the medium in *m* different time-slots, SL_0 to SL_{m-1}

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TDMA in GSM 8 transmitting WSs

- Distinct time-slots SL0, SL1, …, SL7 using the same radio-carrier frequency f_c using TDMA
- A limit to the number of wireless stations that can be served using different slots

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TDMA in GSM 8 transmitting WSs

- Transmission slots for a WS repeated after small intervals (called frame intervals)
- Total data throughput from each WS does not become too small

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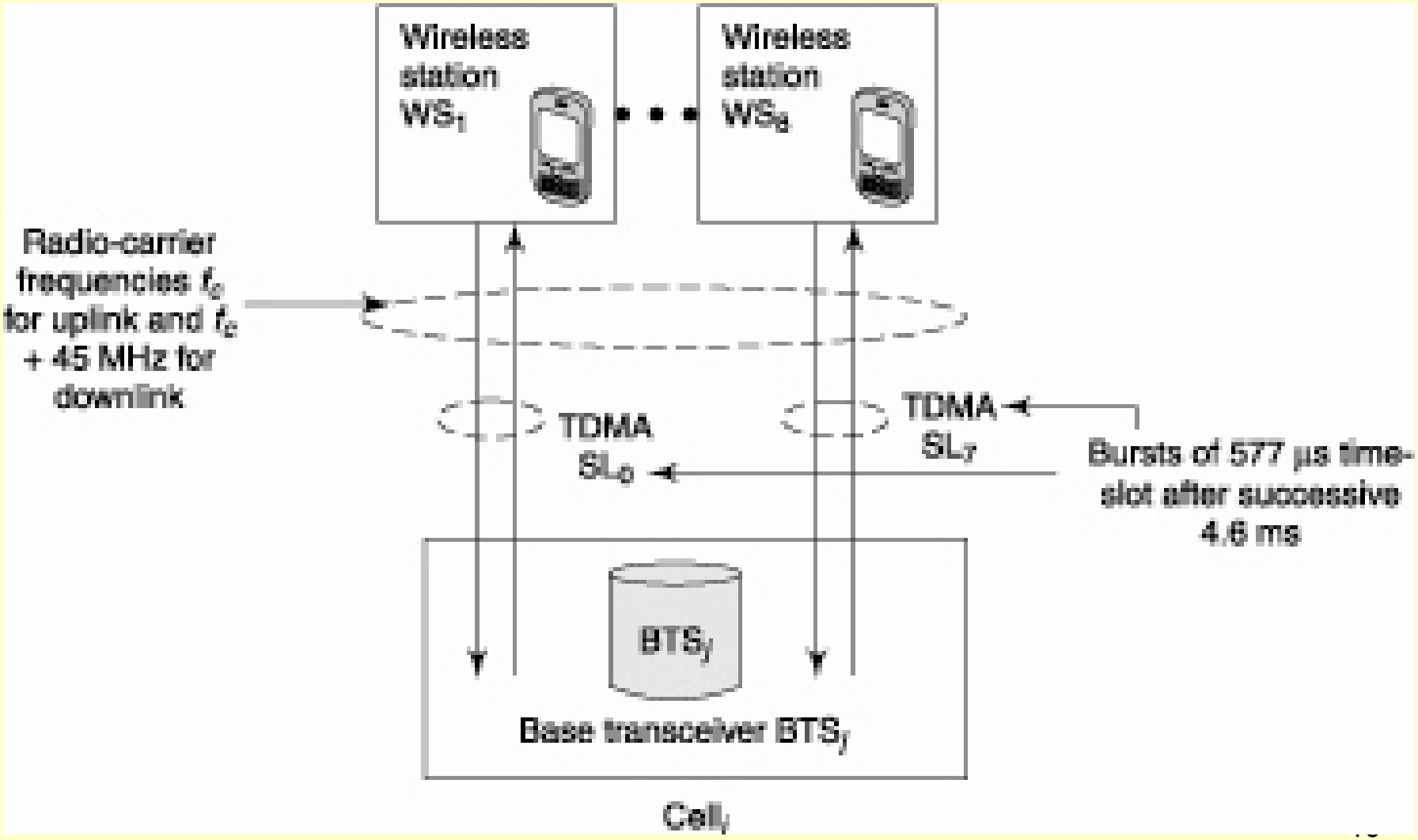
8 WSs transmitting in distinct time-slots SL0, SL1, …, SL7 using the same f_c using TDMA



GSM system

- Provides for 8 time-slots of 577 μs
- Transmitting WS channels allotted a fixed pattern by the BTS
- If there are two WSs in place of 8 WSs, then the BTS reserves each alternate slot for each WS
- 8 WSs then the BTS reserves each alternate frame slot for each WS

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GSM system

- Maximum transmission interval that a WS has between successive slots (frame interval) = 4.615 ms in TDMA
- Guard space of 15.25 μs at the beginning and at the end of each 577 μs slot
- Collisions avoided due to drifts in receiver and transmitter clock frequency or computational delays in placing the data in a slot

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GPRS

- *k* = 4 receiving time-slots in successive data bursts for packet transmission in a class 10 mobile station

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DECT WSs medium access control by TDMA

- Half of the TDMA slots are used for uplink and half for downlink
- The transmitting WS channels allotted a fixed pattern by the BTS
- Each of the *m* stations can transmit with a maximum delay interval equal to the frame interval $m \times (t' - t'')$

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DECT WSs medium access control by TDMA

- Data bursts transmit in time-slots of 417 μs
- Total 12 uplink and 12 downlink channels in 24 slots in a total duration of 10 ms
- After each successive 10 ms interval, the slots in a frame are repeated
- Uplink and downlink frequencies can now be kept identical, as the time-slots used for them are distinct

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FDD (frequency division duplex) Uplink and downlink accesses of the WSs

- In different time-slots or in the same slots (shifted by a constant delay), SL0 to SL_{m-1}
- The uplink and downlink frequencies of the radio carrier, f_c, are distinct
- Example— *fc* and *fc* + 45 MHz for FDD access to the medium
- Different uplink–downlink frequency-pairs are assigned distinct f_cs (out of the *n* values from f_{c0} to f_{cn-1}) in a cell

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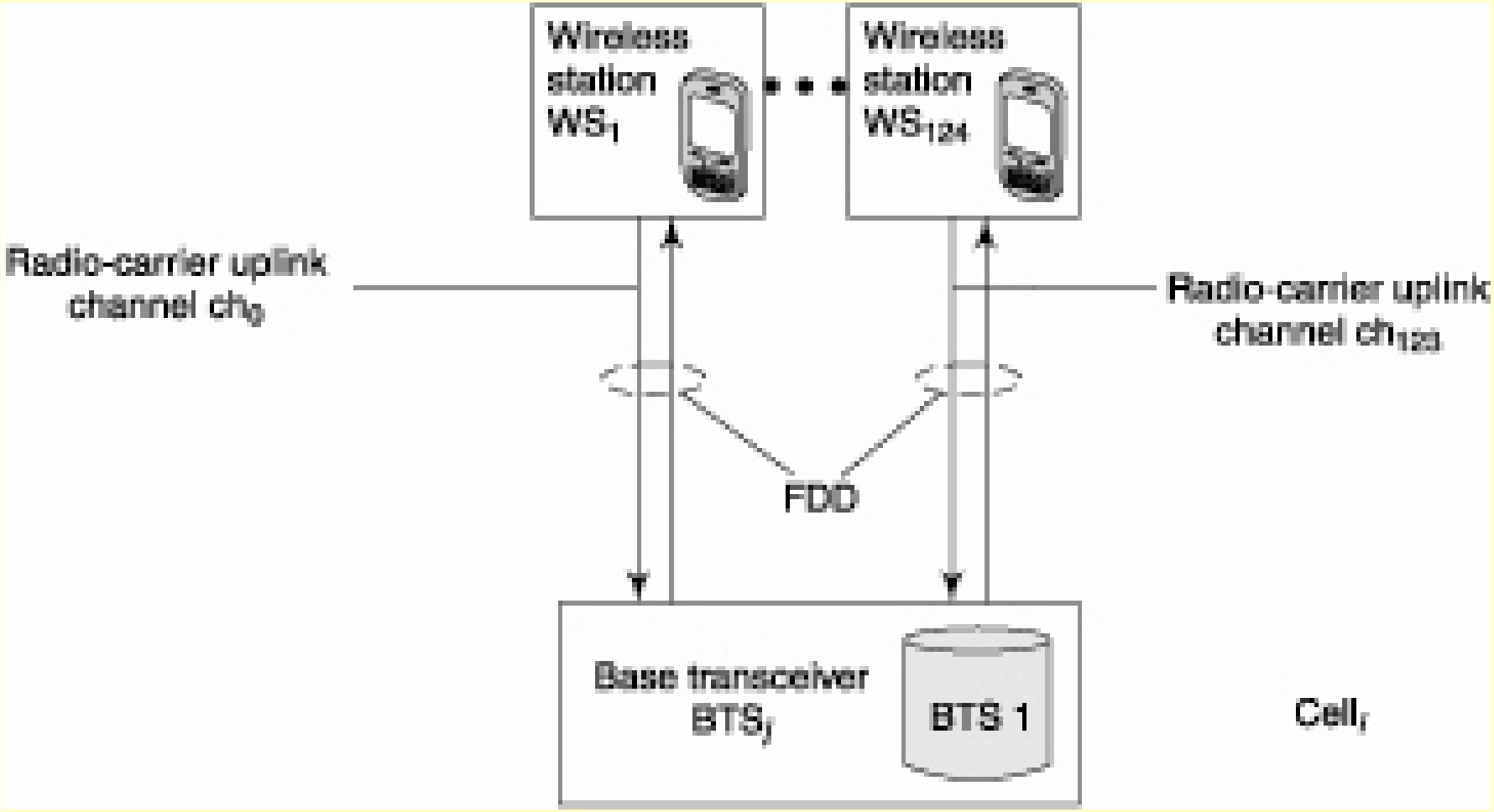
Cell *i* with 124 radio-carrier channels using FDMA and f_c for uplink and f_c + 45 MHz for downlink



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FDMA (frequency division multiple access)

- Access to the medium by distinct f_c at any given instant *t*, when there are many WSs (n > *m*) accessing the medium simultaneously
- m = 0 for only FDMA
- m ≠ 0 for FDMA-TDMA simultaneous use

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Radio-carrier channels in GSM 900

- A set of maximum 124 radio-carrier channels
- Each separated by 200 kHz
- Used in the GSM 900 downlink channel
- Another set of 124 in the uplink channel

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TDMA-FDD-FDMA for medium access control

- GSM
- GPRS
- HSCSD

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CDMA (Code Division Multiple Access) based system

- When the WSs using the same space (cell), same time-slot, and same frequency f_c, then there is the CDMA alternative to access the medium
- Each WS uses a distinct code between C_0 and C_{p-1} when accessing the medium
- p values from C_0 to C_{p-1}

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Summary

- SDMA
- TDMA
- FDMA
- FDD
- CDMA

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End of Lesson 02
Medium Access using SDMA, TDMA, FDMA and CDMA

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Wireless Medium Access Control and CDMA-based Communication

Lesson 03

Medium Access Control using ALOHA and CSMA

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Medium Access Problem

- Controlling medium access so that wireless stations (WSs) transmit at any instant without collision (interference) with signals from other WSs

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Collisions

- There may be collisions between signals from different sources
- Then the problem is to control (restrict, coordinate, or synchronize) the access to the medium

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Collisions

- Collisions may lead to interference of signals from different sources, which, in turn, causes loss of information
- Therefore, it is a must that collision (interference) between the signals from different WSs is eliminated or, at least, reduced

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ALOHA

- Reducing collisions– the basic ALOHAnet protocol for a point-to-point or broadcast network
- Whenever a WS has any voice-data or data to transmit, it just transmits that data
- In case there is interference or collision, the WS retransmits the data at a later instant

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ALOHA

- ALOHAnet developed in 1970 at the University of Hawaii
- Variants of ALOHAnet– LAPD*m* and RLC protocols in GSM as well as GPRS

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Variants of ALOHAnet

- Instance of retransmission
- One version– randomly select the time
- Chance of success in such a case are small (average is about 18%)
- Improved version– slotted ALOHA

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Slotted ALOHA

- WS retransmits in a discrete time-slot instead of transmitting at a random time
- Chances of collisions reduced
- Chance of success is improved (average is about 36%)

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Reservation ALOHA

- Slots for the WSs reserved as per the current demand of the WSs

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Variants of the ALOHA protocol

- Slotted ALOHA– used in Mobitex (a protocol for transmitting text on mobile)
- Hubbed Ethernet and non-switching Ethernet use a variant of ALOHA
- Wi-Fi systems use the IEEE 802.11b protocol, which is an ALOHA-based system for multiple access

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CSMA (carrier Sense Multiple Access)

- ALOHA-based multiple access has low success rates in cases where there are large numbers of users and in case of transmission of data bursts
- CSMA– a vaient of ALOHA

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CSMA (carrier Sense Multiple Access)

- Each WS first listens (senses) whether the carrier f_c already present in the channel to be used and transmits only when there is no carrier present
- Negligible chance of interference or collision

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CSMA scheme

- All nodes attempt to sense at the same time
- One of the nodes transmits as soon as it finds no carrier

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CSMA/CA (CSMA/collision avoidance)

- Each node waits (backs off) for a certain period of time after sensing the carrier, after which the carrier is sensed again
- A priority-assignments-based scheme can also be used
- Higher priority nodes shorter back-off periods

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CSMA/CD (CSMA/collision detect)

- A protocol in which it is checked whether a collision is detected at the transceiver before transmitting
- Ethernet LAN uses the CSMA/CD protocol

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CSMA

- Assumes that each WS can sense the presence or absence of each carrier on the network
- On a wired network, it is easy for each transmitter to sense the presence or absence of a carrier on the network

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CSMA and CSMA/CA in a wireless medium

- Listening (sensing) also means consuming energy at the terminal station
- Also spending time in sensing

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Cellular digital packet data (CDPD)

- CSMA/CD
- When the channel is busy and medium access is not feasible, the BTS transmits the *transmission inhibit information* (TI)
- A data burst is sent to the MS for the TI
- The MS senses only the TI data burst and backs off from transmission

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DSMA (digital sense multiple access)

- An acknowledgement (ACK) data burst sent to the MS
- If ACK is not received by the MS, it means that a collision has been detected

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ARCNET (Attached Resource Computer Network)

- A token having an address passed, first to the nearest node, then to the next nearest, and so on in the form of a token-passing ring
- The addressed node receives the signals

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Summary

- Transmit and retransmit if required
- ALOHA and its variants
- Listen and sense carrier, if carrier found back-off and sense again and retransmit
- CSMA, CSMA/CA in wired networks
- CSMA/CD in wireless networks

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End of Lesson 03

Medium Access Control using ALOHA and CSMA

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Wireless Medium Access Control and CDMA-based Communication

Lesson 04

Exposed, Hidden, Near and Far Mobile terminal problems and Power control methods

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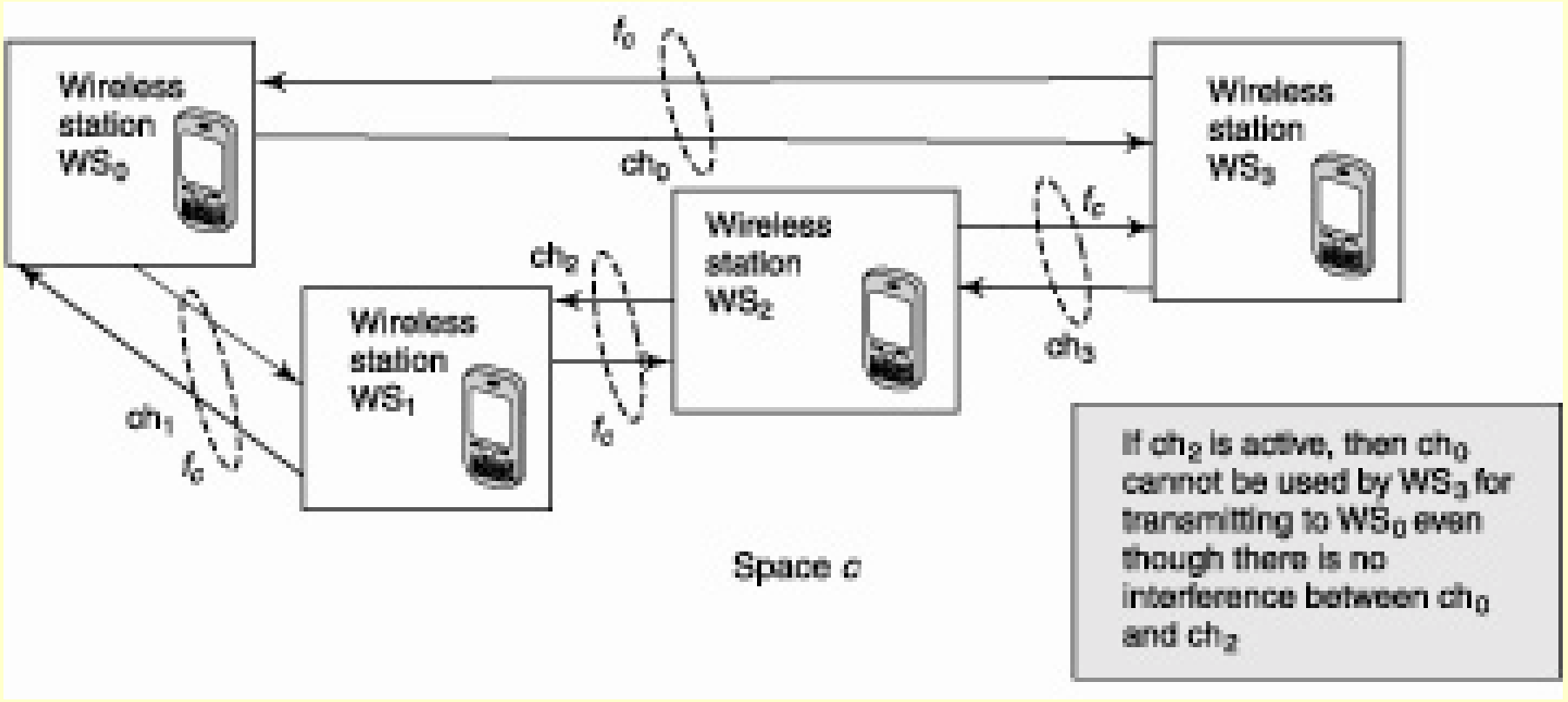
A cell *c* with four radio-carriers using the same radio carrier frequency f_c in the same time-slot and CSMA



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Multiple Access Control for Exposed Terminals in CSMA

- When ch2 is active, then ch0 cannot be used by WS3 for transmitting to WS0 even though there is no interference between ch0 and ch2
- WS3 senses that the radio carrier f_c being used by WS2 and backs off
- WS3 thus *exposed* to the WS2 carrier

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Hidden Terminal Problem in CSMA

- WS_0 cannot sense the ch_0 signals from WS_0 because the signal strength decreases as the inverse of the square of the distance between the two terminals
- When WS_0 transmits to WS_1 or WS_2, since WS_3 does not sense that the radio carrier f_c is being used by WS_0
- WS3 also starts transmission to WS_1 or WS_2

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Hidden Terminal Problem in CSMA

- The radio carriers from WS0 and WS3 interfere (collide) in the region near WS1 and WS2
- The collisions of the signals from WS3 with signals from WS0 are not detected by WS0 in CSMA (but they can be detected in CSMA/CD)
- This is because WS_0 is hidden to the WS_3 carrier

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Multiple Access Control from Near and Far Terminals

- Each WS transmits with a set of frequencies coded with a distinct code
- WS_3 sends signals via ch_0 for WS_0
- The signal strength is weak along the ch_0 region near WS_0
- Signal strength decreases as inverse of the square of the distance between the two terminals

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Multiple Access Control from Near and Far Terminals

- When WS_0 is transmitting to WS_1 or WS_2, the WS_3 signal, being weak in proximity to WS_0, is not listened to by WS_0
- The ch_1 signal strengths are higher near WS_0 as compared to the ch_0 signal strengths

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Multiple Access Control from Near and Far Terminals

- The strong ch_1 signals superimpose on the weak ch_0 signals at WS_0
- WS_3 is the *far terminal* and WS_1 or WS_2 are the *near terminals*
- The radio carriers from both WS_3 and WS_1 will be listened to if the transmission power is raised in ch_0 or decreased in ch_1

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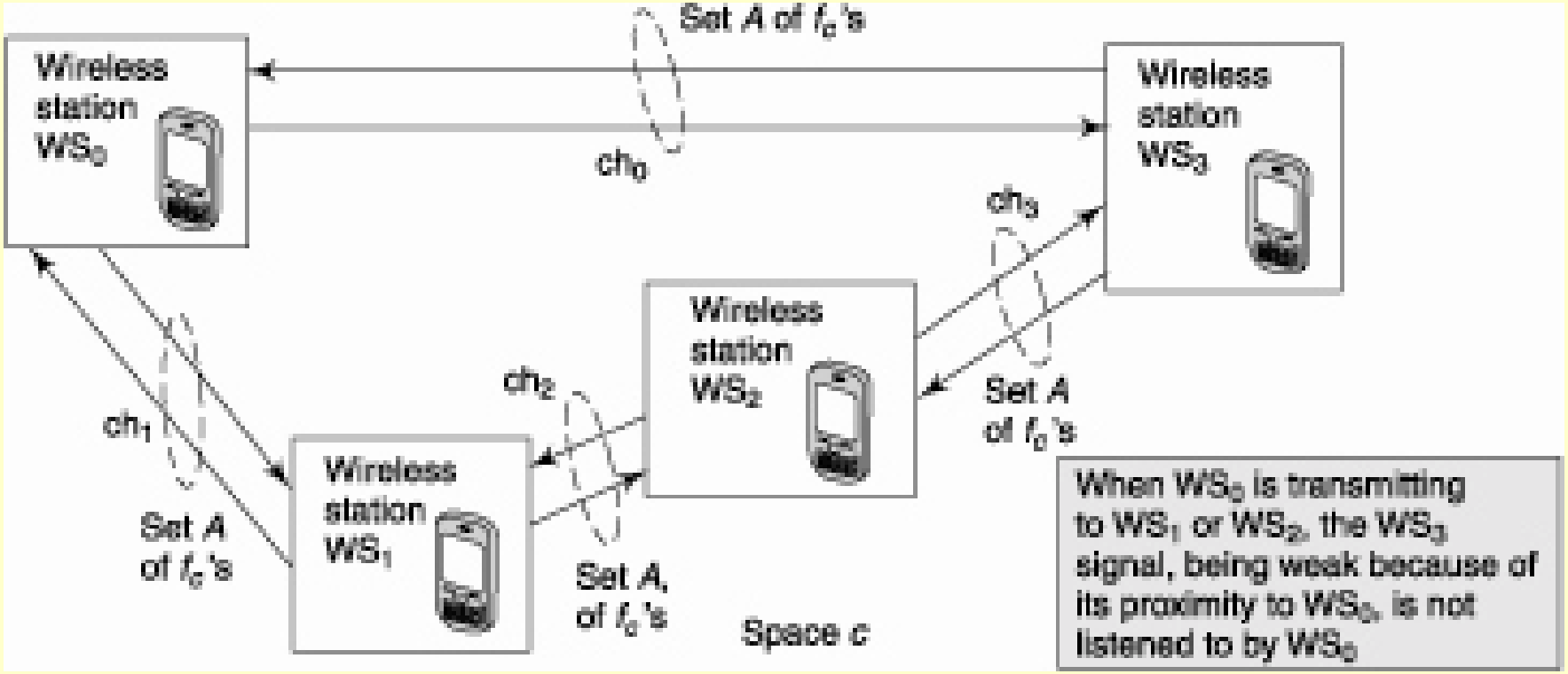
A cell *c* with near and far terminals using four radio-carriers



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Power control

- Required for the far and near terminals to avoid drowning of the far terminal signals in presence of signals from the near terminals

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GSM system BTS transmission

- To an MS during CCH data bursts, the required power transmission level from that MS is decided by measurements of the signal strengths from the MS
- The RRM layer performs the signal measurement and power control tasks
- GSM defines five levels of power transmission

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CDPD transceivers

- Transmit the power-received level during the CSI (channel stream identification) data bursts for an MS by measurements of the signal strengths at the RRM

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GSM systems closed loop power control

- The MS and BTS measures the signal strength
- MS transmits information regarding the signal quality to the BTS
- MS adjusts its power level to minimize the transmitted power and still maintain an acceptable quality of signals
- Both ways transmission of measured power and receiving end adjusts its power accordingly

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GSM systems closed loop power control

- MS adjusts its power level to minimize the transmitted power and still maintain an acceptable quality of signals
- Closed loop– Both ways transmission of measured power and receiving end adjusts its power gain accordingly

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CDMA IS-95 Open loop power control

- Mechanism for near and far terminals
- Open loop– One way transmission of measured power and receiver end adjusts its power gain accordingly

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Summary

- Wireless exposed and hidden terminal problem
- Wireless near and far terminal problem
- Closed loop power control in GSM
- Open loop in CDMA

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End of Lesson 04

Exposed, Hidden, Near and Far Mobile terminal problems and Power control methods

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Wireless Medium Access Control and CDMA-based Communication

Lesson 05

Introduction to CDMA

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CDMA (Code Division Multiple Access) based system

- When the wireless stations (WSs) using the same space (cell), same time-slot, and same frequency f_c, then there is the CDMA alternative to access the medium
- Each WS uses a distinct code between C_0 and C_{p-1} when accessing the medium
- p values from C_0 to C_{p-1}

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CDMA standard

- GSM standards regulate all aspects of the GSM network infrastructure
- CDMA-based standards only govern the radio interface

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First CDMA standard

- IS-95 (interim standard-95) defined by Qualcomm, USA

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CDMA systems

- CDMA more robust for multi-path delays and provides higher immunity towards frequency selective fading
- Each mobile station's or base transceiver's signals are coded with two or three codes

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CDMA systems

- Signals of higher voice and data quality and small bit-error rates
- Soft handover
- Soft handover means that an MS at the boundary of two adjacent cells does not have to drop calls due to signal break during handover at the boundary region
- CDMA systems provide seamless connectivity to the MS

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CDMA systems

- CDMA systems perform power control by open loop or close loop methods to solve the problem of drowning of signals from far mobile terminals by those from the near terminals
- CDMA systems employ spread spectrum techniques (DSSS and FHSS) for medium access control thus problems in narrow band transmission not present

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Narrow band transmission in FSK

- A frequency band equal to f_m for transmission of 1s and 0s (assuming that higher harmonics are filtered)

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Major disadvantages of narrow band transmission

- Frequency selective fading– May be along a path between the MS and BTS
- Co-channel interference– The signals close in frequency to f_{c0} may also be exposed to interference from mobile stations operating at the same frequency in a nearby cell

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Solution to Frequency selective fading and Co-channel interference

- Data-frame channel frequency, assigned to each wireless (or mobile) station by the BTS, can be changed (hop) at select frequencies at a certain rate according to a predetermined sequence
- The GSM hopping rate is 207.4 hops/s
- Use of hopping is optional for a GSM system

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Spread spectrum

- A transmission technique that provides a novel solution to the interference problem
- Direct sequence spread spectrum (DSSS)
- Frequency hopping spread spectrum (FHSS)
- CDMA systems use DS spread spectrum
- Signals at frequencies f_{c0}, $f_{c0} + f_s$, $f_{c0} + 2f_s$, …, $f_{c0} + (n–2)f_s$, $f_{c0} + (n–1)f_s$

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Spread spectrum

- Spectrum widens by a factor of *n*
- Spread between f_{c0} and $f_{c0} + (n-1)f_s$, where *n* is the number of chipping frequencies used and f_s is symbol frequency (symbol/s, number of symbols chipped/s)
- The spread = $n \times f_s$

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Equally spaced Frequencies

- A set of n equally spaced frequencies, called chipping or hopping frequencies used for transmission
- Either in direct sequence or by frequency hopping

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CDMA systems

- An *n*-symbol code assigned for each mobile or base transceiver wireless-station (WS) and each channel of that user
- Another *m*-symbol code can also be assigned to each user channel, for example, synchronization, paging, traffic, and pilot channels
- Another *k*-symbol code can also be assigned for each carrier of the user

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CDMA system codes

- Use a good set of codes
- Orthogonal codes
- Codes which results in autocorrelation at the receiver

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Reduction in co-channel interference in spread spectrum

- Each chipping or hopping frequency can be transmitted at much less power as compared to the case of narrow band transmission
- This reduces the co-channel interference of signals from neighbouring WSs which are also transmitting at the same frequencies

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Reduction in narrow band interference in spread spectrum

- Spread spectrum method reduces greatly the narrow band interference

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Number of channels in spread spectrum

- Multiple access by greater number of channels
- The chipping or hopping frequencies coded distinctly for different wireless stations (WSs)
- Greater number of channels can access the medium simultaneously

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Number of channels in spread spectrum

- Assume that *p* WSs are coded in *p* ways out of 2^n possible ways of coding when using *n* chipping frequencies in the spread spectrum
- Number of codes can be considered good (which provide orthogonal and autocorrelation) for transmission and reception

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Spread spectrum

- Receiver using complex computational processing with the help of the digital signal processors (DSPs)
- Use of a large frequency band

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Spread spectrum

- Frequencies of the band can interfere with other station and transceiver signals in the wireless medium and therefore an appropriate power control strategy is thus required to control the near and far terminal effects

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Spread spectrum

- All the codes formed by combination of bits are not usable and therefore selection of an appropriate set of codes code is important

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Summary

- Code division multiple access
- Each mobile station's or base transceiver's signals coded with two or three codes
- DSSS using equally spaced chipping frequencies
- Co-channel interference and frequency selective fading problems non existent

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End of Lesson 05

Introduction to CDMA

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Wireless Medium Access Control and CDMA-based Communication

Lesson 06

Direct Sequence Spread Spectrum (DSSS)

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Spread spectrum

- A transmission technique that provides a novel solution to the interference problem
- Direct sequence spread spectrum (DSSS)
- Frequency hopping spread spectrum (FHSS)
- CDMA systems use DS spread spectrum
- Signals at frequencies f_{c0}, $f_{c0} + f_s$, $f_{c0} + 2f_s$, …, $f_{c0} + (n–2)f_s$, $f_{c0} + (n–1)f_s$

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Spread spectrum

- Spectrum widens by a factor of *n*
- Spread between f_{c0} and $f_{c0} + (n-1)f_s$, where *n* is the number of chipping frequencies used and f_s is symbol frequency (symbol/s, number of symbols chipped/s)
- The spread in the present case = $n \times f_s$

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DSSS frequency signals for chipping

- $s_0(t) = S_0 .\sin(2\pi .f_{c0} .t + \phi_{t0})$
- $s_1(t) = S_0 .\sin\{2\pi .(f_{c0} + f_s) .t + \phi_{t0}\}$
- $s_{n-1}(t) = S_0 .\sin\{2\pi .(f_{c0} + (n-1) f_s) .t + \phi_{t0}\}$

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DSSS

- A symbol in DSSS using the code transmits as such after chipping when transmitting the symbol 0 and using the code's complement when transmitting 1
- This means XORing between the user-signal symbols and chips
- The chips are used as per the code

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XORing

- B XORed with each of the *n* chips of code
- XORing– if B = 1 and S = 1 or B = 0 and S = 0 then the amplitude is 0, else it is 1
- i_{th} chip– The second term after the multiplication sign $[(s0/\sqrt{n}) \sin \{2\pi .(f_{c0} + (i - 1) . f_S)t + \phi_{t0}\}]$
- First term [(B .XOR S_{i-1}) for the i^{th} chip]– the operation performed at the spreader

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DSSS frequency signals after chipping with user symbol B

- $s_0(t) = (S_0/\sqrt{n})\,(B.XOR.S_0) \sin(2\pi .f_{c0} .t + \phi_{t0})$ } in time interval t = 0 to t_{chip}
- $s_1(t) = (S_0/\sqrt{n})\,(B.XOR.S_1) \sin\{2\pi .(f_{c0} + f_s) .t + \phi_{t0}\}$ in time interval t = t_{chip} to $2.t_{chip}$
- $s_{n-1}(t) = (S_0/\sqrt{n})\,(B.XOR.S_{n-1}) .\sin\{2\pi .(f_{c0} + (n-1) f_s) .t + \phi_{t0}\}$ in time interval t = $(n-1) .t_{chip}$ to $n .t_{chip}$

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i^{th} chip of user symbol B

- $S_i (0 < i < n - 1)$, is the in the sequence (code), f_s is symbol frequency and f_{chip} is the number of chips of user symbols per second
- $t_{chip} = f_{chip}^{-1}$ and $t_s = n \times t_{chip}$

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Number of chips for each symbol

- *n* chips, if there are *n* chipping intervals for spreading
- The signals are transmitted after modulation with a carrier frequency f_{c0}

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DSSS (direct sequence spread spectrum) technique)

- All the frequencies simultaneously, in direct sequence during interval = n. t_{chip}
- The frequency spread is between f_{c0} and $f_{c0} + (n–1) .f_s$

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Example of chips for a symbol code

- The frequency spread and signal strengths for an exemplary code 1110000111100001 consisting of 16 chips

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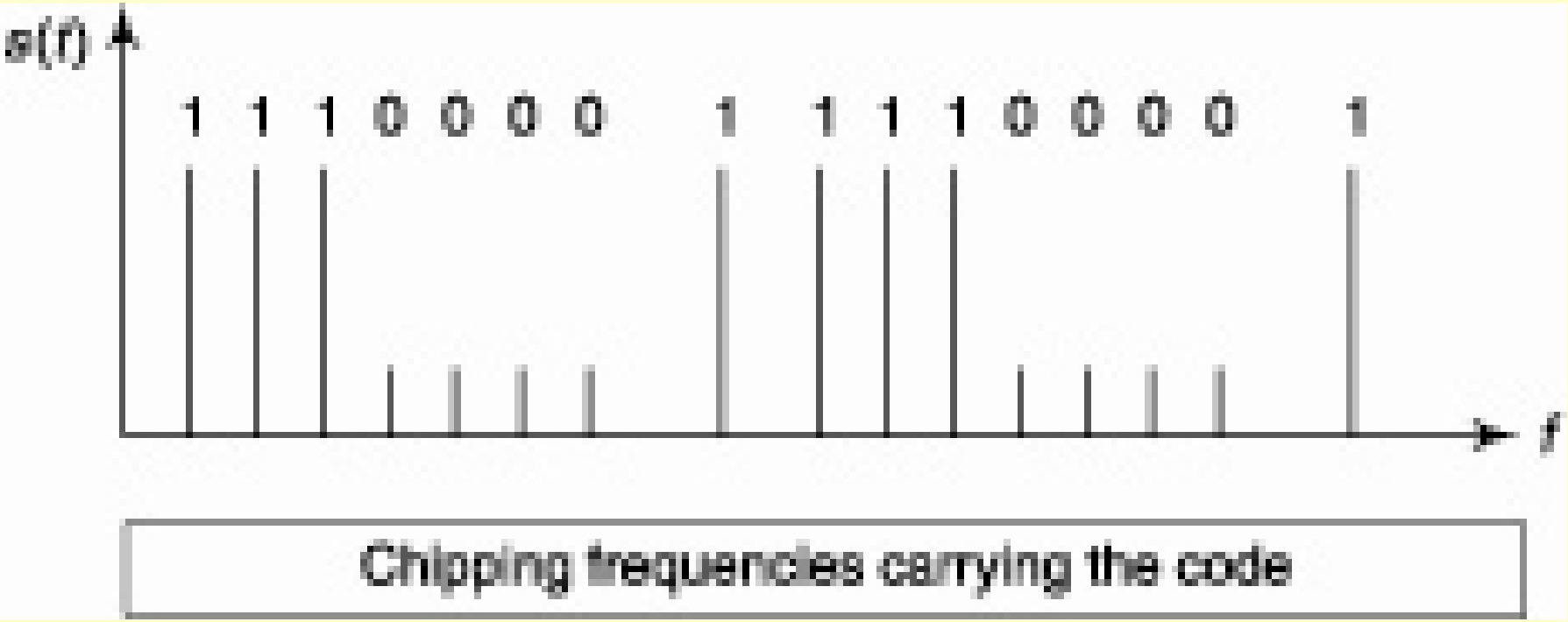
Code 1110000111100001 consisting of 16 chips



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Spread factor, D_{dsss} for the bandwidth in DSSS

- Defined as the ratio of the period of a bit, t_{symbol}, in the data to be transmitted to the chipping time interval t_{chip}
- t_{chip} = The frequency band used by one symbol for chipping f_{chip}^{-1}
- *Ddsss* = t_{symbol}/ t_{chip}
- Bandwidth of DSSS data = $D_{dsss} \times f_s$

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Example

- DSSS at a rate of 0.0192 Msymbol/s
- Chipping rate is 1.2288 Mchip/s
- t_{symbol} = (1/ 0.0192)μs = 52 μs
- t_{chip} = (1/ 1.2288) μs = 0.814 52 μs
- Spread factor D_{dsss} = 52 μs/ 0.814 52 μs= 64
- bandwidth = 19.2 ksymbol/s × D_{dsss} = 1.2288 Mchip/s

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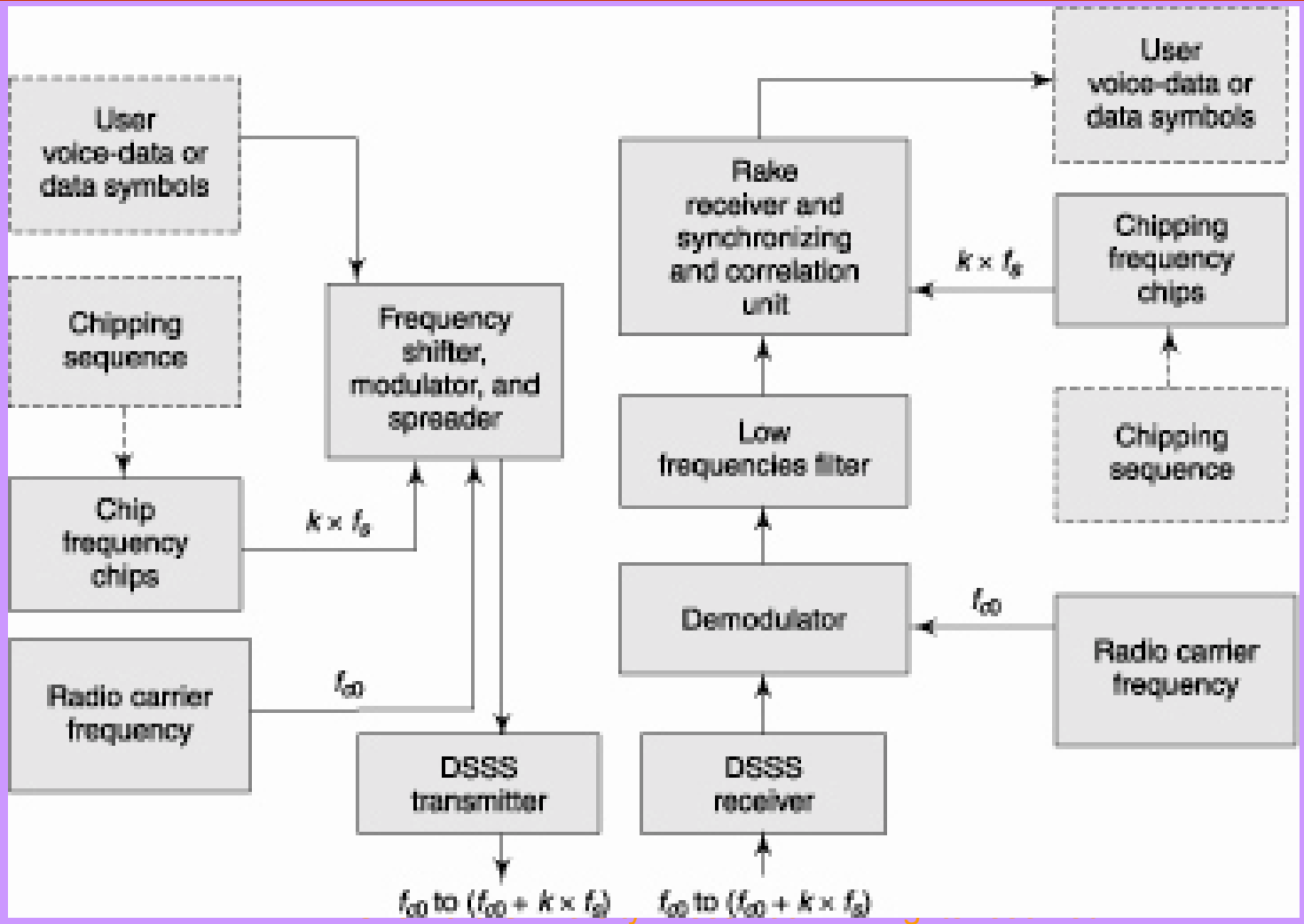
A CDMA DSSS transmitter and receiver



Low pass filter

- Step 1: Input of the DSSS receiver demodulated
- Step 2: Given to a low frequency filter to separate the f_{c0} carrier

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Rake Receiver

- Step 3: Rake receiver with synchronizing and correlation units gets the input chips as per the chipping sequence used by the transmitter
- The output from the rake receiver— the user voice-data or data symbols

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Rake Receiver

- The receiver might be receiving the transmitted signals through multiple paths
- A rake receiver— is a specialized receiver, which selects the signals of the strongest paths
- Reconstructs the signal by accounting for the variable delays in these paths
- Correlates with the chip sequences used for transmission

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Rake Receiver

- The user voice-data or data symbols retrieved in DSSS even in the presence of multiple path delays and narrow band and co-channel interferences

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Correlation unit

- Performs the XOR operation between the demodulator output and the filtered output using the same chipping sequence as used by the transmitter

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Correlation unit

- When the result of XORing either 0 or a value expected from the chipping code, then there is correlation between the transmitted and received data and the user symbol is correctly interpreted as 0 or 1

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Autocorrelation

- Even if the correlation is not perfect the user symbol can be correctly found for a certain range of errors
- This happens when the code chosen is such that it results in autocorrelation, even when there is some chipping interval delay between the received signal and the receiver generated chipping sequence

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Bits after despreading

- b_0 = (S'_0 .XOR. S0), ...
- b_{n-1} = (S'_{n-1} .XOR. S_{n-1})
- b_0 = b_{n-1} = 0 if user data symbol = 0
- = 1 if user data symbol = 0

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Summary

- DSSS uses chipping frequency f_s
- Spread = Spread factor $\times$ f_s
- XORing of user symbol with the code at chipping frequencies
- Receiver low pass filter and rake receiver
- Synchronizing and correlation units

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End of Lesson 06

Direct Sequence Spread Spectrum

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Wireless Medium Access Control and CDMA-based Communication

Lesson 07

Frequency Hopping Spread Spectrum

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Spread spectrum

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Spread spectrum

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- The spread in the present case = $n \times f_s$

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FHSS (Frequency hopping spread spectrum) technique

- One frequency at an instance in a hopping sequence as per the code used
- Hopping sequence is randomly designed for each code
- Code (3, 10, 0, 9, 7) means first hop interval frequency is 3rd hopping frequency, second is 10th, 3rd is 0th, fourth 9th and fifth the 7th
- The frequency spread— between f_{c0} and f_{c0} + (n–1) .f_s for 0th, 1st,…, (n–1)th hop frequency

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FHSS (Frequency hopping spread spectrum) technique

- Example—Code (3, 10, 0, 9, 7) means first hop interval frequency is 3rd hopping frequency, second is 10th, 3rd is 0th, fourth 9th and fifth the 7th
- The frequency spread— between f_{c0} and f_{c0} + (n–1) .f_s for 0th, 1st,…, (n–1)th hop frequency

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FHSS difference from DSSS

- FHSS bandwidth during transmission at each given instant of time is just equal to the inter-channel separation
- The DSSS bandwidth for transmission at each instant is equal to the full assigned spread spectrum

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FHSS difference from DSSS

- Signal radio carrier band is a narrow band, but the frequencies span over the spread spectrum during a complete sequence of hopping
- Each frequency channel is separated by a guard space

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FHSS

- Symbol in a hop interval is transmitted using FHSS
- The channel frequency used for transmission at a given hop interval is as per the hop sequence defined by the code

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n hopping frequency signals

- $s_0(t) = (S_0/\sqrt{n}) \times \sin(2\pi \times f'_c \times t + \phi_{t0})$,
- $s_1(t) = (S_0/\sqrt{n}) \times \sin(2\pi \times (f'_c + f_s) \times t + \phi_{t0})$,
- $s_{n-1}(t) = (S_0/\sqrt{n}) \times \sin\{2\pi \times (f'_c + (n-1) f_s) \times t + \phi_{t0}\}$

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n hopping frequencies

- $f_0 = f'_c$
- $f_{1 =} f'_c + f_s$
- $f_{n-1} = f'_c + (n-1) f_s) \times t + \phi_{t0}$

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FHSS

- A symbol in FHSS using the code transmits as such after hopping sequence of frequencies when transmitting the symbol 0 and using the code's complement when transmitting 1

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FSSS

- XORing between the user-signal symbols and hopping frequency signal
- The hopping sequence in transmitted frequencies are used as per the code

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XORing

- B XORed with each of the *n* symbols of code
- XORing– if B = 1 and S = 1 or B = 0 and S = 0 then the amplitude is 0, else it is 1

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XORing

- i_{th} hopping frequency signal in q^{th} sequence– The second term after the multiplication sign [($s0 / \sqrt{n}$) sin {2π .(f_{c0} + i. f_s + B .f_m) .t + ϕ_{t0}}] where B = 0 or 1
- First term [(B .XOR. S_{i-1}) for the q^{th} hopping sequence]– the operation performed at the spreader

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FHSS frequency signals after hopping with symbol B

- Hopping sequence (i, j, …., p)
- $s_0(t) = (S_0/\sqrt{n})\,(B.XOR.S_0) \sin \{2\pi [f'_c + (i.f_s) + B \,.\, f_m] .t + \phi_{t0}) \}$ in time interval t = 0 to t_{hop}
- $s_1(t) = (S_0/\sqrt{n})\,(B.XOR.S_1) \sin \{2\pi [f'_c + (j.f_s) + B \,.\, f_m] .t + \phi_{t0}) \}$ in time interval t = t_{hop} to $2.t_{hop}$

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FHSS frequency signals after hopping with symbol B

- $s_{n-1}(t) = (S_0/\sqrt{n})\ (B.XOR.S_{n-1})\ .\sin\ \{2\pi\ [f'_c + (p\ .f_s) + B\ .\ f_m]\ .t + \phi_{t0})\ \}$ in time interval t = (n–1) $.t_{hop}$ to n $.t_{hop}$

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FHSS frequencies after hopping with symbol B

- Hopping sequence (i, j, …., p)
- $f_0 = f'_c + i \,.f_s + B \,.\, f_m$ in time interval t = 0 to t_{hop}
- $f_1(t) = f'_c + (j \,.f_s) + B \,.\, f_m$ in time interval t = t_{hop} to $2.t_{hop}$
- $f_{n-1}(t) = f'_c + (p \,.f_s) + B \,.\, f_m$ in time interval t = t_{hop} to $2.t_{hop}$

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q^{th} hopping-sequence

- S_q ($0 < q < n-1$), is the in the sequence (code), f_s is symbol frequency and f_{hop} is the number of hopping sequences per second
- $t_{hop} = f_{hop}^{-1}$ and $f_{spread} = (n-1) \times f_s$

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Slow FHSS

- FHSS spectrum in which the interval during a hop, $t_{hop} >> t_s$ (where $t_s = f_s^{-1}$)
- A number of symbols get transmitted during a channel hop period

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Advantage of Slow FHSS

- Even if one of the hopped frequency signal is faded at the receiver due to narrow band interference, the other symbols are received correctly

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Slow FHSS Example

- Assume that out of 78 channels, the 35th channel is affected by interference
- Then the signals from the 35th channel are rejected
- Transmitter later retransmits these symbols at another channel frequency
- If FHSS is not used, then even retransmission does not help, because that channel will fade again

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Fast FHSS

- Interval during a hop, $t_{hop} << t_s$
- During a symbol period a large number of frequency hops take place

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Advantage of fast FHSS

- Even if a few channel frequencies are faded at the receiver due to narrow band interference, the symbol is received correctly
- The synchronization of fast FHSS between the BTS and WS is more complex than that of slow FHSS

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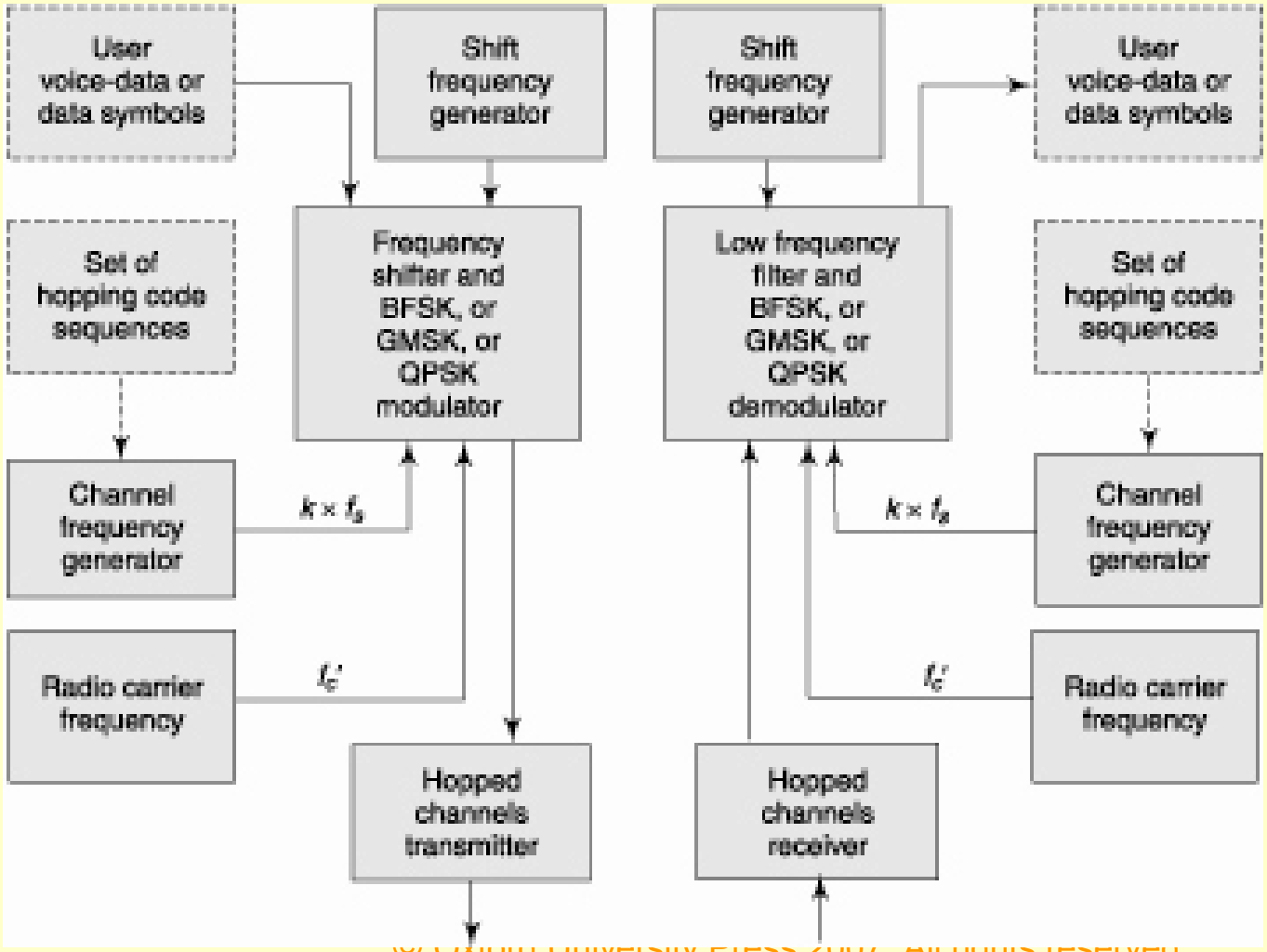
FHSS transmitter and receiver



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FHSS Transmitter

- A hopping sequence for the WS or BTS channel is fed to generate frequency channels as per the hopped channels for the FHSS modulator
- The channel frequency (hopped frequency signal) and carrier frequency are inputs to the modulator
- The output of the modulator is sent to the FHSS transmitter

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FHSS Receiver

- The input demodulated
- Given to the low-frequencies filter to separate the $f'_c + (k \times f_s)$ carriers
- The output of the filter unit is user voice-data or data symbols

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FHSS Examples

- The Bluetooth protocol uses FHSS.
- An example of a hopping sequence is that of the IEEE standard 802.11 wireless-LAN—The transmitter transmits a set of three sequences. Hopping sequences are not repeated in the three sequences.

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- Each of three sequences consists of 26 channels
- Total of 78 channels
- The LAN specification is that frequency channel separations, f_s = 1 MHz and basic radio carrier frequency, f_{c0}= 2.4 GHz

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Spread spectrum bandwidth

- If the hop cycle frequency is f_{hop}, then, the hopping interval, $t_{hop} = f_{hop}^{-1}$
- A set of three sequences with 26 channels
- 78 equations representing the signals from the 1st to the 78th hop
- 78 channels
- f_s inter-channel separation = 1 MHz
- Spread spectrum bandwidth = 78 MHz

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Summary

- Frequency hops from one value to another in FHSS after each hopping interval t_{hop}
- Hopping frequency sequence is the code used for transmission
- n-channels and frequency spread = n $\times$ t_{hop}
- Slow and fast FHSSs
- FHSS Transmitter and receiver

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End of Lesson 07

Frequency Hopping Spread Spectrum

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Wireless Medium Access Control and CDMA-based Communication

Lesson 08

Auto-correlation and Barker Codes

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Coding Methods in CDMA

- Use distinctive spreading codes to spread the symbols before transmission
- At the receiving end, a correlator used to despread the original signal
- Unwanted signals not correlated and, thus, not despread

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CDMA codes

- The original data rates are called symbols per second and the code chipping rates are called chip rates
- These codes uniquely distinguish sets of data from each other

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CDMA codes

- Carefully designed sequences of ones and zeros
- These sequences are produced from the codes as per the chips at rates much higher than those of the symbols (Spread factor > 1)
- Example: f_s = 19.2 ks/s, f_{chip} = 1.2288Mchip/s and spread factor = 64

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CDMA codes

- Enable unique identification of signals from different sources and allow different signals to be transmitted through the same space, time, and frequency slots without interference
- No correlation to other codes or to time shifted versions of themselves

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Correlation

- Consider coded symbols of *n* bits between time interval t_0 and t_0 + (n–1)T, where T is the period between successive bits
- The sequence at the receiver in the interval between t_0' and t_0' + (*n*–1)T when (t_0' – t_0) = the propagation delay

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Correlation between Codes

- When the receiver attempts to correlate the received coded symbols with respect to any of the codes which it internally generates, it is not able to correlate even when it uses exactly the same code as the one used for transmission

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Reasons for no correlation

- Propagation delay— The receiver uses the code for extracting symbols within the interval t_0" and t_0" + (n–1)T and t_0" and t_0 do not differ by n .T
- Inappropriate code— The reason can be that the sequence of bits in the code itself is such that correlation is not possible by using a correlation method at the receiver

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Correlation functions

- Propagation delay taken care of by the receiver by successively shifting the receiver generated sequence by a period = m . T
- m = 0, 1, 2, 3, …, (n–1)

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Sum of product (SOP)

- A code symbol a_i for i = 0, 1,..., n–2, n–1 is given by the SOP from i = 0 to $n - k$ for all values of k between 1 and n
- SOP = $|\sum a_i . a_{i+k}|$

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Correlation Method

- The correlation method is to find the sum of products (SOP) to correlate the sequence of bits between t_0" + (m. T) and t_0" + (n–1)T + (m .T) with the received coded signal
- Vary m till the SOP is maximum
- Inappropriate code taken care of by using an autocorrelation code

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Autocorrelation code

- A multi-bit code which, when used for coding the symbols before a transmission, enables the receiver to automatically correlate and extract the symbols using the correlation method
- SOP = $|\sum a_i . a_{i+k}| \leq 1$ for $i = 1 \leq k < n$
- SOP maximum when k = 0

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Example– Barker code

- Assume that the chipping signal symbol is 1 for +1 and 0 for −1
- The Barker code is a sequence of *n* values (code-symbols) of +1 and −1
- {+1, +1, +1, −1, −1, −1, +1, −1, −1, +1, −1} 11-bit Code in 802.11 LAN

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13-bit Barker code C13

- {+1, +1, +1, +1, +1, −1, −1, +1, +1, −1, +1, −1, +1}

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Good autocorrelation function

- Gives a large value of sum

$\sum e_i \times r_i$ when $e_i = r_i$

- A very low value, when $e_i \neq r_i$ for $0 \leq i < n$
- e_i = expected chip symbol and r_i = received chip symbol in an i^{th} sequence at the receiver

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Pseudo-noise (PN) sequence

- The code appears random and noise-like but is actually not random

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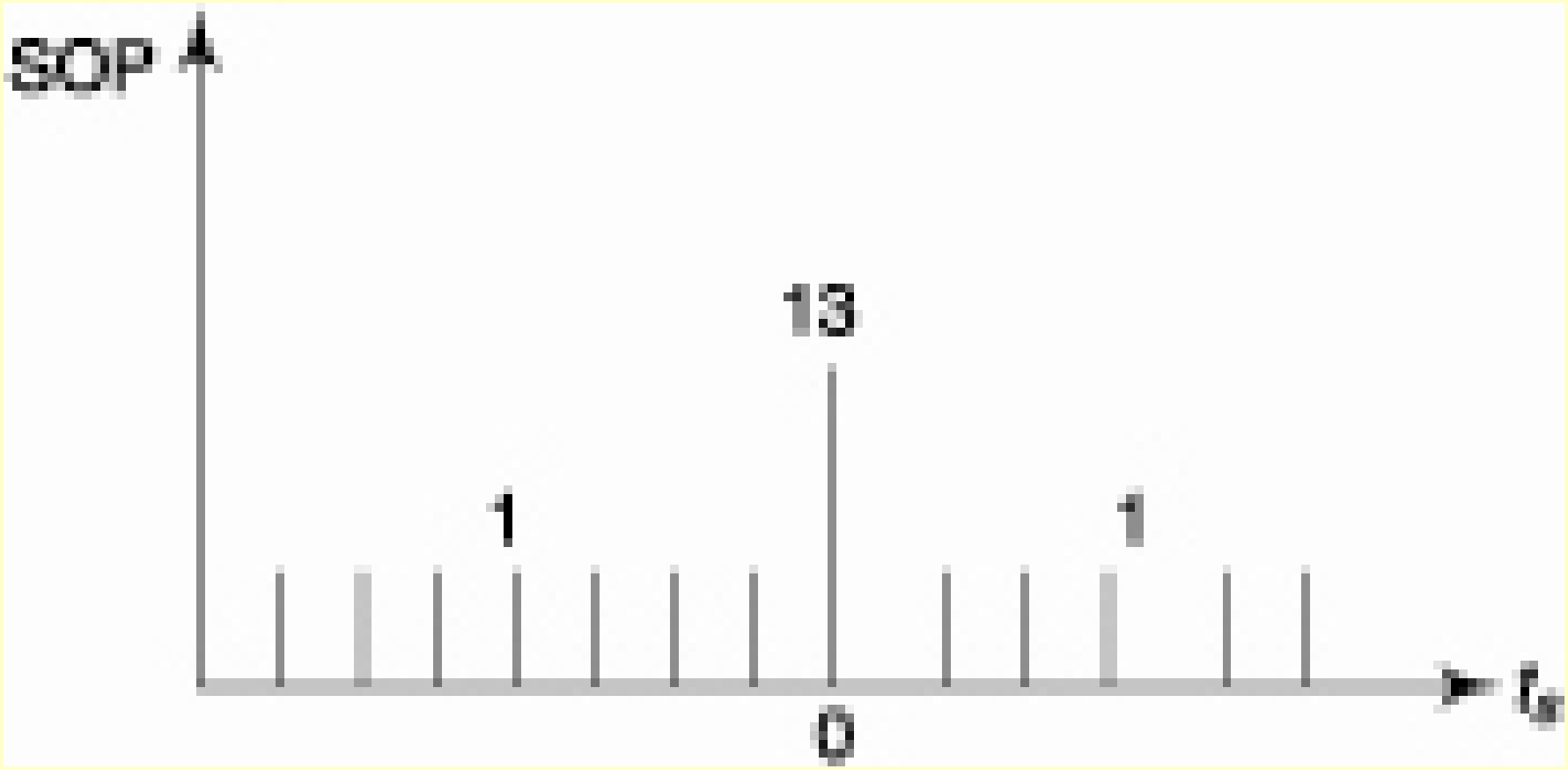
Sum of the 13 products between the coded and received sequences for *n* = 13



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Summary

- Correlation defined by a large value of sum $\sum e_i \times r_i$ when $e_i = r_i$ and a very low value, when $e_i \neq r_i$ for $0 \leq i < n$
- Correlation method is to successively shift the code by 1 till $e_i = r_i$ shown by maximum value of SOP for all values of i
- Barker code– autocorrelation code
- Pseudo-noise code

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End of Lesson 08

Auto-correlation and Barker Codes

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Wireless Medium Access Control and CDMA-based Communication

Lesson 09

Pseudo Noise Codes

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Pseudo-noise (PN) code

- Autocorrelation characteristics
- A code appearing random like noise but is actually not random
- Used to generate one or multiple sequences
- PN codes useful for soft handover

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Pseudo-noise (PN) code

- A second BTS added for the users on the edge of a cell and new PN code used in new cell for soft handover
- Edge signal quality improves and handover becomes robust in soft-handover

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Soft handover in CDMA

- Adjacent cells of a CDMA system use the same set of carrier and chipping frequencies but different codes
- When the cell changes, an offset is added to the pseudo-noise codes
- Each cell has distinct pseudo-noise code offsets

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Soft handover in CDMA

- Pseudo-noise code offset processing can be done easily
- Only the offset value changes in case of handover when the signal of one cell becomes weak
- The call is not dropped, as the offset can be changed by the BTS depending on which cell has stronger signal at the boundary of two adjacent cells

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GSM

- GSM systems have separate operating frequencies in adjacent cells
- This is required to avoid inter-cell interference
- At the edge of the cells, handover is performed
- Call drop occurs

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M-sequences (maximum length sequences) code

- Code generated by using *m* small length shift registers
- The feedback generates a large number of sets, each set having *m* sequences
- Example: a set of 15 registers (*m* = 15) can be used to generate a set of $(2^{15} – 1)$ sequences
- Application as scrambling code

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M-sequence PN codes

- Quadrature component– the 90°-phase-shifted component
- In-phase PN_I component– the same phase component orthogonal to Quadrature component
- IS-95 cdmaOne quadrature and in-phase component code sequences PN_Q and PN_I

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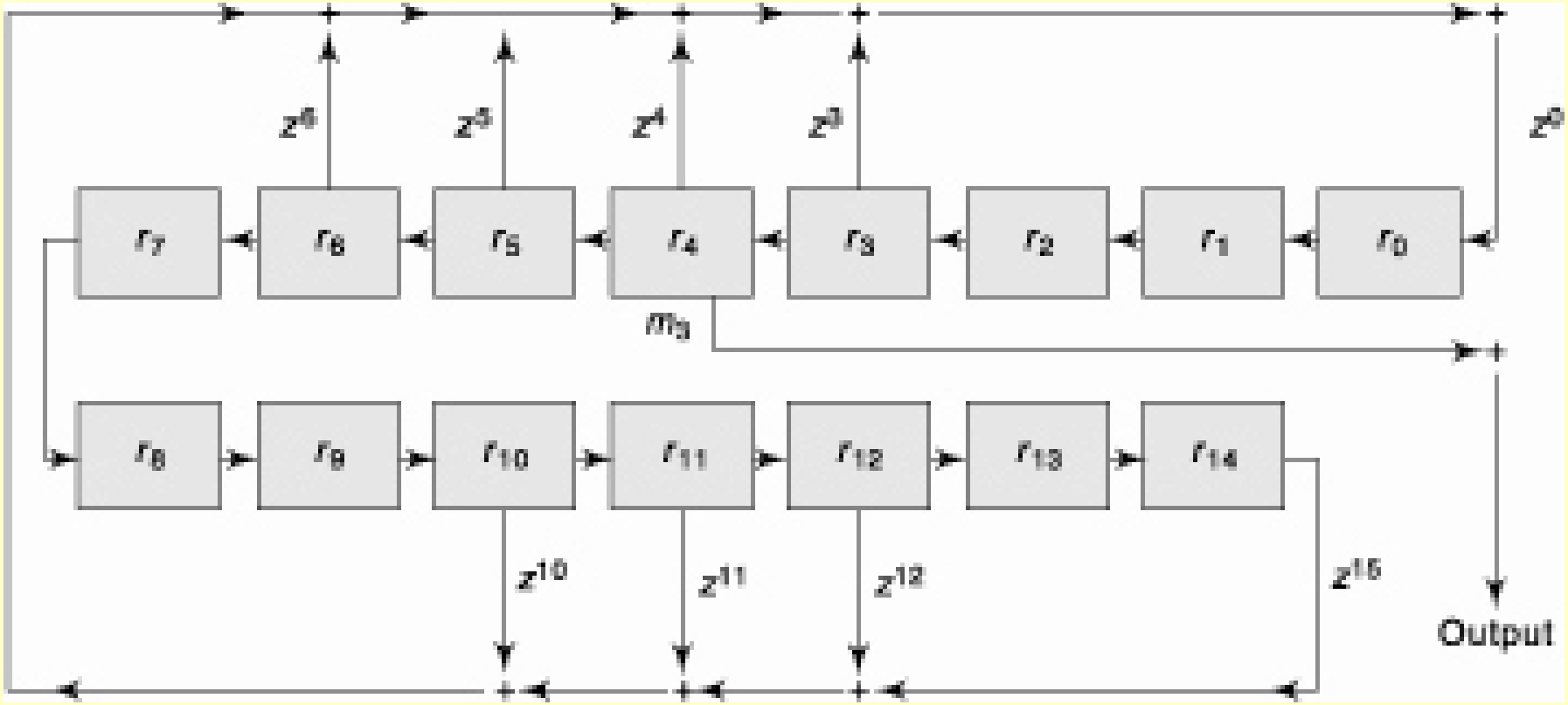
Linear feedback shift register (LFSR) for PN_Q



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Initial State Vector

- An initial state vector has n bits in case of an n degree polynomial
- A set of n shift registers stores this vector on reset (at the start of the sequence generation)

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Initial State Vector for a a set of 15 registers for PN_Q

- r14, …, r1, r0 for G_Q— initial vector is {000 1110 0011 1100}
- r11, r10, r9, r5, r4, r3, and r2 store 1s and rest store 0s at the start of a PN sequence
- Starting sequence should not be 0
- At least one of the registers should store 1 and at least one of the binary numbers in the reset vector is 1

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Initial State Vector

- After n sequences, the same sequence as the first one is used to generate the next output sequence of bits after n .T, where T is the clock period
- Since generator polynomial G_Q results in a different input to r0, the sequence changes after each interval of n .T

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Shift Parameter

- Positive integer
- How much should be shifted after each successive *n* sequences
- If = 3, then it means each sequence starts from register r3 in place of r0
- Skipping r0, r1, and r2
- If shift parameter = 0
- Each sequence starts output from register r0

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Mask Vector

- Specifies which register output is to be taken and is not masked and which set of registers output is masked and is not the input in next sequence
- 16 elements (*m*15, *m*14, *m*13, ..., *m*2, *m*1, and *m*0)

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Mask vector

- {000 0000 0001 0000} for PN_Q defines shift parameter = 4 (because *m*4 = 1)
- The next sequence will start after *n . T* from register r4 in place of r0

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IS-95 PN_Q for generating multiple sequences

- GQ = z15 + z12 + z 11 + z10 + z6 + z5 + z4 + z3 + 1. A generator polynomial must have at least first term *z*n present if the degree of the polynomial is *n* and last term *z*0 = 1

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IS-95 PN_Q for generating multiple sequences

- $G_Q = z^{15} + z^{12} + z^{11} + z^{10} + z^6 + z^5 + z^4 + z^3 + 1$
- A generator polynomial must have at least first term z^n present if the degree of the polynomial is n and last term $z^0 = 1$

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IS-95 PN_Q for generating multiple sequences

- Using generator polynomial G_Q and mask vector (000 0000 0001 0000)
- An output bit is generated on each successive clock pulse
- The + sign shows an XOR operation

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G_Q

- Maximum number of terms in an n degree polynomial is $n + 1$
- G_Q— 16 terms, but coefficients of 7 terms are 0s
- GQ = {1001 1100 0111 1001} or (15, 12, 11, 10, 6, 5, 4, 3, 0)

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PN_I

- $G_I = z^{15} + z^{13} + z^9 + z^8 + z^7 + z^5 + 1$

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Sequence Length

- Sequence length of PN_Q is $2^{15} - 1 = 32767$
- Exactly the same sequences of bits are outputted after each interval of $(2^{15} - 1).T$

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IS-95 Example

- Clock frequency to LFSR = 1.2288 MHz
- Chipping rate is 1.2288 Mchip/s
- The shift in the output occurs after each chipping interval of 1/1.2288 Mchip.s $^{-1}$ = 0.814 μs
- Spread factor = 64

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IS-95 Example

- Output sequence for each user symbol is divided into 64 chips, then the output appears every 0.814 μs
- Symbols and Sequences repetition at the rate = 1.2288 Mchips/s ÷ 64 = 19.2 kSymbol/s

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Gold Codes

- WCDMA uses Gold codes
- Created from two M-sequence codes M1 and M2
- M1 and M2 are added modulo 2

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Gold Codes

- M1 and M2 should be separate and distinct
- Different M1 and M2 are created by just using different starting registers
- Different starting registers can be set by setting the mask vector differently

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Summary

- IS-95 PN-Q and PN-I quadrature and in-phase components
- Pseudo noise codes
- Linear feed Shift Register
- Generator polynomial, Initial State Vector and Mask register used for M-Sequence code
- WCDMA Gold Codes

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End of Lesson 09

Pseudo Noise Codes

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Wireless Medium Access Control and CDMA-based Communication

Lesson 10

Orthogonal, Channelization, Scrambling and carrier modulation codes

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Barker Code

- Barker code *C*13– nine 1*s* and four 0*s*
- Shows strong autocorrelation

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Pseudo-noise (PN) codes

- Almost equal number of 0s and 1s
- PN code shows a strong peak with a few low, non-zero values
- This may result in interference with the other users using the same spread

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Orthogonal Codes

- When there is no effect of interference between the two sets of signals on the received output
- Require synchronization between the transmitter and receiver
- Do not show a strong autocorrelation property

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Orthogonal Codes

- Zero cross-correlation
- Cross-correlation refers to the product of the ith symbol in two codes and the sum of products for all values of *i*

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Orthogonal Codes

- When each transmitter adopts a unique orthogonal code, then there is no effect of interference on the received output because the fact that cross-correlation of two codes = 0 can be used to filter the other transmitter signals out

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Orthogonality condition for two Codes

- SOP of their components = 0
- $\sum p_i . q_i = 0$ when $p_i = q_i$ for $0 \leq i < n$
- p_i = first code
- q_i = second code at the i^{th} chip

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Synchronization

- Instant of the received first bit of coded symbols and first bit of generated code for extracting symbols are in the same phase

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Best codes

- Optimized codes which enable significant correlation
- Do not cause significant interference among the different channels

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Best codes

- A WS can use PN sequences for uplink
- BTS can transmit using orthogonal codes for downlink, because the BTS has special synchronization units
- Auto correlation important for synchronization
- Use codes that are almost orthogonal, i.e. $\sum p_i \,.\, q_i \sim 0$

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Codes

- Orthogonal codes almost zero cross-correlation and are used in identifying the user, user channel, and carrier

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PN Codes

- Long M-sequence PN codes have strong autocorrelation and are used in synchronizing and detecting the user channel signals
- Short PN codes also have strong autocorrelation and are used in synchronizing and detecting the user carriers

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CDMA

- All three coding schemes simultaneously used in a CDMA system
- PN long
- Walsh Orthogonal
- PN short

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Walsh Codes

- Used in IS-95 cdmaOne
- 64 $\times$ 64 matrix
- All pairs of rows orthogonal
- Generated from a matrix called the Hadamard matrix

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Pilot and Synchronization Channel Walsh Codes

- Pilot channel– W0, zero-th row Walsh code = {0, 0, …,0,0}
- Synchronization channel– W32, 32nd row Walsh code = {0, 0, …,0,0} all 0s for first half columns elements and {1,1,..., 1,1} all ones for next half elements

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Paging channel Walsh Code

- W1, 1st row Walsh code = {0, 0, …,0,0} all 0s for first half columns elements and {1,1, .., 1,1} all ones for next half elements
- IS-95 employs it for the paging channel

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Traffic channel Walsh Codes

- W2–31, 33–63 can be used by traffic channels
- If more than 1 and up to 7 paging channels are being used, then W8-31, 33-63 are used for the traffic channels

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W0 and W2 orthoganilty

- 0th row in the 8 ×8 matrix Walsh code W0 = {0, 0, 0, 0, 0, 0, 0, 0}
- 2nd row Walsh code W2 = {0, 0, 1, 1, 0, 0, 1, 1}
- The codes can be rewritten as {–1, –1, –1, –1, –1, –1, –1, –1} and {–1, –1, +1, +1, –1, –1, +1, +1}
- $\sum p_i \,.\, q_i = 0$

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Variable spread factor by using variable-length Walsh codes

- During multi-rate transmission
- CDMA2000
- Transmitting data at variable rates
- Each user channel uses a distinct Walsh code W_m

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Variable spread factor by using variable-length Walsh codes

- The receiver uses the same code W_m for identifying the data and for identifying that user and user channel
- The chipping length of the Walsh code varied
- The code length depends upon the chipping rate and the data rate

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Example user signal transmitting with a chipping interval of 814 ns

- Chipping rate = $(814 \text{ ns})^{-1}$ =1.2288 Mchip/s
- Code length for a very low data rate of 4.8 ksymbolps = 1.2288 Mchip/s ÷ 4.8
  ksymbolps = 256

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Example

- Chipping rate = $(814\ \text{ns})^{-1}$ =1.2288 Mchip/s
- Code length for a very low data rate of 19.2 ksymbolps = 1.2288 Mchip/s ÷ 19.2 ksymbolps = 64

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Example

- Data rate to transmit files of the CIF picture format at 384 ksymbol/s with a rate matching reduction by a factor of 1.25 = = 384 ksymbol/s ÷ 1.25 = 307.2 ksymbol/s
- Code length = 1.2288 Mchip/s ÷ 307.2 ksymbolps = 4
- Rate matching means reducing bit rate by removing select bits, fifth bit after every 4

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Scrambling Codes

- Long sequence lengths to code a transceiver
- Large number of users and user channels
- Long autocorrelation codes required
- A scrambling code can be a PN *M*-sequence code
- Must exhibit strong autocorrelation property

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Scrambling code

- The long code generator polynomial G_l = $z^{42} + z^{35} + z^{33} + z^{31} + z^{27} + z^{26} + z^{25} + z^{22} + z^{21} + z^{19} + z^{18} + z^{17} + z^{16} + z^{10} + z^7 + z^6 + z^5 + z^3 + z^2 + z + 1$ used in cdmaOne scrambling code
- Uplink from an MS, a short-code can also be used, for example, in WCDMA

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Channelization Codes

- Channelization code has a short length sequence and must exhibit the orthogonality property
- Walsh codes used for channelization due to their orthogonality property
- These are scrambled with long codes to achieve orthogonality as well as autocorrelation

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Channelization Codes in cdmaOne as well as CDMA2000 systems

- Walsh code performs the chipping of the signals after a PN M-sequence (2^{42}-1) long code scrambles the user channel symbols
- In both cases a processing unit performs XORing of the user symbols (scrambled with a PN long-sequence-code) with the orthogonal coded chips

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Carrier Modulation Codes

- Transceiver can support a limited number of carriers (<< 2^{14})
- Short autocorrelation codes PN-short suffice

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Carrier Modulation Codes

- Orthogonal phase modulation (QPSK) performed on the I- and Q-PN short code pilot waveforms XORed with the scrambled and then chipped signals
- The modulated signals transmitted using a carrier

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Carrier Modulation Codes

- Orthogonal phase modulation is in time-space
- Orthogonal code or PN code modulation (spreading) is in code-space

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Carrier Modulation Codes

- The purpose of the Orthogonal code is to synchronize the carriers of different base stations and the purpose of the second is to identify the multiple user channels
- For example, two short PN codes called PN_Q and PN_I form two pilots and are used for orthogonal phase modulation

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Carrier Modulation Codes

- IS-95 cdmaOne as well as CDMA2000 employ orthogonal waveforms
- Which are first coded using a PN short code of (2^{15}-1) sequences before modulation

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Summary

- Orthogonal codes
- Channelization codes
- Autocorrelation codes
- Scrambling code– long PN
- Carrier modulation codes– short PN
- cdmaOne and CDMA2000– all three coding- Long PN, Orthognal Walsh and PN-short codes

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End of Lesson 10

Orthogonal, Channelization, Scrambling and carrier modulation codes

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Wireless Medium Access Control and CDMA-based Communication

Lesson 11

IS-95 CdmaOne– Part 1

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IS-95 cdmaOne System

- Developed by QUALCOM, USA in 1991
- Accepted as a standard in 1997
- A 2G+ technology
- 824-849 MHz and 869-894 MHz with multiple analog channels forming one digital carrier
- The standard uses FDD for forward and reverse links, as in the case of GSM systems

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Forward link

- Called downlink in GSM between the BTS and MS
- Frequency 870.000 MHz + 0.030*i*, where *i* is the channel number
- The channel numbers are between channel 1 to 777 when $1 \leq i \leq n1$; $n1 = 777$
- Channel numbers are between channel number 1013 to 1023 when $-10 \leq i \leq 0$

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Reverse link

- Frequency 45 MHz less than the forward link
- 825.000 MHz + 0.030*i*, where *i* = channel number
- The channel numbers are $1 \leq i \leq n1$ between 1 and 777 where $n1 = 777$and are $n2 \leq i \leq n3$

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Reverse link

- Channel numbers, when *n*2 is between –10 and *n*3 = 0, are called channels 1013 to 1023

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System A services

- Using channels 1 to 311, 689 to 694, and 1013 to 1023

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System B services

- Ones using channels 356 to 644 and 739 to 777
- Guard band between the A and B services

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Pseudo-noise spreading codes PN_Q and PN_I

- 15 degree generator polynomials G_Q and G_I
- 32767 (= 2^{15}–1) chip sequence generator using the LFSR based circuit used for spreading

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Pseudo-noise spreading codes PN_Q and PN_I in BTS

- Each BTS adds one of the 512 offsets to the PN codes, so that each BTS in a cell is identified
- During the handover, the offset value changes when an MS moves from a cell to another cell

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Carrier Modulation

- Quadrature and in-phase base-band signals then modulated by QPSK in forward channels
- OQPSK in reverse channels

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Forward Link Channels

- Four channels
- Traffic
- Paging
- Synchronization
- Pilot channels
- The forward channel from the BTS uses orthogonal Walsh codes

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Power Control

- BTS transmitter TR
- *R*eceiver MS R
- TR raises or lowers its power as per *R*'s data for received signal power
- Close loop control– both ends BTS TR and MS *R* transmit the signal strengths received from the other ends and use it for power control

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Power Control

- Open loop control— only one end (BTS TR) transmits the signal strength received from the MS *R* data
- The input data of signal strength detected at an end controls the power used by the transmitter
- The forward channel uses open loop power control

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Pilot Channel

- Transmitted by the BTS to MS before the data is transmitted
- MS transmits the data at reduced power if the pilot is strong and raises the power if the pilot is weak
- Provides a reference to all the MSs in a cell

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Pilot Channel

- Transmits with all 0s in place of voice-data traffic through the in-phase and quadrature spreading units
- Uses the Walsh code W_0
- A circuit consisting of PN_I in-phase and PN_Q quadrature spreaders, base-band filters, and QPSK modulator

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Traffic Channel

- Processing units used for base-band transmission of traffic channel and power control messages
- Uses of long code and mask, PN_Q, PN_I, and Walsh coding units

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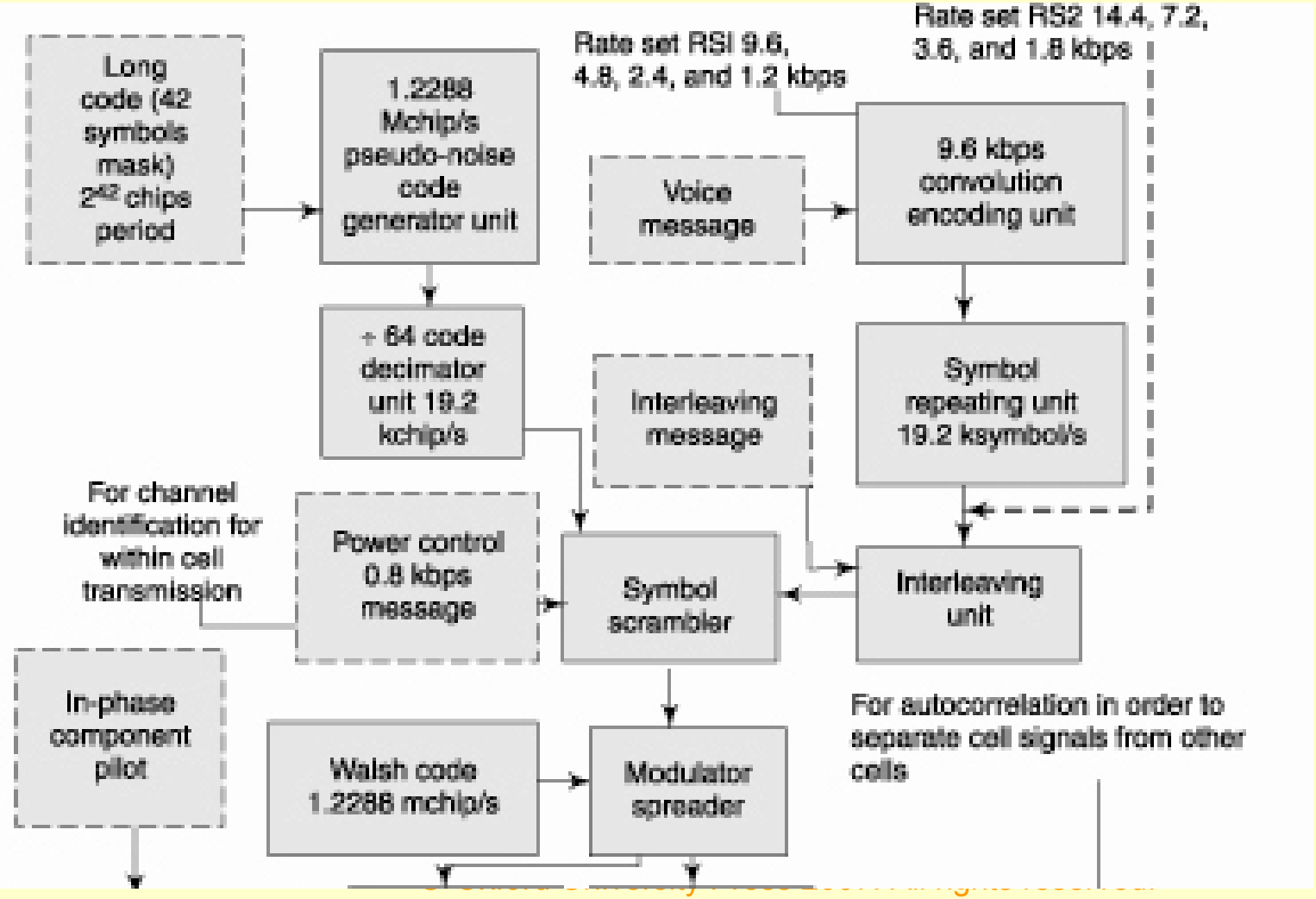
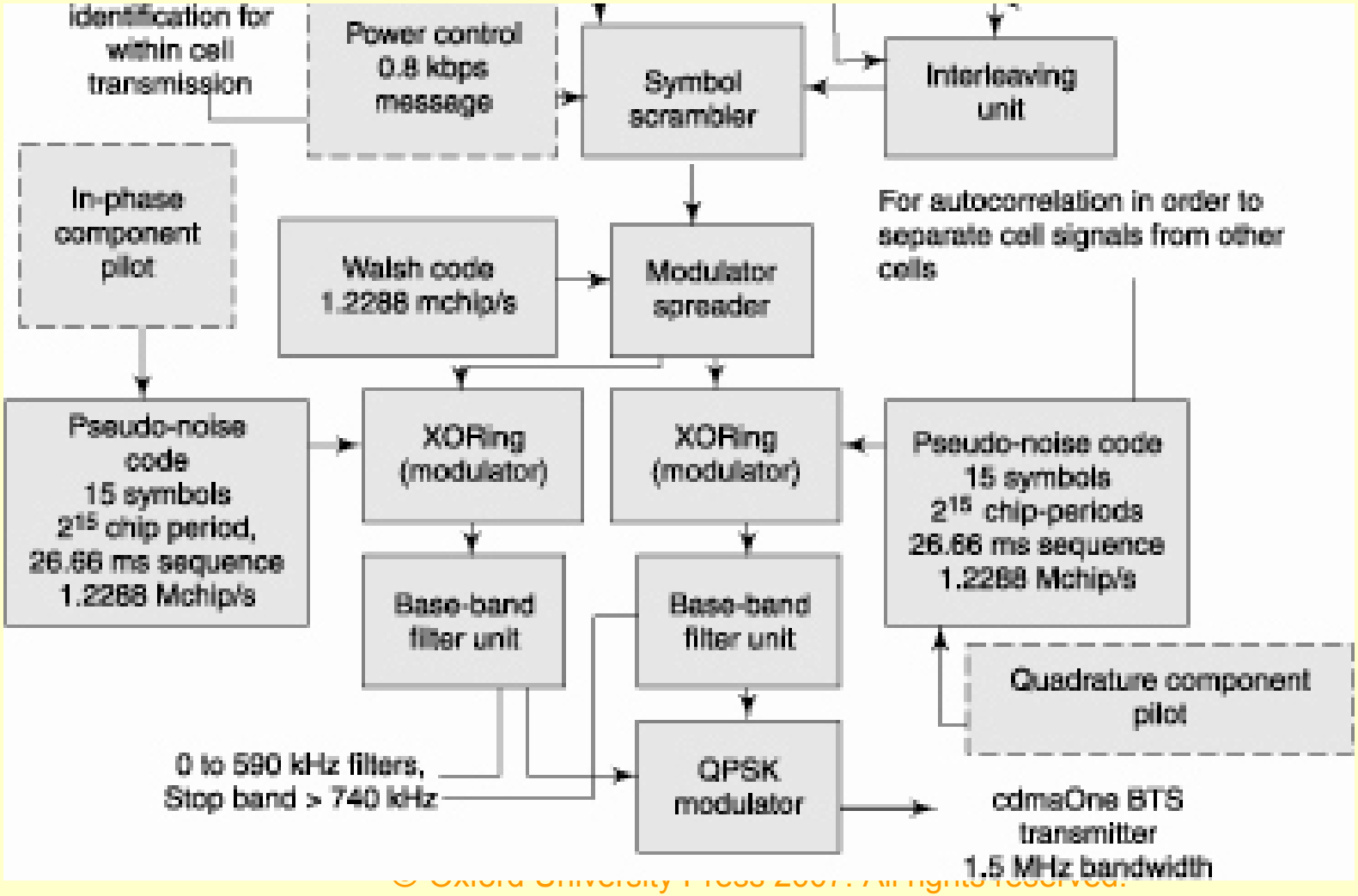
Processing units in Traffic channel and power control messages



Processing units and Walsh, PN_Q, PN_I, coding units



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Multi-encoded Transmission of Signals in a Traffic Channel

- Signals at variable data rates after convolution coding
- RS1 and RS2 data rate symbols are matched, repeated, and interleaved so that before chipping, the symbol transmission rate is constant at 19.2 ksymbol/s

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Data rate matching with a fixed rate for a channel

- Used to transmit multi-encoded signals using a constant spread factor and fixed length codes
- If a set of bits repeated in the same time period (for example, when matching a preset symbol rate by doubling it), then the symbol transmission rate doubles

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Symbol

- Bit is user signal to be transmitted and extracted at the receiver
- Refers to the symbol to be XORed with the code at a given chipping frequency

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Data Rate Matching

- Two rate sets, RS1 and RS2
- RS2 is optional in cdmaOne
- When a rate set is fast, for example, RS2, the puncturing of two bits out of every six inputs slows the data rate when using an additional puncturing unit

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Symbol repetition and Interleaving units

- Symbol repetition doubles the data rate
- Interleaving allows two or more sets of data to be transmitted in the same channel
- Interleaving two sets of data doubles the traffic transmission rate

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Example

- User symbols of RS2 rate 7.2 kbps are to be transmitted
- When bits in voice-data of rate 7.2 kbps are punctured, the data rate will become 4.8 kbps

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Example

- 4.8 kbps signal after passing through a symbol repetition unit, the signal data burst will change to 9.6 ksymbol/s from 4.8 kbps
- After interleaving two RS2 7.2 kbps rate traffic channels, the rate will become 19.8 ksymbol/s

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Puncturing, Symbol Repetition and Block Interleaving units

- The puncturing unit– match data after it is processed through the puncturing (slow data rate), symbol repetition and interleaving units
- Symbol repetition doubles the data rate
- Interleaving allows two or more sets of data to be transmitted in the same channel
- Doubles the traffic transmission rate

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Interleaving

- A technique which enables the use of idle time-slots in the frames which have a pre-defined bit (or symbol) transmission rate in a channel
- Block interleaving means that between successive blocks of a data set, another data set block is inserted

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Interleaving

- Block interleaving helps in sending two data sets simultaneously
- After two or four data sets interleave at a block-interleaving unit, the data symbol rate is kept the same at 19.2 ksymbol/s

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Interleaving

- Interleaving is possible only when the interleaved signal frequencies are integral multiples of each other
- For example, an 800 bps signal can be interleaved with a 19.2 ksymbol/s signal because 19.2 ksymbol/s, when divided by 800 bps, gives 24 which is an integer

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Long Code Scrambling

- long code used for identifying a traffic channel
- The chip generation rate is chosen as 19.2 kchip/s $\times$ 64 = 1.2288 Mchip/s
- A long code decimator reduces the chipping signal rate by a factor of 64

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Long Code Scrambling

- The 19.2 ksymbol/s input, the 19.2 kchips/s input, and the 0.8 kbps power control input are interleaved and are coded at 1.2288 Mchip/s by a 64-bit Walsh code

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Summary

- IS-95 cdmaOne
- Chipping rate 19.2 ksymbol/s
- Data rate matching
- PN long, Walsh and PN-short coding

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End of Lesson 11

IS-95 CdmaOne– Part 1

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Wireless Medium Access Control and CDMA-based Communication

Lesson 12

IS-95 CdmaOne– Part 2

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I and Q pilots for carrier Identification and Synchronization

- Walsh coded signal spread after scrambling of user symbols with long PN codes
- The pilots are modulated after the spread with a pseudo-noise code of 15 symbols with 2^{15} chip period sequences in the I-pilot and Q-pilot channels

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QPSK modulator

- Gets inputs from both the channels and then transmits with a bandwidth of 1.25 MHz for each carrier
- The efficiency of transmission = (1.2288 Mcps/1.25 MHz) . 100 = 0.98 . 100 = 98%.

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Traffic channels and multiple user data channels

- Spread by Walsh codes to enable their distinct identification at the receiver
- Coded traffic channel data transmitted by PN long code sequencing to synchronize multiple channels

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Traffic channels and multiple user data channels

- PN short code sequencing of I and Q pilots to synchronize the multiple transmitter carriers (the short code is used to identify the multiple transmitter carriers at the receiver

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Paging Channel Data

- Base-band transmission of the paging messages and paging mask
- The paging channel sends the TMSI (temporary mobile subscriber ID), information about the traffic channel, response of MS access request during call setup, and information about the adjacent cell base station and its PN offsets
- One or more paging channels can be used
- Each paging channel uses a distinct Walsh code

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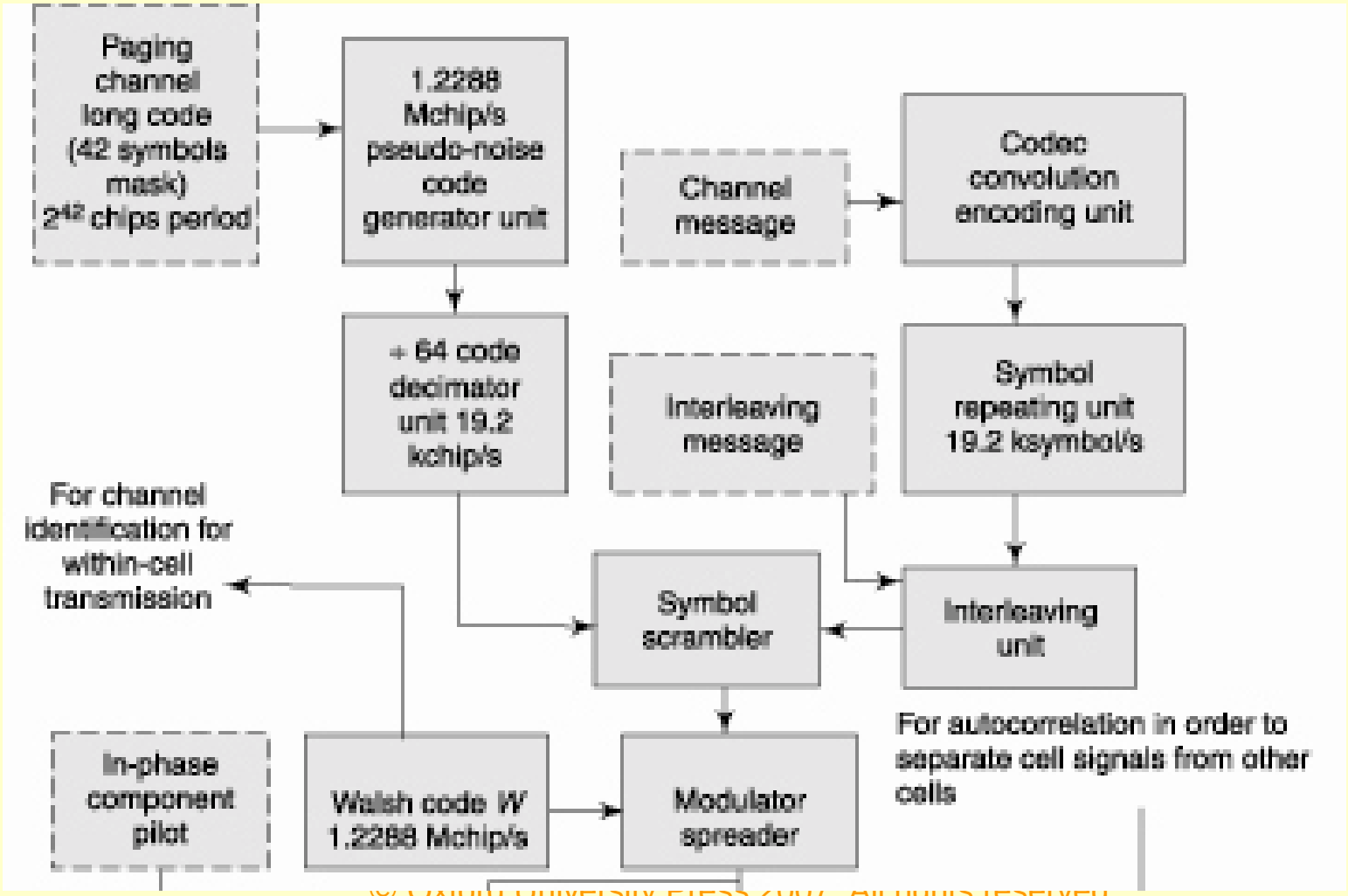
Processing units for paging channel message and paging channel long code



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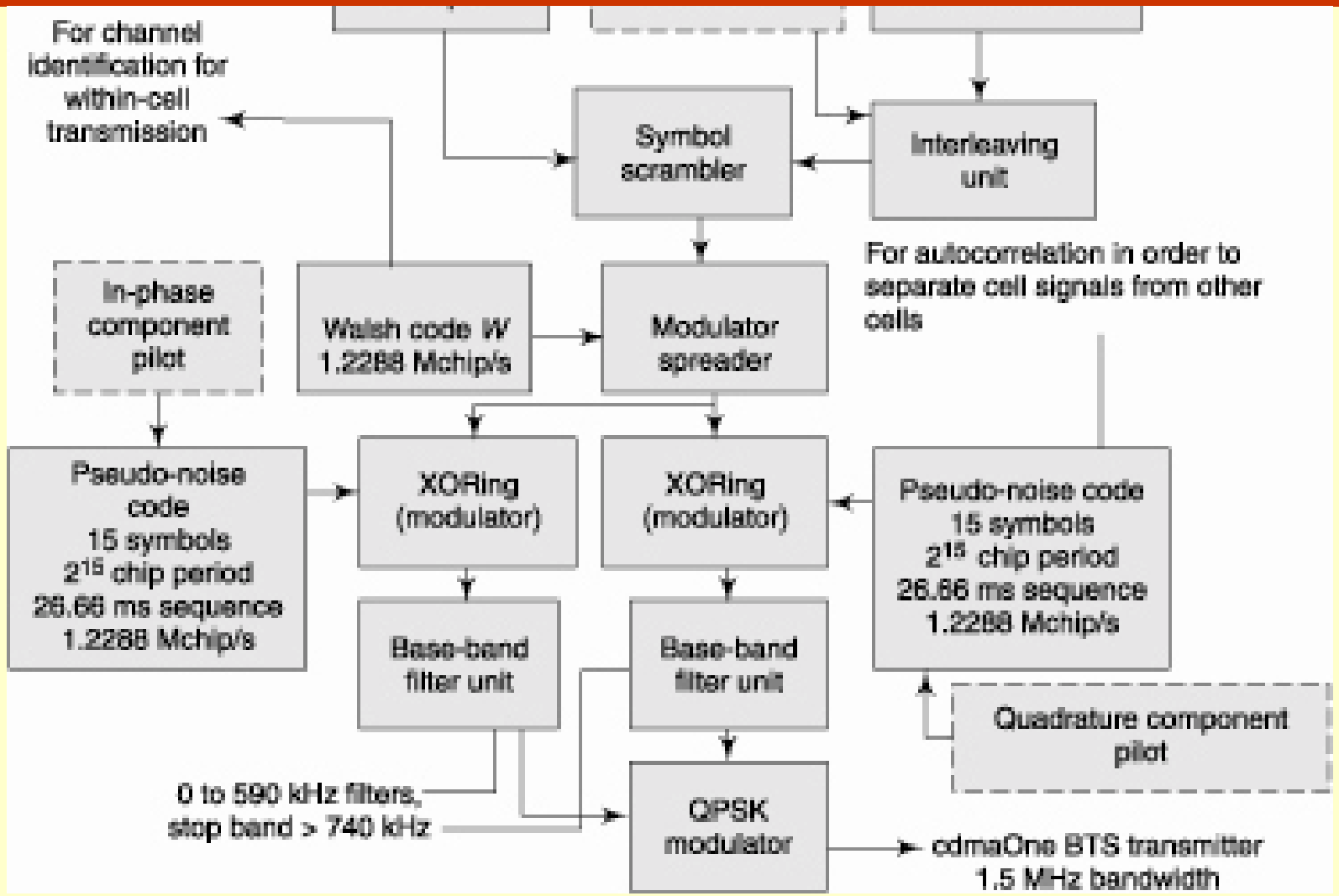
Processing units for paging channel message and paging channel long code



Synchronous Channel Data

- Base-band transmission of synchronous channel data at 1.2 kbps
- The synchronous channel message is used for synchronization of chip sequences at the MS
- Its messages include the system identification (SID), network identification (NID), system time, PN short sequence offset, and PN long sequence codes state

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Synchronous Channel Data

- After passing through the synchronizing symbol repetition unit, the signal data burst will become 4.8 ksymbol/s
- After going through a block-interleaving 4.8 ksymbol/s coded at a rate of 1.2288 Mchip/s
- The synchronization channel uses Walsh code *W*32 and PN_Q and PN_I pilot channels

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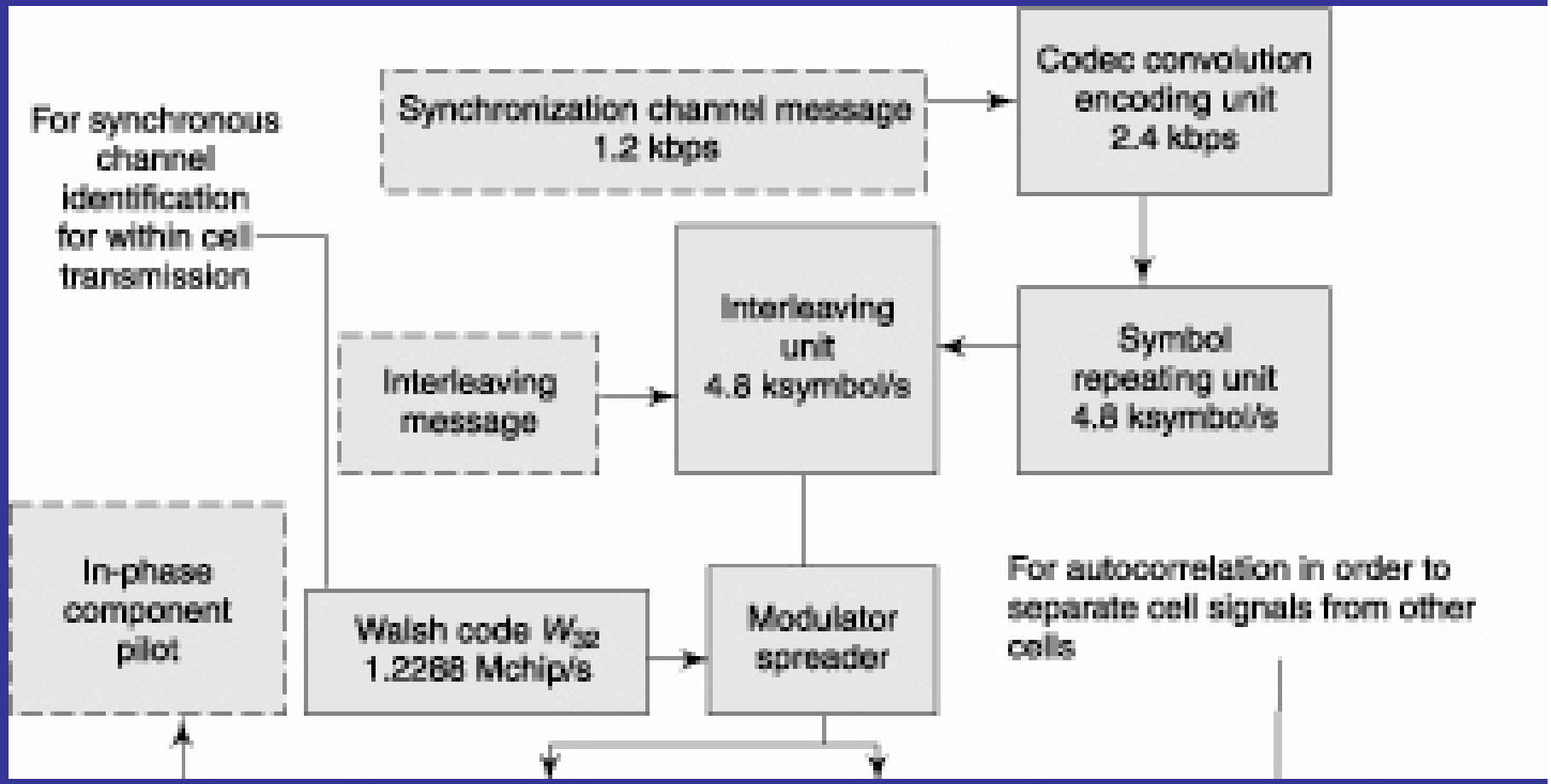
Processing units for base-band transmission of synchronous channel message



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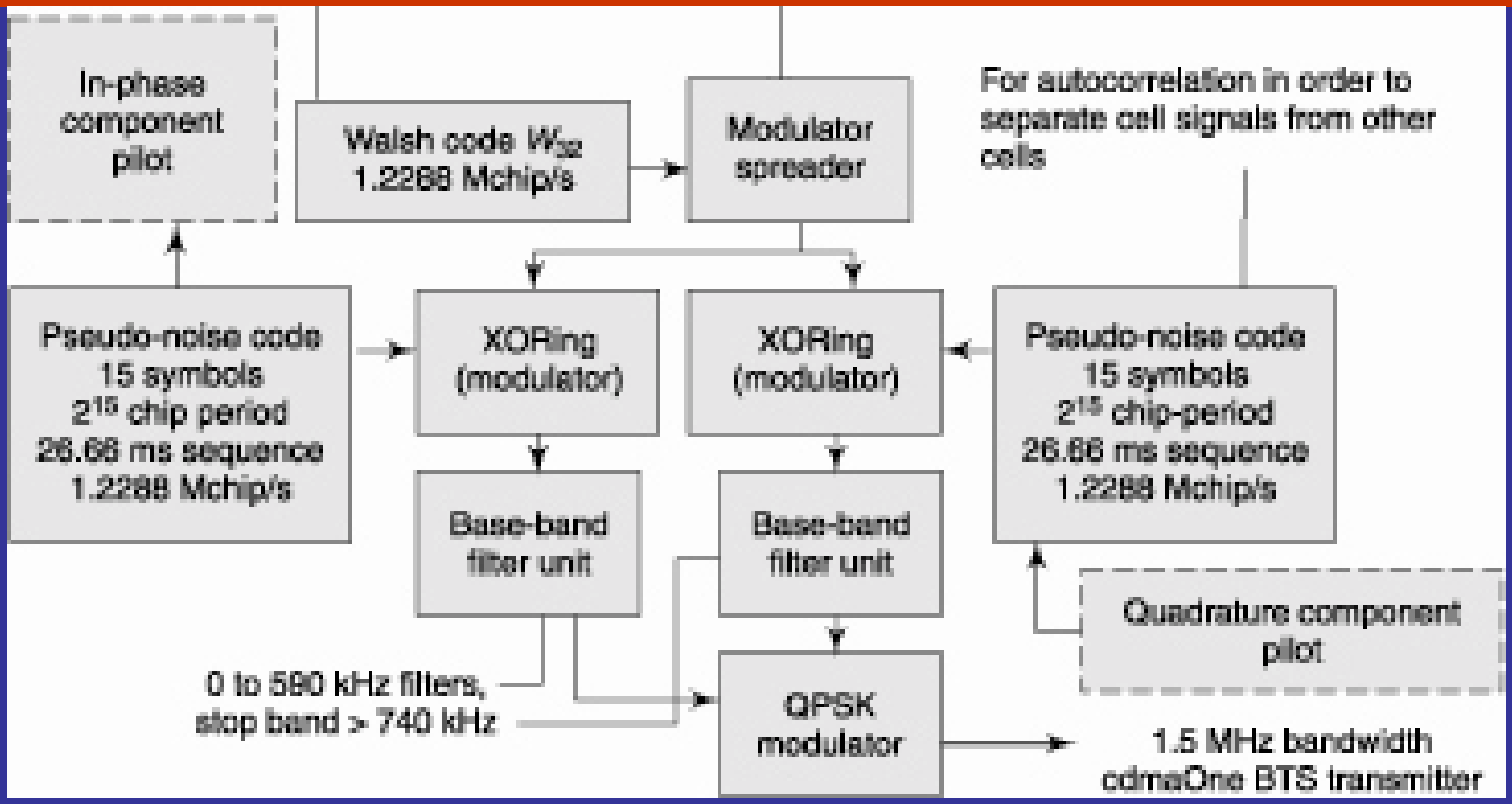
Processing units for base-band transmission of synchronous channel message



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Base Transceiver Forward Transmission

- IS-95 forward transmission has a bandwidth of 1.25 MHz
- Pilot (coded with Walsh code *W*0)
- Synchronizing channel (coded with Walsh code *W*32)
- Paging channels 1–7 (coded with Walsh codes *W*1–7)

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IS-95 cdmaOne Reverse channel

- Include fundamental mode traffic channels and access channels (for access message transmission)
- 64-symbol orthogonal spreader links directly to a PN long sequence spreader in case of the access channel
- Processing units differ from the forward channel

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IS-95 cdmaOne Reverse channel

- Reverse channel 64-symbol orthogonal modulation performed directly (not after the PN long M-sequence coding) on the user data (voice or access channel data)
- The user-signal waveform mapped with the orthogonal Walsh codes

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IS-95 cdmaOne Reverse channel

- User-signal waveform encoding is to reduce the bit error rates at the receiver
- Orthogonal spreading modulation used to identify the user data
- The signal also spreads by long pseudo-noise coding (for scrambling later with the orthogonal channelization codes), but at the next stage after orthogonal coding modulation

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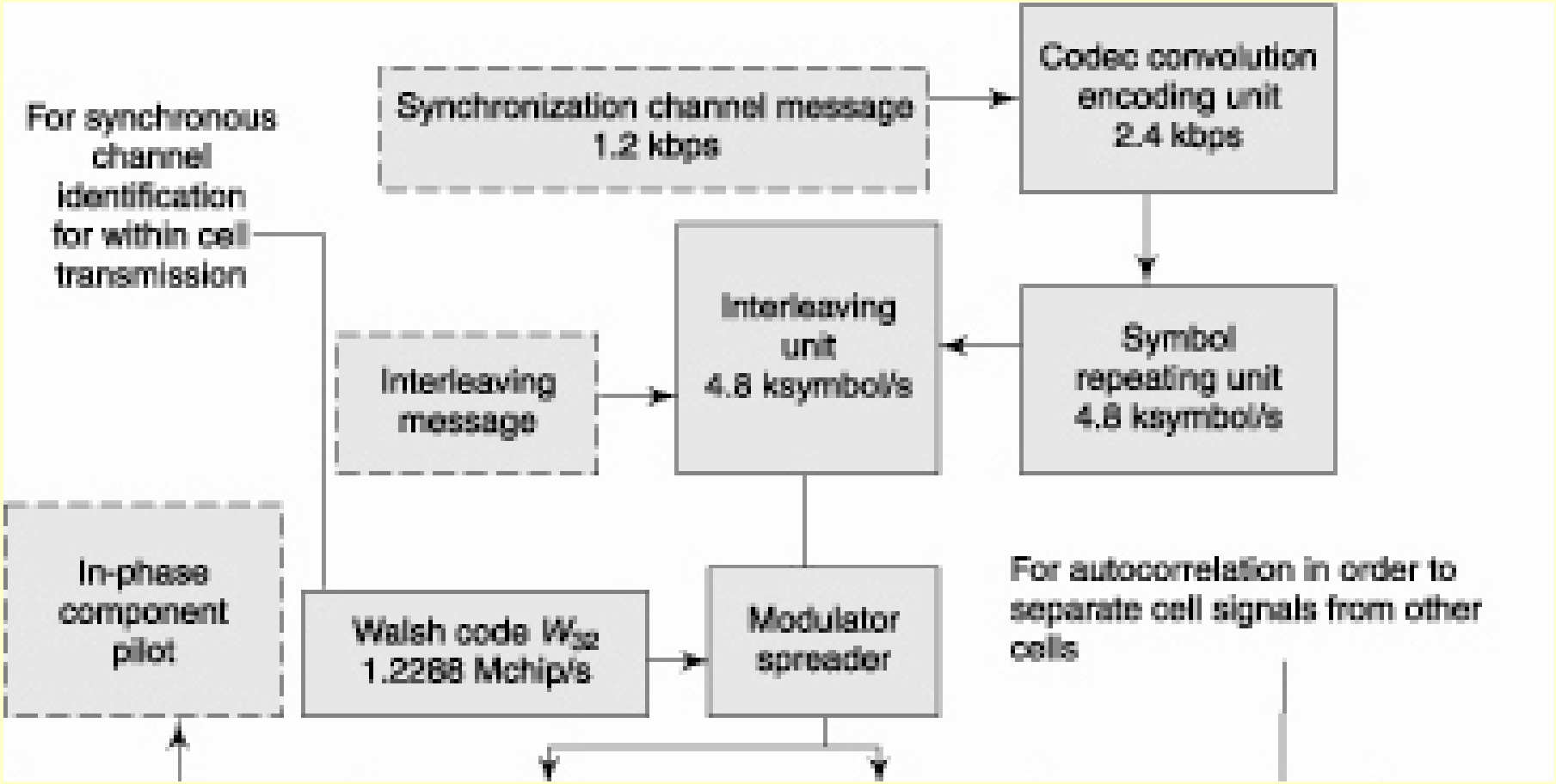
Processing units used in base-band transmission of reverse channel access



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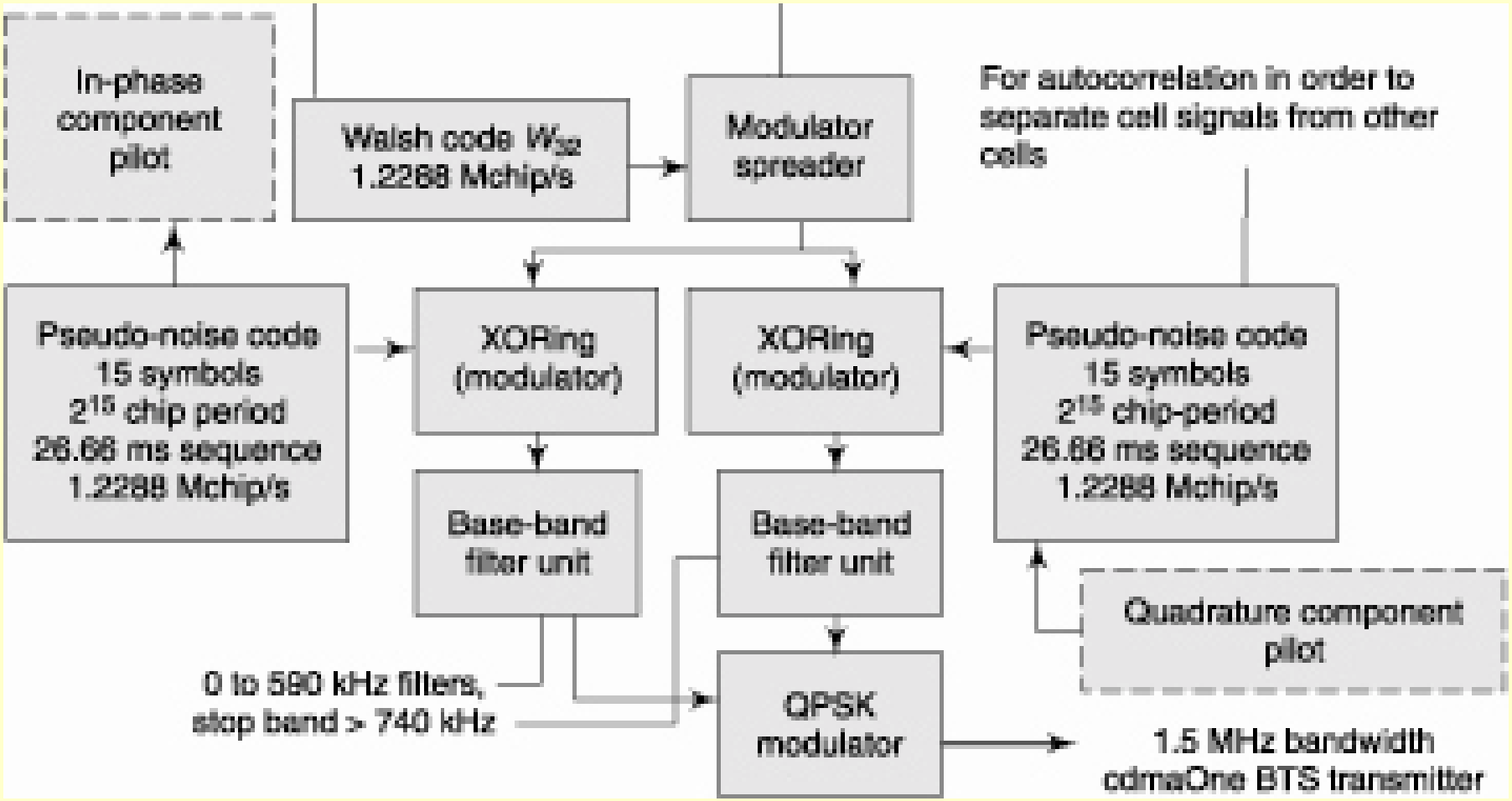
Processing units used in base-band transmission of reverse channel access



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Transmission

- The access and reverse traffic channels
- Bandwidth of 1.25 MHz
- A preamble transmits before each access channel message
- The preamble contains the information regarding message bits so that the receiver can decode that information to process the succeeding message bits appropriately

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Transmission

- No spreading of symbols with orthogonal codes
- The orthogonal codes used only for encoding the waveform

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Combining circuit

- Identical to the forward channels
- Combines the PN_Q and PN_I base-band channel outputs from the 64 reverse traffic and access channels
- The OQPSK modulator modulates the signals in reverse link

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Frames

- The frame structures in the forward channel of the cdmaOne system
- Traffic 14.4 kbps RS2 frame consists of a sequence of 267 user symbols, 12 CRC bits, and 9 tail plus reserved bits
- Paging channel half frame of 9.6 kbps consists of 8 slots of 10 ms

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Frames

- 1-bit SCI (synchronization capsule indicator) preceding 95 paging bits in a 10 ms half frame
- There can be 8 slots in a paging message
- SCI = 0 indicates the end of one message and the start of another message in a slot

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Frames

- SCI = 1 indicates continuation of the message
- Paging channel 4.6 kbps consists of 8 slots of 10 ms with 47 bits after the SCI bit in each slot for the paging message
- Synchronous channel 9.6 kbps consists of 96 bits

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Frames

- A start of message (SOM) bit is indicated as 1 for first sub-frame of the message and as 0 for the successive extension of the message

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Frames

- Sequence is SOM bit, 31 data bits, SOM bit, 31 data bits, SOM bit, and 31 data bits. A frame is combined with other frames into a superframe
- Each message consists of message length at the beginning, followed by data, error checking codes, and padding bits

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Frame structure in forward channels

- Refer Table 4.1

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Frame structure in reverse channels

- Refer Table 4.2

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Summary

- Pilot channel (coded with W_0)
- Synchronizing channel (coded with W_{32})
- Paging channels 1–7 (coded Walsh codes $W_{1–7}$)
- Traffic channels forward channels
- QPSK modulation
- Access and Reverse channels
- OQPSK modulation

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…Summary

- Forward channel Traffic RS2, RS1, paging and synchronous channel frame structures
- Reverse channel Traffic, traffic-Power control and access channel frame structures

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End of Lesson 12

IS-95 CdmaOne– Part 2

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Wireless Medium Access Control and CDMA-based Communication

Lesson 13

WCDMA

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International mobile telecommunications-2000 (IMT-2000)

- 3G wireless communications standard
- Defined by the recommendations of the International Telecommunication Union (ITU)
- Below 3G— Data rates lower than 153.6 kbps are considered
- 3G technologies — High quality of service and high data rate support for multimedia (audio, pictures, text, and video) transfer

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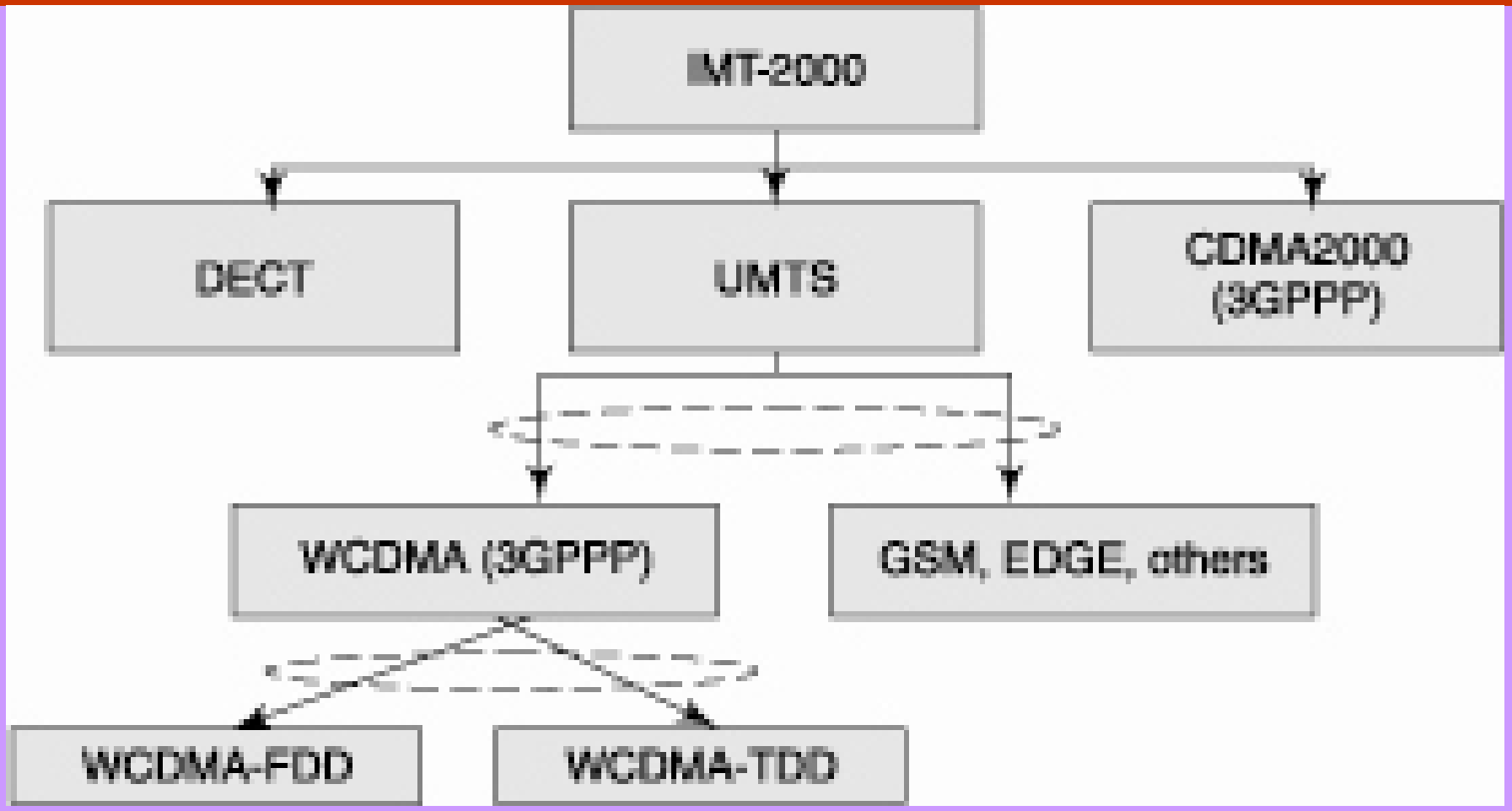
3G technologies covered in IMT-2000 global standards



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WCDMA

- Supports data rates of 2 Mbps or higher for short distances
- 384 kbps for long distances

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WCDMA-FDD

- WCDMA access is either FDD or TDD (time division duplex)
- WCDMA-FDD Also referred to as UTRA-FDD (universal (or sometimes UMTS) terrestrial radio access-frequency division duplex)
- FDD separates reverse link (called uplink in GSM) and forward link (called downlink in GSM) frequencies

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WCDMA-FDD

- 1.920–1.980 GHz for uplink
- 2.110–2.170 GHz for downlink
- Each 5 MHz bandwidth
- Wider than the 1.25 MHz of the IS-95 (2G CDMA) system

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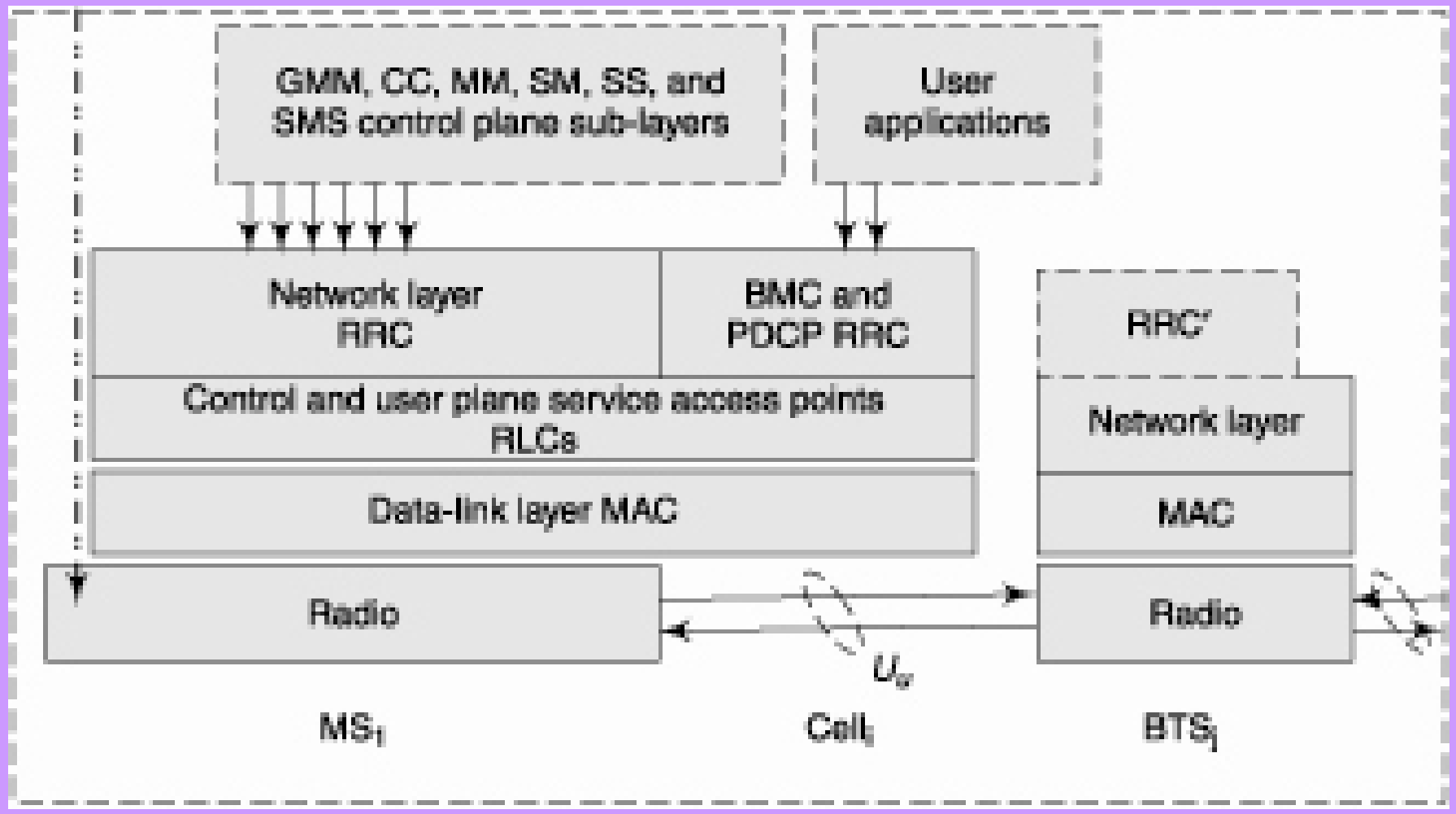
All the protocol layers in the WCDMA uplink terminal (MS) and downlink equipment (BTS)



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All the protocol layers in the WCDMA uplink terminal (MS) and downlink equipment (BTS)

Radio

- FDD, asynchronous or (optionally) synchronous
- Dedicated physical channel
- Compressed mode
- Bursting and 10 ms, 15-slot framing
- Power control
- Synchronizing the MSs and MS path-delay corrections, identification of primary and secondary synchronization codes
- Identification of scrambling code
- 3.84 Mchip/s chipping, spreading and scrambling
- Channelization (OVSF) and scrambler (S2 or long 38400 Gold) coding
- Transport channel combining, data interleaving, and encryption
- Measurements and soft handover
- QPSK modulation and transmission
- QPSK demodulation and reception

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Physical layer

- Physical layer U_u radio interface
- Supports asynchronous transmission
- Can also support synchronous transmission

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Data-link layer MAC

- Controls the flow of packets to and from the network layer
- Ciphering function
- Sends and receives data from control and user plane service access points at the radio link control (RLC) layer and sends it to the physical layer

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Network layer above the RLCs

- Provides access to multiple services such as BMC (broadcast and multicast control protocol) for the user applications
- PDCP (packet data convergence protocol) for the user applications

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Application Layer

- GMM (GPRS mobility management)
- CC [call (connection) control]
- MM (mobility management)
- SM (session management)
- SS (supplementary service)
- SMS (short message service)
- User Applications

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WCDMA

- Direct access CDMA (DS-CDMA)
- Supports fast power control messages at 1.5 kbps closed loop control (IS-95 uses 0.8 kbps open loop control)
- Frame duration in WCDMA 10 ms
- 15 separate time-slots of 0.666 ms for reverse and forward links for the periodic functions not related to user data bursts

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Chipping Rate

- Chipping frequency used in WCDMA 3.84 Mchip/s
- Not compatible with IS-95 as 3.84 Mchip/s — not an integral multiple of the IS-95 chipping rate of 1.2288 Mchip/s
- Modulation type used QPSK for both reverse and forward link frequencies
- Timing synchronization of base stations does not follow GPS system timings

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Dedicated and Common Channels

- Data link layer MAC two types of channels
- The common channels are control, paging, broadcast, and shared channels
- There are three dedicated channels—dedicated physical control channel (DPCCH), dedicated physical data channel (DPDCH), and dedicated physical channel (DPCH)

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Channels

- Dedicated channels assigned to the MSs for uplink
- Also a common channel for traffic
- Transport channels (like access channel in cdmaOne)
- The channel code and structure different for the uplink DPCCH and for the downlink DPDCH channel

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Random access bursts

- Transmitted in 10 ms slots at fixed rates by a control mechanism and slotted Aloha protocol is used for access

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Short Data Packets

- Short data packets directly appended to the random access bursts in common (not dedicated) channel packet transmission

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Long Data Packets

- Longer packets transmitted by dedicated channels at variable power, controlled by a power control message appended to the user symbols

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Different types of physical channels.

- Special (distinct) waveforms only
- Each pair of spreading and scrambling codes defines the remaining physical channels

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WCDMA uplink channelization codes

- For controlling and synchronizing multiple data rate channels
- UMTS terrestrial radio access network (UTRAN) channelization codes for synchronizing the multiple user terminals (MSs)

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Code allocation functions

- The MS performs code allocation functions for uplink channelization code as per the data rate
- BTS performs the code allocation at the downlink radio-planning layer for the scrambling code

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Power control signals

- WCDMA reverse link (mobile terminal uplink) transmits pilot symbols, which are multiplexed with rate information as well as power control messages
- Rate information facilitates coherent detection

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Multi-rate transmission of signals

- Single code used when transmitting small data rate signals multiplexed in time-space and multiple codes are used when transmitting large data rate signals multiplexed in code-space
- A single code for small data rates
- Multiple codes for large data rates

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Use of variable rates by WCDMA processing units

- Types of data need to be transmitted at fast rates and some other types of data, for example, voice-data, power control data, and SMS text, require slow transmission rates
- Variable rates required in different types of services to form a system

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Use of variable rates by WCDMA processing units

- Orthogonal coding for channelization asymmetrical in uplink and downlink
- WCDMA employs a constant chipping rate for spreading but variable spread factors, called OVSF (orthogonal variable spreading factors)

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Spread factor control

- Controls the user data rate. When spread factor = 4, user data rate becomes ¼ of the rate corresponding to spread factor = 1
- OVSF codes support both orthogonality as well as variable data rates for a physical channel
- Uplink OVSF does not separate the users due to different delays expected from the near and far terminals (MSs)

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Variable spread factor

- WCDMA also uses variable spreading codes but ones that are different from the Walsh code
- Use of variable spread factor controls the signals with multiple data rates
- The code length used per symbol is 4 when the downlink user symbol data rate needed is 1.92 Mbps
- 512, when the data rate needed is 15 kbps

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Variable spread factor

- Spreading codes of different lengths thus used and orthogonality of the codes is maintained
- The source (MS) and channel for these symbols when using orthogonal code spreading then gets uniquely identified on de-spreading at the receiver

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Reverse channels

- Uses Gold and S(2) codes
- Chipping rates for these codes are 38400 and 256 chips, respectively
- Gold codes used for the MS user symbols
- S(2) codes identify the user at the receiver

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Compatibility with cdmaOne and CDMA2000 Systems

- WCDMA systems can be made compatible with cdmaOne and CDMA2000 systems
- Use of synchronous base stations
- Employing multi-carrier mode with a chipping rate of 3.6864 Mchip/s (which is an integral multiple of the IS-95 chipping rate of 1.2288 Mchip/s)
- Adding a CDMA pilot to the direct spread mode data

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Summary

- WCDMA data rates of 2 Mbps or higher for short distances
- 384 kbps for long distances
- FDD asynchronous communication
- Dedicated physical channels
- Bandwidth 5 MHz uplink and 5 MHz downlink

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- Different type of physical channels
- Power control open loop
- Multi-rate transmission
- 3.8 Mchips/s
- OVSF
- QPSK

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End of Lesson 13

WCDMA

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Wireless Medium Access Control and CDMA-based Communication

Lesson 14

CDMA2000

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CDMA2000

- 400 MHz, 800 MHz, 900 MHz, 1700 MHz, 1800 MHz, 1900 MHz, and 2100 MHz
- Compatible with the cdmaOne standard
- A set of 3G communication CDMA2000 standards

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CDMA2000 standards

- CDMA2000 1x, CDMA2000 1xEV-DV (evolution for high speed integrated data and voice), and CDMA2000 1xEV-DO (evolution for data optimized)— approved IMT-2000 standards
- CDMA2000 1xEV-DV transmission rates are up to 614 kbps
- CDMA2000 1xEV-DO rates up to 2.05 Mbps

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CDMA2000

- CDMA2000 1xEV-DO and CDMA2000 1xEV-DV enhancements of CDMA2000 1x— accepted as standards in 2004
- CDMA2000 3x — three 1.2288 Mbps channels
- Channel bandwidths for CDMA channels are 1.25, 5, 10, 15, and 20 MHz

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External synchronization mechanism

- Base stations (BTSs) use an external synchronization mechanism– satellite based GPS
- A period of time is required for synchronization among the adjacent base stations in asynchronous stations in WCDMA, not in case of CDMA2000

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External synchronization mechanism

- Adjacent cells can use the same frequency but must use distinct phase angles

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Dedicated and Common Channels

- Reverse access and reverse pilot channels are the only common control channels present during the access setup phase
- The frame structure is 172 user data bits, 12 CRC bits, and 8 tail bits as 0s for a 4.8 kbps access channel
- There is a preamble before a message

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Access channels

- Access is random
- Uses the slotted Aloha protocol

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User data through dedicated channels

- Rate sets RS1 or RS2
- On putting the user channel data in the 20 ms time-slots, the rate becomes 307.2 kbps
- A four chip Walsh code (spread factor = 4)
- Chipping rate becomes 1.2288 Mchip/s

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Data rate

- Low data rate employ one fundamental mode
- High data rate services and multimedia services employ a greater number of dedicated channels

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Dedicated pilot

- A pilot signal is a reference signal
- The MS uses the continuously transmitting, code-divided, dedicated pilot for uplink
- The BTS uses the code-divided common pilot and dedicated or common auxiliary pilots for downlink

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Code-divided dedicated pilot

- Helps in coherent detection of the reference signal
- The BTS pilot channel multiplexes the power control and a control bit called erasure indicator bit

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Short and Long Data Packets

- Frame length modulation QPSK for downlink
- BPSK for uplink
- Frame length modulation gives frames of 5, 10, 20, 40, and 80 ms duration as per the packet size

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Short and Long Data Packets

- Short data bursts use the slotted Aloha protocol
- Transmitted at variable power
- Power level enhanced after an unsuccessful access

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Different types of physical channels

- CDMA2000 supports several different types of physical channels
- Chip rates are $n \times 1.2288$ Mchip/s, where n is a positive integer
- $n > 1$ facilitates multi-rate or single rate data transmission at higher rates, which are n times 1.2288 Mbps

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Supplementary channels

- For reverse link (uplink) use turbo codes
- Other physical channels use ¼ convolution coding
- The signals are scrambled with long code sequences before chipping with orthogonal codes
- Followed by short code spreading of the carrier channels

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Multi-rate transmission of signals

- Low data rate signals used for voice and messages
- High data rate signals for pictures, videos, and large packets
- An RS2 signal can be punctured to reduce data rates
- Low data rate signals of up to 19.2 kbps can be interleaved

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Multi-rate transmission of signals

- A picture in CIF format has resolution of 352×288 pixels
- Transmitted at a data rate of 384 kbps
- Voice or other low data rate services and power control messages are transmitted at RS1 data rates of 9.6, 4.8, 2.4, or 1.2 kbps or at RS2 data rates of 14.4, 7.2, 3.6, or 1.8 kbps

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High data rate signals

- Rate Reduction at 307.2 kbps for 384 kbps data
- Up to 307.2 kbps, variable length Walsh codes support both orthogonality as well as variable data rate for a physical channel

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Multi-rate transmission of signals

- IS_95 spread factor is constant at 64
- Spread factor can vary from 4 to 256 depending upon the data rates in CDMA2000

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Coding

- Downlink uses Walsh codes or quasi-orthogonal codes and uplink uses Walsh codes
- Quasi-orthogonal means not strongly orthogonal
- Orthogonal coding for channelization asymmetrical in uplink and downlink

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Multi-rate data encoding in Traffic Channels

- Rate Set RS1 transmits at 9.6, 4.8, 2.4 or 1.2 kbps
- An optional rate set RS2 transmits at 14.4, 7.2, 3.6 or 1.8 kbps
- Requires different type of convolution encoding and error encoding depending on considerations of service quality
- Service quality low or high– high or low bit error rates, respectively

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Multi-rate data encoding in Traffic Channels

- Multi-encoded rate signals are systems that transmit at variable data rates after convolution coding
- In IS-95, RS1 and RS2 data rate symbols are matched, repeated, and interleaved so that before chipping, the symbol transmission rate is constant at 19.2 ksymbol/s

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Pilots

- Downlink and uplink Modulations of Spreading Signals (Pilots)
- Spreading signal (pilots) modulation is balanced QPSK modulation for downlink and dual channel QPSK modulation for uplink
- The modulation of radio carrier frequency is asymmetrical for uplink and downlink

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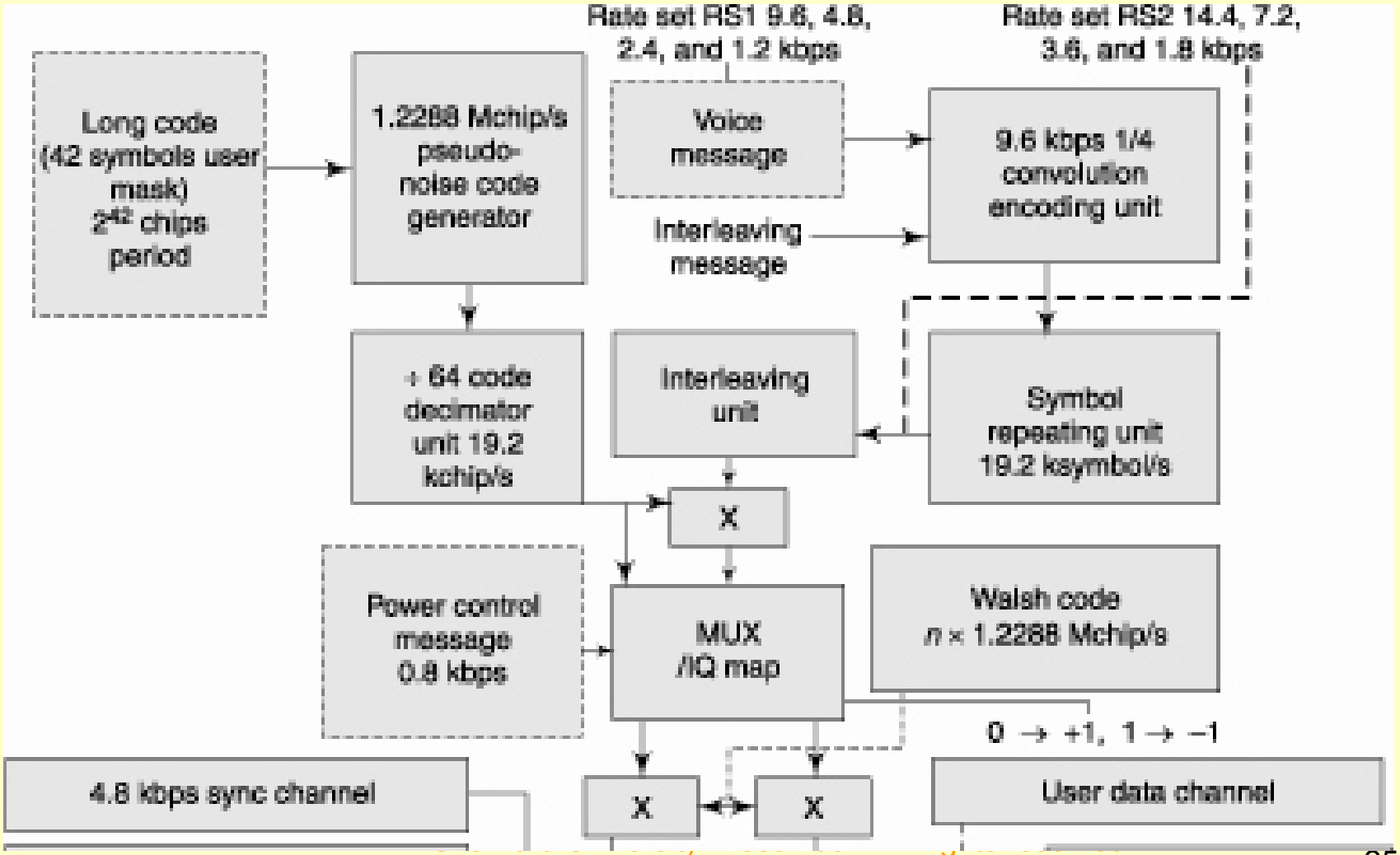
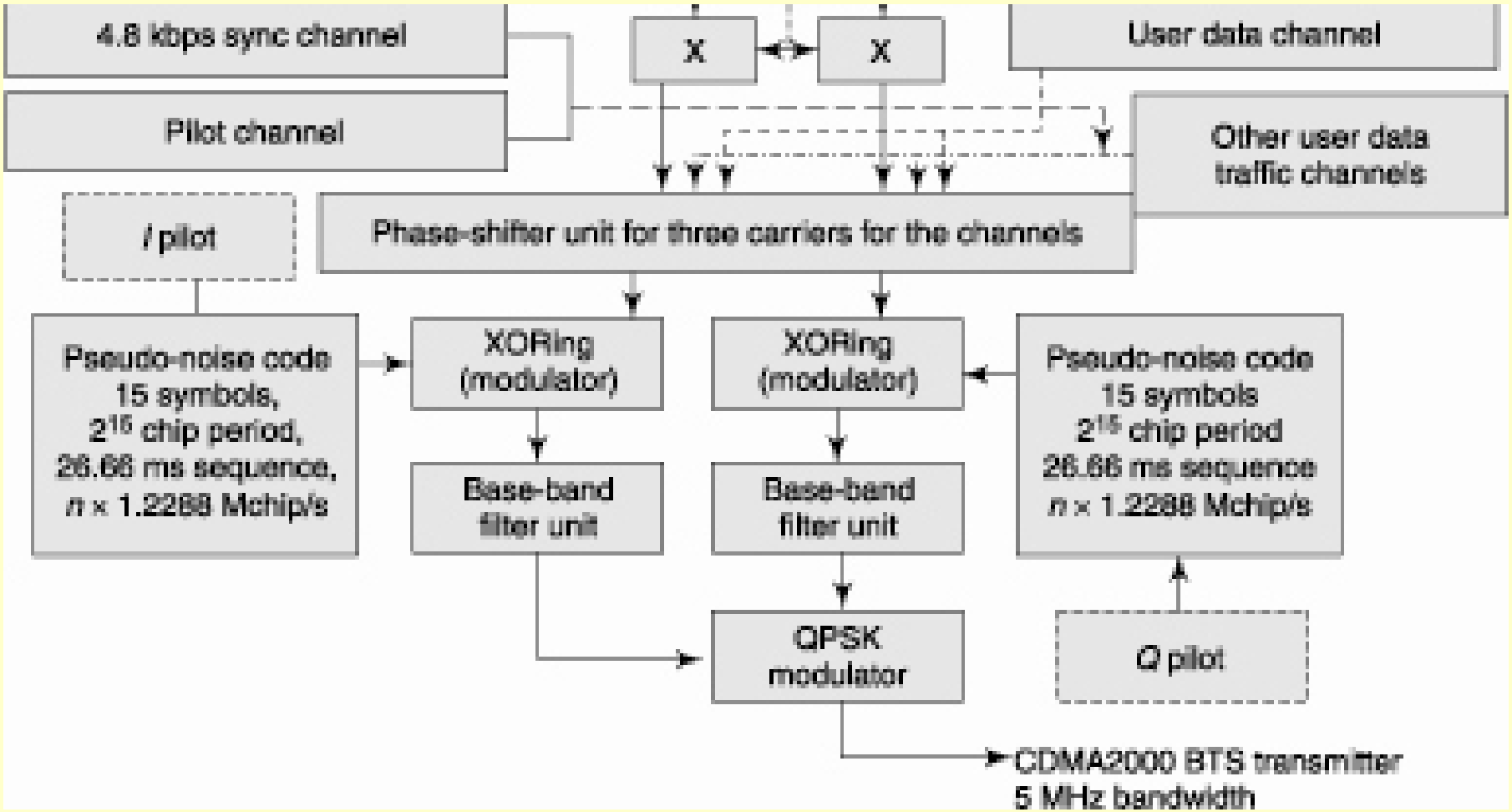
Processing units for power control messages and channels for data, sync, pilot, and traffic



Processing units for power control messages and channels for data, sync, pilot, and traffic



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Processing units

- Use of a MUX/IQ unit
- Long code and mask
- PN_Q and PN_I, and Walsh codes

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Long codes

- Use the same length M-sequences
- Used for channels data divided in two different phases (I and Q) for each channel before scrambling

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Processing units

- In IS-95 the data channel divided into the *I* (in-phase) and *Q* (quadrature) components after chipping with Walsh codes
- In CDMA2000 it is divided before scrambling

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Processing units

- The main difference with respect to the IS-95 processing unit is that in CDMA2000, the MUX/IQ (multiplexer and signal mapping unit) first divides the signal into the I and Q components
- Followed by chipping of the signal using Walsh codes and then encoding using short code PN sequences

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MUX/IQ

- An MUX/IQ unit performs signal mapping
- Each 0 is mapped to + 1 and each 1 is mapped to —1as per 3GPP specifications

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MUX unit

- Multiplexes (i) the user data after decimation (dividing by a factor) by a decimator, and (ii) the power control bits. *I* and *Q* components are then coded with Walsh codes

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Walsh coded components I and Q

- From the units and Walsh coded components *I* and *Q* from other user traffic, user data, pilot, and synchronization channels multiplexed
- Pass through PN-short-code spreaders
- Base-band filters

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MUX unit

- Three sets of chips after multiplexing when the chipping rate is 3×1.2288 Mchip/s
- Each chip has two components, *I* and *Q*

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Modulation

- After the PN short code encoding with *I* and *Q* pilots and base-band filtering of *I* and *Q* components, a balance QPSK modulator modulates the signal for downlink
- A dual channel QPSK modulator modulates it for uplink

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Multi-Carrier Rate support for transmission of signals

- Chipping rates of $n \times 1.2288$ Mchip/s (n = 1, 3, 6, 9, or 12) can be used
- Bandwidth for CDMA2000 3x = 5 MHz.
- While uplink uses DS-CDMA, downlink can use either multi-chip rate CDMA $n \times 1.2288$ Mchip/s, where n is the number of carriers)
- DS-CDMA (Assuming that there is no mapping of 1s and 0s)

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Three carriers

- 3 carriers of 1.25 MHz each for *n* = 3 and all carriers have a separate code for each channel

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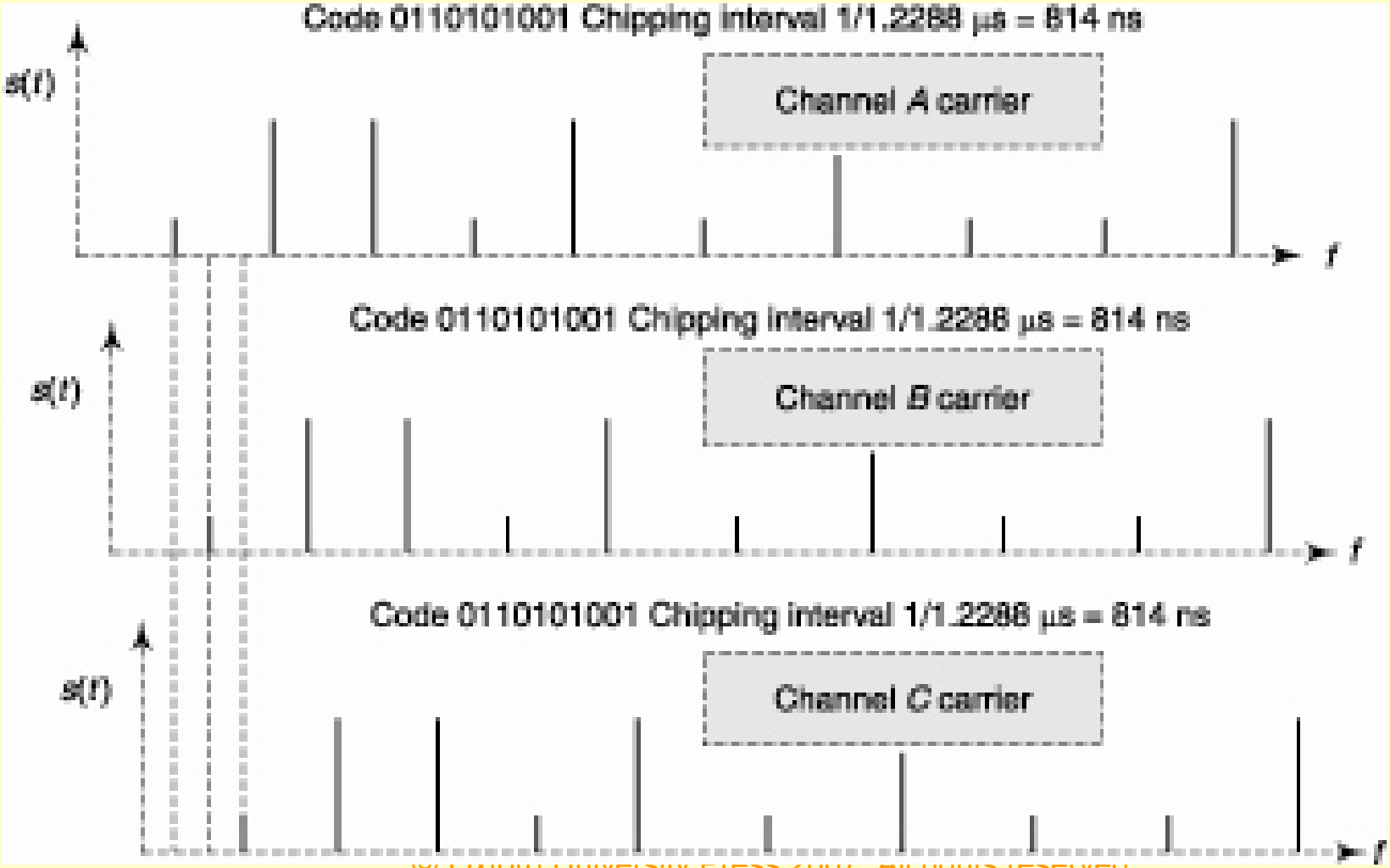
3 carrier signal frequencies with three chipping codes of 10 symbol (code 110101001) example



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Multi-carrier transmission

- Uses multiplexing in time-space
- All channel carriers chipped using the same orthogonal code and scrambled using the same PN long codes, but the chipping instants of each carrier channel are shifted by $(1/n) \times 814$ ns (phase angle change of $360°/n$) in CDMA2000

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Multi-carrier rates

- Can be adopted in CDMA2000
- When *n* channel data is to be transmitted, then each carrier uses 1.2288 Mchip/s for transmission
- When single channel data or time division multiplexed data of different channels is to be transmitted at high data rates, then a single carrier uses $n \times 1.2288$ Mchip/s for chipping

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Summary

- CDMA2000 3G technology
- Synchronous base stations
- Interleaving of signals of low data rates (between 0.8 kbps to 4.8 kbps)
- Multi-rate transmission by variable spread factor (between 4 and 256) for data rates of 307.2 kbps to 4.8 kbps

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…Summary

- Use of a MUX/IQ unit
- Long code and mask
- PN_Q and PN_I, and Walsh codes
- Data channel divided into the *I* (in-phase) and *Q* (quadrature) components before chipping with Walsh codes
- Divided before scrambling

…

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…Summary

- Multi-carrier (MC) FDD mode-2 transmission by using chipping rate = *n* × 1.2288 Mchip/s (where n = 1, 3, 6, 9, or 12
- All *n* carriers have unified power control)
- Distinct uplink and downlink multiple access, modulation, spreading, and channelization codes

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End of Lesson 14

CDMA2000

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Wireless Medium Access Control and CDMA-based Communication

Lesson 15

i-Mode

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i-mode

- i-Mode Internet services WCDMA based
- NTT DoCoMo in Japan

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i-mode

- Uses adaptive multi-rate encoding
- A cost-effective method for high-speed packet-switched data transfer
- Communicate user voice data and provide Internet access

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i-mode

- Provides integrated services for voice, data, Internet, picture, music attachment to mail, gaming applications, ringtone downloads, remote monitoring, and control services
- Named as FOMA (freedom of mobile multimedia access)

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Services integrated into the i-mode FOMA service

FOMA teleservices
(point-to-point cellular broadcast)

- Telephone/fax
- Voice full 13 kbps
- SMS
- MMS—GIF, JPG, WBMP
- Videotext access
- Videophone with 64 kbps
- Call system-related services

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Services integrated into the i-mode FOMA service

FOMA application services

- Email
- Web browsing
- Java applications
- Gaming
- Advertisements
- Ring tones, music, and video clips distribution
- Bluetooth interface

Packet-oriented bearer services data transmission

- Full duplex
- 64-kbps uplink
- 384-kbps downlink
- Synchronous, asynchronous, or synchronous packet data
- Simultaneous voice and data multiple access

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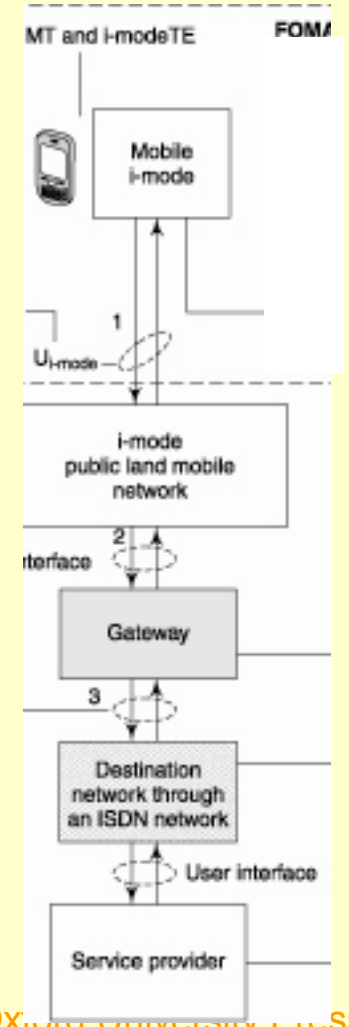
A connection of an i-mode TE to the service provider



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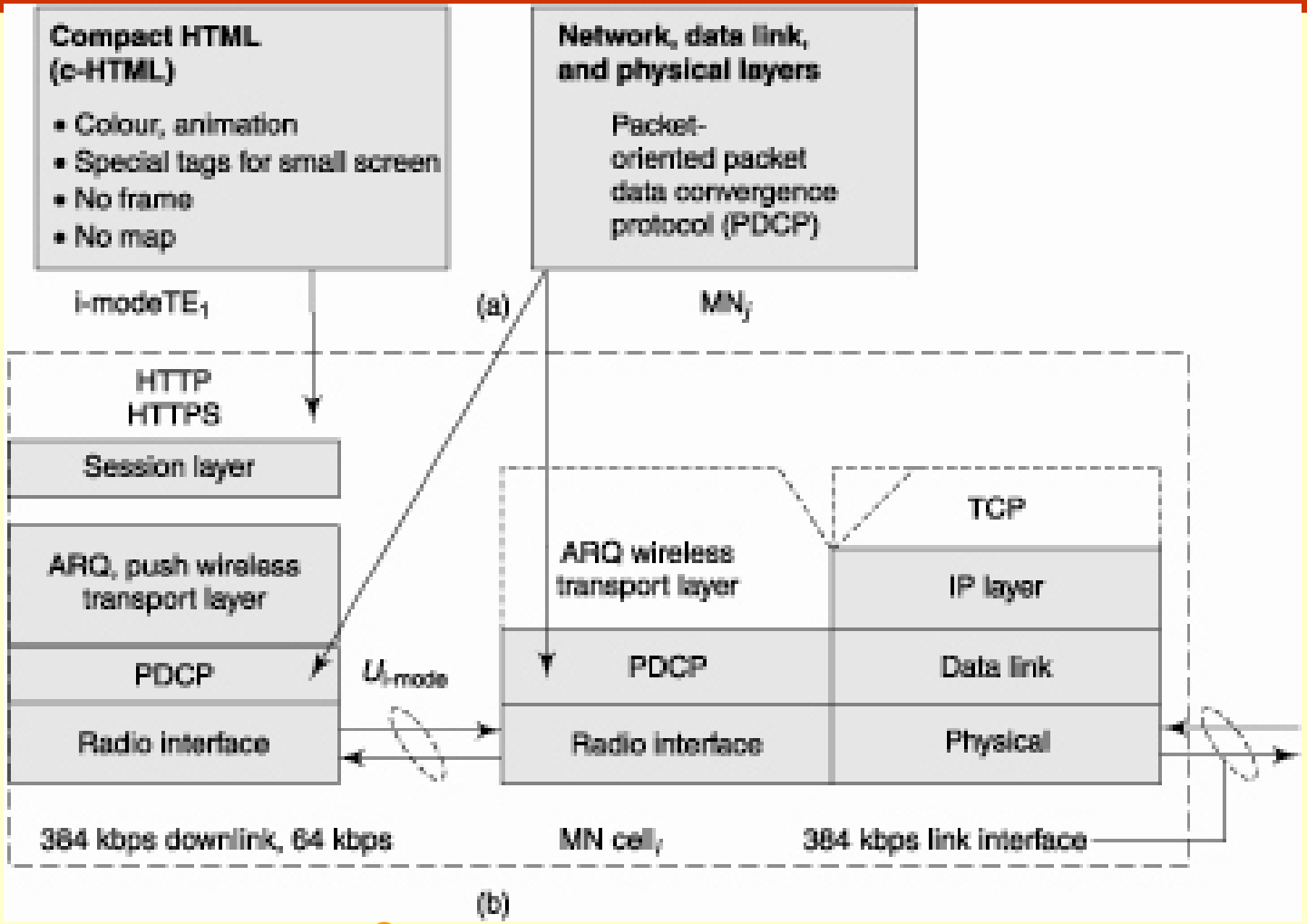
i-mode TE and MN Signalling Protocols



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Physical layer between the i-mode TE and MN

- Radio interface
- Data rates of 64 kbps for uplink
- 384 kbps for downlink

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Data Link Layer

- Layer use the PDCP protocol (Packet data convergence protocol)
- WDP (wireless data link protocol)
- The pushed data is transferred from SP using the SMS protocol

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Network layer

- Defines how the addressed messages received from the data link layer are to be implemented by the operations of a protocol
- Defines the addresses of the messages
- Transmits the logical channel (FOMA service and control channels) data and information bits to the data link layer from a service provider address (SPA)

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Network layer

- Receives the logical channel data and information bits
- Controls the flow of packets to and from the transport layer and provides access (through transport layer) to multiple FOMA services

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Network sub-layer

- Support all services as packet oriented services
- Also controls mobility management issues when the i-mode TE moves into some other MN area

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Transport layer

- Sub-layers for transport between the i-mode TE and MN
- ARQ (automatic repeat request)
- Push access, and push-over-the-air service protocols
- Data link layer protocols are WTP (wireless transport protocol)

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Session layer WSP (wireless session protocol)

- For i-mode application layer pushes to transport layer

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Application layer

- HTTP (hyper-text transfer protocol)
- HTTPS (hyper-text transfer protocol over SSL)
- SSL means secure socket sub-layer for HTTP

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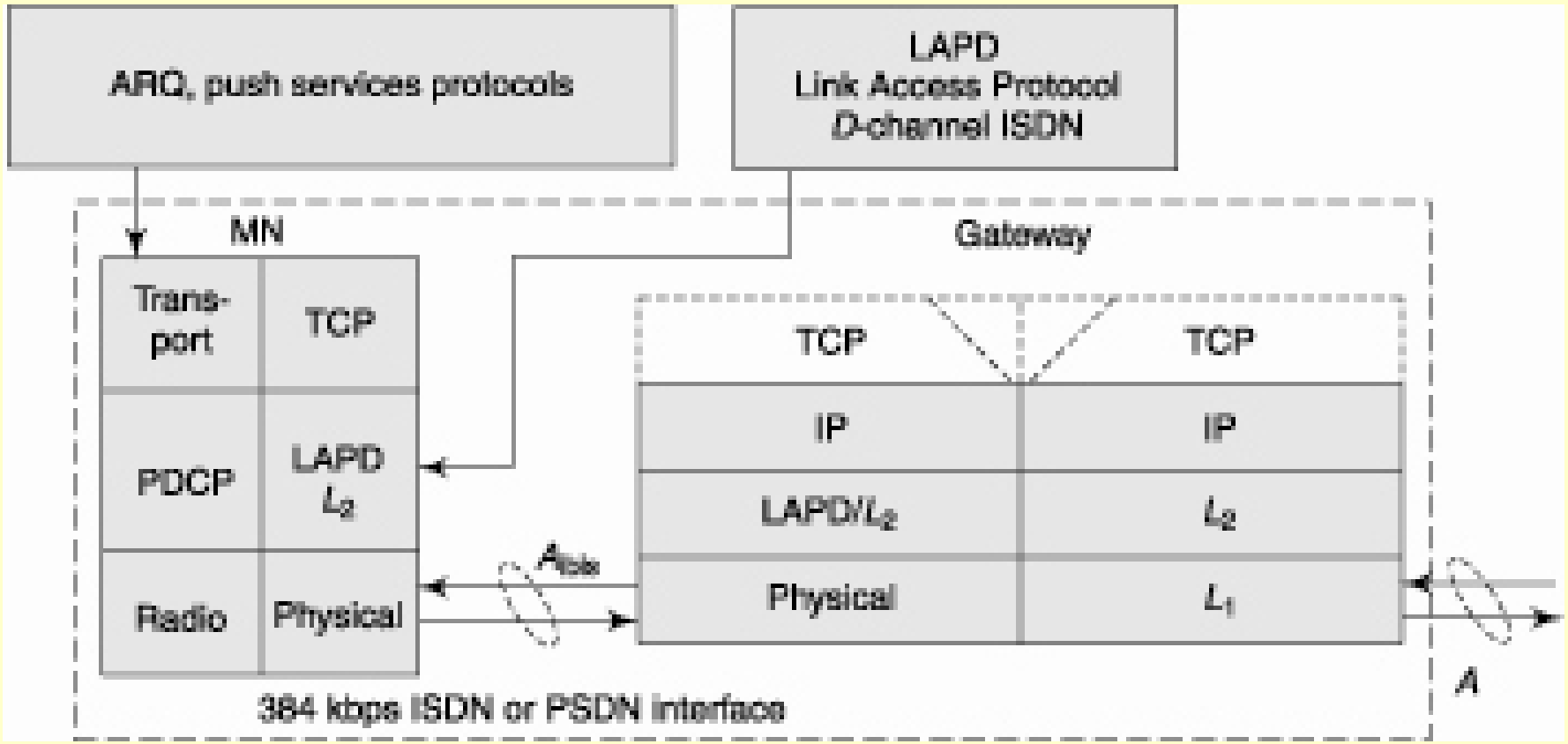
MN and Gateway Signaling physical layer protocols



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MN and Gateway Signaling physical layer

- Between the MN and the gateway uses an ISDN or PSPDN network
- The link operates at 384 kbps (6 links of 64 kbps or 4 $\times$ 6 multiplexed 16 kbps channels)
- The interface between the MN and the gateway uses ISDN or PSPDN network
- Wired transmission and reception

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Data-link Layer

- Data link layer protocol between the MN and the gateway LAPD (link access protocol D-channel) when using the ISDN
- A_{bis} interface or other *L2* layer protocol

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Network Layer

- Protocol between the MN and the gateway is the globally used IP layer

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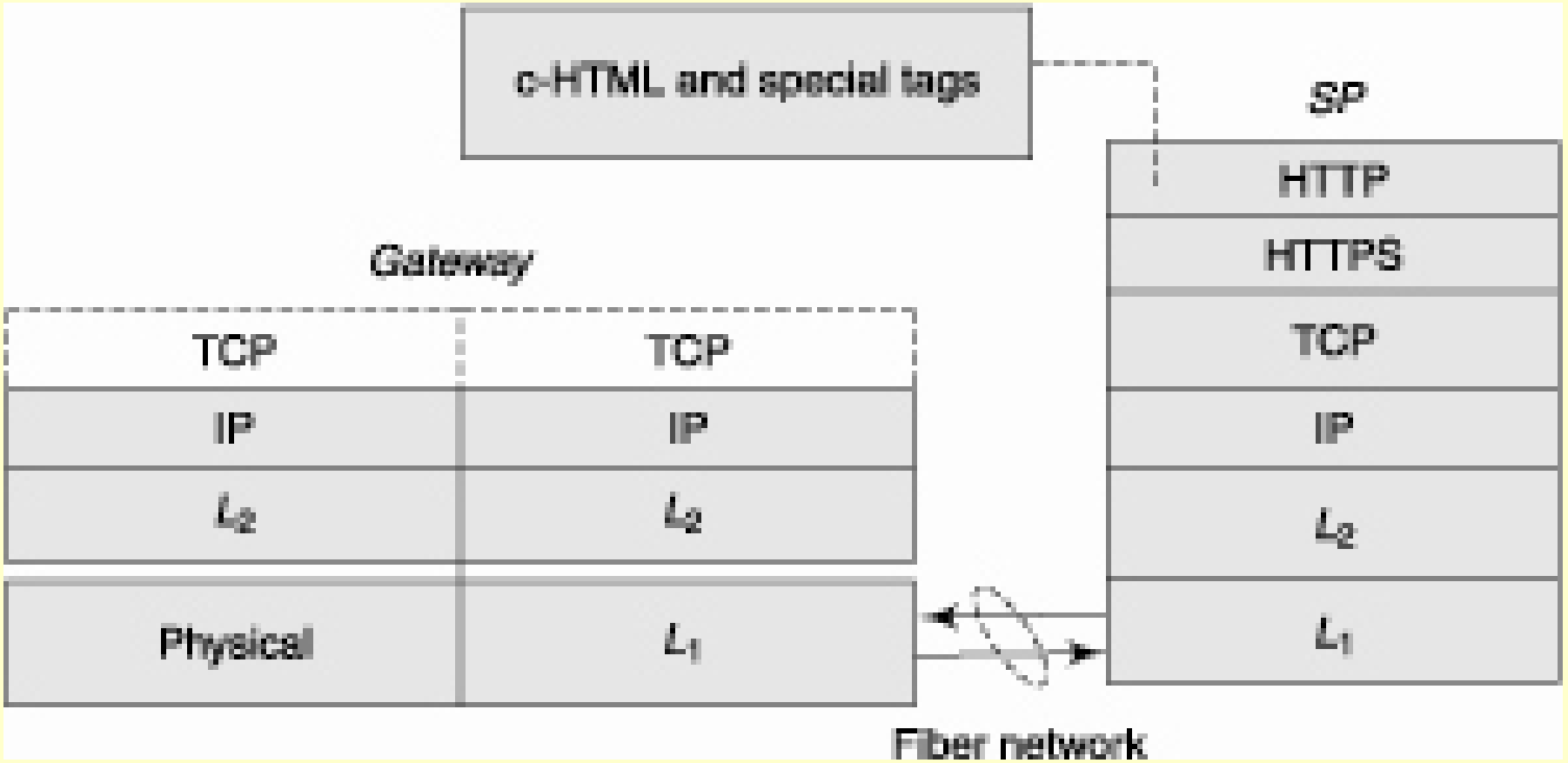
Gateway and Service Provider Signalling protocols



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Protocols

- Physical to transport layers between the gateway and the SP use the same protocols as the global Internet service protocols

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Protocols

- The protocols prescribe a standard procedure for the MTP (message transfer part) and SCCP (signalling connection control part) for SS7 (signalling system 7) transmission and reception in a 2 Mbps CCITT PSTN/ISDN/PSPDN network
- MTP is the part of the SS7

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Protocols

- SCCP is also a part of SS7 which provides connectionless and connection-oriented network services above the MTP.
- The application layer uses c-HTML and special tags
- The layer employs HTTP or HTTPS for providing the services by network layer protocols

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Summary

- i-Mode Internet services WCDMA based
- Radio interface
- Data rates of 64 kbps for uplink
- 384 kbps for downlink
- c-HTML

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End of Lesson 15

i-Mode

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Wireless Medium Access Control and CDMA-based Communication

Lesson 16

Orthogonal Frequency Division Medium Access (OFDM)

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4G

- File transfer at 10 Mbps
- High resolution 1024 × 1920 pixel hi-vision picture transfer at 24 Mb/s
- High resolution video transfer
- High speeds of data transfer, the three to twelve carriers of CDMA2000 phase shifted in time-space do not suffice

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OFDM

- Mobile multimedia services
- Number of carriers required increases
- Futuristic 4G systems

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OFDM (orthogonal frequency division multiplexing in code-space)

- A new multi-carrier transmission technique for cellular mobile devices

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OFDM

- A spread spectrum based technique for distribution (spreading) of data over large number of sub-carriers that are spaced at precise frequency intervals with a coding scheme
- Multi-carrier transmission in OFDM uses multiplexing in code-space

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OFDM

- Multiple carriers use mutually orthogonal codes, which enables separation of carriers in case of multi-path transmissions and interference of signals.
- All channel carriers (adjacent channel codes) are using different but mutually orthogonal codes

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OFDM

- Each channel carrier has distinct amplitude (power level) and may have a time guard
- Bandwidth remains equal to that in the single carrier case

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Three most important characteristics of OFDM

- High spectral efficiency
- Strong resiliency to RF inter symbol interferences
- Lower multi-path distortions

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OFDM

- Peak to average power ratio (PAR) high in an OFDM system as compared to a single carrier system
- Gives a many carrier system with bandwidth equal to that of a single carrier system
- Digital video broadcasting OFDM system
- HyperLAN-2 OFDM system

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OFDM

- Also called COFDM (code orthogonal frequency division multiplexing)
- Also called spread-spectrum based multi-carrier or discrete multi-tone modulation

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OFDM

- COFDM distinct from quadrature modulation QPSK or OQPSK
- OQPSK also an orthogonal modulation in time-space, where different frequency carriers transmits in different time-space (at different phase angles)

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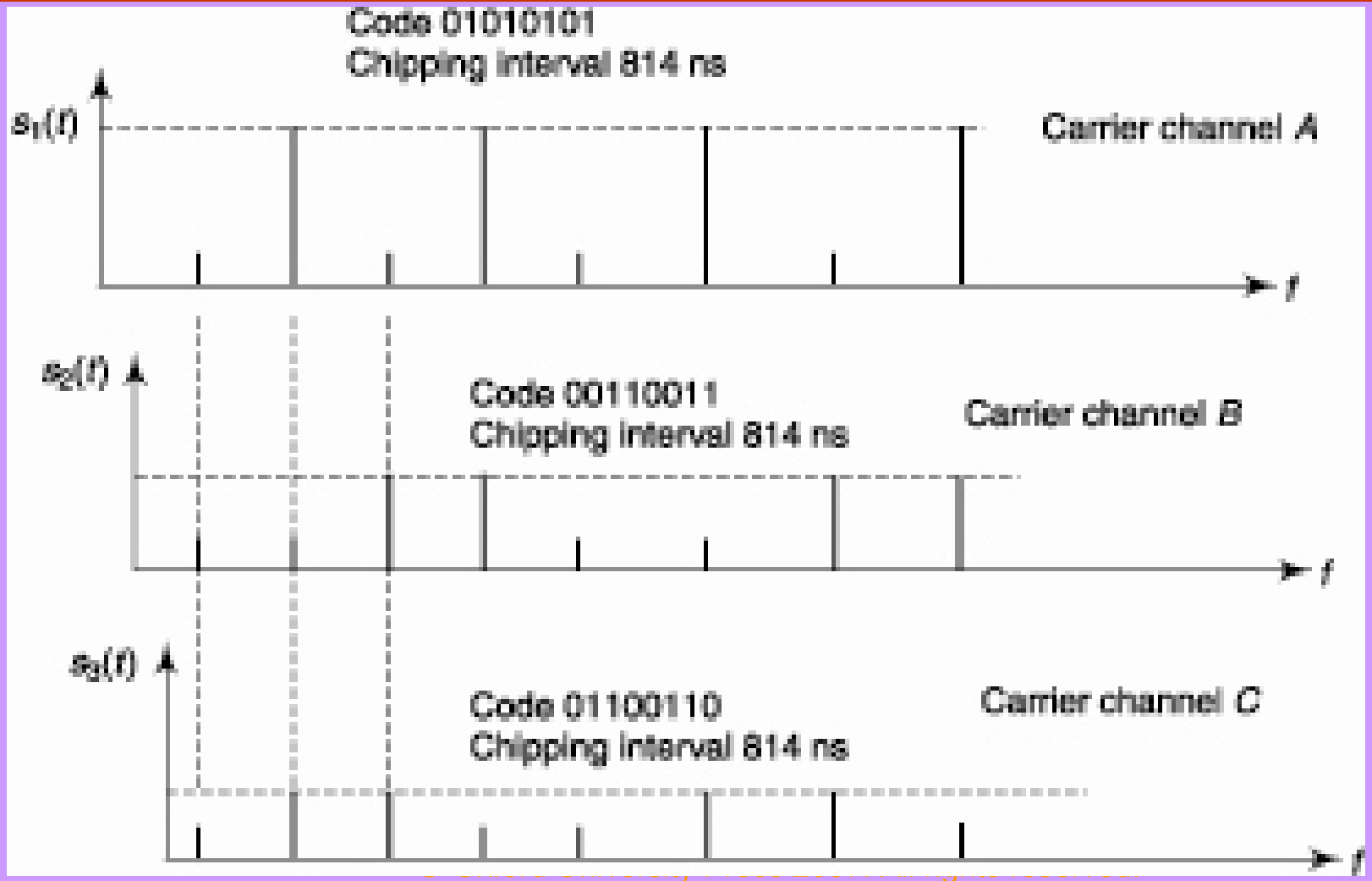
Orthogonal code-shifted three-carrier transmission of channels by multiplexing in code-space



OFDM

- Each carrier has a different peak amplitude of signals $s1(t)$, $s2(t)$, and $s3(t)$
- There are three codes 01010101, 00110011, and 01100110
- These codes are Walsh codes of length 8, used here as examples

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OFDM

- Actual code length may vary
- The codes themselves may be from a different set of orthogonal codes
- The only condition put on them is that they should all be orthogonal with no cross correlation
- Also, 0s are transmitted as + 1s and 1s are transmitted as –1s for signal mapping as per 3GPP specifications

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OFDM Carrier chipping

- Each chipping using distinct orthogonal codes
- Scrambled using the same or distinct PN long codes
- Chipping instants of each carrier channel use a different code (code-space divides into *n* when using *n* distinct orthogonal codes)

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OFDM Carrier chipping

- Combined chipping rate remains 1.2288 Mchip/s with a bandwidth of 1.25 MHz as an example
- Actual chipping rate may be higher
- Spread spectrum frequency is 1.2288 MHz only when the bandwidth used is 1.25 MHz
- For *n* = 12, twelve carrier channels transmit with *n* codes

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OFDM Carriers

- Each carrier uses different power levels (amplitudes)
- To enable separation of carriers at the receiver
- A guard space in time between different OFDM carriers may also be used
- This will affect the effective data transmission rates

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OFDM Carriers

- The wireless LAN (HyperLAN-2) IEEE 802.11a standard 0.800 μs guard time
- Some carriers may be used by pilot channels for synchronizing and some may be redundant

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Use of Digital signal processors

- Perform modulation and demodulation in OFDM systems
- Processing expressions for COFDM modulation based on fast Fourier transforms and inverse Fourier transforms

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Wireless LAN Applications

- For point-to-point transmission and for multicasting
- OFDM 5.8 GHz band
- 802.11a prescribes a chipping rate of 0.250 Mchip/s, 4 pilot carriers, 48 data carriers, and 12 virtual carriers

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802.11a Applications

- 64-QAM method for modulation
- This entails a shift in time as well as in peak amplitude space
- A set of six symbols is transmitted through a single carrier

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802.11a Applications

- Each set of symbols has a distinct phase angle or amplitude
- Bit transmission rate is 6× 0.250 Mchip/s = 1.5 Mchip/s
- When using convolution encoding to reduce bit error rates, the rate achieved is 1.125 Mbps (3/4th of the rate without convolution encoding)

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Applications

- Digital audio broadcasting (DAB)
- Digital video broadcasting (DVB)
- DVB-H (DVB for handheld devices) to enable users to watch TV on their mobile devices

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Wideband OFDM (WOFDM)

- A technique in which spacing between multi-carrier channels is made large
- Therefore, any frequency errors between the transmitter and the receiver do not affect system performance

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Flash-OFDM (fast low-latency access with seamless handoff OFDM)

- Based on the FHSS spectrum
- Fast-hopped OFDM

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MIMO-OFDM (multiple input, multiple output OFDM)

- A technique in which multiple antennae are used for inputs and outputs
- Provides broadband wireless access (BWA) and performs well in multiple non-line-of-sight multiple-path environments

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VOFDM (vector OFDM)

- Technique based on MIMO-OFDM
- Developed by Cisco Systems, Inc

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Summary

- COFDM
- Spread-spectrum based multi-carrier or discrete multi-tone modulation

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End of Lesson 16

Orthogonal Frequency Division Medium Access

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Mobile IP Network Layer

Lesson 01

OSI (open systems interconnection) Seven Layer Model and Internet Protocol Layers

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OSI (open systems interconnection) Seven Layer Model

- For data communication between two ends

(i) physical (*L*1) for sending and receiving signals wirelessly (for example, TDMA or CDMA coding with FEC) or over wire or fibre

(ii) data-link (*L*2) (for example, for linking to the destination computer by MAC address)

(iii) network (*L*3) (for example, for routing through a chain of routers)

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OSI (open systems interconnection) Seven Layer Model

(iv) transport (*L*4) (for example, for defining sequencing and for repeat transmission, if required)

(v) session (*L*5) (for example, for defining the transaction and session protocol for establishing end-to-end connectivity)

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OSI (open systems interconnection) Seven Layer Model

(vi) presentation (*L*6) (for example, for defining the data encoding format)

(vii) application (*L*7) (for example, for running a web browser, mail transfer, or mobile e-business application)

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Transmission

- A physical network transmits data of one-end application (L7) to another-end application (L7) through the various intermediate layers
- At a layer, data received from the upper layer can be suitably divided (for example, packetized at the *L*3 IP layer)

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L7 to L1 Transmission

- At each layer, data or each section of data suitably encoded (for example, by adding a header) for transmission to the lower layer

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L1 to L7 reception

- At the receiving end of the network, the bits in the header fields are decoded (for example, by extracting the header) upon reception before passing the data to the upper layer

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L2 and L1

- Usually associated with the communication and physical network radio and switching infrastructure, for example, in GSM or CDMA systems

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L3

- For networking (using a path chosen among the large number of paths available) through a chain of in-between routers
- IP protocol
- Mobile IP protocol

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L4 layer

- Data transfer after a session is established through the session layer (*L*5) between two ports on the network to the L4
- Transport layer, *L*4: The protocol header fields of this layer define the sequences and other required fields for data transfer to and from a port in a network

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L4 layer in TCP/IP model

- Additional function of session establishment

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L5 layer

- Defines how various sessions are established (for example, a call set up session)
- Not present in the TCP/IP model does not provide for a separate session layer and establishment and close functions included at L4

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L6 layer

- Defines how the data from the port is to be presented or formatted
- Not present in the TCP/IP model does not provide for a separate session layer and presentation functions included at L7

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L7 layer

- Supports multiple applications
- Defines a protocol for transferring application contents and data of a port

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L7 layer — Port for specifying a distinct application

- Each port (application) defines a service access point at the *L7* layer
- Each port deploy a protocol for data transfer between the *L7*s at the transmitter and the receiver

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L7 layer – Output Port (software) (service access point) at the *L7* layer

- An output port transmits the service (application) contents and data employing a distinct protocol
- Example– HTTP (hypertext transfer protocol)

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L7 layer – Input Port (software) (service access point) at the *L7* layer

- A corresponding data input port (software) at the receiver *L7* layer (service access point)
- Same protocol used to retrieve the service (application) contents and data as during transmission
- Example– HTTP (hypertext transfer protocol)

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L7 layer– Port number for specifying an application

- A port number can be defined for each application
- A port can be numbered in order to define and distinguish each application's data easily
- Example– HTTP port in the TCP/IP model, through which all the HTML files are transferred through the network, is numbered 80

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Internet Protocol— IP

- The basic protocol at *L*3 which is used for transmission over the Internet
- Designed for use by networks which employ packet-switched data communication

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IP

- Provisions the transmission of data packets
- Each packet treated independently
- Every packet must contain complete destination addressing information

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Header fields

- Carry information which is used by the successive layers at the transmitting end and by the corresponding layers at the receiving end
- At a layer at the receiving end, data received from the lower layer can be suitably assembled (for example, packetized IP layer data from *L*4 is assembled at *L*3)

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Summary

- OSI Seven Model layers L7 to L1 transmission and L1 to L7 receiving functions
- TCP/IP model– No L5 layer
- Session establishment function by Transport layer
- TCP/IP model – No L6 layer
- Presentation function by an application layer protocol

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… Summary

- IP protocol or Mobile IP protocol at L3 in TCP/IP model
- Port specify the protocol used for L7 layer application
- Port number specify distinct application

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End of Lesson 01

OSI (open systems interconnection) Seven Layer Model and Internet Protocol Layers

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Mobile IP Network Layer

Lesson 02
TCP/IP Suite and IP Protocol

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TCP/IP protocol suite

- A suite of protocols for networking for the Internet
- Transmission control protocol (TCP) or User Datagram protocol (UDP) at *L*4
- The Internet protocol (IP) at *L*3
- The suite contains many protocols at L7 or L2 or L1
- L5 and L6 not present

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TCP/IP protocol suite

- Originally designed to have four layers but evolved to a five-layer format
- The functions of *L*5 (session layer) incorporated into *L*4 (transport layer)
- *L*6 (presentation layer) incorporated into *L*7 (application layer) in TCP/IP
- The five layers— *L*7, *L*4, *L*3, *L*2, and *L*1

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IP at *L*3, functions– Network layer

- Facilitate transmission of data from one system with a common address for the ports (like service access points in a mobile system) to another with a common address for the ports
- The address– called the IP address
- Connections to the Internet employ the IP protocol

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IP

- Provides the connection to the router for transmission
- A communication between two addresses on a physical network carried out through routers

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IP protocol Header

- Encapsulates data from the upper layers, for example, the *L*3 header encapsulates the *L*4 data after formatting it into packets

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Packet Formation in IP

- Packets of maximum size = 2^{16} bytes (2^{14} words) after the data from *L*4 (transport layer) divided
- A packet-switched network can be used for transmission
- Hopping of data packets different routes to reach a destination

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Packet Formation in IP

- More packets can be sent simultaneously through the network unlike in a circuit-switched network, where only one data frame can be transmitted at an instant (for example, in GSM or HSCSD

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An IP packet transmitted in fragments

- MTU (maximum transferable units per effort) may be much less than 2^{16} bytes in a source-destination path or sub-path in the network

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Header, Source, and Destination IP Addressing

- IP specifies certain header fields— a field is a set of bits placed in a word for a specific action, condition, or purpose
- Encoding data from the transport layer at the transmitter
- Decoding the data received from the data-link layer before passing it to the transport layer at the receiver

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Header fields– First word

- 32-bit word
- Specify IP version (IPv4 or IPv6 for Internet or broadband Internet)
- Length of the IP header
- Precedence of the IP packet
- Total packet length

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IPv4 Header fields– Second word

- 32-bit word
- ID for the packet
- Flags
- Fragment offset for the fragments of same ID

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IPv4 Header fields– Third word

- 32-bit word
- Time-to-live (not in seconds but in number of attempts to hop before expiry of packets in the network)
- Type of protocol
- Checksum of the header (for finding transmission errors, if any)

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IPv4 Header fields– Fourth word

- 32-bit word
- IP address of the source (as per four decimal numbers, each separated by dots and each lesser than 256)

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IPv4 Header fields– Fifth word

- 32-bit word
- IP address of the destination (four decimal numbers each separated by dots and each lesser than 256)

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IP address– Example

- Assume that the source IP address for routing is (*ns*1 . *ns*2 . *ns*3 . *ns*4)
- Destination IP address (*nd*1 . *nd*2. *nd*3 . *nd*4)

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Packet transmission from the source IP address to the destination

- By hopping among the various routers on a path
- Paths can be different for different packets from the same source
- Path for the routing of a packet depends on the paths and sub-paths which are available in the network at a given instant

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Routing between two IP Addresses

- Router receives a packet from a source or a previous stage router
- Gets the destination address from the IP header
- Forwards the packet to the next router or the destination router for that destination address
- Each router maintains a table for selecting the path in the route for the packet

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Routing table

- Maintained and regularly updated by the router
- Has a large number of rows depending upon the maximum number of entries possible in it

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Routing table entries

- In each row, the destination router's address and the next router's address so that packets for that destination hop to that particular router

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Router

- Not possible for a router to hold routing table entries for all the IP destination addresses on the Internet
- Not possible to store information about a large number of source and destination systems each having a distinct IP address

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Router

- Belong to either a class *A*, *B*, or *C* subnet
- The Internet consists of class *A*, *B*, and *C* subnets that are connected to the hosts (computers, nodes, and service terminals)
- Each subnet consists of a large number of connected local subnets or hosts

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Summary

- TCP/IP suite 5 layer protocol suite
- L7, L4, L3, L2 and L1
- TCP or UDP at L4
- IP protocol for L3 networking layer
- Packetization befor transmission
- Each packet IP header of minimum 5 word
- Size 2^{16}

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… Summary

- Router for sending packets simultaneously to multiple available paths to destination
- Routing table regularly maintained and updated
- Router belong to a class A or B or C subnet

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End of Lesson 02

TCP/IP Suite and IP Protocol

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Mobile IP Network Layer

Lesson 03
Subnet, Multicasting, UDP and ICMP

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Subnet

- Each router has a 32-bit IP address
- A router can connect to a maximum of 2^7, 2^{14}, or 2^{21} other routers depending upon the subnet in which class (A or B or C) subnet) the router is placed

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Concept of subnets on the Internet

- A subnet– a sub-network using standard specifications and protocols when connecting to the Internet on one end and to the host on the other end

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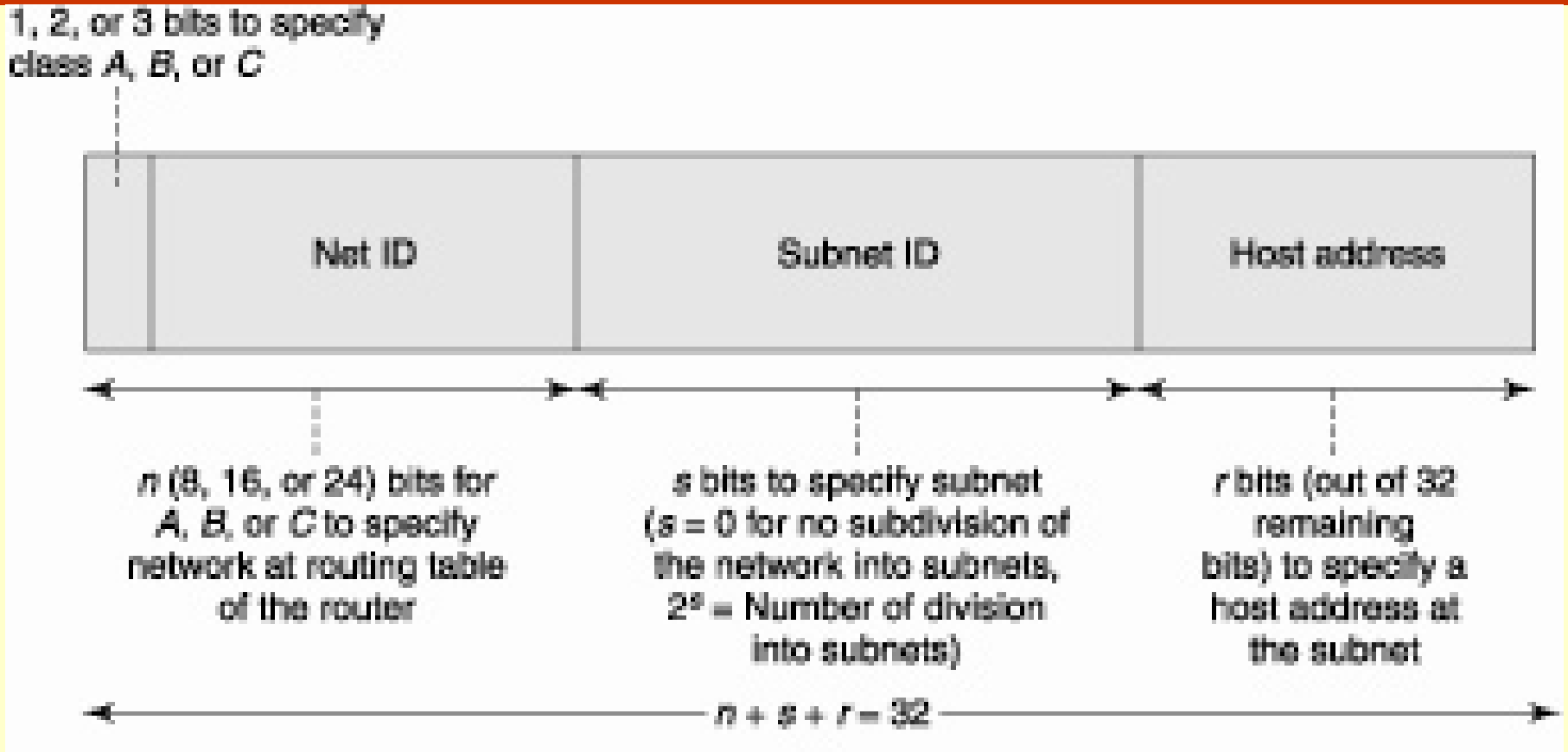
An IP address and its structure



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Msbs for classes A, B and C

- Identify *A*, *B*, and *C* type of networks
- Msbs = 0, 10, and 110 (1 or 2 or 3 bits before netID)

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NetID bits for classes A, B and C after Msbs

- 7 or 14 or 24
- Specify network ID among 2^7, 2^{14} or 2^{21} class A or B or C networks

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Subnet ID– *s* bits and host address– *r* bits

- s + r = 24 or 16 or 8 for A or B or C class subnets

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Subnet router for multicasting– class *D* network

- Uses four msbs (1110) for network identification and 32 – 4 = 28 bits specify the address of the multicasting subnet

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Subnet router– class *E* network

- Five msbs (11110) used for network identification
- Reserved for future applications

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Subnet Mask

- Unmasks the *r*-bits (*nd*4 when *r* = 8 and finds *nd*4 of the computer)
- Finds the addressed host's IP address (*nd*1 . *nd*2 . *nd*3 . *nd*4)

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Address resolution Protocol (ARP)

- An Ethernet LAN computer has a 48-bit MAC (medium access control) address
- ARP maps *r*-bits to the 48-bit MAC address

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Address resolution Protocol (ARP)

- ARP– finds the destination computer MAC address on the LAN and forwards the packet to the destined computer
- An ARP cache– stores the MAC address to enable ARP to translate the host IP address into the MAC address

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Subnet Mask

s + r subnet mask bits from which host computer address is found using ARP and subnet is found when host connects the subnet using RARP

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Reverse Address resolution Protocol (RARP)

- From the source computer, the packet is transmitted to a source router, using RARP (reverse ARP) and subnet mask
- The subnet mask masks the extra bits (nd4 when *r* = 8)
- An RARP cache– saves the IP address and the computer address
- Enables the RARP to reverse translate the MAC address into the IP address

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Reverse Address resolution Protocol (RARP)

- The packet forwards to the source router on the subnet with an *n*-bit source router net ID (for example, (*ns*1 . *ns*2 . *ns*3) on class *C*)

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Point to Point Unicast transfer

- Message or packet transmits to the destined IP address only

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Multicast transfer

- Message or packet transmits to a group of IP addresses
- The IP protocol specifies the use of a class *D* subnet for multicasting

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Multicast IP address bits

- Multicasting subnet four msbs (1110) in the net ID part of the IP address for defining subnet as *multicast* network
- 32 – 4 = 28 bits specify the address for the multicasting net ID and the subnet and host (s and r) addresses

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Example

- The address (224 . 0 . 0 .1) multicasts to all hosts in the links of a router
- (*ns*1 = 224 in decimal system = 11100000 in binary system)

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Multicast tree

- A multicasting source (root) multicasting to select multicast nodes (subnets) at level 1
- Each level 1 node, then, transmits to multicast nodes (subnets) at level 2 and so on

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Multicast tree

- A hierarchy of nodes present in a multicast tree
- Multicast tree nodes at one level can transmit to multicast nodes at another level simultaneously, via multiple paths
- Time taken in multicasting a message greatly reduced

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Multicasting applications

- Flooding a UDP (user datagram protocol) datagram on the network
- Sending information along many paths
- Required for advertisement

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Spanning tree protocol

- Protocol to block nodes, which have already received the relevant information during flooding

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Broadcasting

- Message or packet transmits to all the IP addresses which are set for listening
- The IP protocol specifies an address for broadcasting
- All 32 bits— 1s (255 . 255 . 255 . 255)
- Used when broadcasting to all hosts and links of a router

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Datagram

- Provides independent information
- A datagram is stateless
- Not necessarily a sequential successor of a previous one or a predecessor of the next
- Data sent using a connectionless protocol

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Connectionless protocol

- No session establishment before the data transfer begins
- Example– , on phones there are hotlines where one can just speak without the usual dialling and waiting business

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UDP and Datagram

- UDP (User datagram protocol) for sending datagram using a connectionless protocol
- Maximum of 2^{16} bytes, transmitted as sequences of words, each of 32-bits (4 bytes)

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UDP 6 fields at header

- Source port number
- Destination port number
- Source IP address
- Destination IP address
- Length of data
- Checksum bytes for the header (to check erroneous receipt of header)

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Internet Control Message Protocol

- Another connectionless protocol
- A part of the IP network protocol suite
- ICMP uses a datagram

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ICMP Uses

- Sending the messages for querying to find information
- Reporting errors
- Making route address advertisement
- Router seeking (soliciting) messages to get the IP addresses of the linked subnets

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ICMP Header

- First word of 32-bits to specify a byte for type of message, a byte for the code, and a two-byte checksum
- Second word of 32-bits, which specifies the number of addresses for advertising along with the address field size and the lifetime of message validity

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ICMP Header Remaining words

- A set of pairs of words
- Router address and preference
- The router of higher preference gets the messages earlier than the others
- The pairs arranged in sequence for level 1, level 2, and so on in a tree

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ICMP Header Remaining words

- Options– extended words in headers
- First byte = 16 means that options being used
- One example of option use– the mobile IP protocol extension when an agent advertises

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Summary

- Class A or B or C
- Subnet msbs, netID, subnetID and hostID bits
- ARP to use subnet mask to find host MAC from IP address
- RARP to use subnet mask to find IP from MAC address

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… Summary

- Unicast, multicast and broadcast
- Multicasting for advertising
- Spanning tree protocol
- Datagram stateless data
- UDP connectionless protocol for datagram
- ICMP for sending the messages for querying, reporting errors, route address advertisement and solicitation

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End of Lesson 03
Subnet, Multicasting, UDP and ICMP

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Mobile IP Network Layer

Lesson 04

Mobile IP, Packet Delivery and handover Management

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Mobile Internet protocol (mobile IP)

- Defined by the Internet Engineering Task Force (IETF)
- Described in the IETF RFC 3344
- A protocol developed to allow inter-network mobility for wireless nodes without them having to change their IP addresses

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Requirements for the evolution of the new mobile IP protocol

- Need for Enhancing IP Network capacity—Use of the existing IP protocol by large number of Mobile nodes (MNs) will lead to a decrease in the network

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Need for Upgrading capacity of Routers, and Data-link and Physical layers

- IP network protocols support 48-bit MAC addresses
- But when the number of MNs is large, then other interfaces and lower level protocols required
- For mobile nodes to move from one place to another while using the existing IP protocol , new protocols are required at the data-link and physical layers

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Security Needs

- The mobility of the called MN must be hidden from the calling MN
- When a new IP address allocates at the new hosting subnet of the existing IP-based infrastructure, the identity of the mobile node is not hidden from another host
- The MN exposes and lacks security when using the existing IP protocol

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Need for Non-Transparency from higher layers

- The transport layer establishes a connection between a given port at a given IP address (called socket) with another port at another IP address
- The connection, once established by the transport layers between the sockets, is broken as soon as the new address is assigned

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Reestablishment problems due to Non-Transparency from higher layers

(a) Reestablishment of the connection takes time which means loss of data during that interval

(b) Reestablishment process has to share the same network and the given transmission rate

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Need of Non-Transparency from higher layers

- Any movement of the MN will be transparent to the TCP and to *L7* in case the TCP layer re-establishes the connection when the IP protocol used by the MN
- There is, therefore, a need for non-transparency of the MN to distant ports

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Examples of Non-Transparency from higher layers

- Assume a distant router is sending data packets for an IP address, presently assigned to a mobile terminal using another router
- When the terminal moves from one service area to another, the routing tables on the route need to be updated
- Till this is done the packets will not reach their new destination

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Routing table problems

- The reconfiguration messages for updating the routing tables have to share the same network and the given transmission rate

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Reestablishment Problems

- Reestablishment of the connection takes time and this means loss of data during that interval
- Any movement on the part of the MN transparent and, thus, not secure from the distant hosts on the network of distant routers

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Working of Mobile IP

- A router has a home agent (HA) for a set of home networked MNs, as well as a foreign agent (FA) for the visiting MNs
- An agent– software employed at a router or the host serviced by a router

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Use of HAs and FAs

- The same software can function as both the HA and the FA at different instants of time
- An MN can also have software which functions as an FA instead of the FA at the router

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Working of Mobile IP

- The HA and the FA play a location management role similar to that of the HLR and the VLR in a GSM system

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Working of Mobile IP

- An MN can access Internet services using the mobile IP protocol
- The MN can change its service router when visiting another location (which is serviced by a different router)

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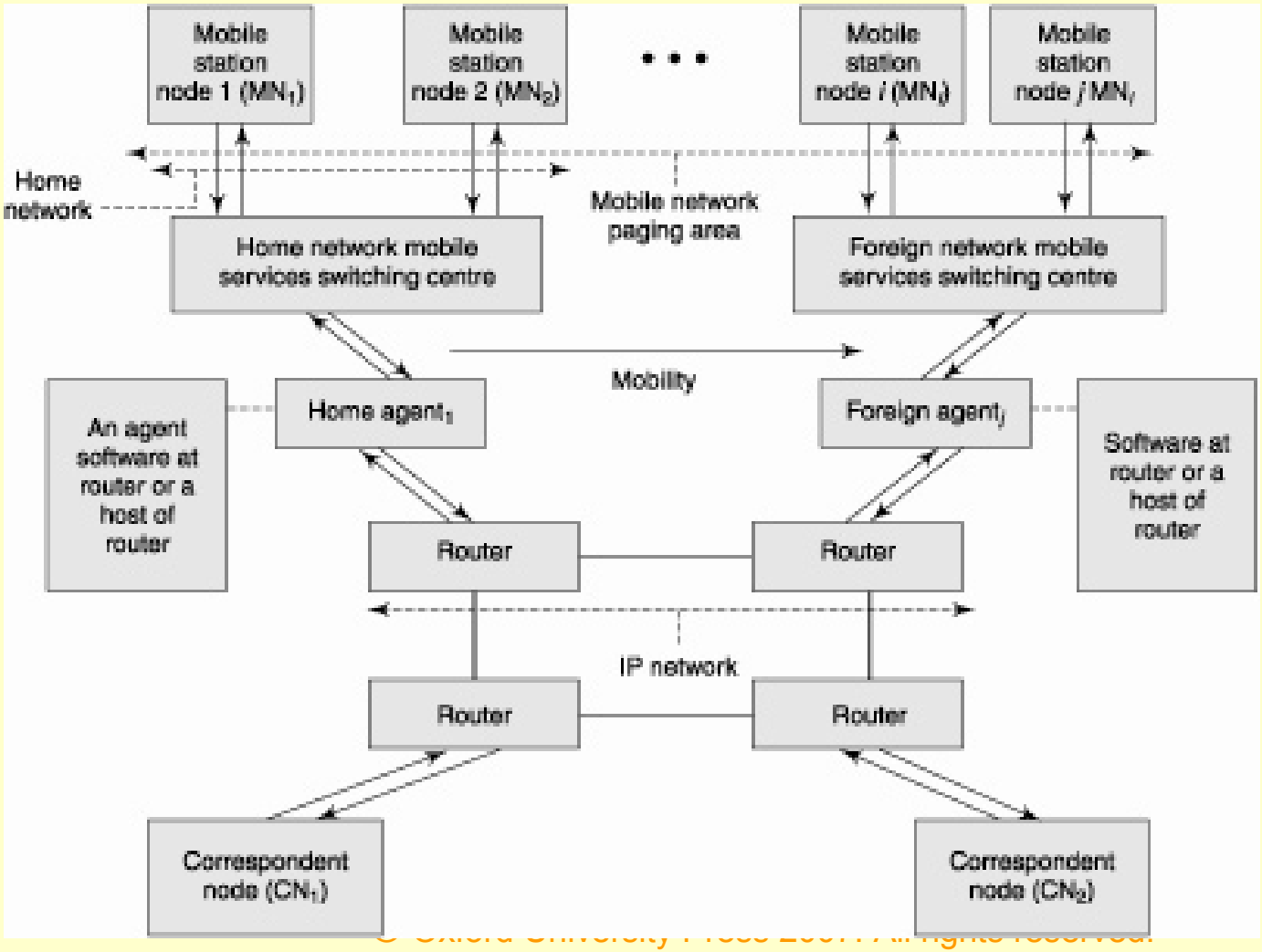
Mobile IP network employing home and foreign agents



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Switching Center home agent (HA)

- Provides services to an MN at the registered home network including transmitting and receiving packets from the Internet
- A home agent assigns MNs to routers which support the MNs

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Switching Center home agent (HA)

- A home network is a mobile radio subsystems network within an area, called paging area
- The home network is like a subnet
- Just like a subnet has a number of IP hosts, a home network has the MNs

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Paging area

- Area in which the MNs of home as well as foreign networks can be approached through a single MSC or a set of MSCs
- Routing of packets through the routers performed when an MN moves within one paging area

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Switching centre foreign agent for a foreign network of visiting MNs

- Foreign network— another mobile radio subsystem network which the MNs of home network visit within the paging area
- Foreign agent— a provider of the IP address and services, including transmitting and receiving packets from the Internet, for MNs on visit to a foreign network

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Switching centre foreign agent for a foreign network of visiting MNs

- Foreign agent– assigns MNs to a router, which supports the MNs of other home networks

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Different paging areas interconnected through gateway routers

- Form a backbone network
- Rerouting of the packets done through the gateway routers when an MN moves from one paging area to another

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Packet Delivery and Handover Management

- Correspondent node (CN)– an MN or a fixed IP host linked to a router, which communicates IP packets to another MN in a home or foreign network (when on visit)

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Case 1: CN a fixed node and MN_l at the home network

- CN message transmits for connection establishment or a packet using the IP protocol
- HA_l (the home agent for MN_l) receives the message or packet and, using the information that the destined MN_l is at the home network itself, it delivers the message or packet to MN_l

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Case 1: CN a fixed node and MN_l at the home network

- Receives the response message or packet from MN_l
- Delivers it to the CN using the IP protocol

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Case 1: CN a fixed node and MN_l at the home network

- Receives the response message or packet from MN_l
- Delivers it to the CN using the IP protocol

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Case 2: CN an MN_k and MN_l both at home networks with agents HA_k and HA_l

- MN_k message for connection establishment or a packet using the IP protocol transmits through HA_k
- Same way as in case 1
- The packet delivers to HA_l and then to MN_l
- MN_l response like in case 1

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Case 2: CN an MN_k and MN_l both at home networks with agents HA_k and HA_l

- HA_k and HA_l deliver the packets from one end to another and vice versa by just forwarding the packets to their respective MNs using the IP protocol

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Case 3: CN a fixed node and MN_l is at a foreign network

- CN transmits a message for connection establishment or a packet using the IP protocol
- As in case 1
- HA_l receives the packets and uses the information that the destined mobile node MN_l is not at the home network and is presently visiting a foreign network and is reachable via a foreign agent FA_j

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Case 3: CN a fixed node and MN_l is at a foreign network

- HA_l encapsulates the received IP packet using a new header
- Care-of address (COA) at the new header over the IP packet sent by HA_l
- Handover– Packet encapsulated with the new header with COA transmits to FA_j by tunnelling

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Case 3: CN a fixed node and MN_l is at a foreign network

- The FA_j reads the COA and decapsulates the IP packet
- Reads the destination IP address and transfers the packet to MN_l

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Case 3: CN a fixed node and MN_l is at a foreign network

- When MN_l sends the response message or IP packet with CN as the destination address, FA_j transfers the packet to CN as would have been done by HA_l in case the MN_l is at the home network
- The mobility of MN_l is secured from the CN as any movement on the part of MN_l is known only to HA_l and FA_j

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Case 4: CN is MN_k and MN_l at the foreign and home networks with FA_k and HA_s

- The packet delivery process similar to the step in Case 3
- MN_l transmits to CN MN*k* delivers the packet to FA_k
- Here, FA_k is used instead of HA_k as now MN_k is on a visit
- FA_k transfers the message to HA_l like in case 1 where CN transfers the message to HA_l

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Case 5: CN MN_k and MN_l at foreign networks with agents $FA_{k'}$ and FA_j

- MN_k transmits → $FA_{k'}$
- $FA_{k'} \rightarrow HA_l$
- $HA_l \rightarrow FA_j$
- $FA_j \rightarrow MN_l$
- $HA_l \rightarrow FA_j$ through tunnel T_{lj}

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Case 5: CN MN_k and MN_l at foreign networks with agents $FA_{k'}$ and FA_j

- MN_l responds $\rightarrow$ $FA_{k'}$
- $FA_j \rightarrow HA_k$
- $HA_k \rightarrow FA_{k'}$
- $FA_{k'} \rightarrow MN_k$
- $HA_k \rightarrow FA_{k'}$ through another tunnel $T_{kk'}$

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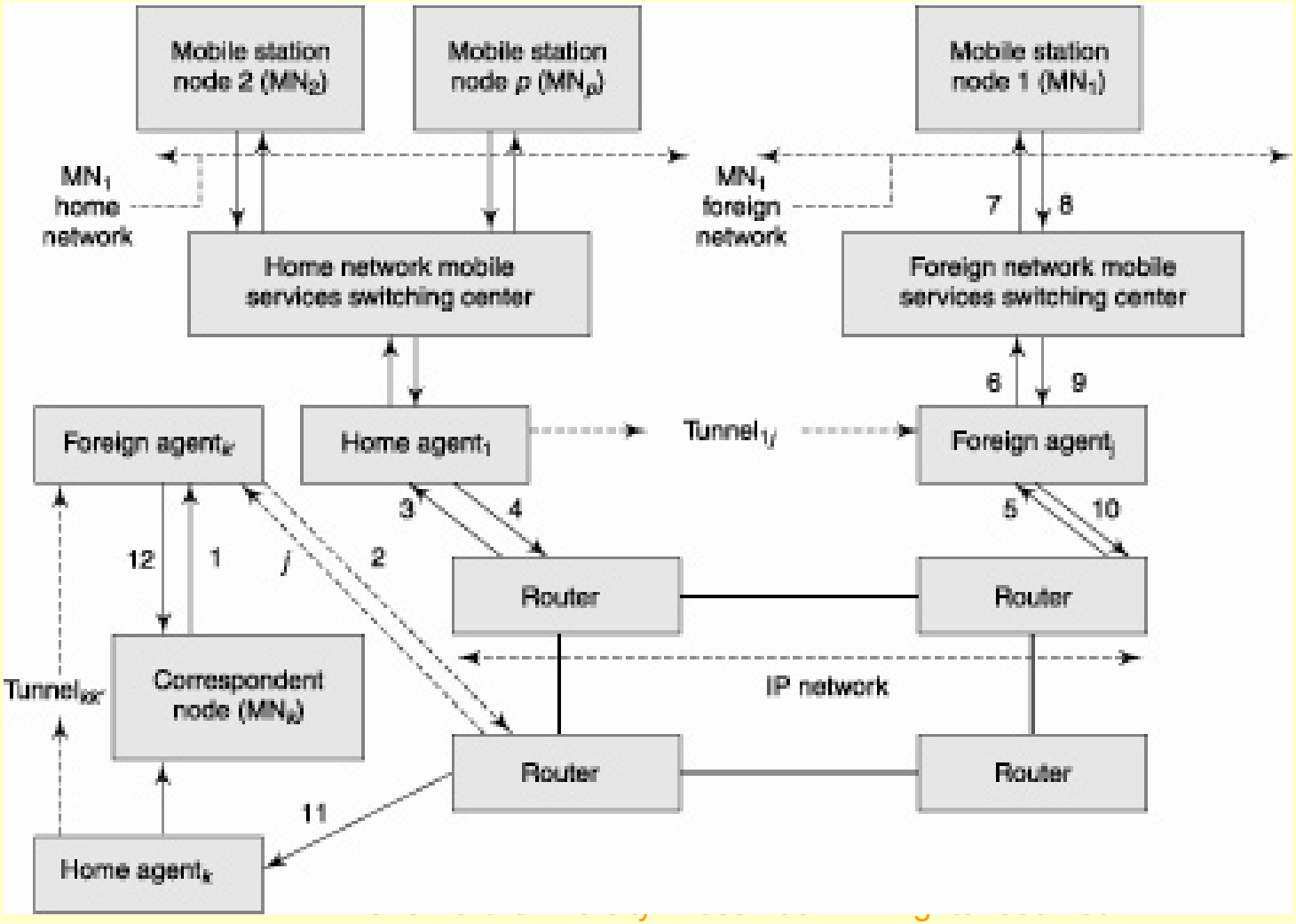
CN MN_k and MN_l at foreign networks with agents $FA_{k'}$ and FA_j



Case 6: CN an MN_k at the home and MN_l at a foreign network with FA_j

- Case just opposite to the case 4
- MN_k transmits to the CN
- FA_j delivers the packet to MN_l
- FA_j is used instead of HA_l as now MN_l is on a visit
- FA_j transfers the message to HA_l

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Summary

- Need for mobile IP because of need to address large number of MNs
- Capacity up gradation need at data and physical layers
- Security
- Non transparency
- Mobile IP protocol uses home and foreign agents …

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Summary

- CN transmits to corresponding home agent of destination mobile node
- Handover– Home agent encapsulates header with care of address
- Tunnelling of the message to foreign agent if source or destination is at foreign network

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End of Lesson 04

Mobile IP, Packet Delivery and handover Management

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Mobile IP Network Layer

Lesson 05

Agent Discovery, advertisement and Registration

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Handover Management protocols

- Mobile node (MN) moves
- Visits foreign networks often
- Handover management– managing the transfer of service availability to the new location network

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Use of appropriate location management protocols

- By the network for management of the MNs location
- Preparing for the services (packet receiving and packet transmitting) at the new network
- Agent discovery through agent advertisement
- Agent discovery and agent solicitation

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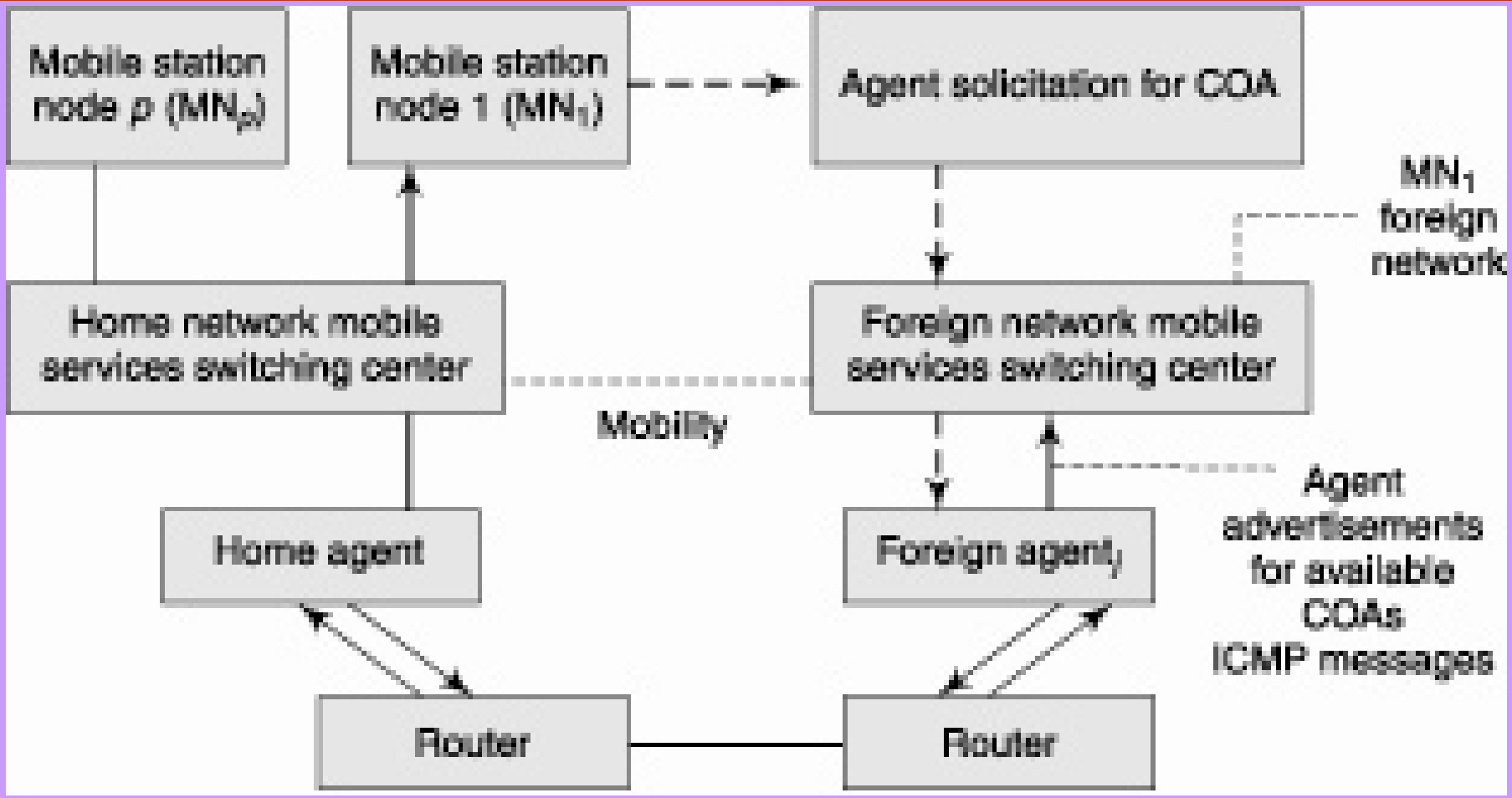
FA discovery by MN by receiving COA during advertisement if not then by solicitation



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Agent Discovery

- MN must discover (find) a foreign agent (FA) when visiting a foreign network
- Agent discovery by a mobile node MN_l— receiving the COA (care-of-address)
- COA enables FA to get messages for MN_l
- Home agent (HA) of MN_l transfers the messages from sender
- Uses COA

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Steps 1 and 2 in the protocol for discovering an agent

1. Listen to an advertisement (ICMP message) from an agent
2. Proceed to step 3 if the advertisement is found, else solicit the agent from the routers

- If agent found then proceed to step 3, else repeat the step

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Steps 3 and 4 in the protocol for discovering an agent

3. If the COA discovered from the message is found to be the same as the previous COA, go back to step 1, else proceed to step 4
4. If the discovered COA is the same as the home network, deregister at this network and go back to step 1, else if the current COA is a new COA then register with the new COA

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Agent advertisements

- Agent advertisements— essentially ICMP messages
- Sent to a number of addresses

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ICMP message options and words

- Added mobility extension fields in the ICMP header

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Header extension

- One 32-bit word format — First byte = 00010000
- Second byte for length
- Length = 2 words + number of COAs specified in the extension to which the ICMP message is to be sent + two bytes for the 16-bit sequence number (for the ICMP message advertised

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Header extension Next word format

- Two-byte lifetime in second plus 8 bits for flags
- Remaining byte is not used — reserved for any future requirements of modifications or specification expansion in ICMP
- Lifetime— During which the MN can register with the new COA (step 4 in agent discovery)

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Header extension Next set of words

- For the COA addresses for the MN at that agent

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Co-located COA

- COA when the MN acquires temporarily an additional IP address while on visit to a new network
- Else the COA is the same IP address for that MN while on visit and when at home

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FA

- Obtains the co-located COA using the dynamic host configuration protocol (DHCP)

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Flags

- flag1– whether the COA is a co-located COA
- flag2– whether the advertising agent is the HA
- flag3– whether the advertising agent is an FA

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Flags

- flag4– specifies whether there is reverse tunnelling support by the FA for encapsulation and sending packets by tunnelling to the HA
- flag5– specifies whether the encapsulation method is generic

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Flags

- flag6– specifies whether the encapsulation method is a minimal mandatory method
- flag7–specifies if the agent is busy and cannot register the visiting MN

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Agent solicitation

- A method by which an MN visiting a network discovers the FA and the COA in case COA not found from advertisements

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Agent Solicitation

- If an advertisement is not listened to, solicitation can be done three times at 1 s intervals
- Later this interval can be increased

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Registration after an MN discovering FA for service and finding a COA

- Needed for the service of receiving and transmitting of IP packets with the new agent FA
- For creating a tunnel between HA_l and FA_j

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Function of HA after registration

- To encapsulate the IP packets and transmit them to the discovered FA (through tunnelling), whenever a CN (corresponding node) communicates with the MN

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Deregistration for the receiving and transmitting of IP packets

- Also needed with the HA (step 4 of agent discovery in the protocol)

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Registration steps

- Requests and replies are made by the MN, FA, and HA using a UDP datagram
- Let us assume that the MN has IP address of the HA
- If not, then the MN broadcasts the registration request to a paging area
- The HAs then send the registration replies
- The MN requests one of the HAs (out of those which reply) for registration

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Step 1 for registration at an agent

1. The MN sends a registration request to FA
- FA sends that request to the HA
- When the COA is a co-located COA, then the request sent directly to the HA

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Step 2 for registration at an agent

2. The HA binds itself for mobility (binds itself for encapsulating and tunnelling the packets to the MN through a new FA)
- The binding period equals the lifetime of the COA

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Step 3 for registration at an agent

3. The MN registers again before the binding period expires

- when it moves to another foreign network
- when it returns back to the home network

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Step 4 for registration at an agent

4. The HA sends a registration reply to the FA and the FA to the MN
- The MN checks whether the reply shows successful registration

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Registration

- Success— mobility binding now exists from the HA to FA
- Failure — when there are too many tunnels created at the HA and the HA does not have the resources to handle new requests or there is an authentication failure or the HA not reachable to the FA

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Words after UDP header in the Registration Request

- One 32-bit word with first byte = 00000001, 8 bits for flags, and two bytes for the lifetime (in seconds)
- Next 32-bit word for the home IP address of the MN

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Words after UDP header in the Registration Request

- Next 32-bit word for the home agent IP address of the MN
- Next 32-bit word for the COA of the MN at the new agent
- Next 32-bit word for the identification of the MN
- Next– A set of words for extensions

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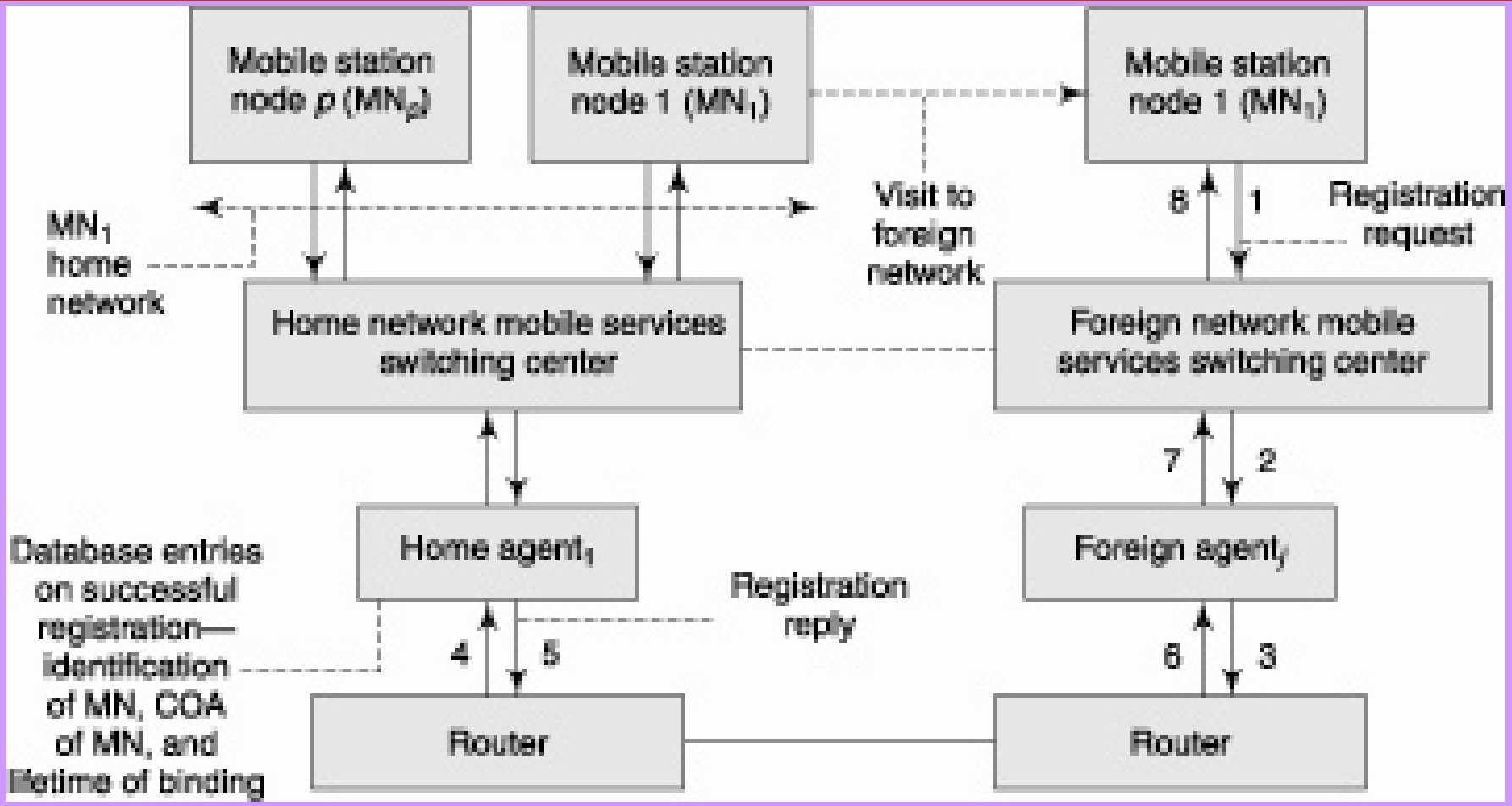
MN_k after discovery of FA_j seeking registration for creating tunnel between HA_l and FA_j



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8 flag bits

- flag1— specifies whether the COA is a co-located COA
- flag2— whether the advertising agent is the HA

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8 flag bits

- flag3– whether the advertising agent is the FA
- flag4–specifies whether the MN requests previous mobility binding to be retained. This permits both—the new and previous mobility bindings

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8 flag bits

- flag5– specifies whether the encapsulation method is generic.
- flag6– specifies whether the encapsulation method is a minimal mandatory method

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8 flag bits

- flag7— specifies whether the MN wishes to receive broadcast (multicast) messages, which the HA receives for tunnelling to the new FA. If not, then the broadcast messages are filtered at the HA
- flag8— specify if there is reverse tunnelling support from the FA

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Words after UDP header in the Registration Reply

- 32-bit word with first byte = 00000011, 8 bits for a code specifying the result of registration, and two bytes for the lifetime (in seconds)
- Next 32-bit word for the home IP address of the MN

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Words after UDP header in the Registration Reply

- Next 32-bit word for the home agent IP address of the MN
- Next 32-bit word for identification of the MN
- Next a set of words for extensions

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New database entry fields after registration at the HA

1. ID for identification of MN
2. COA of the MN
3. Lifetime of binding to tunnel the packets to the MN's COA

- When the binding life expires the tunnel is not forwarding from the HA to the FA using the COA

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Database Entries in the fields at the FA after registration at the HA

(a) MN identification field

(b) home IP address of the MN

(c) IP address of the HA

(d) MN link layer address for sending and receiving packets and messages to and from the MN

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Database Entries in the fields at the FA after registration at the HA

(e) UDP source port of the registration request

(f) received identification of the MN

(g) COA of the MN and lifetime of binding to tunnel the packets to the MN's COA

(h) remaining lifetime

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Summary

- Handover management
- Location management by agent discovery
- Advertisements and solicitation if COA not found
- Registration of MN at HA after finding COA and FA

...

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… Summary

- ICMP messages for mobility binding
- Registration request words
- Registration reply words
- Database entries at HA and FA

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End of Lesson 05

Agent Discovery, advertisement and Registration

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Mobile IP Network Layer

Lesson 06

Tunnelling and Encapsulation

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Mobile node (MN) foreign agent (FA) at visiting foreign network

- FA has the COA (care-of address) of the MN
- The FA receives the IP packets, that were received at the home agent (HA) through a tunnel from the HA to the FA– from HA IP address to the COA IP address at the FA
- Packets received at the HA– transmitted through the tunnel after encapsulation

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Tunnelling

- Establishing of a pipe
- Pipe— a data stream between two connected ends
- The data stream— inserted from one end
- FIFO (first in first out) words from the other end

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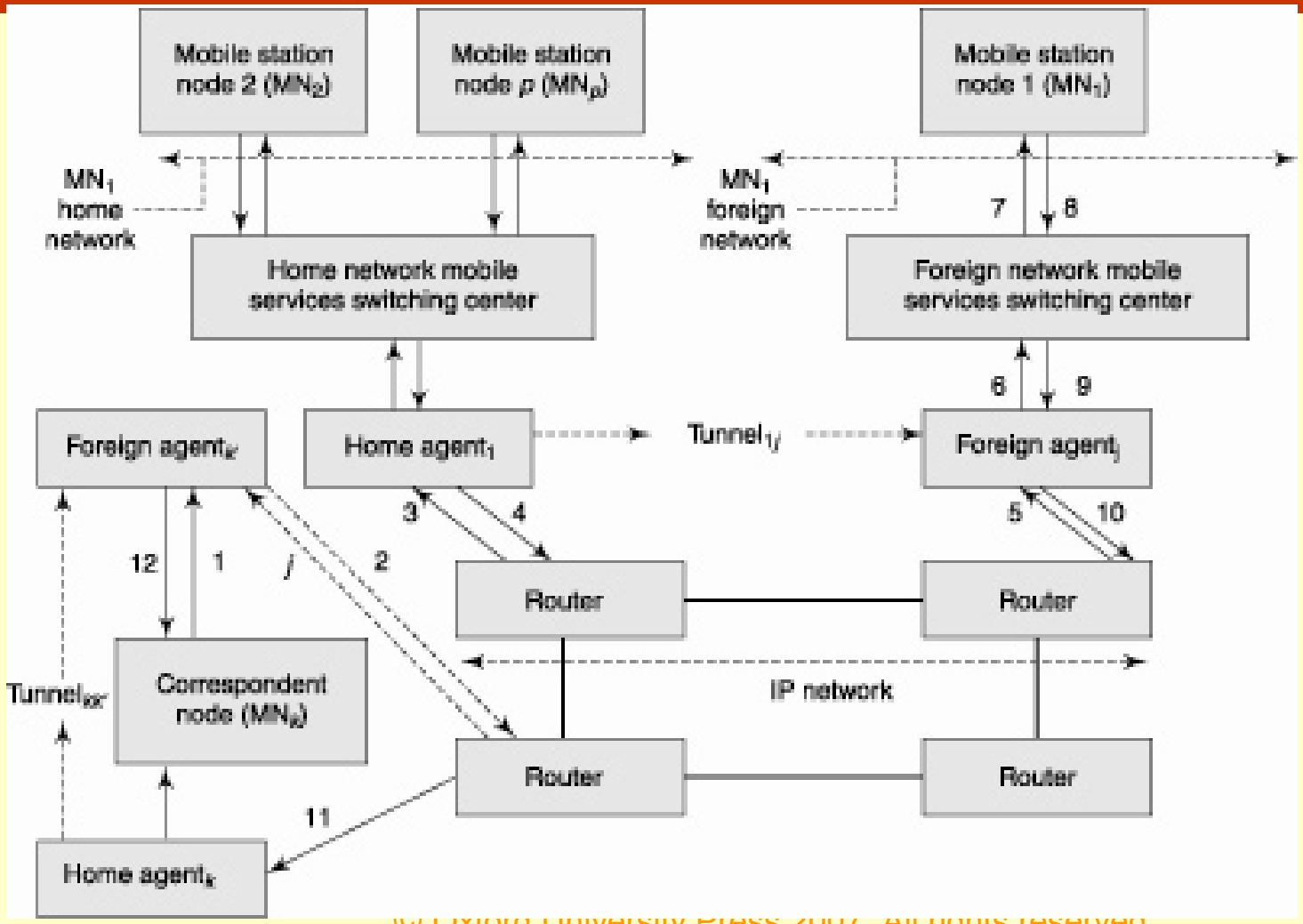
Two tunnels T_{lj} and $T_{kk'}$



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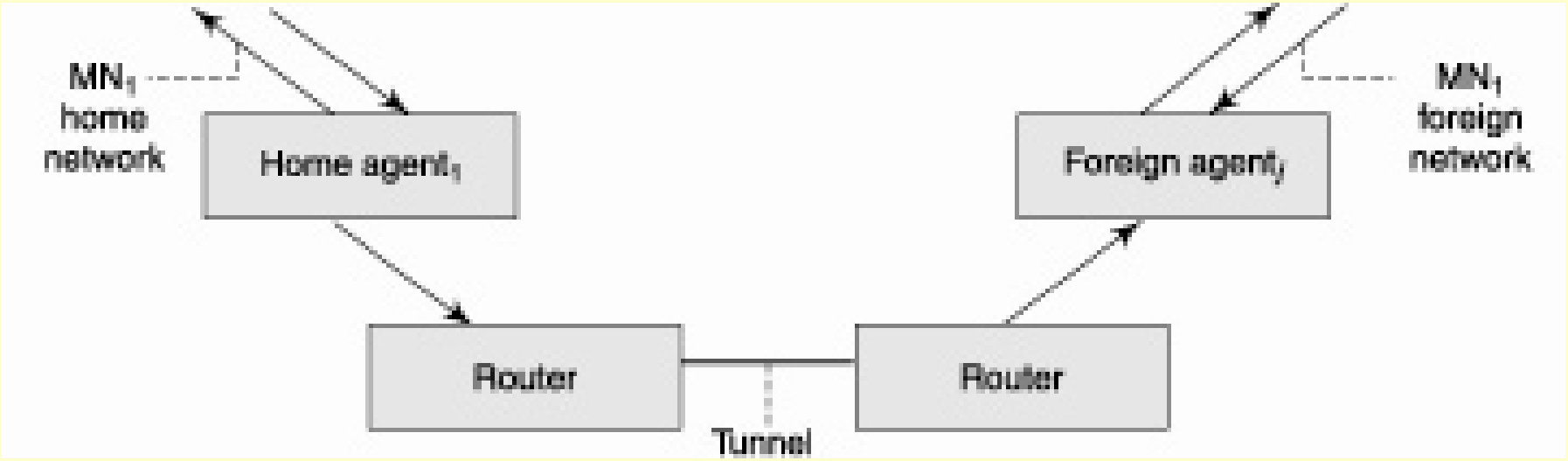
A tunnel between the HA and FA to carry the encapsulated packet



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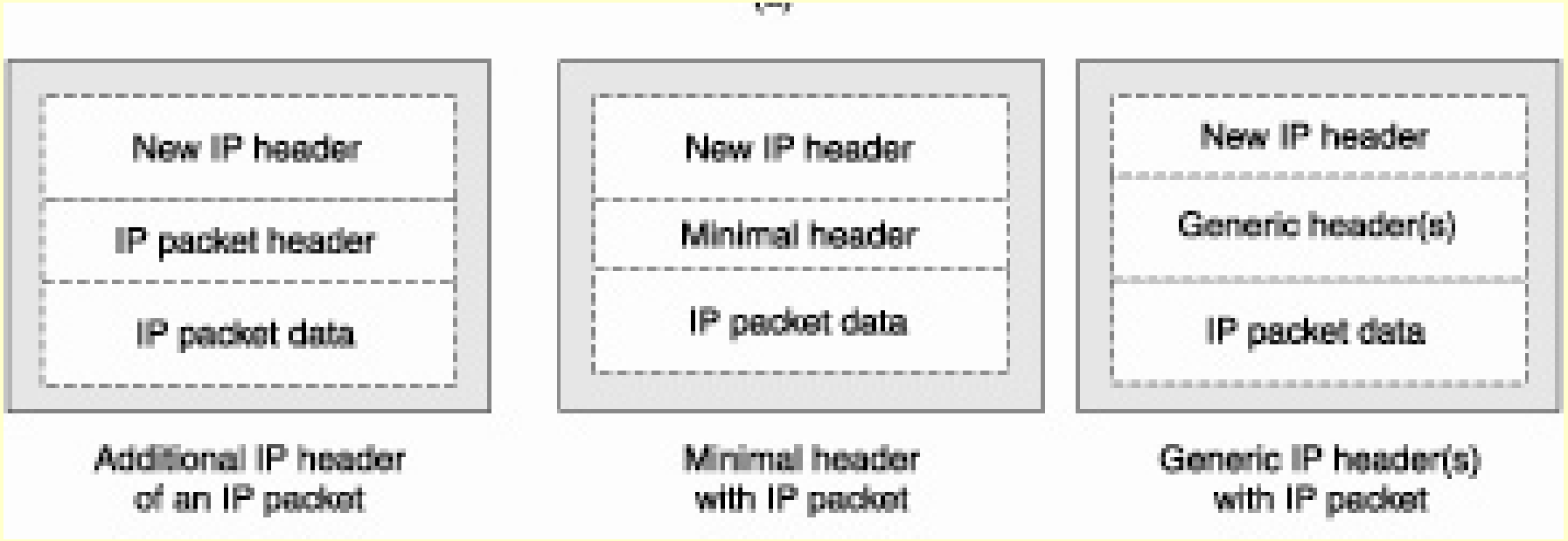
Three ways of encapsulation



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IP header-in-IP header Method of encapsulation

- Over the IP packet received at the HA
- Maximum 2^{16}-byte IP packet
- New IP header– the IP address of the HA as the source and the IP address of the FA as the destination

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Format of Encapsulated data

- First 32-bit word to specify the IP version (IPv4 or IPv6 for Internet or broadband Internet), length of header (= 5 words), precedence of the packet, and total packet-length (which is now 5 words more than that of IP packet received at the HA)
- Second 32-bit word, to specify the ID for the packet, flags, and fragment offset for the same packet ID

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Format of Encapsulated data

- Third 32-bit word, to specify the time-to-live (number of attempts to hop before expiry of packets at the network), type of protocol, checksum of the header (for finding transmission errors, if any)
- Fourth 32-bit word (four decimal numbers separated by dots and each less than 256) to specify the IP address of the home agent

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Format of Encapsulated data

- Fifth 32-bit word (four decimal numbers separated by dots and each less than 256) to specify the IP address of the destination COA (care-of address)
- sixth to tenth words are the IP header of 5 words with the fourth word as the IP address of the correspondent node (CN), and the fifth word as the IP address of the MN

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IP header-in-IP header encapsulation Format of Encapsulated data

7. IP Packet data received from the transport layer at the correspondent node, so that each packet has a maximum of 2^{16} bytes

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Redundancy in IP header-in-IP header method

- First words in the new IP header (of five words) and the IP packet header (of five words) are the same and are duplicating in case of IP-in-IP encapsulation

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Minimum Encapsulation (ME) method by IP header of an IP Packet

- Combines header of 10 words specified into 7 or 8 words
- The 6th and 7th words in the 6th item of the new IP header are not present in ME as both words are mere repetitions

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ME method b IP header to an IP Packet

- The 8th word in the 6th item— changed and now specifies the type of protocol, a one bit flag, seven reserved bits, and a 16-bit checksum of the modified three-word IP header (from the original five) for finding transmission error, if any.

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ME method by IP header to an IP Packet

- The 9th word in the 6th item– changed and now specifies (instead of the CN IP address) the MN IP address (which was earlier specified by the 10th word)

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ME method by IP header of an IP Packet

- The 10th word in the 6th item– changed and now specifies (instead of the MN IP address) the CN IP address in case the flag bit is set to 1 and the 10th word in the 6th item is removed in case the flag bit is set to 0.

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Action by FA in case of ME method

- Reads the first five words in ME
- Transmits the packet to the MN using the COA
- The MN IP address is specified by the 7th or the 8th word, depending upon the flag bit

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Deficiencies in the IP header-in-IP header and ME methods

(a) Routing information for tunnelling– not given

(b) No provision for recursive encapsulations

- Recursive encapsulations needed when the tunnel transmits multiple pieces of information for the MN and each piece of information encapsulates in one protocol

(c) No provision for a key that can be used for authentication or encryption

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Generic Routing Encapsulation (GRE) by IP header of an IP Packet

- One or more GRE headers depending on the number of recursions required to send multiple pieces of information

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Tunnel characteristics

- The tunnel does not need an extra hop (attempt) so time-to-live can be set to 1
- Tunnel does not get blocked like routers due to external IP address transmissions
- Has fixed source and destination endpoints

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GRE by IP header of an IP Packet

- Same as the 1st to 5th words in the 1st to 5th items of the new IP header
- Time-to-live is however set as 1
- Results in once-only forwarding to the FA by the HA

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GRE (GRE) Header(s)

- The 6th 32-bit word in encapsulation and the 1st word of the first GRE header
- 16-bit flags– bits to define the number of recursions, reserve bits, and version bits
- Next 16 bits– specify the protocol for encapsulating the information sent with the GRE header

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GRE (GRE) Header(s)

- The 7th word– specifies a 16-bit checksum and a 16-bit offset

Both are optional as indicated by the flag bits used to define these options

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GRE (GRE) Header(s)

- The 8th word– a 32-bit key
- Optional as indicated by the flag bit to used define the key-option
- The key at the GRE header– enables authentication or encryption at the FA

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GRE (GRE) Header(s)

- The 9th word– specifies a 32-bit sequence number information
- Optional as indicated by the flag bit used to define the sequencing-option
- Sequencing at the GRE header enables the FA to rearrange the packets sent by the HA

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GRE (GRE) Header(s)

- The 10th word— specifies a 32-bit routing information
- optional as indicated by the flag bit used to define the routing-option
- Routing at the GRE header enables use of routing information at the FA

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GRE (GRE) Header(s)

- 11th word onwards– , if number of recursions are defined in the first word of the GRE header, then the next GRE header is inserted before the IP header and IP data sent by the HA

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GRE (GRE) Header(s)

- If number of recursions specified in the 11th word in the GRE header is two, then the next two GRE headers are also inserted before the IP header and IP data sent by the HA

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IP Header and IP Packet data

- This part remains the same as that in the un-encapsulated IP header and the data received from the CN (correspondent node) IP packet at the HA

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IP Header and IP Packet data

- The first word has 5 flag bits and three recursion-number-defining bits
- The five flag bits are—checksum option flag, sequence number field option flag, key-option flag, and source-routing option flag

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Source routing

- Source of a packet provides the route information
- Router uses the routing information word for routing a packet

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Summary

- Tunnelling by HA to FA
- From HA IP address to new COA address of visiting mobile node
- Encapsulation
- IP header-in-IP header method of encapsulation
- Minimum encapsulation method
- Generic routing encapsulation method

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End of Lesson 06

Tunnelling and Encapsulation

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Mobile IP Network Layer

Lesson 07

Route Optimisation, Mobility Binding, Reverse Tunnelling in the Multicasting and Firewall

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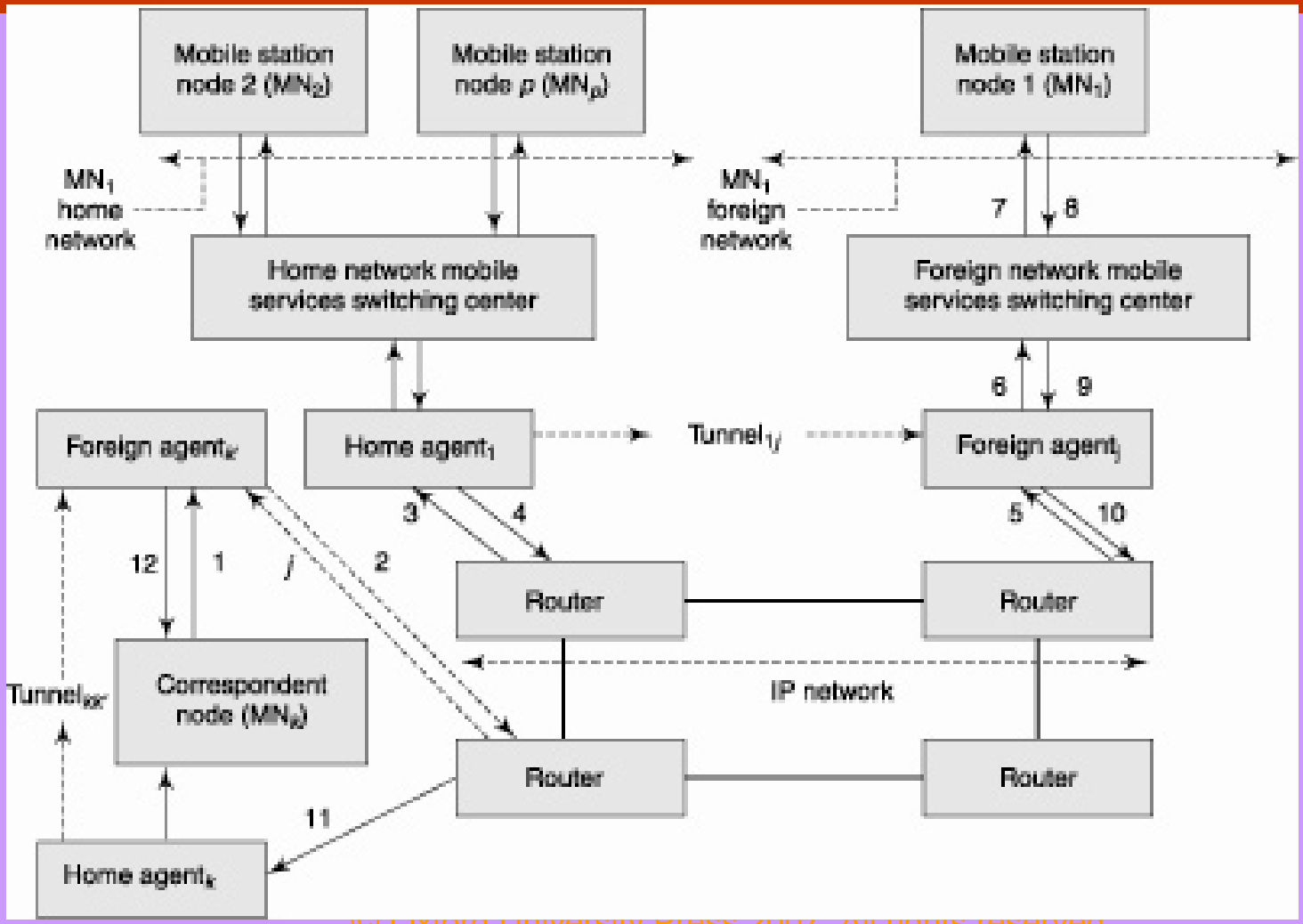
CN (MN_k) corresponding with visiting MN_l



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Mobile IP network employing home and foreign agents FA_k and FA_j

- Packet delivers to and from the MN_k at a foreign network with FA_k and MN1 at the foreign network with FA_j

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Example

- Assume that MN_l visiting a foreign network which happens to be the home network of CN2
- CN2 is very close to CN

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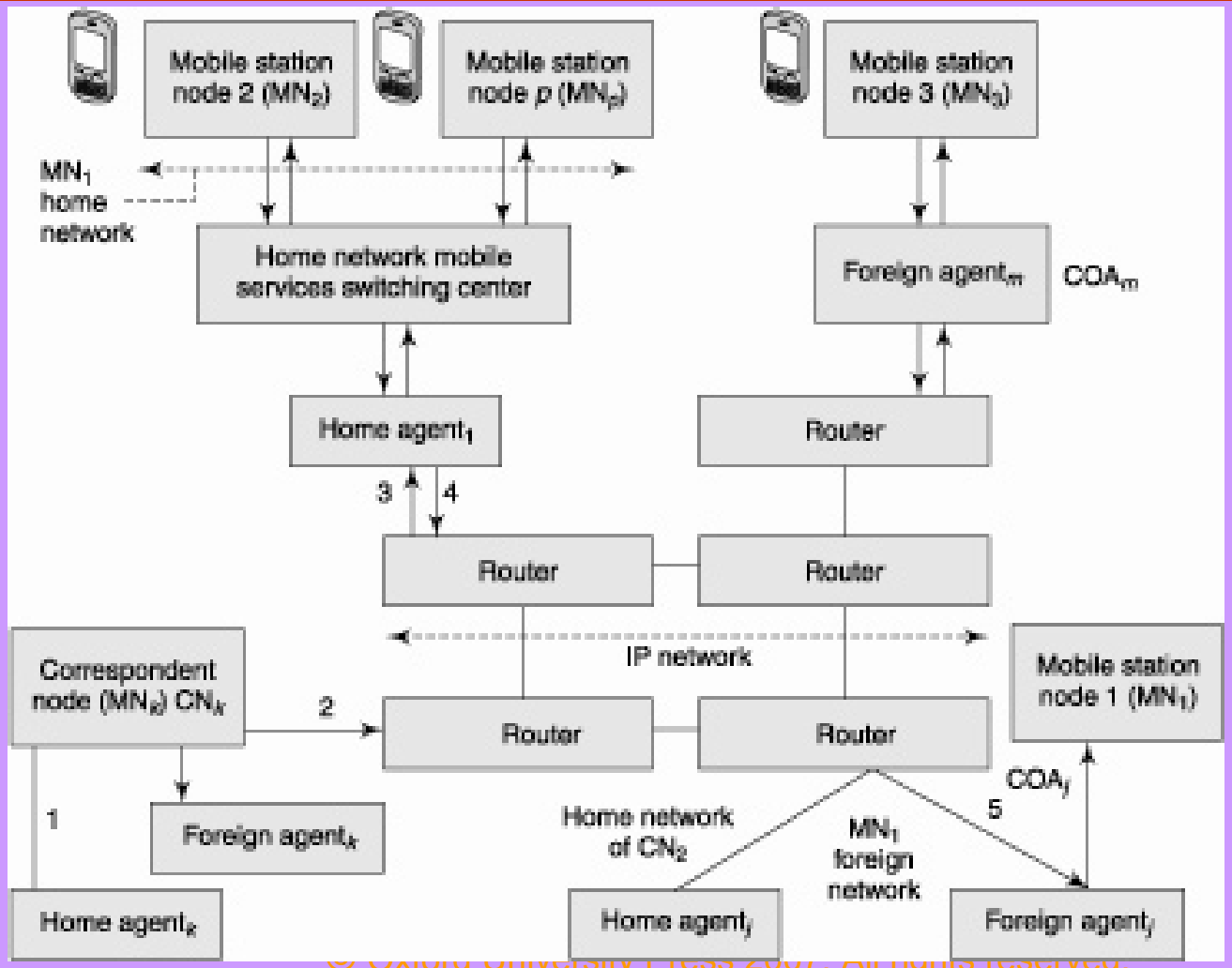
Packets make a triangular trip to reach from CN_k to MN_l



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Triangular route

- Triangular route without mobility binding between COA_j and CN_k
- Also possible that FA*k* and FA*j* are identical

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Optimization of route for the triangular routing example

- Can be made in case the MN_l opts to make its mobility known

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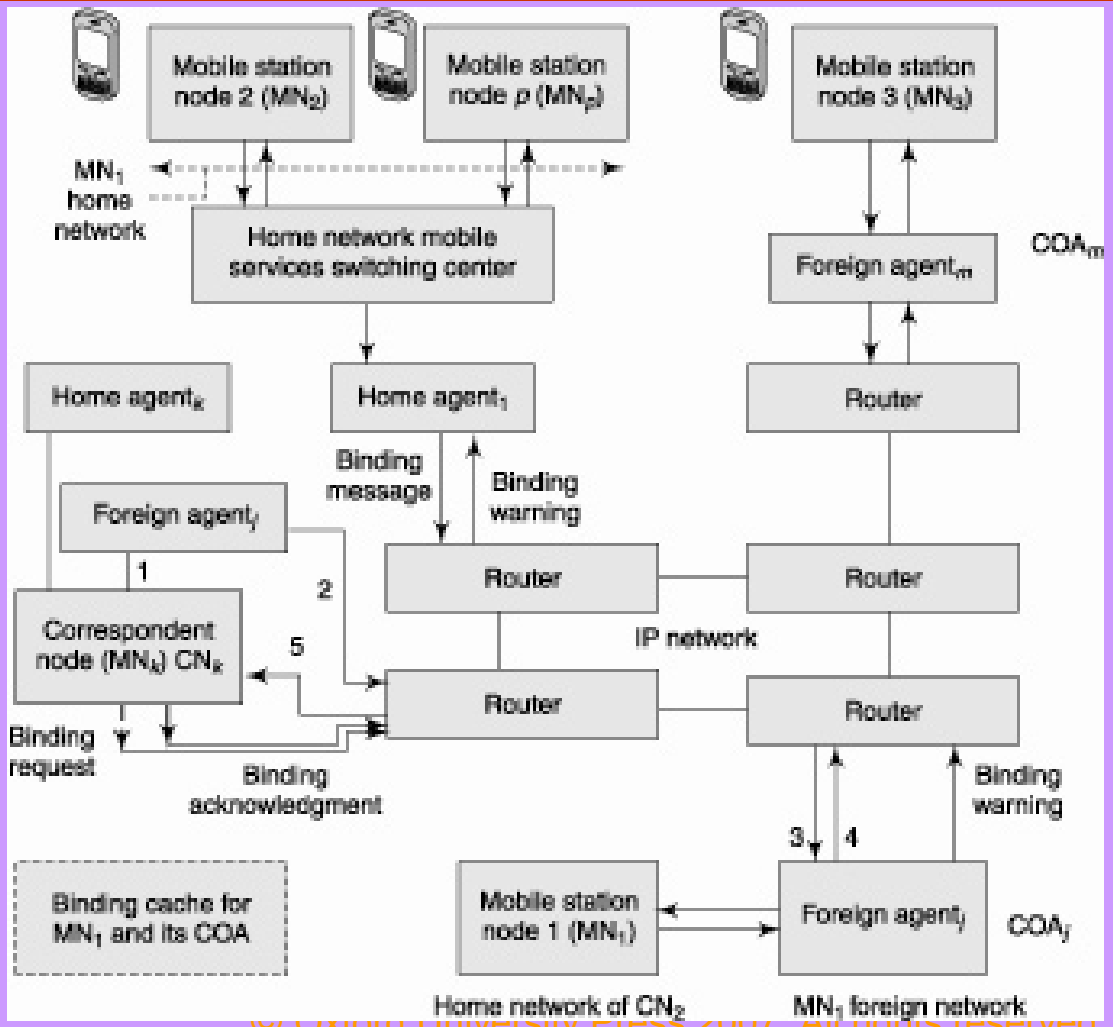
Route optimization and path 1, 2, 3, 4, 5 after mobility binding of MN1 at COA_j with CN_k



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Mobility binding Steps in the calling network

1. CN_k (fixed) or MN_k (mobile) network sends a mobility-binding request to HA_l
2. HA_l detects whether MN_l (for which binding request is made) has blocked external mobility binding requests

- If not, then HA_l sends the update for the mobility-binding message to the CN_k network
- External— does not include the visiting network FA

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Mobility binding Steps in the calling network

3. Mobility binding message has the IP address of MN1 and the present COA (COA_j) of MN_l when on visit to a foreign network and registered with FA_j

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Mobility binding Steps in the calling network

4. CNk issues an acknowledgement to HA_i on receiving the binding message.
5. CN2 network decapsulates the IP packet (this decapsulation would have been performed by FA_j through HA1 if MN1 had blocked external binding requests) and sends a warning for binding

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Warning sent to HA_l of MN_l

- Serves a purpose– HA_l sending the binding update to CN_k when MN_l moves to visit another foreign network or when it returns to the home network

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Warning for binding

- A message to the effect that the new IP addresses of MN_l and CN_2 will decapsulate the encapsulated IP packets (from the moment that the warning is aired) instead of FA_j

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Smooth handover in Mobile IP protocol method of optimization

- FA_j sends a binding warning to CN_k when MN1 deregisters with it
- Lets CN_k initiate another binding request to HA_l of MN_l
- CN_k gets the new binding and COA_m address from HA_l in the binding cache

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Tunnelling and forwarding of IP packets by encapsulation

- Paths 4 to 5

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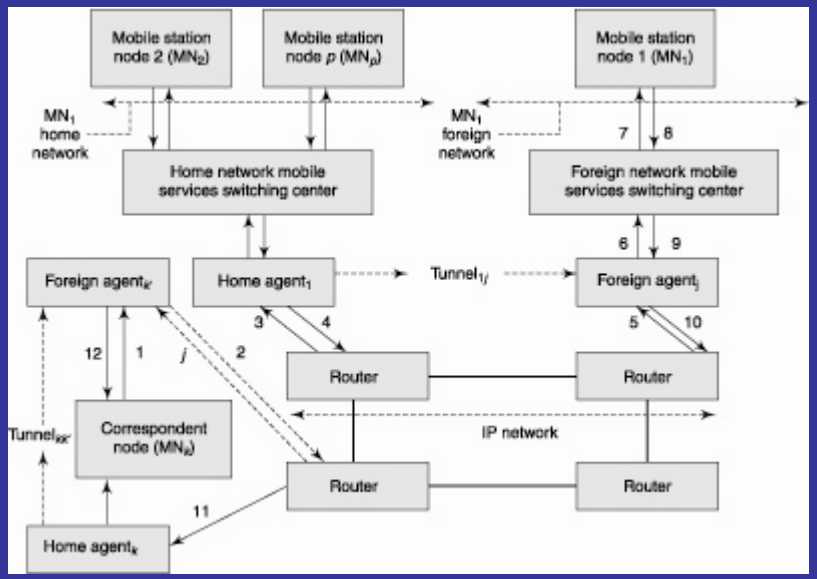
Data Frame in a Channel



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Reverse Tunnel

- If a reverse tunnel is formed then another tunnel is present through the paths from 10 to 3
- Reverse tunnelling from FA to HA

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Advantage of reverse tunnelling

- Multicasting needs bi-directional tunnelling
- Reverse tunnelling is required when a firewall is employed

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Time-to-live for forward and reverse tunnelling

- Time-to-live defines the number of attempts to hop before expiry of packets at the network
- GRE header encapsulation during tunnelling sets time-to-live = 1, so the packets are forwarded only once
- The tunnel does not need extra hops, has fixed endpoints

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Time-to-live = 1 for forward tunnelling

- Results in once-only forwarding through the tunnel from the home agent (HA) to the foreign agent (FA) when the mobile node (MN) visits a foreign network
- The tunnel does not need extra hops
- It has fixed endpoints

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Time-to-live for MN_l on visit sending to CN_k

- At the foreign agent, the time-to-live setting might be too low
- Therefore, when the MN_l sends the response to the correspondent network (CN_k), then the time-to-live set at the FA may not be sufficient

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Time-to-live for forward and reverse tunnelling

- When the COA is used to send the response to the CN without reverse tunnelling, then a very low setting of time-to-live blocks the packets after a very small number of hops (attempts) to the CN

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Time-to-live for reverse tunnelling

- Sets the time-to-live equal to 1 because IP packets need to be sent only once
- The tunnel does not need extra hop
- It has fixed source and destination endpoints

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Reverse tunnelling

- Facilitates guaranteed transmission of the IP packet responses through the tunnel to the HA
- Now, the HA transmits the response to the CN
- A low value of time-to-live at the FA does not lead to packet expiries

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Summary

- Triangular routing when MN_l visiting a foreign network happens to be the home network of CN2 which is close to CN
- Route optimization by Mobility binding protocol
- Reverse tunnelling FA to HA for multicasting and firewalls

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End of Lesson 07

Route Optimisation, Mobility Binding, Reverse Tunnelling in the Multicasting and Firewall

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Mobile IP Network Layer

Lesson 08

Multicasting and Firewall Security

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Multicasting by reverse tunnelling

- Information is multicast to an MN when it sets the option for multicast listening
- Bi-directional tunnelling method over a mobile IP network

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Multicasting by reverse tunnelling

- Assume that a mobile node MN_i visits a foreign network with foreign agent FA_j
- A multicast tree multicasts a packet to HA_j
- HA_j forwards the multicast IP packets to MN_j after registration

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Multicasting by reverse tunnelling

- HA_j establishes a bi-directional tunnel between HA*i* and FA_j
- FA_j transmits the received multicast message or packet to MN_j

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Multicasting by reverse tunnelling

- Suppose MN_i visits another foreign network with foreign agent FA_k
- MN_i requests FA_k and FA_k forwards the transmit request for the multicast to HA_j

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Disadvantages of reverse tunnel approach

- Duplication of multicast IP packets when multiple MNs of HA_j and other HAs visit the same FA
- Because several HAs create several bi-directional tunnels, through which they transmit multicast packets multiple times
- When the built bi-directional tunnels do not converge into one, the packets maybe duplicated

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Disadvantages of reverse tunnel approach

- IP packets reach by short and long paths, when there is no DMSP (designated multicast provider)

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Mobile multicast (MoM) protocol

- Convergence of the tunnels by defining an HA as the DMSP
- Only the DMSP can build bi-direction tunnels
- When DMSP providing the multicast service– the IP packets reach by the longer path
- The DMSP-route length may not be the shortest

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The advantage of multicasting by reverse tunnelling

- There is no reconfiguration (updating of the routing tables) of routers at the multicast tree

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Remote subscription approach of multicast approach

- Without the reverse tunnelling
- Assume that MN_i visits a foreign network with foreign agent FA_i
- FA_i transmits a 'join' request in case it is not presently registered for multicast at the multicast tree

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Remote subscription approach advantages

- No duplication of multicast IP packets
- IP packets reach through an optimal (shortest) path
- When MN_i moves to the next foreign agent FA_k , it again transmits a 'join' request and the previous subscription cancels

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Firewall Security

- Filters the packets assigned to an IP address received from another IP address
- IP address of the MN is at the home agent
- When MN moves to a foreign agent, the MN sends the IP packets using the care-of address (COA) assigned at the foreign agent

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Firewall Security

- In case the firewall that permits another IP address (at the FA) assigned to an IP address (at the HA), there is a security risk

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Advantage of reverse tunnelling of the packet from the COA

- FA to the home agent
- Home agent transmits to the correspondent node (CN)
- The firewall gets the packets from the same IP address as the IP address registered at the firewall
- It does not filter these packets

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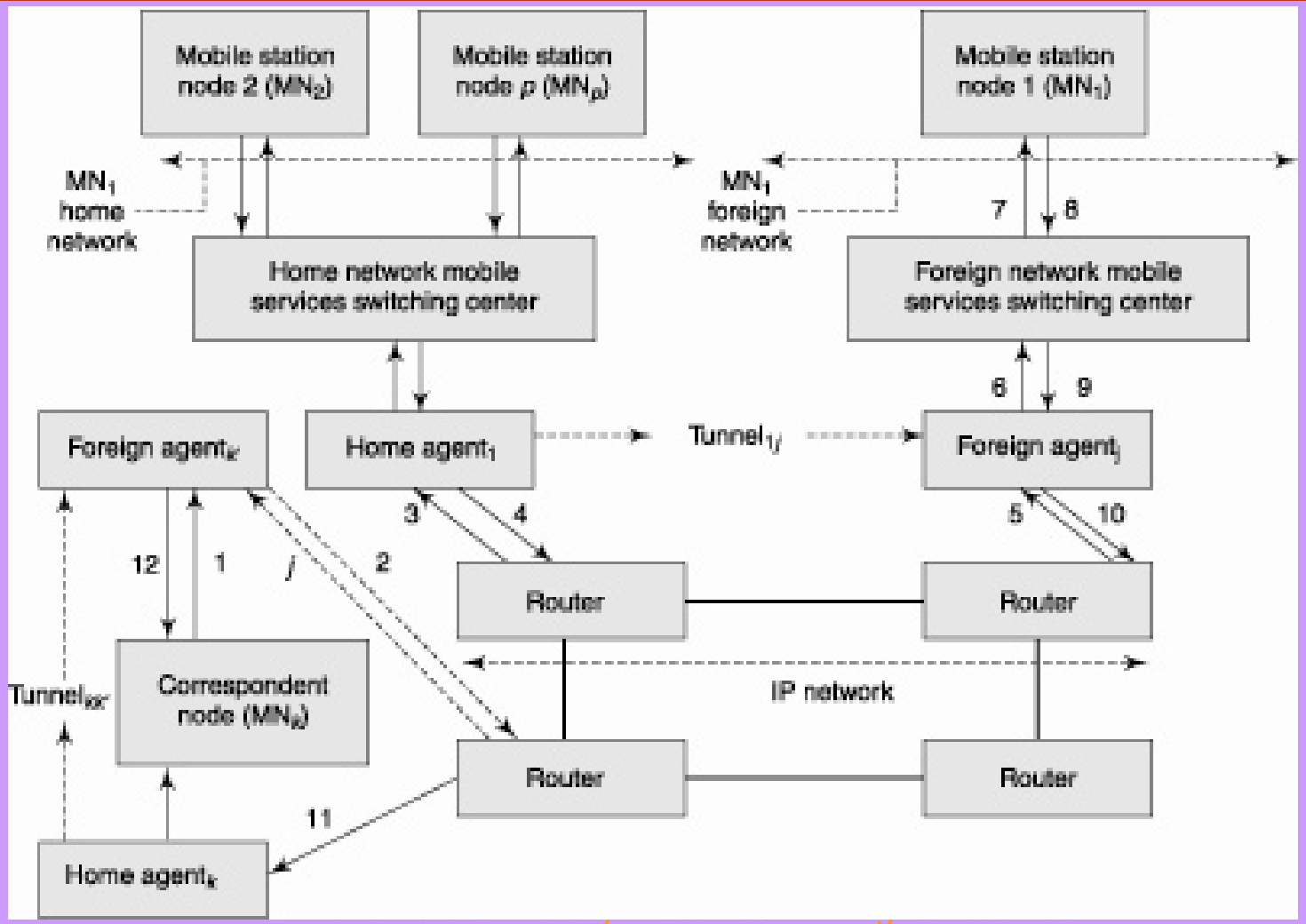
Tunnels


Mobile station node 2 (MN_2)
Mobile station node p (MN_p)
Mobile station node 1 (MN_1)
MN_1 home network
MN_1 foreign network
7
8
Home network mobile services switching center
Foreign network mobile services switching center
6
9
Foreign agent$_k$
Home agent$_i$
Tunnel$_{ij}$
Foreign agent$_j$
3
4
5
10
12
1
j
2
Router
Router
IP network
Tunnel$_{kk'}$
Correspondent node (MN_k)
Router
Router
11
Home agent$_k$

Firewall at the CN sending the IP packets to MN_l

- The path followed– 1, 2, 3, 4, 5, 6 and 7
- Sub-paths 4 and 5– across the forward tunnel
- When the firewall at the CN receives the IP packets sent to MN_l, then the path followed will be 8, 9, 10, 3, 4, and *i*

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Firewall at the CN sending the IP packets to MN_I

- Sub-paths 10 and 3— across the reverse tunnel
- The CN firewall continues to use the same IP address for the MN when transmitting and receiving packets

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Summary

- Multicasting
- Reverse tunnelling approach for short paths
- Remote subscription approach
- No duplication of multicast IP packets
- IP packets reach through an optimal (shortest) path
- Firewall security by reverse tunnelling

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End of Lesson 08

Multicasting and Firewall Security

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Mobile IP Network Layer

Lesson 09

Dynamic Host Configuration Protocol

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Mobile computer (laptop or other) visiting another network

- Another network— a separate domain name server identity on the network
- Functions as a subnet on the Internet
- The computer gets a new IP address

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Mobile node visiting a foreign network

- Also gets a new IP address
- Care-of address (COA) by agent discovery process and advertisement of the COAs by the foreign agent
- Co-located COA obtained by the dynamic host configuration protocol (DHCP)

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Server for Mobile computer (laptop or other) visiting another network

- Provides a dynamic IP address, subnet mask, and ARP and RARP caches to enable the computer to transmit and receive the IP packets at the new IP address from the Internet via the subnet
- Server (subnet) has its own IP address to provide connectivity to the Internet

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Dynamic host configuration protocol (DHCP)

- A protocol to dynamically provide new IP addresses
- Set subnet masks for the visiting computer
- Enables use of the server and subnet router at the place being visited
- Guarantees that any assigned network address is in use by only one DHCP client or none at a given instant

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DHCP client

- Software in an agent (for example, foreign agent for visiting mobile node)
- Device software for connecting to the network using a software component
- Protocol communicates with a server
- Number of steps in the DHCP protocol for dynamically configuring the client IP address and other networks

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DHCP server

- The server— software for allocation of network addresses to the computer
- A number of DHCP servers at a subnet, a request is broadcasted to several servers
- Server may be part of the operating system of the computer seeking connection to the network

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Step 1

- The DHCP client in an agent or device or computer broadcasts DHCPDISCOVER—a discover request
- Directly or through a DHCP relay agent to the servers

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Step 2

- Each server listening to the discover-request DHCPDISCOVER finds the configuration, which can be offered to the client
- Server(s) send(s) the configuration parameters including an IP address not presently in use at the subnet
- The configuration parameters are in the DHCPOFFER for the offered configuration

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Step 3

- Client can reject the DHCPOFFER from a server or servers
- When DHCP offers from all the servers are rejected, the client repeats the steps from step 1
- Else step 4

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Step 4

- The client replies to the servers, through a DHCPREQUEST to each server
- The option ‘reject’ is set in each reply to those DHCP servers to which the client reply is ‘reject’
- The option ‘select’ is set for those servers to which the client reply is ‘select’

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Step 5

- The selected DHCP server creates and manages bindings
- Sets a time interval during which the offered IP address will be valid for the DHCP client
- The required interval can vary
- Depends on the likely Internet connection interval at a particular Internet serving network

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Binding

- A collection of configuration parameters, including at least one IP address, which is associated with and binds to the DHCP client
- Periodically provide new IP addresses

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Step 6

- The DHCP server confirms the binding through a message
- It sends DHCPACK after creating the binding

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Step 7

- When the DHCP client computer leaves the subnet, it sends DHCPRELEASE message
- In case the client does not send DHCPRELEASE within a specified time interval, the server frees the created binding

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Step 8

- The server and client also use the authentication protocols before considering the DHCPDISCOVER from a client and before accepting a DHCPOFFER, respectively

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Summary

- COA by agent discovery process
- Co-located COA obtained by DHCP
- DHCP server assigns dynamically the client IP address and other network configuring parameters to a DHCP client

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End of Lesson 09

Dynamic Host Configuration Protocol

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Mobile Transport Layer

Lesson 01

User datagram protocol (UDP) and Transmission control protocol (TCP)

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Conventional Transport Control Protocols

- Application data is first encoded using the application layer protocol header words by prefixing them over the data
- Then the encoded data from the application layer is encoded again using the transport layer protocol header words by prefixing them over the previously encoded data

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Conventional Transport Control Protocols

- At the receiver end the reverse process of decoding at each layer to retrieve back the application data takes place

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Conventional Transmission Control Protocols– UDP and TCP

- The data transported from the transport layer to next layer (*L*3) using TCP (or UDP in case of datagram)
- TCP– a connection-oriented protocol
- TCP– a transport layer protocol for the Internet

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TCP

- A connection oriented less protocol
- Session for establishment, data flow and congestion control, and session termination in TCP

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Port

- Means a service access point (software) for data input and output
- A service (application) is rendered by a node
- Examples of services through the Internet are e-mail transmission, e-mail reception, and web browsing
- Example of a port– port number 80 which specifies the www (HTTP) application in the TCP/IP protocol suite

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User Datagram Protocol

- A connectionless protocol— there is no session for establishment, data flow and congestion control, and session termination in UDP
- Transmits like a person using a phone who just speaks without waiting, irrespective of whether the receiver at the other end is listening or not, replying or not

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Function of the transport layer

- To transport the port data
- UDP header specifies the ports
- Used at the subsequent layers (from the transmitter transport layer up to the receiver transport layer) during transmission of port data (application layer data) to the receiver

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UDP

- Useful in transmitting datagrams
- One datagram length ≤ 2^{16} words
- Usage Examples– as those for multicasting, registration request and registration reply

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UDP header fields

- First-word bits *b*0–*b*15 for source port (optional) and *b*16–*b*31 for destination port
- Second-word bits *b*0–*b*15 for length of the datagram and *b*16–*b*31 for the header checksum

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Pseudo header after the header

- Used as prefix to datagram
- First word– source IP address
- Second word– destination IP address
- Third word for the protocol and length– bits b0–b7 are all zeros, b8–b15 specify the network layer protocol, and b16–b31 specify the UDP length

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UDP Pseudo Header

- Pseudo header enables identification of source and destination IP addresses of the ports, for example, when a datagram for registration request or registration reply is sent

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UDP Pseudo Header

- Enables identification of the protocol to be used to route the datagram
- For example, ‘protocol = 17’ shows the use of the IP protocol by the network layer

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UDP Pseudo Header

- Also enables specification of the length up to which the UDP header and data extends so that the remaining part of datagram may be used for conveying other information

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Transmission of data streams

- A segment from higher layer transmitted as a data stream of bytes to lower layer IP where it is packetized using IP protocol
- Octets (bytes of the words) transmit sequentially

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Receiving of data streams

- Octets received by the transport layer at the other end in the same sequence as they are sent

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TCP header inclusion of sequence number

- A sequence number is first assigned to each byte (octet) before a TCP connection transfers the data
- A set of 32 bits of a word (4 bytes) has four sequences

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TCP header inclusion of sequence number

- The application layer data is transmitted and received as a stream consisting of sequences
- The TCP header includes the sequence number of the first byte (not of each byte) to be transmitted through the stream

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Buffering

- The TCP transmitter buffers the segment(s)
- Receiver acknowledges a data-sequence
- The transmitter empties the bytes up to the acknowledged sequence from the buffer

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Retransmission

- From the byte next to the data sequence number of the last successfully transmitted byte
- Also retransmits in case no acknowledgement received within a timeout period

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Fully acknowledged end-to-end

- Acknowledgement of Session-start, data transfer, and session-finish
- Handshaking of packets— for acknowledgement
- All transactions (connection start, establishment, data streaming, and finish) acknowledged

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In-order delivery

- The TCP transport layer delivers the segments in sequential order When the n^{th} segment has been delivered, only then is the $(n + 1)^{th}$ delivered to the application layer and not before that

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Congestion control

- Congestion– lack of acknowledgement within the timeout period in a step or receipt of DACK (duplicate acknowledgement)
- Number of methods to control congestion

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A method of controlling congestion

- To slowly increase exponentially the number of bytes in the stream in successive steps
- The number of transmitted bytes in a step reduced to half on encountering congestion

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TCP Header

- First word: The function of the transport layer is to transport the port data
- Therefore, the first 16 bits (*b*0–*b*15) are for the source port number and the next 16 (*b*16–*b*31) for the destination port number

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TCP Header

- Second word: This 32-bit field defines a 32-bit sequence number.
- The sequence number field reset to 0 in case there are no more octets left to transmit from the segment

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TCP Header

- Using the sequence numbers (data byte number sent in the sequence), the packets, which reach non-sequentially, are reassembled and the receiver sets the acknowledgment number field as per the sequences successfully received by it

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TCP Header

- Third word: It gives a 32-bit acknowledgement number (interpreted when the *A*-flag is set)– the value of the next sequence number (byte number), which the sender of the segment is expecting to receive from the receiver in case the sequences of bytes has been received successfully

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TCP Header

- Acknowledgement number helps the receiver in knowing how much of the segment data was successfully transported
- Helps the transmitter in knowing from which sequence number is the data now to be sent to the receiver

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TCP Header

- When the connection is established, both, the transmitter and the receiver, use the field to inform each other about the upcoming sequences

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TCP Header

- Fourth word: First 4 bits (*b*0–*b*3) are for the data offset and the next 6 bits (*b*4–*b*9) are reserved
- Reserved bits facilitate the addition of more flag bits or provide a provision for extension of the present functions and features of TCP in any subsequent changes in the recommendations for TCP

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Field for offset

- The offset field specifies the word from where the application layer data octets will begin (after the header, options, and padding)

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Fields for flags and window size

- The next 6 bits (*b*10–*b*15) are flags (*F*, *S*, *R*, *P*, *A*, and *U*) and the next 16 bits (*b*16–*b*31) are for setting window size, which is used for congestion control during transport
- The window size field specifies the number of bytes the sender is willing to receive starting from the acknowledgement field value

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TCP Header

- Fifth word: The first 16 bits (*b*0–*b*15) for checksum of the header and the data and the next 16 bits (*b*16–*b*31) are for the urgent field
- Urgent field interpreted when the U-flag has been set during segment transport

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Urgent field

- Communicates an offset value to be added to get a sequence number from the sequence number of the present segment
- The value then points to the sequence number of the octet (in application layer data) following the urgent data
- Helps in data flow control by specifying the urgent part of the data octets for transporting to the other end

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TCP Header

- Sixth and subsequent header words: These are used for options (each of 8 bits) and padding

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Flags

- U– URG, set means urgent pointer field is being used for control of data flow
- A– ACK is set means acknowledgement number word field has significance and can be used to control flow and congestion
- *P* – PSH set means push the data

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Flags

- *R*– RST set means reset the connection (sequence from the beginning)
- *S*– SYN set means synchronize the sequence number
- *F*– (FIN) set means data is finished (no more data for sending at present)

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Summary

- UDP for sending datagrams using connectionless protocol
- TCP for sending segment of data from application layer using connection oriented protocol
- Sessions for establishment, data flow and congestion control, and session termination in TCP

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… Summary

- TCP header fields for port numbers of source and destination, sequence number, acknowledgement number, offset, flags and window size, check-sum and urgent sequence offset
- TCP header options and paddings

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End of Lesson 01

User datagram protocol (UDP) and Transmission control protocol (TCP)

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Mobile Transport Layer

Lesson 02
TCP Data Stream and Data Delivery

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TCP Data Stream

- Consists of bytes
- Delivered using a virtual connection between sockets
- Each socket has the port number and IP address for rendering service to an application

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TCP Data Stream

- The number of bytes = equal to the transport protocol data units (TPDU) that are placed in a memory buffer and transmitted by the TCP protocol
- A TCP segment defines the TPDUs in a TCP data stream
- PDU depends on MTU (maximum transfer unit) presentable in a given network state

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TCP Protocol

- Employs timers to synchronize the data stream between both ends
- Provides a delivery mechanism for data streams

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RTT (round trip time)

- The time interval between the start of the transmission to the receiver layer and receiving the acknowledgement of successful transmission
- To set the time interval during which the transmitter expects the receiver to send a TCP stream with the acknowledgement field set to indicate the successfully sent bytes

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RTT (round trip time)

- The transmitter retransmits from the acknowledge-field sequence number onwards

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TCP Data Delivery

- In TCP there is acknowledgment of sequences sent from one end to the other. (The acknowledgement field specifies the sequenced byte number from which the receiver end expects the sender end to transmit in the next sequence.)
- The bytes that do not reach the receiver successfully within a timeout period are retransmitted

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Checksum field

- Detects errors
- Receiver discards any erroneous packets in a data stream
- Transmitter started retransmitting as per the previous acknowledgement and thus it retransmitted the delayed octets
- Receiver discards the duplicate packets

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TCP Data Delivery

- Retransmission in case of no acknowledgement
- To ensure reliable, guaranteed, and error-free data transfer
- Unlike UDP— in which transmission is with no buffering, no acknowledgement, and no retransmission

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Similarity to the transparent and non-transparent data transmission

- No retransmission mechanism similar to the transparent data transmission Retransmission mechanism similar to the non-transparent data transmission in the radio layer of a GSM system

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Step 1 for delivering the data

- Step 1: Connection establishment during four states LISTEN, SYN_SENT, SYN_RECEIVED, and ESTABLISHED
- Three data streams are transferred in the last three phases
- Third one– with the data octets

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Step 2 for delivering the data

- Step 2: Data stream of application layer octets transferred after establishment of the connection
- Before termination of the connection on completion of the transmission data octets

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Step 3 for delivering the data

- Step 3: Connection Finish and then Close

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State LISTEN of TCP connection between the TCP_A and receiver TCP_B

- LISTEN: TCP_B receiver waiting for listening a connection request from TCP_A

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State SYN_SENT

- SYN_SENT: A SYN data stream sent by the transmitter TCP_A with the *S* (SYN) flag set to 1
- Waiting for the TCP_B data stream with SYN and ACK

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State SYN-RECEIVED

- SYN-RECEIVED: A SYN_ACK*B* sent by receiver data stream TCP_B for TCP_A with the *S* (SYN) and *A* (ACK) flags set to 1
- TCP_B uses the acknowledgment field at the packet and sends an acknowledgment to TCP_A

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Example

- SYN sequence number sent in SYN_SENT = *n*
- Then TCP_B transmits an acknowledgement with the sequence number in the acknowledgement field set as *n* + 1 and the *A*-flag set to 1 in SYN-RECEIVED state

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Example

- TCP_A expects the sequence number request $n + 1$ from TCP_B
- TCP_B sequence number field has sequence number *m* in it when TCP*B* sends a sequence *m* to TCP*B*

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State DATA _TRANSFER

- DATA _TRANSFER: A TCP_A stream always has the sequence number field for the byte starting from which the data of a segment is being transferred through the stream and the acknowledgement number field for the byte starting from which the data of a segment is expected by TCP_B

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State DATA _TRANSFER

- TCP_B stream always has the sequence number field for the byte starting from which the data of a segment is being transferred through the stream and the acknowledgement number field for the byte starting from which the data of a segment is expected in a TCP_A stream

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State DATA _TRANSFER

- TCP_B acknowledges a data stream by setting the acknowledgement field value to the sequence number of the last byte received successfully (from other end) plus 1
- TCP_A is expected to send the new data stream starting from this (last successfully received byte + 1) position

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Example

- A segment of 4020 bytes with sequence numbers from 1025 to 5044 is to be transmitted
- If the TCP_A layer begins transmitting 4020 bytes with a sequence number field = 1025
- All bytes are transmitted without loss and without error, then the TCP_B stream acknowledgement number field = 5045

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Example

- If only the bytes up to sequence number 2047 received successfully by the TCP_B layer in RTT, then the receiver will send the TCP_B stream with an acknowledgement number field = 2048, as the receiver expects the transmitter to send bytes starting from sequence number 2048

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State DATA _TRANSFER of TCP connection between the TCP_A and TCP_B

- Acknowledgements for data sent to the receiver, or the lack of acknowledgements from the receiver within a timeout period—Used by the sender to judge the present network conditions between the TCP sender and receiver

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State FIN_WAIT_1 of TCP connection between the TCP_A and TCP_B

- FIN_WAIT_1: TCP_A sends a data stream with the *F*-flag (FIN) set to 1 and expects a FIN_ACK from TCP_B within a wait period

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TIME_WAIT state in FIN_WAIT_1

- Used to wait for FIN_ACK (acknowledgement of FIN) from the other end
- After that the state changes to FIN_WAIT_2, else if the FIN_ACK received from TCP_B, then the receiver TCP_B state changes to CLOSING

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State FIN_WAIT_1

- FIN_WAIT_2: TCP_A sends a data stream with the *F*-flag (FIN) set to 1 and expects a FIN_ACK from TCP_B during a wait period

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TIME_WAIT state in FIN_WAIT_2

- TIME_WAIT: Used to wait for FIN_ACK (acknowledgement of FIN) from the other end and after that if no FIN_ACK is received, then the state changes (after timeout) to CLOSED
- If FIN_ACK received then the TCP_B state changes to CLOSING

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CLOSE_WAIT state

- CLOSE_WAIT: TCP_A goes to CLOSE_WAIT state on receipt of the FIN_ACK in either FIN_WAIT_1 or CLOSE_WAIT, LAST_ACK is sent after CLOSE_WAIT to finally close the connection

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States CLOSING and CLOSED

- CLOSING: TCP_B sends a CLOSING ACK to TCP_A, waits for timeout, and goes to the CLOSED state

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Summary

- TCP
- TCP acknowledgment of sequences sent from one end to the other
- The acknowledgement field specifies the sequenced byte number from which other end expects the sender end to transmit in the next sequence
- RTT

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… Summary

- Connection establishment during four states LISTEN, SYN_SENT, SYN_RECEIVED, and ESTABLISHED
- Then Data transfer
- Then Finish and Close

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End of Lesson 02
TCP Data Stream and Data Delivery

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Mobile Transport Layer

Lesson 03
TCP Data flow control and Congestion control

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TCP Data Flow Control

- Octets in a segment transmit as data streams which are transmitted after packetizing
- A few packets of a data stream may reach the other end with an error, may be lost, or may not reach in the expected time
- They need retransmission starting from the octet succeeding the last successfully received one. A controlled data flow prevents need of large number of retransmissions

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Window size adjustment (TCP tuning) Method

- Adjusted and throughput depends on RTT (round trip time) interval for the acknowledgement
- The transmitter transmits all bytes received up to a sequence number specified by *w* at the window size field of the other end

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Window size adjustment (TCP tuning) Method

- Transmit from *i* to *i* + *w* in case the next sequence number (in the acknowledgement field from receiver) to be sent from transmitter is *i*

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Timeout

- At the transmitter sets equal to the RTT for acknowledgement
- If there is no acknowledgment in the timeout period
- Then the bytes sent using the window are considered as lost and are retransmitted

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Cumulative acknowledgement

- Receiver acknowledges all bytes received up to a sequence number defined in the acknowledgement field

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Cumulative acknowledgement

- Cumulative acknowledgement from the TCP_B end called partial acknowledgement (PACK) if the acknowledgement field shows a lesser value than expected after transmission of all the bytes from the TCP_A end
- PACK— shows the lost packets or data during transmission to the TCP_B end

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Reverse packet acknowledgement

- Reverse packet from the receiver piggybacks the acknowledgement

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Duplicate acknowledgement (DACK)

- One of the packets of a segment may reach after a delay in comparison to the packet succeeding it
- Acknowledgement from the receiver is duplicated by retransmission of an earlier acknowledgement without delay
- DACK thus shows recovery of lost packets or data received after a delay at the TCP_B end

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Delayed acknowledgement

- Acknowledgement from the receiver is delayed if the receiver responds by including, after the TCP header, a large number of octets of the receiver-end segment
- Due to packetization time at the receiver network layer and the packets tracking different paths and hops to the transmitter

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Delayed Acknowledgement

- Receiver has started receiving another transmitted data stream from the next sequence number at the transmitter
- Receiver now assigned a dual role at the same time
- Delay at the transmitter can be set at 100 ms to 250 ms in order to reduce the number of delayed acknowledgements

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Adjusting the window-size field method

- Window-size field is varied for congestion control during data flow
- Window size, *w*, a 16-bit field specifies the number of bytes the receiver (TCP_A or TCP_B) is ready to receive from the sender (TCP_B or TCP_A, respectively
- *w* set to maximum 2^{16} bytes

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TCP tuning

- Method of specifying window size
- The bytes (from the other end) start from the acknowledgement field value *i* and are transmitted up to the *i* + *w* value of the sequence number in a TCP segment
- Refer Examples 6.1 and 6.2 in the text

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Window scaling method

- During high speed data transfer, the window scaling method
- The TCP tuning method scales up the widow size to 2^{30} bytes in case of high-speed networks

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Window scaling method

- Number of bits, which left shifts the bits *w* at the window-size field, is set during a three way handshake session SYN_SENT, SYN_RECEIVED and ESTABLISHED
- A left shift of 1 multiplies *w* by 2, a left shift of 2 multiplies *w* by 4, and so on

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Window scaling method

- Number of shifts can be between 0 and 14 and the window size = $2^{30 + s}$, where s is the number of shifts
- Window scaling factor, $s_w = 2^s$

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Sliding Window Method

- A window specified from a sequence number to another sequence number
- S_{A0} and S_{A1} are the two sequence numbers which define the lower and upper boundaries of the window. $S_{A0} – S_{A1} = S_W$ (sliding window size)

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Sliding Window Method

- TCP_A can send only S_W bytes before it must wait for an acknowledgment and a window update from the receiving end TCP_B

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Example

- TCP_A transmit as per its present sliding window setting
- The setting such that the TCP_A data stream is transmitted between S_{A0} and S_{A1} before an acknowledgement is expected from the receiving end

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Example

- TCP_A sets the sliding window to the next set of sequence numbers $S_{A1} – S_{A2}$.
- When the receiver's acknowledgement is not received in a specified interval, then the window slides back to the original and the sequences between S_{A0} and S_{A1} are retransmitted

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Example

- When the receiver's acknowledgement is received in the specified interval and it equals S'_{A0}, then the window slides back and sequences between S'_{A0} and S'_{A0} + S_W is retransmitted
- Sliding window size, S_W, also defines an acknowledgement delay period

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RTT

- Assume that one sequence is transmitted and acknowledged in time RTT_0, then the next acknowledgement is expected after $RTT_0 \times S_W$
- S_W specified in the TCP_A data stream at the window-size field
- TCP_B receives the stream and sends the acknowledgement number field after setting the acknowledging time interval as per the S_W value received from TCP_A

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Congestion Control

- A TCP data stream receiver sets a window
- The data from TCP_A (transmitter) to be sent from sequence number S_0 and S_4
- Let us assume that the data from a transmitter is received and sent to an application or a service access point (SAP) up to sequence number S_0

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Congestion control

- Assume that at an instant, the situation is as follows—transmitted TCP_A octets are received and acknowledged by TCP_B receiver up to the sequence number S_1
- But data is still being sent to the receiver SAP (application layer)
- TCP_A octets transmit from sequence number $S1 + 1$

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Congestion control

- Let us now assume that at the next instant, the situation is as follows—the data from TCP_A is received at TCP_B up to sequence number S_2 but has not yet been acknowledged and that it is yet to be sent to SAP

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Congestion control

- TCP_A octets retransmit from sequence number $S1 + 1$ after the timeout
- The data from the transmitter can be received up to a maximum of sequence number S_3 when the window of the receiver extends from S_1 to S_3 and the window-size field bits in the TCP_A data stream header equal $(S_3 - S_1) \div s_w$, and s_w is 1

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Congestion control

- Congestion network window size (cnwd) = ($S_3 – S_1$) and the window is for ($S_3 – S_1$) octets and when s_w = 2 the window is for [($S_3 – S_1$) ÷ 2] octets
- The window scaling factor is set at the transmitter
- By adjusting s_w the congestion can be controlled

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Methods for congestion control in conventional TCP

- Slow start and congestion avoidance
- Fast recovery (in place of slow start) after packet loss

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The problems faced while employing the conventional TCP on a mobile network

(a) Slow start method employed in the conventional TCP presumes that a packet is lost due to congestion, not due to any other reason

- Mobile network— The transmission quality problem more likely reason for packet loss

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The problems faced while employing the conventional TCP on a mobile network

(b) Mobile network— BERs high, which leads to high transmission repetition rates and, therefore, the higher window slide-back rates (Transmission repeats due to windows slide back in TCP)

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The problems faced while employing the conventional TCP on a mobile network

(c) The duplicate acknowledgements (DACKs)– lead to reduced window sizes

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Methods for Wireless and Mobile Networks

- Split TCP— TCP splits into two layers
- The upper layer to take care of requirements in mobile networks and send the data streams to the conventional TCP layer
- Four methods using split TCP— indirect TCP, selective repeat TCP, mobile-end Transport, and mobile TCP

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Methods for Wireless and Mobile Networks

- Fast retransmit and fast recovery
- Selective acknowledgement
- Explicit congestion notification

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TCP-aware link-layer methods for Wireless and Mobile Networks

- The three TCP-aware link layer protocols — snooping TCP, WTCP, and delayed duplicate acknowledgement protocol
- Snooping— secretly looking into or examining something
- The data-link layer snoops into the TCP layer data

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Link-layer (L2) modification methods for Wireless and Mobile Networks

- Data-link layer in the mobile nodes (MNs) FEC and ARQ methods (in place of methods like L4 TCP window sliding method) for error control
- FEC: FEC code lengths and frame sizes can be varied depending on the bit error rate (BER)

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Link-layer (L2) modification methods for Wireless and Mobile Networks

- ARQ (automatic repeat request): When errors are detected, a repeat request is generated
- The throughput is not affected in case there are no errors
- However, in case of errors, the throughput, round trip time (RTT), and congestion in the network affected due to repeated retransmission of data streams

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Link-layer (L2) modification methods for Wireless and Mobile Networks

- When using adaptive techniques, retransmission can be limited and can be varied depending on the bit error rate (BER)
- For example, in voice communication, a certain BER is tolerable
- Hence, retransmission can be skipped

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Summary

- Data flow
- Window size adjustment
- Cumulative partial acknowledgement
- Reverse packet acknowledgement
- Delayed acknowledgement
- Adjusting window size field
- window scaling method
- Sliding window method

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…Summary

- Slow start and slow-start fast-recovery
- Wireless and mobile network methods
- Split TCP methods for congestion control in wireless and mobile networks
- TCP aware link layer methods
- Link layer modification methods
- Explicit notification methods

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End of Lesson 03
TCP Data flow control and Congestion control

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Mobile Transport Layer

Lesson 04

Slow start and Fast Recovery Methods for congestion control in conventional networks

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Slow start method for conventional networks

- The entails starting from a very small window
- Increasing the window size exponentially up to a threshold value
- Then linearly till congestion sets in
- Once congestion sets in, the window slow starts again with the new threshold value set to one half of the window size at congestion

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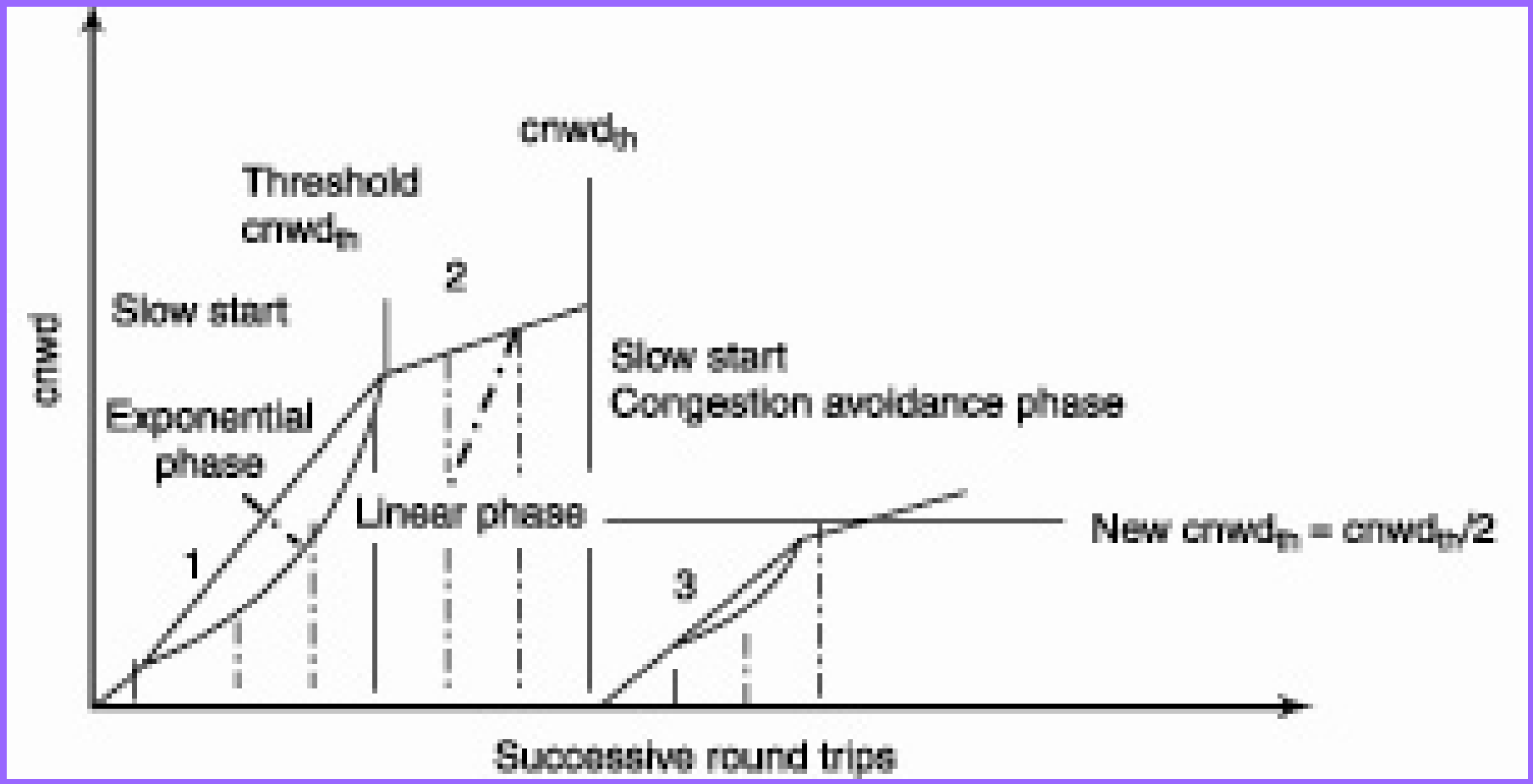
Window sizes on successive round trips in four phases of the slow start method



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First exponential growth phase– slow start phase

- Congestion network window size (cnwd) is equal to 1 at the start of a new data stream
- After each RTT (after which the acknowledgement field is used to send the next data stream), for each subsequent stream, the window is doubled till a window threshold is reached
- Now, cnwd = cnwd $\times$ 2 when 1 $\times$ cnwd $\leq$ $cnwd_{th}$, where $cnwd_{th}$ is threshold window

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Second linear growth phase—congestion avoidance phase

- After cnwd = $cnwd_{th}$ the linear growth starts
- Control further exponential growth in order to avoid congestion

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Example

- Assume RTT_0 (RTT when cndw =1)
- Assume the exponential phase consists of up to the 10th round trip
- So $cnwd_{th} = 2^9$
- The number of segments transmitted 1 + 2 + 4 +… + 256 + 512 = 1023
- At 11^{th} RTT cndw = 513
- At 12^{th} RTT cndw = 514
- Timeout for 12^{th} RTT = $518 \times RTT_0$

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Third phase– Congestion avoidance phase

- Starts after linear growth causes congestion and cndw = $cnwd_{cntrl}$, and this congestion needs to be controlled by two actions

(i) resetting cnwd to cnwd ÷ cnwd = 1

(ii) Reducing $cndw_{th}$ = $cnwd_{cntrl}$ ÷ 2 or 2 (which ever is more) after the timeout period of the last trip indicating congestion

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Third phase– Congestion avoidance phase

- In the congestion avoidance phase, the exponential phase (slow start phase) step starts again

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Fourth linear phase— after new threshold

- After cndw reaches the new cndwth, the linear phase starts

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Fifth phase

- Actions similar to one at third phase recurs at fifth phase (cndw = 1 and new $cndw_{th}$ = new $cndw_{cntrl} \div 2$

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Example

- Assume that cnwd at the start of congestion phase in the 17th RTT
- $cndw_{cntrl}$ sets $cnwd_{th}$ to 518/2
- New $cnwd_{th}$ = 259
- 18th RTT, cnwd = 1
- 19th, cnwd = 2, and so on till cnwd becomes 256 in 26th RTT since $cnwd_{th}$ = 259

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Example

- 27th RTT, cndw = cnwdth = 259
- During the slow start phase, 1 ≥ cnwd ≥ new $cnwd_{th}$
- During the linear phase cnwd will be incremented by 1 after each RTT, starting from the 28th RTT

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Fast Recovery

- First phase: Slow start exponential from cnwd = 1and cndw = cndw $\times$ 2 after each RTT
- Second phase: Slow start linear after cndw = $cndw_{th}$ and cndw = cndw +1 till = $cndw_{ca}$
- Third phase: Timeout

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Fast Recovery Phase– Modification of slow start third phase

- Third phase and fourth now differ
- Between third congestion avoidance phase earlier and linear second phase, in place of exponential phase, a timeout region added with constant and = $cndw_{ca}$
- Lost packet retrieves during timeout
- Further cndw does not restart from 1 as earlier but from $cndw_{th} \div 2$

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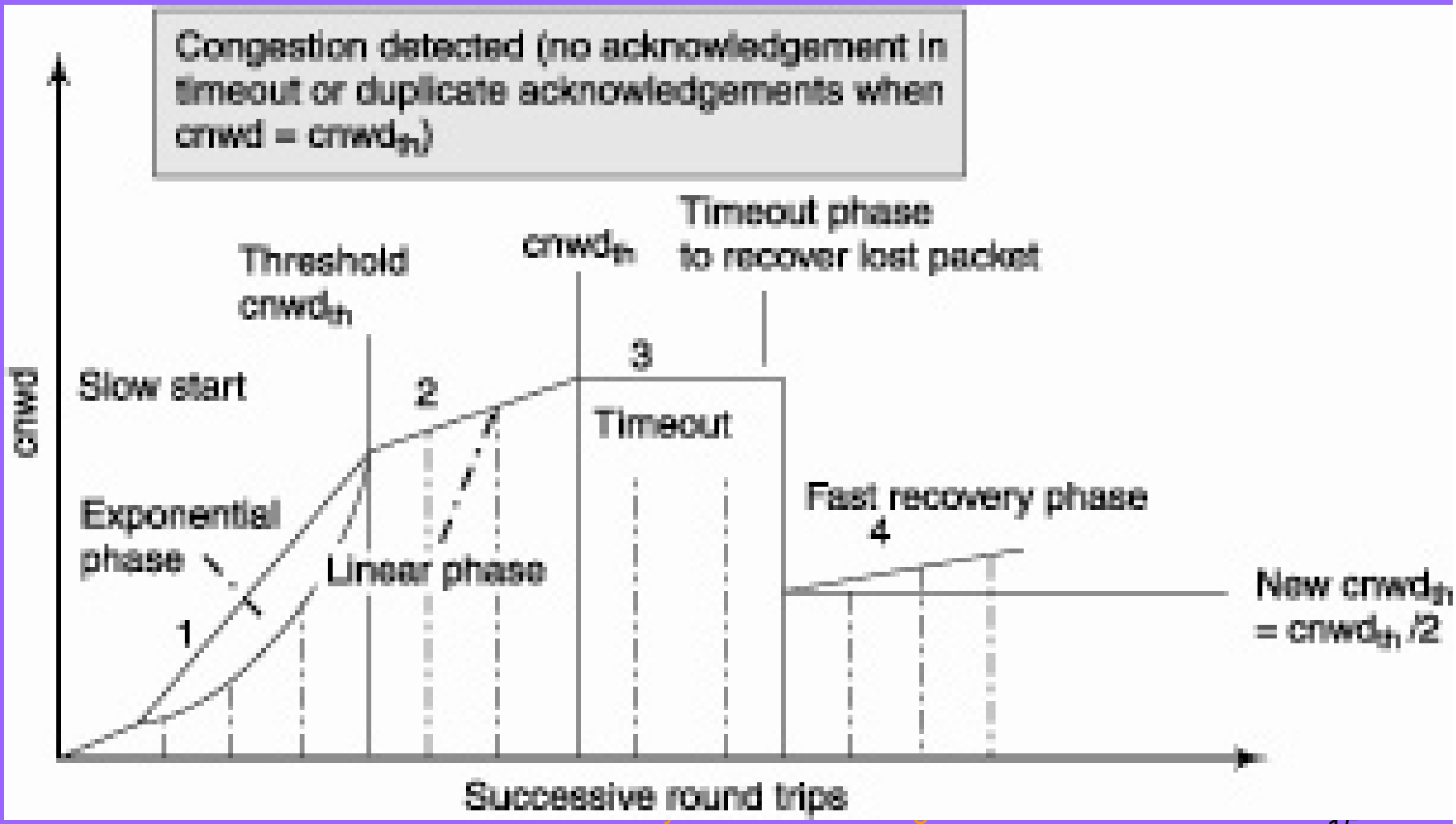
Modification of slow start by fast recovery congestion avoidance phase after a timeout



Example

- Assume that cnwd at the start of congestion avoidance phase in the 17th RTT
- $cndw_{ca}$ sets $cnwd_{th}$ to 518/2
- New $cnwd_{th}$ = 259
- 18th RTT, cnwd = $cndw_{ca}$ till a timeout period
- After timeout in 26th RTT since $cnwd_{th}$ = 259; new cndw = 259

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Example

- 27th RTT, cndw = cnwdth = 259
- During the linear phase cnwd will be incremented by 1 after each RTT, starting from the 28th RTT till cndw = $cndw_{ca}$ = 518 or till congestion starts

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Summary

- Slow-start and Slow-start fast-recovery methods
- First phase and third phase in Slow-start method cndw start from 1, doubles in each RTT till threshold
- Third phase in slow-start fast-recovery method differ cndw is constant for a timeout period and = $cndw_{ca}$

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…Summary

- Fourth phase in slow-start fast-recovery method same as fourth phase in slow start, cndw starts from new threshold $cndw_{ca} \div 2$ and after each RTT change linearly till $cndw_{ca}$

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End of Lesson 04

Slow start and Fast Recovery Methods for congestion control in conventional networks

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Mobile Transport Layer

Lesson 05

Indirect TCP, selective repeat and mobile-end transport protocols

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Indirect TCP suggests splitting of the TCP layer into two TCP sub-layers

1. TCP_M connection— between the mobile node (MN) and the base transceiver (BTS) and between the BTS and a fixed node (FN)
2. TCP connection— Fixed nodes (FN)

- The BTS has an access point at an agent TCP_M for TCP connection
- TCP_M sends and receives the packets to and from the MN through the BTS

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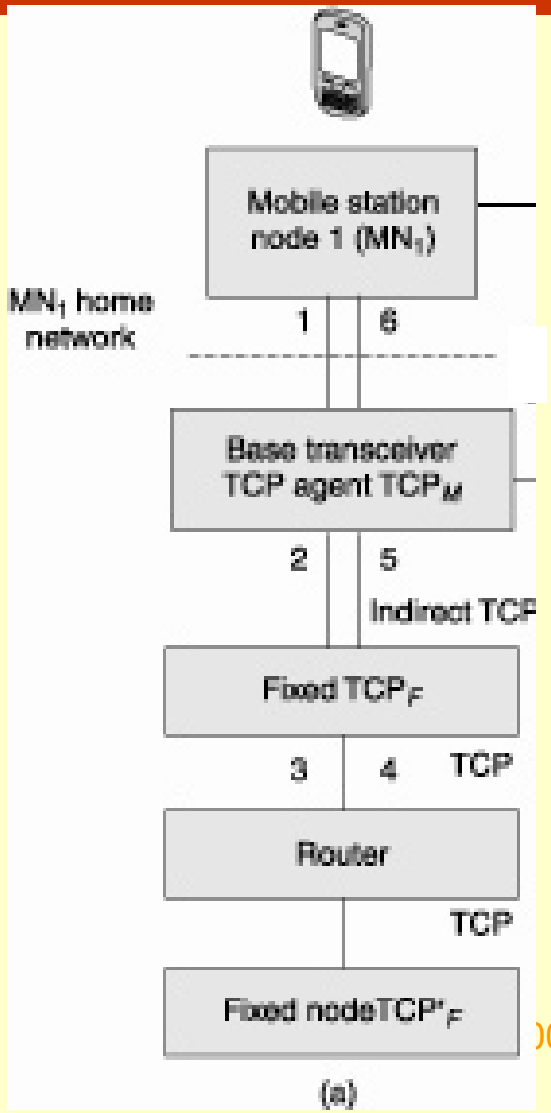
Indirect TCP sub-layer between BTS and fixed node and conventional TCP between fixed nodes



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Indirect TCP functions

1. TCP_M sends and receives the packets to and from the TCP_F layer at the fixed node
- The transfer mechanism simple as there only one hop
- Retransmission delay between TCP_M to TCP_F very small, unlike that between the fixed nodes

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TCP_M functioning

- The data streams received from the service access point (application) at the MN and buffered at TCP_M

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Indirect TCP functions

2. TCP_F layer at the fixed node sends and receives the packets to and from another fixed node TCP'_F

- TCP_F to TCP'_F transfer mechanism using multiple hops through the routers

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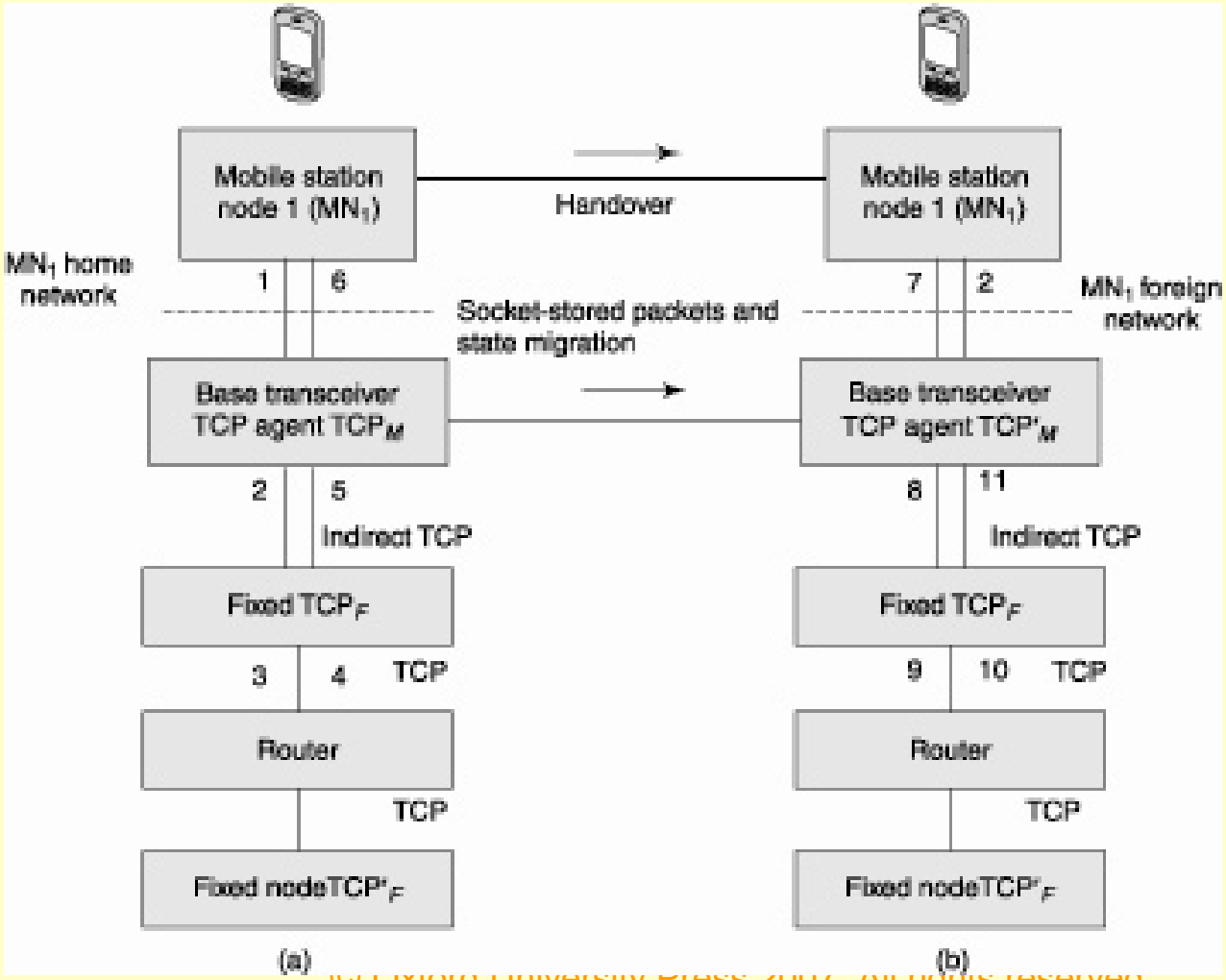
Handover mechanism in case of indirect TCP



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Handover mechanism when the MN visits a foreign network

- Packets for transmission buffered at TCP_M are transferred to TCP'_M
- On handover, the socket (port and IP address) and its present state migrate from TCP_M to TCP'_M
- The transfer from TCP_M to TCP'_M latency period

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Advantage of indirect TCP

- Mobile part of the network isolated from the conventional
- No change required in the existing TCP network

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Disadvantages of indirect TCP

- High latency period during handover of packets
- Possible loss of data at the base
- Deviation from the end-to-end connection feature of conventional TCP, which guarantees reliable packet delivery
- Deviation– an acknowledgement to a sender may be lost during handover latency

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Selective Repeat Protocol

- Modification of the indirect TCP
- Between TCP_M at the BTS and MN selective repetition of the data using UDP
- Between TCP_M at one end and TCP'_F and TCP'_M at the other end, the data stream transferred, as in case of conventional fixed-end TCP

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Use of UDP in Selective Repeat Protocol

- UDP— a connectionless protocol
- Selective repeat protocol does not guarantee the in-order delivery between the BTS and the MN, unlike TCP

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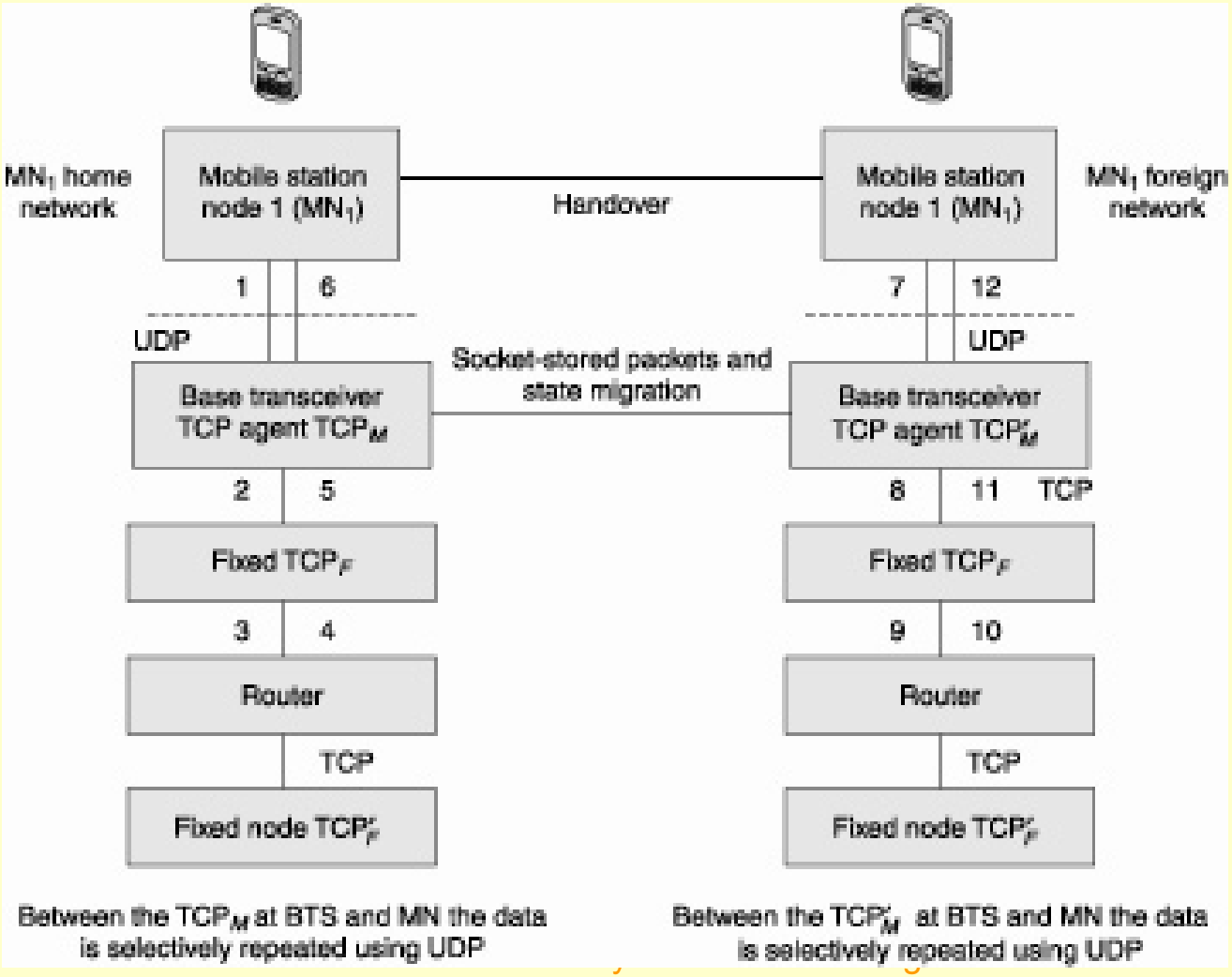
Modification in indirect TCP in selective repeat protocol using the UDP between BTS and MN



Mobile-end transport protocol— Modification of indirect TCP

- Guarantees the in-order delivery between the BTS and the MN, like TCP
- Data transferred between TCP_M at the BTS and the MN by using the mobile-end transport protocol
- Data stream transferred between TCP_M at one end and TCP_F and TCP_M at the other end, the, as in case of conventional fixed end TCP

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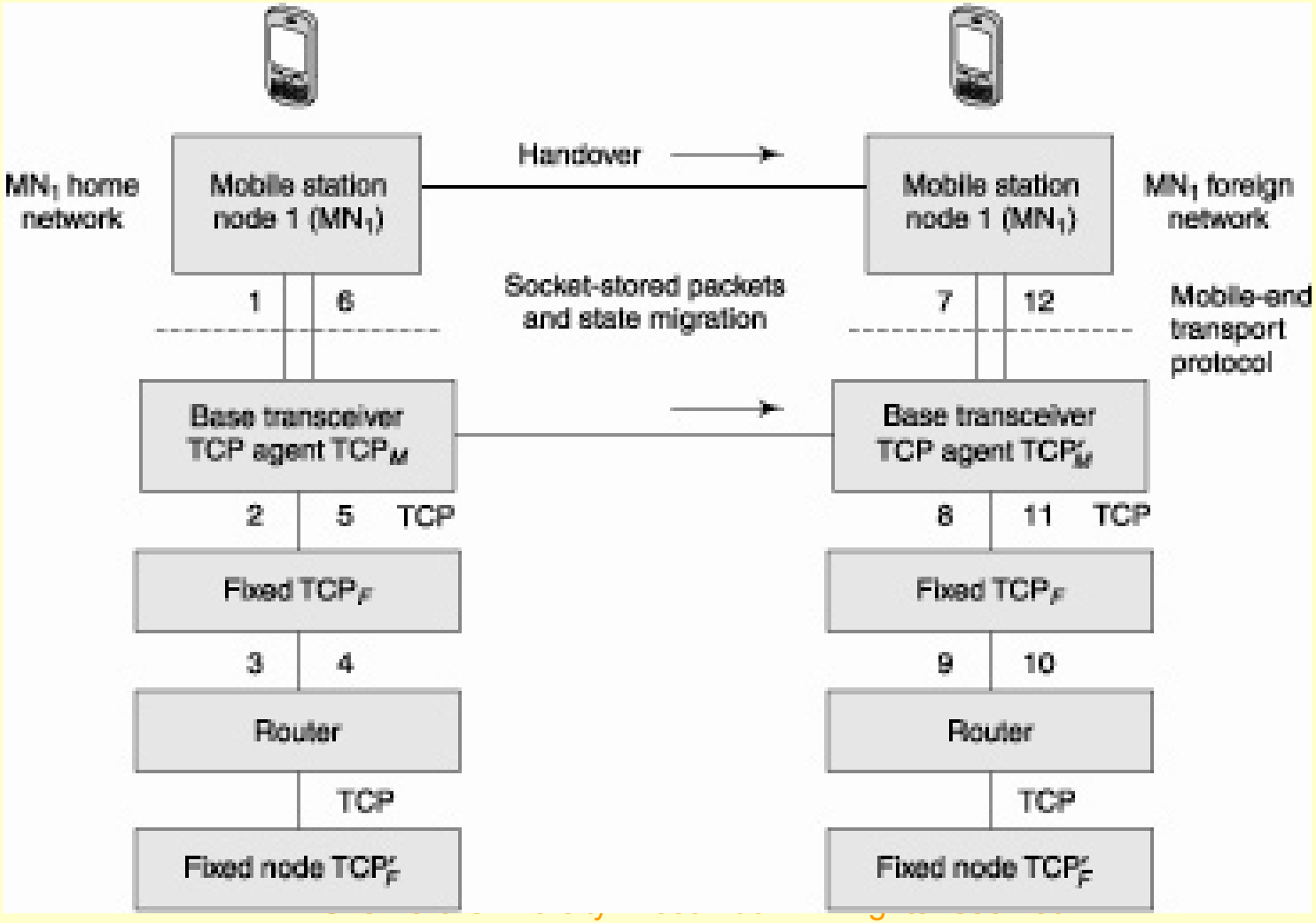
Modification in indirect TCP by using mobile-end transport protocol



Summary

- Split TCP protocol
- TCP_M sends and receives the packets to and from the TCP_F layer at the fixed node and between fixed points on conventional network by TCP
- Selective repeat Protocol use (i) UDP between MN and BTS, (ii) TCP_M between BTS and fixed node and (iii) TCP between fixed node …

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… Summary

- A TCP agent in Mobile-end transport protocol in place of TCP_M or UDP between MN and BTS

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End of Lesson 05

Indirect TCP, selective repeat and mobile-end transport protocols

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Mobile Transport Layer

Lesson 07

Snooping TCP, Wireless TCP and Delayed DACK Protocol

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TCP-aware link layer based methods

- Snoop TCP
- WirelessTCP (WTCP)
- Delayed Duplicate Acknowledgement protocol (Delayed DACK)

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Snoop

- Looking into or examining something secretly
- A TCP connection splits into two—between the mobile node (MN) and base transceiver (BTS) and other between the BTS and the fixed node (FN)

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Snoop

- Some changes in the BTS and some at the MN
- The BTS has a TCP-aware data-link sub-layer, DL_M
- The sub-layer DL_M — agent for snooping and buffering the TCP connection

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Role of the Agent DL_M

- Ensures the delivery of packets to the MN in their incoming sequence from the fixed network
- Attends to request from the MN for retransmission

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Role of the Agent DL_M

- Buffers during snooping packets from the fixed connection TCP_F layer for transmission to the MN on wireless
- Also buffers the packets on wireless from MN for transmitting to TCP_F layer by a fixed line

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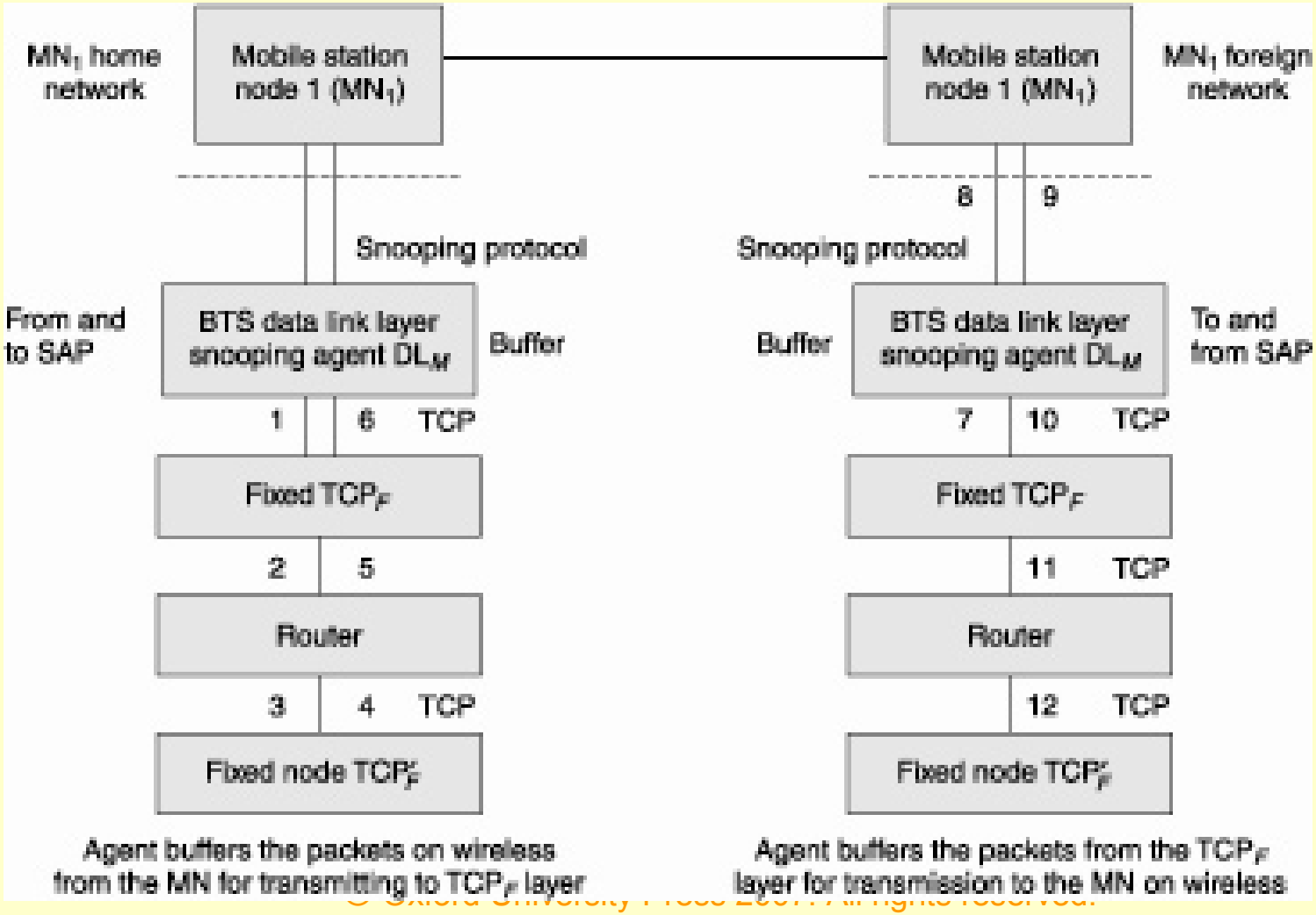
Snooping at the TCP-aware data-link sub-layer DL_M added at the BTS



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Method for acknowledgements to and from the MN

- Acknowledgements at agent detected on timeouts or duplicated acknowledgements detected from the MN

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Alternate method for acknowledgement to and from the MN

- Acknowledgements at the MN detected by negative acknowledgement
- A request for retransmission is conveyed to the MN, in case the packets are not received (lost) through the wireless network

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The method for acknowledgements to and from the MN

- Using snooping, the agent takes note of the acknowledgements from the MN and requests the MN for retransmission by sending a negative acknowledgement

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Snooping TCP functioning

1. Data streams are received from the service access point (application) at the MN and buffered at the agent

   The data streams sent to the service access point (application) at the MN are buffered at the agent and then sent to the MN

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Snooping TCP functioning

2. DL_M agent at the BTS also buffers the data and sends and receives the packets to and from the TCP_F layer at the fixed node

Transparent connection between the agent and TCP_F

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Snooping TCP functioning

- DL_M layer agent at the BTS sends and receives the packets to and from TCP_F and then from another fixed node TCP'_F by multiple hops through the routers

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Snooping TCP functioning

3. DLM agent at the BTS snoops into the packets (data stream) when sending and receiving to and from the MN

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Snooping TCP functioning

4. The agent and MN control the acknowledgements, lack of acknowledgements, and DACKs of the received data stream from the MN and to the agent, respectively

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Snooping TCP functioning

5. Packet loss discovered at the agent from the timeout or DACKs from the MN

The DL_M retransmits if needed to the MN in case of lost packets that are not acknowledged by the MN in the timeout period or if there are DACKs

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Snooping TCP functioning

Packet loss discovered at the MN from the retransmission request from the agent to the MN

The MN retransmits to DL_M in case of lost packets for which a negative acknowledgement is sent by DL_M

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Snooping TCP functioning

6. The buffer empties to the fixed network through TCP_F on receipt of an acknowledgement at the agent from the MN

   The buffer empties to the MN on receipt of acknowledgement at the agent from the MN

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Snooping TCP functioning

7. The data stream transfer mechanism between the MN and DL_M simple, as in wireless networks

Only one hop. In retransmission from DL_M to MN

The delay is very small, unlike that between the fixed nodes

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Handover of the MN while visiting a foreign network

- The packets for transmission now snooped into at DL'_M at the other end
- On handover, neither the socket (port and IP address) nor its present state migrates from DL_M to DL'_M

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Advantage of snooping TCP

- Transparent end-to-end TCP connection (without any transport layer changes)
- The mobile part of the network between the base and the mobile node has very limited isolation and is completely isolated from the base and the conventional fixed TCP connection

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Advantage of snooping TCP

- No change in the existing TCP network, only a snooping sub-layer is added at the base

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Disadvantages of snooping TCP

- Security risk involved in snooping
- Difficulties in case of encrypted segment transmission
- Insufficient isolation between the fixed node transport layer and the snooping layer in case of an asymmetric path

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Asymmetric path

- A fixed node connecting to the mobile node at the other end
- The node at the other end does not have a snooping layer for retransmission and acknowledgement

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Wireless TCP

- A modification of snooping TCP
- WCTP modifies the time stamp on the packets while returning acknowledgements to compensate for the increased RTT

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Advantage of WTCP

- Modifying Timeout periods by enhancing timestamp time compensating for the increased RTT between the agent at the base and the mobile node
- Useful when retransmission intervals are greater than the timeout period

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Disadvantage of WTCP

- Can not be used on shared LANs

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Delayed DACK protocol for delayed congestion response (TCP-DCR)

- DL_M agent is not TCP aware
- The difference between TCP aware and unaware—Retransmission takes place in TCP-aware DL_M, whenever there is timeout or DACK
- Both of these indicate loss of packets

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Delayed DACK protocol for delayed congestion response (DCR)

- When a packet reaches the receiver out of order (TCP connection, for example the TCP layer in the mobile node) sends the DACK
- Further, the window is adjusted to a lower level for each instance of detection of packet loss, whether due to timeout or DACK

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TCP unaware DL_M

- Packet losses are due to two reasons, congestion and channel transmission errors
- The channel errors are due to interference in the medium
- Retransmission from the DL_M takes place when there is timeout or acknowledgement from the MN, but the MN delays the DACKs so that the channel can recover from the channel errors

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TCP unaware DL_M

- Retransmission from the DL_M takes place when there is timeout or acknowledgement from the MN, but the MN delays the DACKs so that the channel can recover from the channel errors

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TCP unaware DL_M

- The MN attempts to reduce interference between data stream bits of the MN and retransmitted bits from DL_M
- Delays the third and subsequent DACKs by a time interval T_{da}

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TCP unaware DL_M

- When the first consecutive out of order packets (COP) reach, the MN responds by a DACK
- When further consecutive out of order packets reach, each DACK is delayed by a period = T_{da}

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TCP unaware DL_M

- The MN no longer needs to send delayed DACKs if the next packet is in sequence within T_{da}— the channel has recovered from channel errors
- During T_{da}, the DL_M-MN channel recovers from channel errors

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TCP unaware DL_M

- The MN may permit out-of-order packet delivery from the agent and it may also look into the TCP header and reassemble the packets itself in order of sequence
- Between DL_M at one end and TCP_F and TCP'_F at the other, the data stream transfers, as in case of conventional fixed-end TCP

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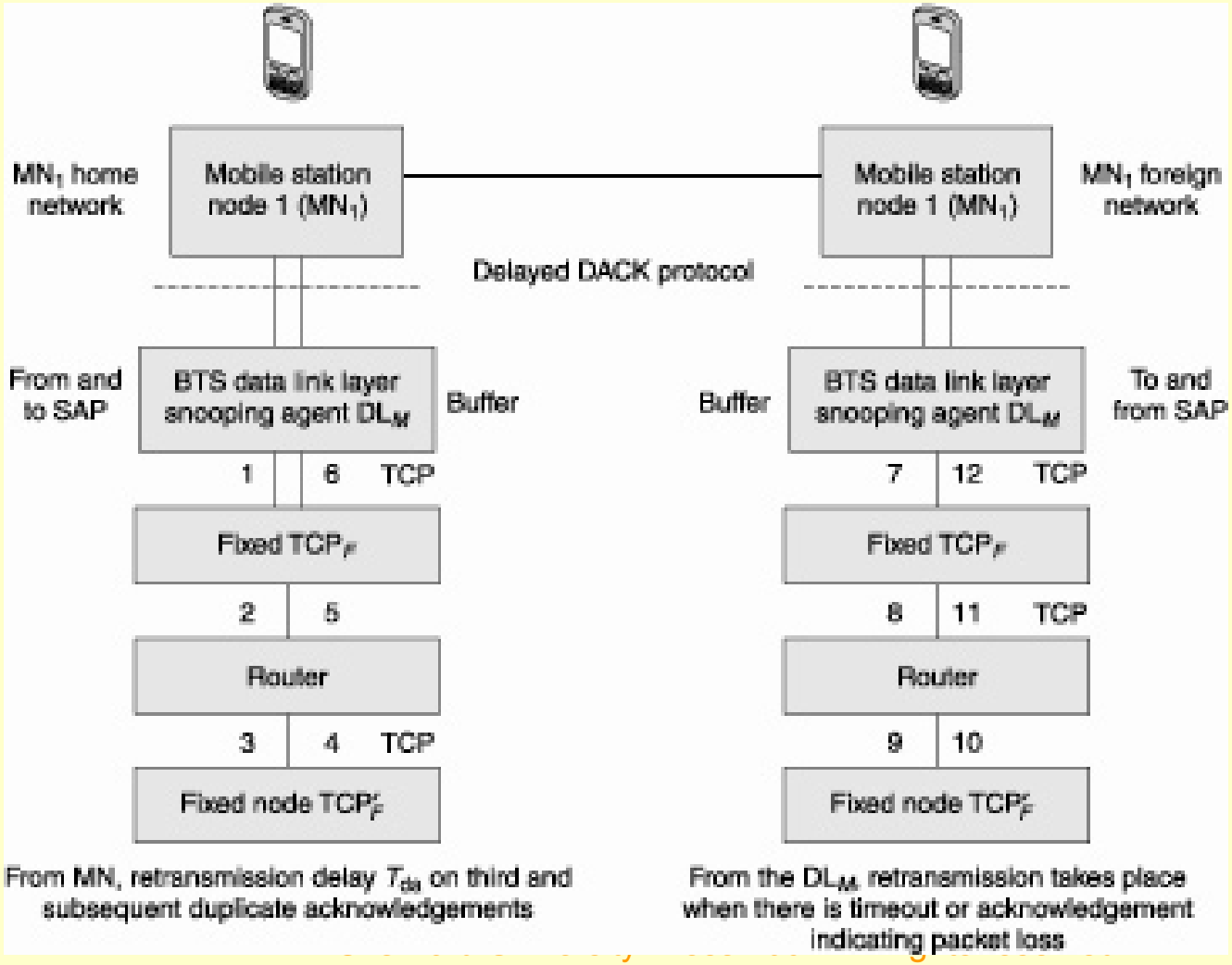
Delayed duplicate acknowledgements protocol, a modification in snooping TCP



Advantage of DelayedACK protocol

- TCP headers can be encrypted, as the agent is not TCP aware

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Disadvantage of DelayedACK protocol

- Duplicate ACKs are delayed, the retransmission of the packets lost due to congestion also delayed

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Summary

- TCP-aware data-link sub-layer, DL_M in TCP snooping
- Agent snooping and buffering the TCP connection
- Agent ensures the delivery of packets to the MN in their incoming sequence from the fixed network
- Attends to request from the MN for retransmission …

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… Summary

- Wireless TCP modifies timestamp on packet for return ACK to compensate for increased RTT— retransmission delayed to enable recovery of lossed packet
- TCP unaware agent Delayed ACKs— retransmission delayed for a timeout to enable recovery of lossed packet

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End of Lesson 07

Snooping TCP, Wireless TCP and Delayed DACK Protocol

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Mobile Transport Layer

Lesson 08

Fast Retransmission and Fast Recovery (FRFR) Method

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Fast Retransmit/Fast Recovery Transmission

- Slow start method presumes that congestion is the only reason for packet loss
- In wireless networks — disconnection, handover, and channel errors due to interference causes congestion

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Need of Fast Recovery

- When a mobile node (MN) moves from the home network to a foreign network, there is a lack of acknowledgement from the other end
- The handover phase lack of acknowledgement is natural

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Fast Recovery

- cnwd can be set to cnwd÷2 and should recover fast to the value at which packet loss was detected
- Method to recover cndw back called fast retransmit/fast recovery (FRR)

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Four phases of fast retransmit and fast recovery method

1. Exponential
2. Fast retransmit/recovery phase 1 (FRR1) on three duplicate-acknowledgements
3. fast retransmit/fast recovery phase 2 (FRR2)
4. Wait (constant timeout and window size)

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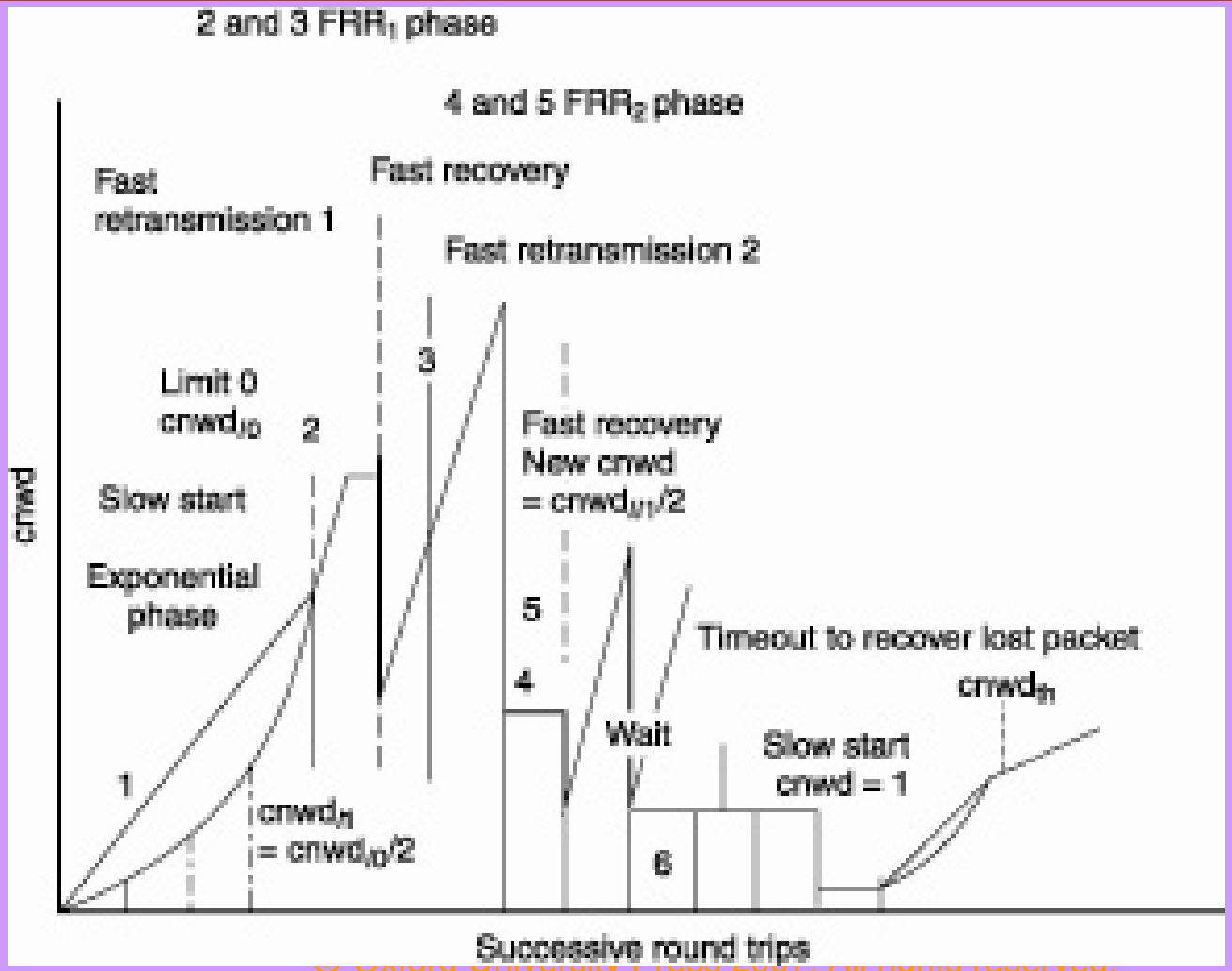
Four phases of fast retransmit and fast recovery method



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First phase— beginning (exponential growth phase)

- Regions 1 and 2
- The congestion window size for new data stream, cnwd is equal to 1 at the beginning
- After each RTT (after which the acknowledgement field is used to send the next data stream) the window is doubled till there are three DACKs within the set timeout interval

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Example

- Let us assume that cnwd reaches a limit $cnwd_{I0}$
- cnwd = cnwd $\times$ 2 for 1 $\leq$ cnwd $\leq$ $cnwd_{I0}$, where $cnwd_{I0}$ is the window at the limit 0, after which the FRR1 phase starts

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Example

- The threshold is defined to control further exponential growth in order to avoid congestion. For example, let us assume that the exponential phase consists of up to the 11th round trip at which the there are three DACKs detected within the timeout interval

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Example

- Therefore, the limit 0 window $cnwd_{/0} = 2^{10}$ and the number of segments transmitted = 1 + 2 + 4 +… + 512 + 1024 = 2047
- FRR1 phase sets in after the 11th round trip

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Second phase– FRR1 (fast retransmit/fast recovery phase 1)

- Boundary of regions 2 and 3
- Forced by the MN on handover registration, by sending a set of three DACKs
- The window size for the new data stream, $cnwd_{/1} = cnwd_{/0} \div 2$
- Retransmission is fast because the link throughput is the same but the window size is now halved

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Fast recovery region in FRR1

- Region 3
- In the subsequent streams cnwd = cnwd $\times$ 2 for $cnwd_{I0} \leq cnwd \leq cnwd_{th}$, where $cnwd_{th}$ the limit of increments in window size for the recovery of lost packet(s)
- This happens when the data stream results in PACK (partial acknowledgement) and, therefore, to recover the lost packets, the window is inflated in this region

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Subsequent fast retransmissions

- A set of three DACKs starts another fast retransmission

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Example

- Assume that the exponential phase terminates at the 11th round trip
- FRR1 phase starts at the 12th round trip
- Now, if a lost packet is recovered in partial acknowledgement at the 13th round trip, then three duplicate acknowledgements are signalled in the 14th round trip as there are three DACKs in the 14th RTT period

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Example

- Window size in 12th round trip is 2048 ÷ 2 = 1024 and in the 13th round trip it is 2048
- Timeout set in the 12th trip = 1024 RTT0
- Timeout set in the 13th trip = 2048
- The number of segments transmitted from the beginning up to the 14th round trip = 1 + 2 + 4 + … + 256 + 1024 +0 + 1024 + 2048 = 5199

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Example

- As the lost packet is recovered the window size is no longer incremented and RTT remains at 2048 $\times$ RTT0, where RTT0 is the time when cnwd = 1
- Timeout set in the 14th trip = 2048 and in that there are three DACKs, hence FRR1 ends at the 14th trip and FRR2 phase starts at the 15th trip

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Third phase FRR2 (fast retransmit/fast recovery phase 2

- The cnwd remains constant (region 4)
- Equals cnwd/1 = $cnwd_{/0} \div 2$ before the beginning of FRR2
- After this occurs the fast recovery (region 5)

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Repeated successions of regions 4 and 5

- Due to additional FRRs
- Three DACKs at any time in FRR2 will trigger another FRR_j
- j = 3 in case it is only one additional FRR
- j = 3 the for first additional FRR
- j = 4 for the second additional FRR

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Fourth phase wait/constant window-size phase after the FRRs

- Region 6
- the cnwd at the start of FRR2 in the 15th round trip is set to 2048 ÷ 2
- Therefore, cnwd = 1024
- In the 16th round trip, cnwd = 1024 ÷ 2 = 512 for fast retransmission 2
- In the 17th round trip cnwd becomes 1024

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Fourth phase wait/constant window-size phase after the FRRs

- In the 18th, cnwd becomes 2048 in the fast recovery phase
- However, in the 18th round trip, there is a lost packet recovery as a result of retransmission after a PACK
- Hence the constant window size 512 sets in and the wait phase sets in with cnwd = 512

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Fourth phase wait/constant window-size phase

- Window size for the new data stream, $cnwd = cnwd_{/1} \div 2$
- Window size remains constant in order to recover lost packets
- In subsequent streams, cnwd remains at $cnwd_{/1} \div 2$
- If there is a missing acknowledgement and consecutive DACKs, the slow start phase sets in

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Fourth phase wait/constant window-size phase

- If there are three DACKs, again the FRR*i* phase sets in. considering the case discussed in the previous example, cnwd at the start of the constant window-size/wait phase in the 19th round trip is set to 512
- $cnwdwait = cnwd_{I1} \div 2 = 512$

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Fourth phase wait/constant window-size phase

- In the 20th to 24th trips, cnwd remains at 512
- Any lost packet is recovered and if a DACK is found in the 25th trip, then the slow start phase starts again on finding consecutive DACKs
- If three DACKs received in antenna RTT, then FRR_i starts once again

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Advantage of fast retransmit/fast recovery method

- Efficient in a mobile network when there are disconnections and handovers

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Disadvantage of fast retransmit/fast recovery method

- Wireless part TCP mixes with that of the fixed network and is not sufficiently isolated
- The fast retransmitted packets can force congestion and not reach the destination over the fixed network part

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Summary

- Fast transmission fast recovery windowsize can be set to windowsize÷ 2 and recoverd fast to the value at which packet loss was detected

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…Summary

- Four phases Six regions: Exponential, Fast retransmit/recovery phase 1 (FRR1) on three duplicate-acknowledgements, fast retransmit/fast recovery phase 2 (FRR2) and Wait (constant timeout and window size)

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End of Lesson 08

Fast Retransmission and Fast Recovery Method

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Mobile Transport Layer

Lesson 10

Timeout Freezing, Selective Retransmission, Transaction Oriented TCP and Explicit Notification Methods

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Timeout freezing of transmission (TFT)

- Used in situations where the mobile node (MN) faces long durations of disconnection

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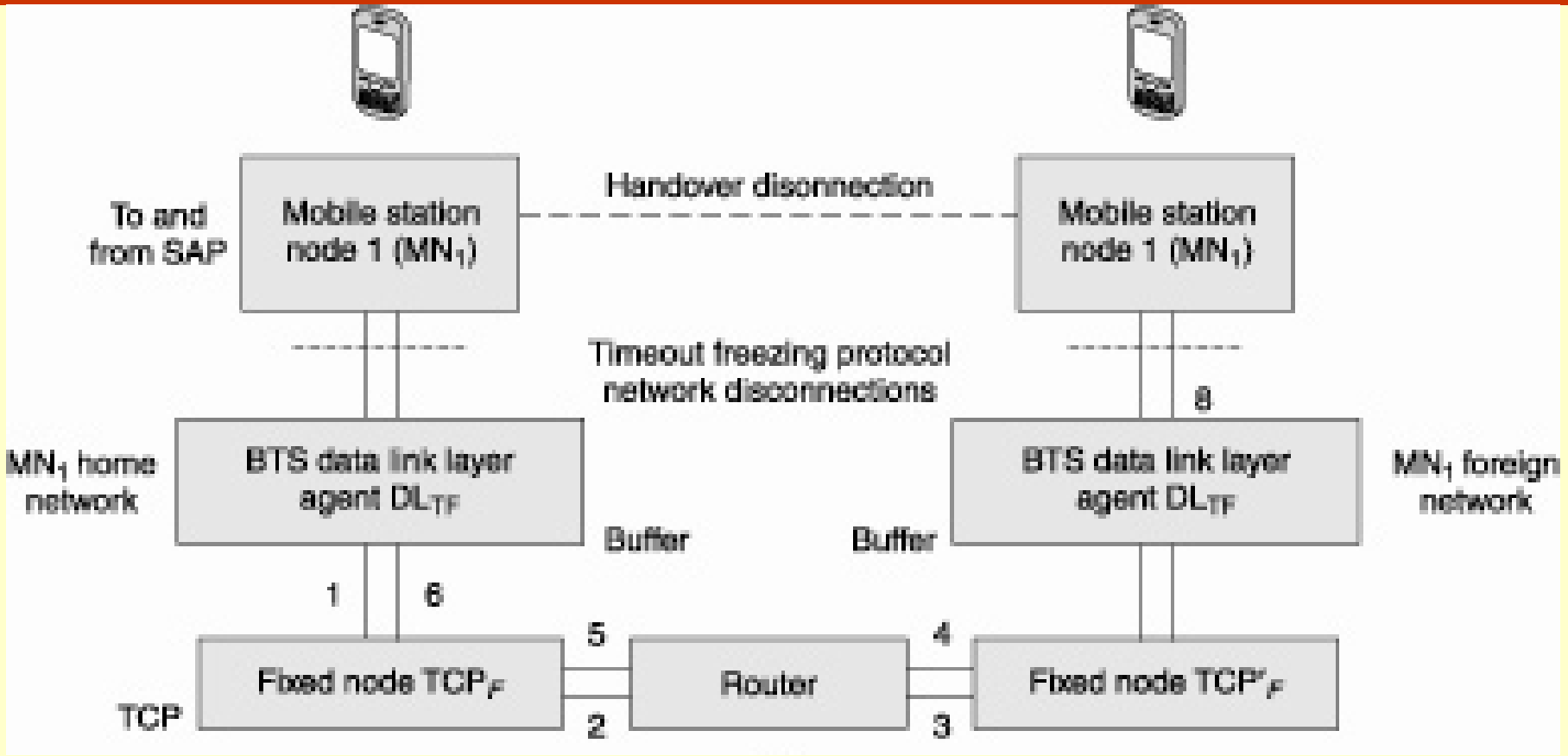
TFT



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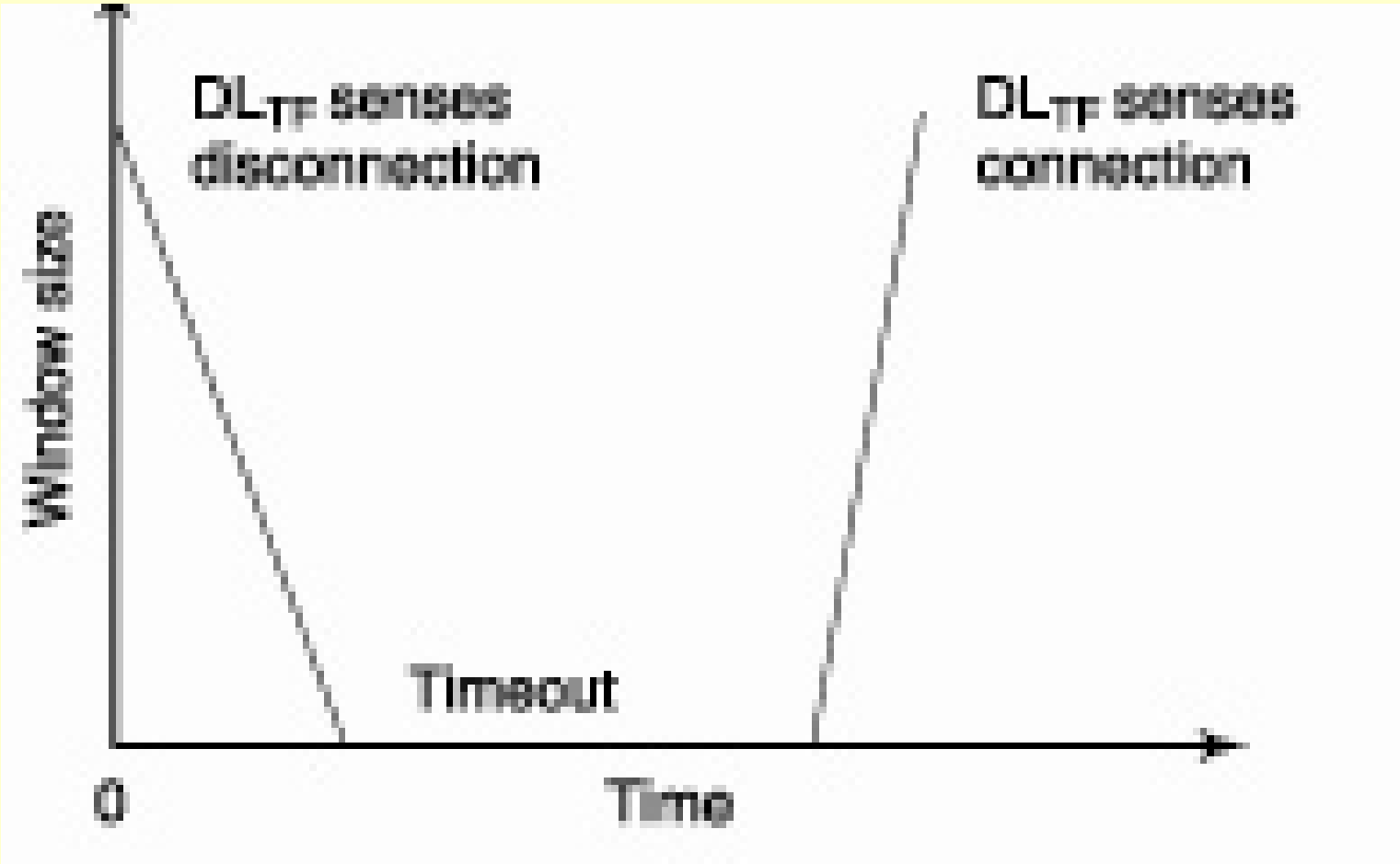
TCP connection timeout freezing



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Timeout freezing transmission functions

1. Agent DL_{TF} senses at data-link layer (MAC) the disconnection a little earlier than the TCP layer at the MN

- The TCP layer stops sending packets when disconnection is sensed by the DL_{TF}
- TCP layer presumes some congestion and, therefore, after a timeout the TCP layer freezes completely

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Timeout freezing transmission functions

- During the timeout period the MN may get some data sequences. After timeout, the TCP transmission freezes

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Timeout freezing transmission functions

2. The TCP SYN and ACK data streams can still be received and transmitted through the lower layer with a suitable encoding by the header

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Timeout freezing transmission functions

3. When the DL_{TF} agent senses the establishment of connection, it activates the TCP transmission

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Advantage of timeout freezing

- Long interruptions of mobile node are accounted for and are independent of the data stream contents

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Disadvantage of TFT

- Mobile node data-link layer needs to be modified by adding an agent to sense the loss and gain of connection and for making changes in the TCP layer at the mobile node to enable listening to the data-link layer agent

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Selective Retransmission

- Acknowledgement field value in the data stream received from TCP_B by a TCP layer transmitter TCP_A gives the next sequence number (byte number), which is expected by TCP_B
- Assume that the field value is $m + 1$

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Selective Retransmission

- Consider the sliding window protocol
- If any packet is lost in transit before the sequence *m*, then all the sequences defined by the sliding window have to be retransmitted in conventional TCP

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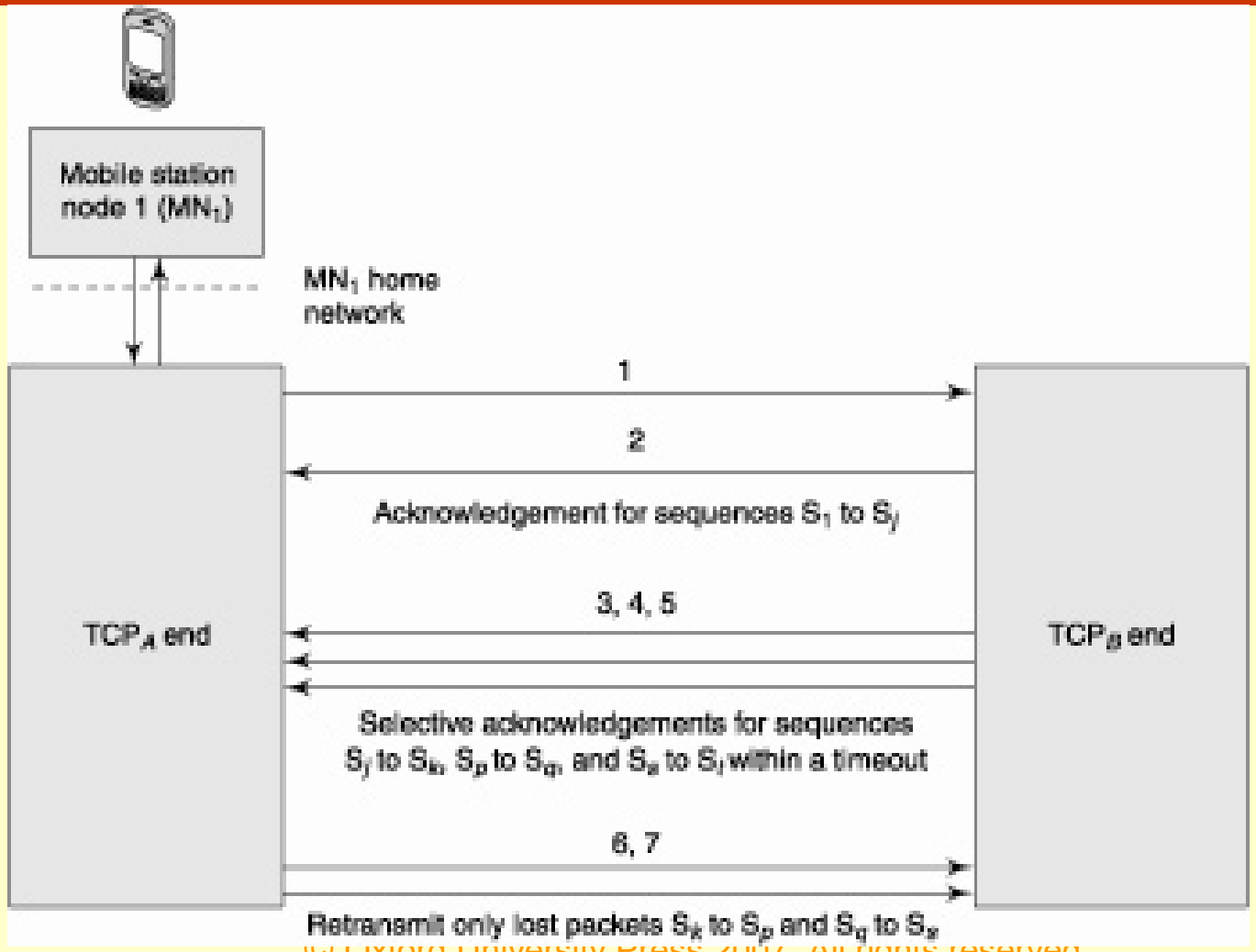
Selective retransmission protocol



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Selective retransmission protocol

- Provides for an additional acknowledgement, selective acknowledgement (SACK)
- A timeout is set at the TCP_A end for receiving SACKs

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Selective retransmission protocol

- Assume that an acknowledgement is sent for sequences S_1 to S_j as no packet is lost in-between
- Assume that there are SACKs only for sequences S_j to S_k, S_p to S_q, S_s to S_t during a preset timeout

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Selective retransmission protocol

- Only the lost packet corresponding to a SACK needs to be retransmitted
- TCP_A end retransmits only the lost packets, i.e., S_k to S_p and S_q to S_s
- After the timeout, the TCP_A end ignores the received but unused SACK information

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Advantage of selective retransmission

- Very efficient as only the lost bytes from a sequence number are retransmitted

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Disadvantage of selective retransmission

- Receiver has to maintain the memory space till the missing packets have reached and are sequentially rearranged for packet delivery to the application layer

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TCP protocol (TCP) Packet delivery

- Takes place after the SYN and SYN_ACK packet exchanges for Connection establishment
- Connection closes after the packet exchanges of FIN and FIN_ACK, CLOSING, and LAST_ACK

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Transactions Oriented TCP (T-TCP)

- Combines the three functions—connection-establishment, data transfer, and connection finish (close) for TCP data delivery
- Only two or three packets are required for these functions
- Used in situations where short messages need to be sent in sequence

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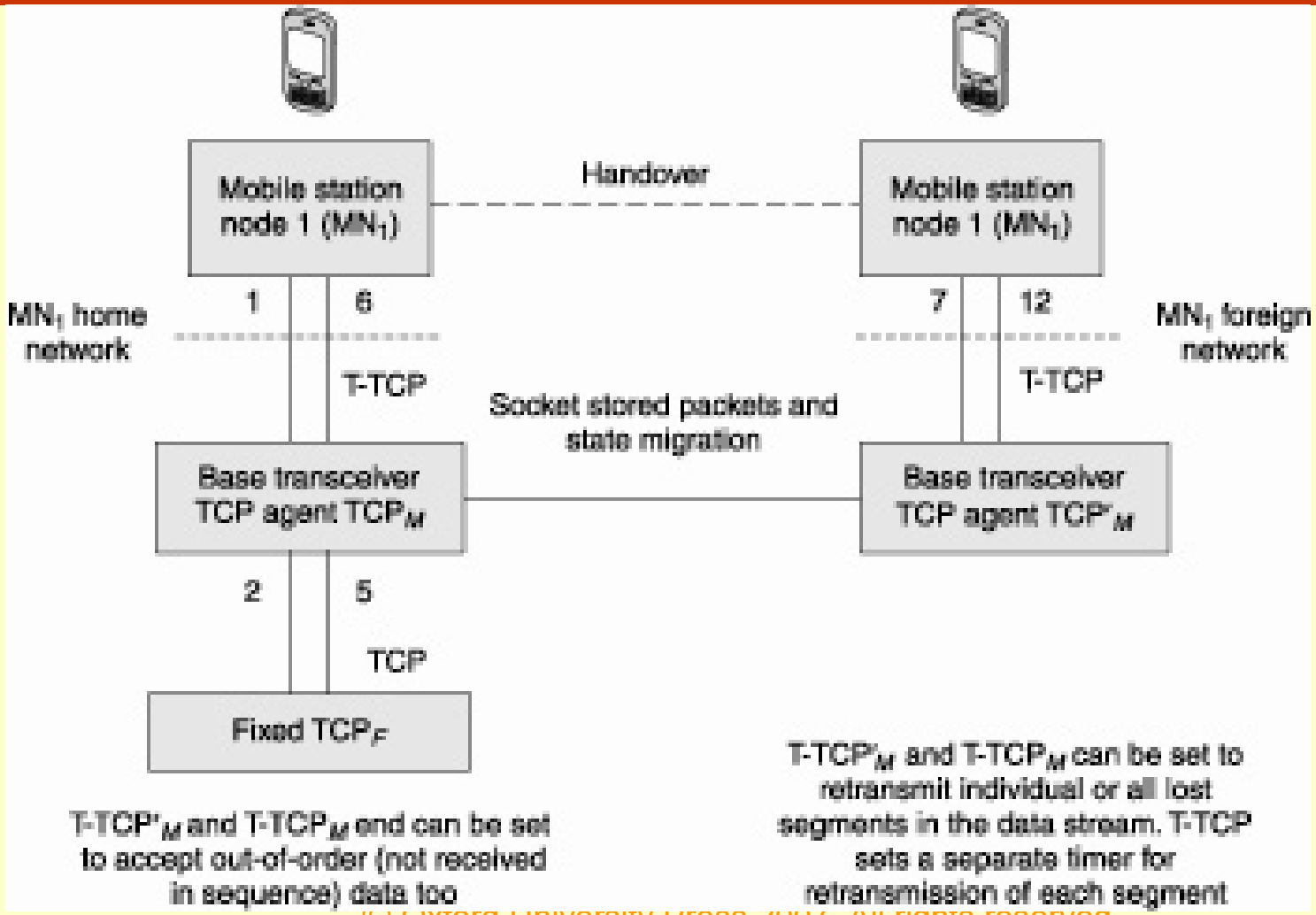
T-TCP



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T-TCP functioning

1. There are no multi-way handshakes

- SYN, SYN_ACK, and ESTABLISHED between the T-TCP$_M$ and T-TCP'$_M$ ends
- Connection messages (SYN, SYN_ACK, ESTABLISHED, FIN, and FIN_ACK) sent along with the data stream and not separately

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T-TCP functioning

2. Sequence numbers for two paired bytes in T-TCP instead of 1 as in the case of TCP

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T-TCP functioning

3. Only immediate (like SYN and SYN_ACK in TCP) and cumulative (no piggyback acknowledgements sent) acknowledgements are sent in T-TCP

- Piggyback acknowledgement— an acknowledgment sent by setting the acknowledgement field along with the data stream octets

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T-TCP functioning

- T-TCP employs caches for each state and RTTs at the transmitter and the receiver

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T-TCP functioning

4. Connection-count (cc) used for keeping count of the number of bytes

- The header has the sequence number of the first byte of octets in a data stream
- T-TCP server caches the cc for each connection at each end to restrict duplicate requests and replies

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T-TCP functioning

5. The data stream pushed during a preset timeout or sent as urgent by setting an urgent pointer

- The timeout is set to a small value, for example, $8 \times RTT_0$, where RTT_0 is time for one round trip with minimum window
- T-TCP thus becomes efficient for short data streams

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Advantage of T-TCP

Increase in efficiency by reducing overhead of packets for connection establishment, data transfer, and connection close

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Disadvantage of T-TCP

- Mobile node TCP layer needs a change to enable the implementation of T-TCP

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Explicit notification method (ELN method)

- A method of congestion control by explicit notification of congestion
- For example, when a base transceiver at the receiver end is not able to transmit a packet to the mobile node then it sends an EBSN (explicit bad state notification) to the sender (on fixed line) at the other end

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Explicit notification method (ELN method)

- A base station transceiver (BTS) detect the missing packets in the incoming TCP data stream from a mobile node (MN)
- This is when the BTS gets a DACK (DA) from the MN

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Explicit notification method (ELN method)

- Explicit notification method (ELN method) works so that the BTS sets an ELN (explicit loss notification) bit when the DA is sent to the MN. When the MN gets the DA with the ELN bit, it retransmits
- This is because the MN interprets the ELN bit from the BTS as signalling of packets loss

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An alternative– ELN2 method

- Only the sequence numbers are buffered (in the cache) at the BTS in place of the packet. Whenever a DA corresponds to a buffered missing sequence number, the ELN bit is set with the DA
- The MN retransmits on receipt of DA with the ELN

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Explicit notification method (ELN method)

- Another alternative that when the BTS receiver end is not able to transmit a packet to the MN, it sends an EBSN (explicit bad state notification) to the sender (fixed line) at the other end
- The BTS can receive a packet from a sender at the other end, but may not be able to send it to the MN

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Summary

- Timeout freezing used in situations where the mobile node (MN) faces long durations of disconnection
- Only the lost packet corresponding to a SACK needs to be retransmitted in selective retransmission protocol
- Transaction Oriented T-TCP

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…Summary

- No multi-way handshakes SYN, SYN_ACK, and ESTABLISHED between the T-TCP$_M$ and T-TCP'$_M$ ends
- SYN, SYN_ACK, ESTABLISHED, FIN, and FIN_ACK) sent along with the data stream and not separately in T-TCP

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…Summary

- Explicit notification method (ELN method) works so that the BTS sets an ELN (explicit loss notification) bit when the DA is sent to the MN. When the MN gets the DA with the ELN bit, it retransmits

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End of Lesson 10

Timeout Freezing, Selective Retransmission, Transaction Oriented TCP and Explicit Notification Methods

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Mobile Operating Systems

Lesson 01

Operating System

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Computations

- Require data
- Better to organise this data in a *database*
- Database enables raising queries, data transactions, and the retrieval of the required section of data during a computation

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Database

- A collection of systematically stored records or information
- Is not just arbitrarily stored data without any logic
- Stores data in a particular logical manner, for example, as lookup tables

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Lookup table

- A database which stores information in tabular form
- Table structure—the first column a reference for looking into the data
- Subsequent column or columns contain the data
- The reference—key to the data-values

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Tags based database

- Another logical structure
- A tag is also the key to the data-values
- For example, "*contact*: 1 John, 2 Lucy." and "*address*: 1 ABC Street, 2 DEF Street."
- *contact* and *address*– tags in the database

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Business (transactions) between the application software and database

- Computational actions– connecting to a database
- Using the database for querying for a record
- Deleting a specific set of records
- Modifications of records
- insertions into the records and
- Appending of the records

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Transaction command

- Command which is sent for retrieving the data from the database, embodies the logic used for obtaining (and storing) the data

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Data stored in databases

- Follows a logic
- Business logic indicates the logical way in which transactions (business) carried out
- Between two ends, for example, between database-client (application) and database-server or between an API and a database

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API (application program interface

- A section of a program used to run an application (software)
- API may run instructions to retrieve a queried record from a database
- The API may also issue outputs or queries and commands to another program and receive the inputs from another program during a program-run

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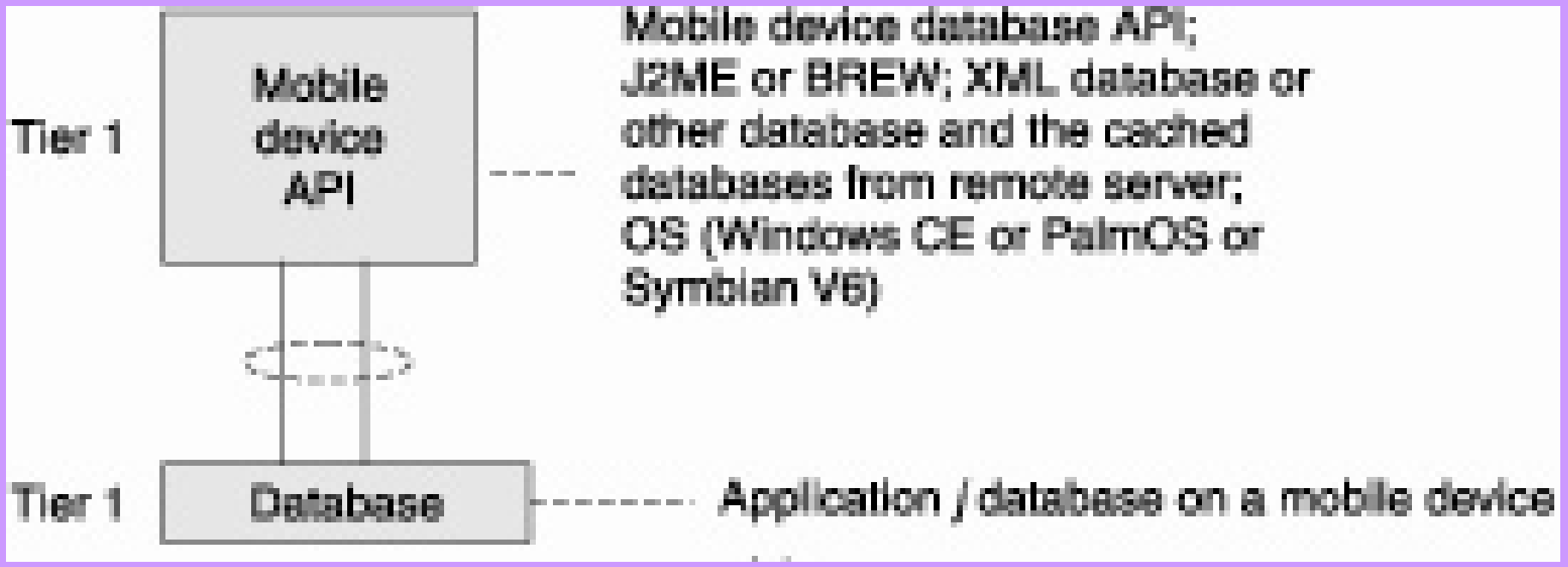
API at mobile device sending queries and retrieving data from local database



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Transactions involving databases

- Establishing connection between API and database
- Updating data records by inserting, adding, replacing, or deleting
- Querying for records
- Terminating the connection between the API and the database

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Implicit Business Logic

- 'Business logic' indicates the logical manner, flow, or pattern, in which business (or transactions) may be carried out with a database
- Implicit business logic– The structure and components of the database itself define, which is used in retrieving (or modifying) data from the database

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Implicit Business Logic

- The logic of transactions (business logic) implicit when it comes from within the database
- No external definition required for the business logic to function

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Example of Implicit Business Logic

- Telephone Directory in which the first word of each line is structured alphabetically

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The telephone directory

- Names and telephone numbers arranged alphabetically shows implicit business logic
- Names and telephone numbers structured in rows with each row having a name and the corresponding address and telephone number

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Search directory in an XML database

- Arranged alphabetically
- Database designed using XML uses a tag as a key
- The key enables business (transaction for retrieving, deleting, inserting, or modifying data)

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Search directory in an XML database

- <search>
- <Allnames first_character = “R”>
- <name_record>
- Raj Kamal
- <address> ABC Street, …. </address>
- <telnumber> 9876543210 </telnumber>
- </name_record>

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Search directory in an XML database

- </Allnames>
- <Allnames first_character = “S”>
- .
- .
- </search>

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Explicit business logic

- Stored queries and procedures define the logic
- A transaction (business) between the API and the database uses an explicitly defined query

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Example of Explicit business logic

- If Structure = most recently added entry list Content_Type = English English_Records, flight origin = Frankfurt, airline = Lufthansa, present time = 0800 hrs and status = Not arrived then Get_Records

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Example of Explicit business logic

- Another query for business can be
- If flight origin = Frankfurt, airline = Lufthansa, present time = 0800 hrs and status = arrived then Delete_Records
- English_Records– a section of the database having English contents
- Get_Records and Delete_Records – two procedures that carry the transaction**s**

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Connectivity Protocol

- An API that has predefined methods to handle the various data access functions
- Defines ways to connect to and access a database and methods for sending queries and updating or retrieving database records
- Connects a client or server to the database

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Connectivity Protocol

- Describes the set of permitted commands, transaction methods, and the order in which commands are interchanged between the API and the database at the server or the client

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Connectivity Protocols

- Describes the set of permitted commands, transaction methods, and the order in which commands are interchanged between the API and the database at the server or the client

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Connectivity Protocols

- Using the connectivity protocol API, a program issues commands
- Access a database and query in order to select and retrieve queried record(s) from the database

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Examples of connectivity protocols

- Java database connectivity (JDBC)
- Open database connectivity (ODBC)
- Simple object access protocol (SOAP)
- Connect the server to the database

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Relational Databases

- Defined as a database structured in accordance with the relational model
- The relational model of data organization helps the database designer to create a consistent and logical representation of information

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The relational model

- Follows a relational logic which means that it is assumed that all data can be represented as *n*-ary (binary means *n* = 2, tertiary means n = 3,...) relations
- An *n*-ary relation is a subset of the Cartesian products of *n*-sets

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Relational database

- Entails that it is always possible to mathematically model the relations between the data records and get the answers to the relational equations for the queries
- The answers are as in two-valued predicate logic

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Two-valued predicate logic

- Means that there are only two possible results on evaluation, for each proposition—*true* or *false* and no third result, for example, ‘null’ or ‘unknown’, is possible

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IBM DB2 Everyplace (DB2e)

- A relational database engine
- Needs a memory of about 100 kB
- Designed to reside at the device
- Supports databases of sizes up to 120 MB
- An enterprise server employing DB2e delivers and synchronizes the local copies of data contents at mobile devices

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DB2e based Synchronization

- DB2e synchronizes with DB2 databases at the synchronization, application, or enterprise server
- Means that if a data record is modified at the server then the copy of that record at the client device also changes accordingly

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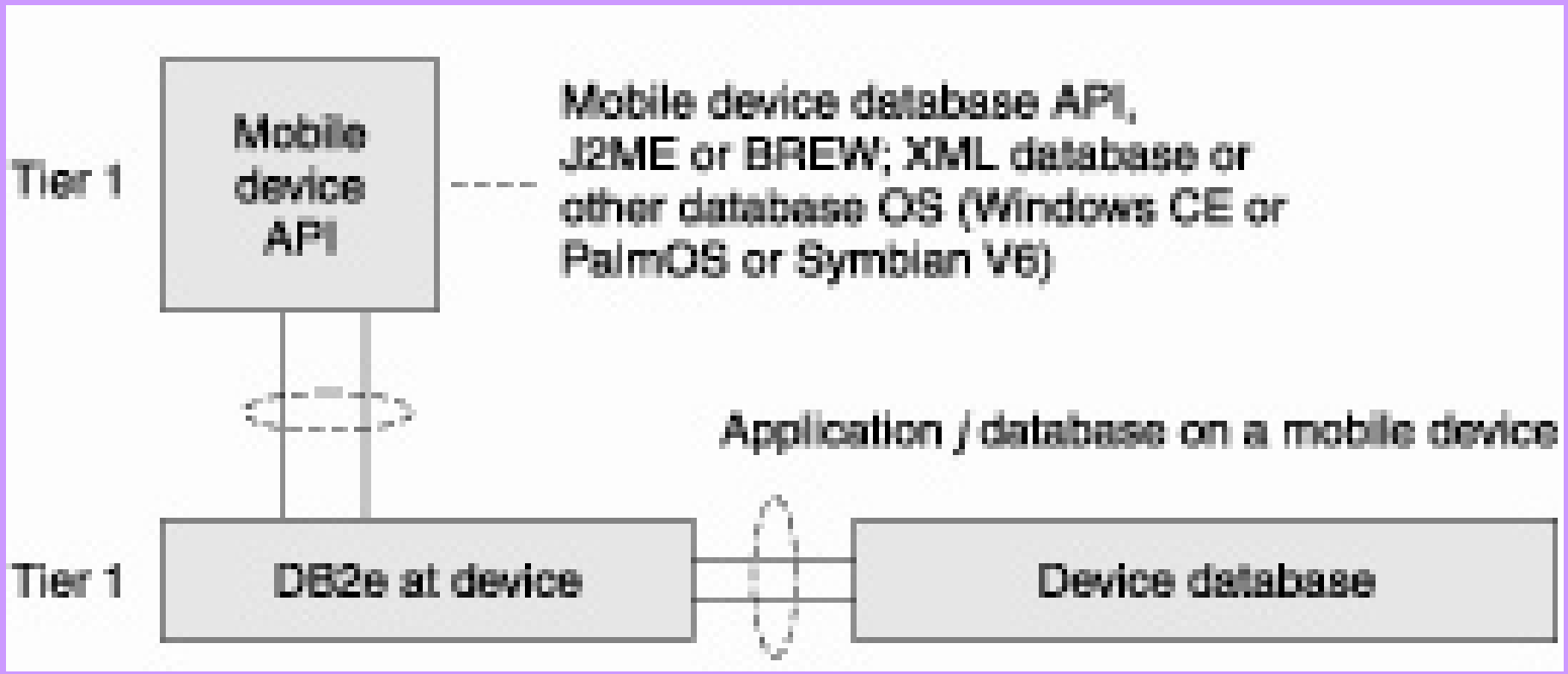
API at mobile device retrieving data from database using DB2e



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Summary

- Database a collection of systematically stored records or information
- Business logic' indicates the logical way in which transactions (business) carried out between two ends
- XML database
- Implicit Business Logic
- Explicit business logic for Stored queries and procedures …

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… Summary

- Transactions involving databases are—(a) establishing connection (b) updating data records by inserting, adding, replacing, or deleting, (c) querying and (d) terminating the connection
- Connectivity protocol
- Relational databases

…

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… Summary

- IBM DB2e EveryPlace for retrieving database records and querying from DB2e server

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End of Lesson 01

Operating System

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Databases

Lesson 02

Data Hoarding and Caching

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Large databases– kept on servers, remote computing systems, or networks

- A mobile device cannot store a large database
- Retrieving the required data from a database server during every computation– impractical due to time constraints

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Hoarding (caching) of specific database in mobile devices

- A mobile device— not always connected to the server or network, neither does the device retrieve data from a server or a network for each computation
- Rather, the device caches required specific data, which may be required for future computations, during the interval in which the device is connected to the server or network

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Hoarding of Cached Data

- Database architecture– Two-tier or multi-tier databases
- Databases reside at the remote servers and the copies of these databases are hoarded and cached at the client tier

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Synchronizing the local copies at the device

- At tier 2 or tier 3, the server retrieves
- Server transmits the data record (s) to tier 1 using business logic and sends and synchronizes the local copies at the device
- Local copies function as device caches

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Advantage of hoarding

- No access latency (delay in retrieving the queried record from the server over wireless mobile networks)
- The client device API has instantaneous data access to hoarded or cached data
- After a device caches the data distributed by the server, the data is hoarded at the device

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Disadvantage of hoarding

- Needs maintain the consistency of the cached data with the database at the server

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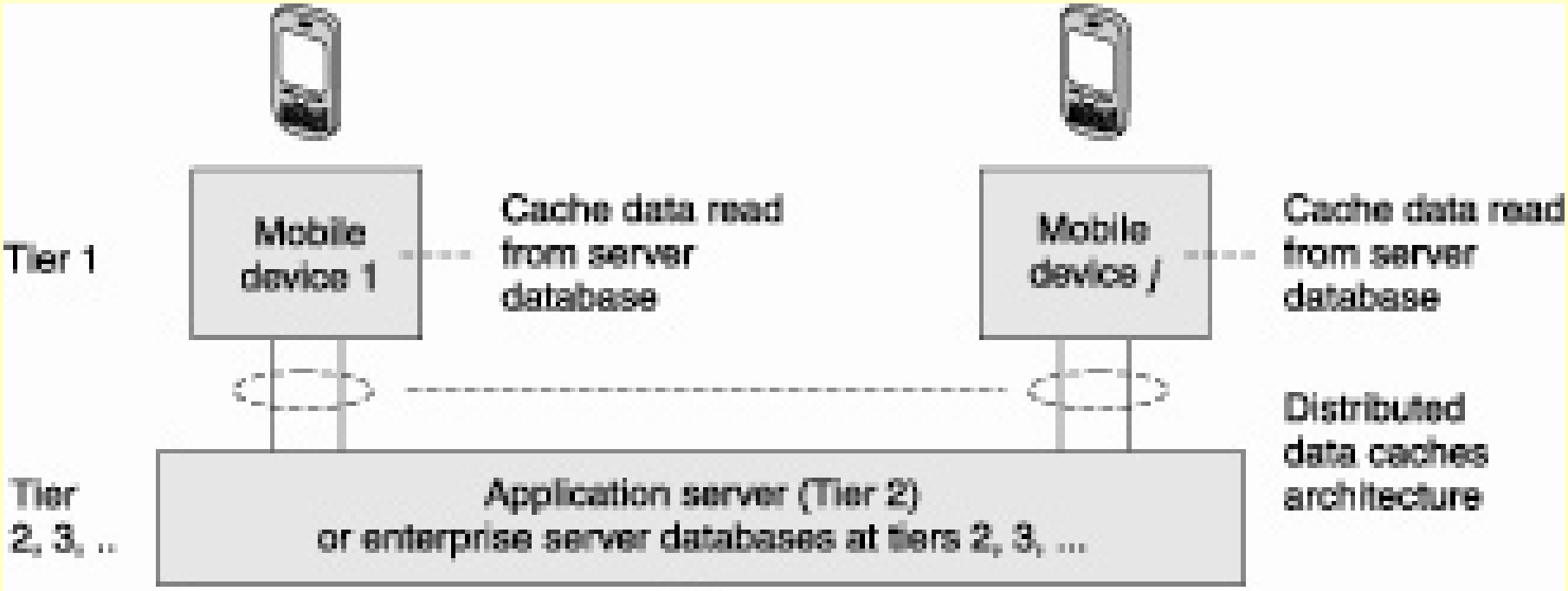
Distributed data caches in mobile devices



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Architecture of distributed data caches in mobile devices

- Similar architecture to distributed cache memory in multiprocessor systems
- The copies cached at the devices are equivalent to the cache memories at the processors in a multiprocessor system with a shared main memory and copies of the main memory data stored at different locations

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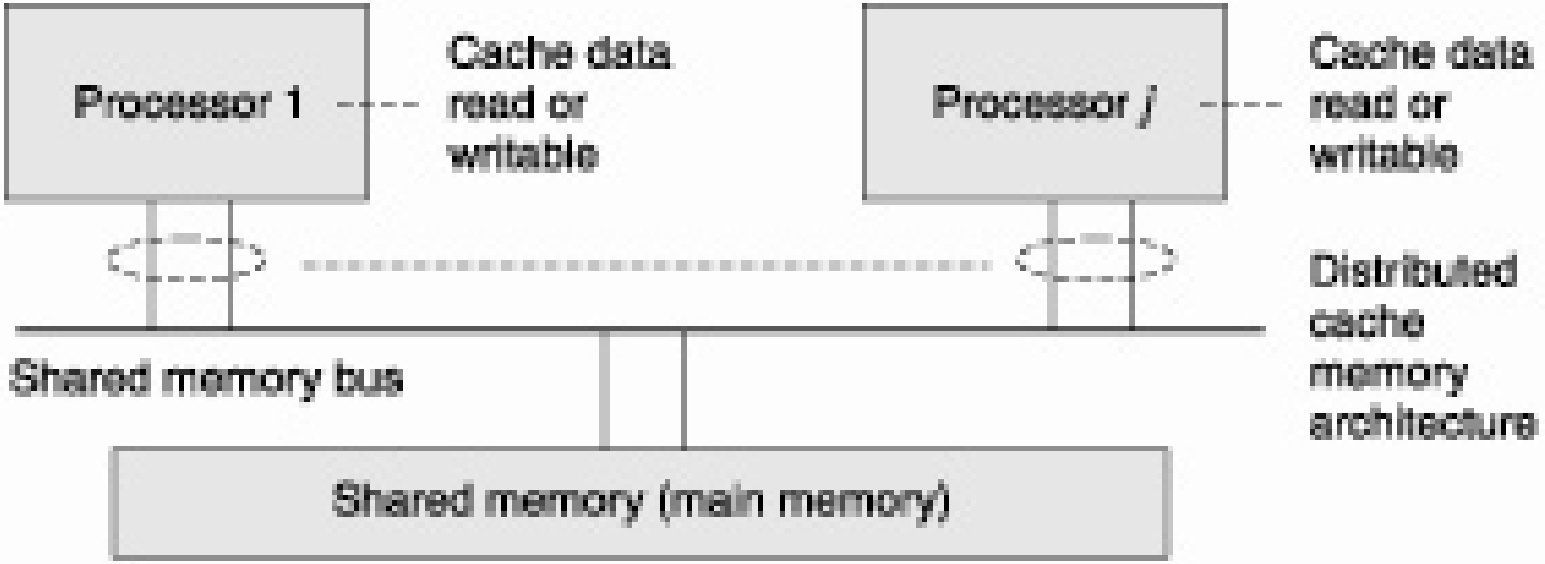
Architecture for a distributed cache memory in multiprocessor systems



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Data Caches at Client device

1. Using the pushed (disseminated) data records from a server
- Caching leads to a reduced access interval as compared to the pull (on-demand) mode of data fetching
- Also reduces the dependence on pushing precedence at the server

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Caching of data records at Client device

2. Can be based on pushed ‘hot records’
3. Cost-based data replacement or caching– Caching can be based on the ratio of two parameters— access probability (at the device) and pushing rates (from the server) for each record

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Cost-based data replacement Method

- Least frequently pushed records and the pushed records having larger access time placed in the database at the device
- This access method, therefore, use the ratio of two parameters— average access time between two successive instances of access to the record and pushing rates for the record

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Pre-fetching

- Alternative to caching of disseminated data entails requesting for and pulling records that may be required later
- Perfetching — keeping future needs in view instead of caching from the pushed records

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Pre-fetching

- Reduces server load
- Reduces the cost of cache-misses
- The term ‘cost of cache-misses’ refers to the time taken in accessing a record at the server in case that record is not found in the device database when required by the device API

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Cache consistency

- Also called cache coherence
- Requires a mechanism to ensure that a database record identical at the server as well as at the device caches and that only the valid cache records are used for computations

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Cache access Protocols based on Caching Invalidation Mechanisms

- Access protocols cached record at the client device invalidated
  — Due to expiry or modification of the record at the database server

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Cache invalidation

- A process by which a cached data item or record becomes invalid and thus unusable because of modification, expiry, or invalidation at another computing system or server.
- Cache invalidation mechanisms are means by which the server conveys this information to client devices

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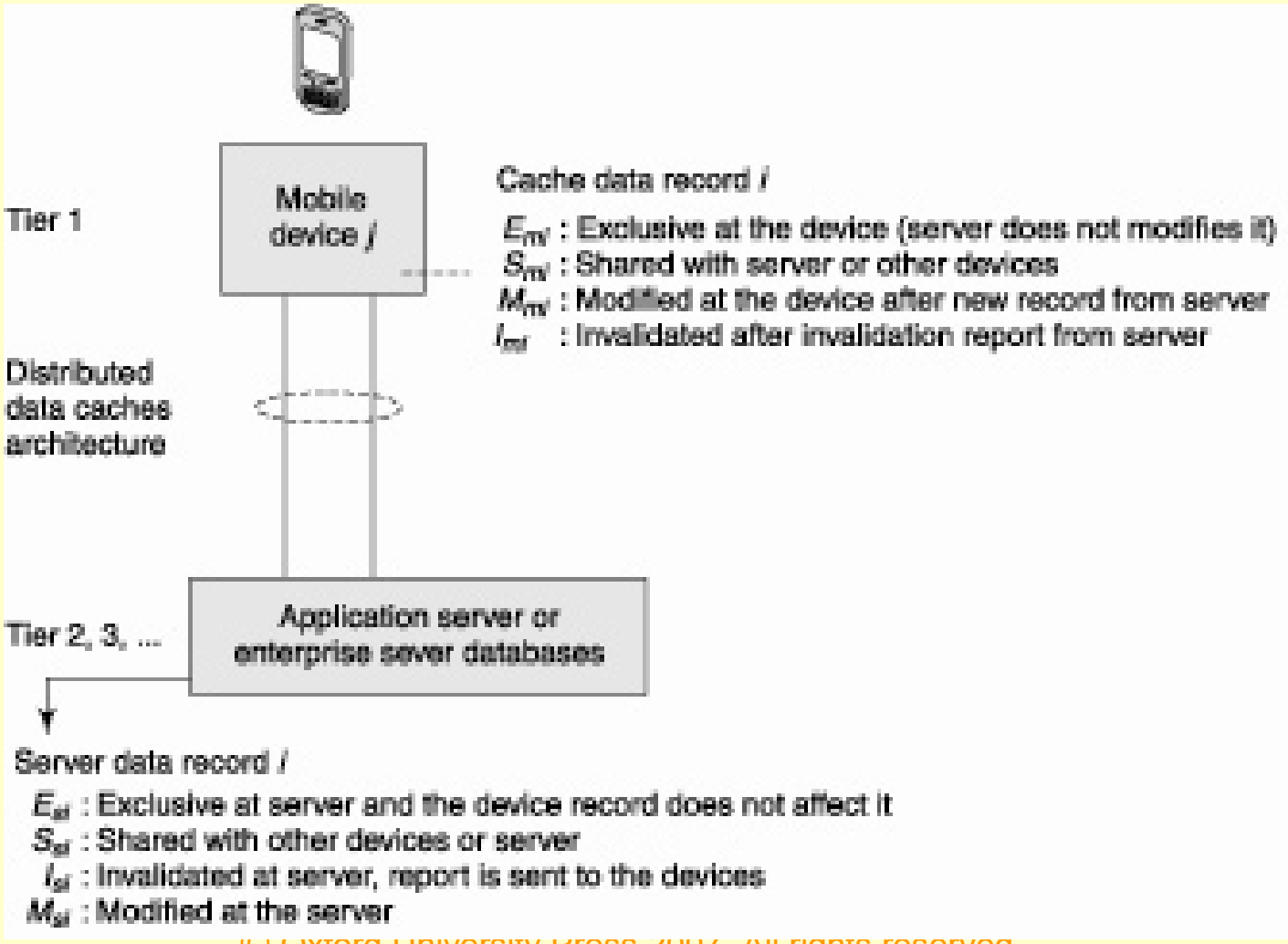
Four possible states (*M*, *E*, *S*, or I) of a data record *i* at any instance at the server database and device *j* cache



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Cache-invalidation mechanisms under the MESI protocol

- Entail that each record (line) in a cache has a tag to specify its state at any given instant and the tag is updated (modified) as soon as the state of the record changes

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MESI Protocol one of four possible tags

- Assigned cache state

1. M– Modified (after rewriting)
2. E– Exclusive
3. S– Shared
4. I – invalidated (after expiry or when new data becomes available) at any given instance.

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Summary

- Two-tier or multi-tier databases
- Databases reside at the remote servers and the copies of these databases are cached at the client tiers
- Computing API at the mobile device (first tier) uses the cached local copy

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… Summary

- Architecture of distributed data caches in mobile devices and a similar architecture of distributed cache memory in multiprocessor systems
- Cache Access Protocols
- Cache Invalidation Mechanisms
- MESI protocol

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End of Lesson 02
Data Hoarding and Caching

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Databases

Lesson 03

Data Cache Consistency Maintenance in Mobile and Web Environments

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Access Latency in mobile environment

- A device needs a data-record during an application, a request must be sent to the server for the data record– mechanism called pulling
- **Access latency**– the interval for the application software to access a particular record

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Data cache maintenance necessity in mobile environment

- Caching and hoarding the record at the device reduces access latency to negligible

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Data Cache inconsistency

- Means that data records cached for applications are not invalidated at the device when modified at the server but not modified at the device

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Methods for Cache consistency Maintenance

1. Cache invalidation mechanism (server-initiated case): the server sends invalidation reports on invalidation of records (asynchronous) or at regular intervals (synchronous)

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Methods for Cache consistency Maintenance

2. Polling mechanism (client-initiated case): Polling means checking from the server, the state of data record whether the record is in valid, invalid, modified, or exclusive state

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Polling Method

- Each cached record copy polled (checked) whenever required
- The device connects to the server and finds out data record copy at the device become invalid or has been modified at the server
- If modified or invalidated, then the device requests for the modified data and replaces

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Method of Time-to-live mechanism (client-initiated case)

- Each cached record assigned a TTL (time-to-live)
- The TTL assignment is adaptive (adjustable) previous update intervals of that record
- After the end of the TTL, the client device polls for invalid or modified state

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Method of Time-to-live mechanism (client-initiated case)

- If invalid or modified state found then the device requests the server to replace
- When TTL is set to 0, the TTL mechanism is equivalent to the polling mechanism

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Cache consistency Maintenance by Invalidation Mechanisms

- If the database server changes a data record (either read-only or writable), of which one or more client devices have copies (read-only), then the server-record invalidated, forcing all client devices that currently have copies of the record to give up (not use further in computations) their cache-copies

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Four Cache Invalidation Mechanisms

- Stateless asynchronous
- Stateless synchronous
- Stateful asynchronous
- Stateful synchronous

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Stateless asynchronous

- Device cache states are not maintained at the server
- The server advertises invalidation report
- On receiving an invalidation report, the client requests for or caches the new data record

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Advantage of the asynchronous approach

- No frequent, unnecessary transfers of data reports
- Mechanism more bandwidth efficient

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Disadvantages of this approach

- Every client device gets an invalidation report, whether that client requires that copy or not
- Client devices presume that as long as there is no invalidation report, the copy is valid for use in computations

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Disadvantages of this approach

- Therefore, even when there is link failure, the devices may be using the invalidated data and the server is unaware of state changes at the clients after it sends the invalidation report

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Stateless synchronous

- Device cache states are not maintained at the server
- The server periodically advertises invalidation report
- The client requests for or caches the data on receiving the invalidation report
- If no report is received till the end of the period, the client requests for the report

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Advantage of the synchronous approach

- Client devices receive periodic information regarding invalidity (and thus validity) of the data caches
- The periodic invalidation reports lead to greater reliability of cached data as update requests for invalid data can be sent to the server by the device-client. This also helps the server and devices maintain cache consistency through periodical exchanges

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Disadvantage of the synchronous approach

- Unnecessary transfers of data invalidation reports take place
- Every client device gets an advertised invalidation report periodically, irrespective of whether that client has a copy of the invalidated data or not

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Disadvantage of the synchronous approach

- During the period between two invalidation reports, the client devices assume that, as long as there is no invalidation report, the copy is valid for use in computations

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Stateful asynchronous

- Device cache states are maintained at the server
- The server transmits invalidation report to concerned devices
- The client requests for new data on receiving the invalidation report and sends its new state after caching new record from the server

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Advantage of the stateful asynchronous approach

- Server keeps track of the state of cached data at the client device
- This enables the server to synchronize with the state of records at the device cache and keep the home locating cache (HLC) updated

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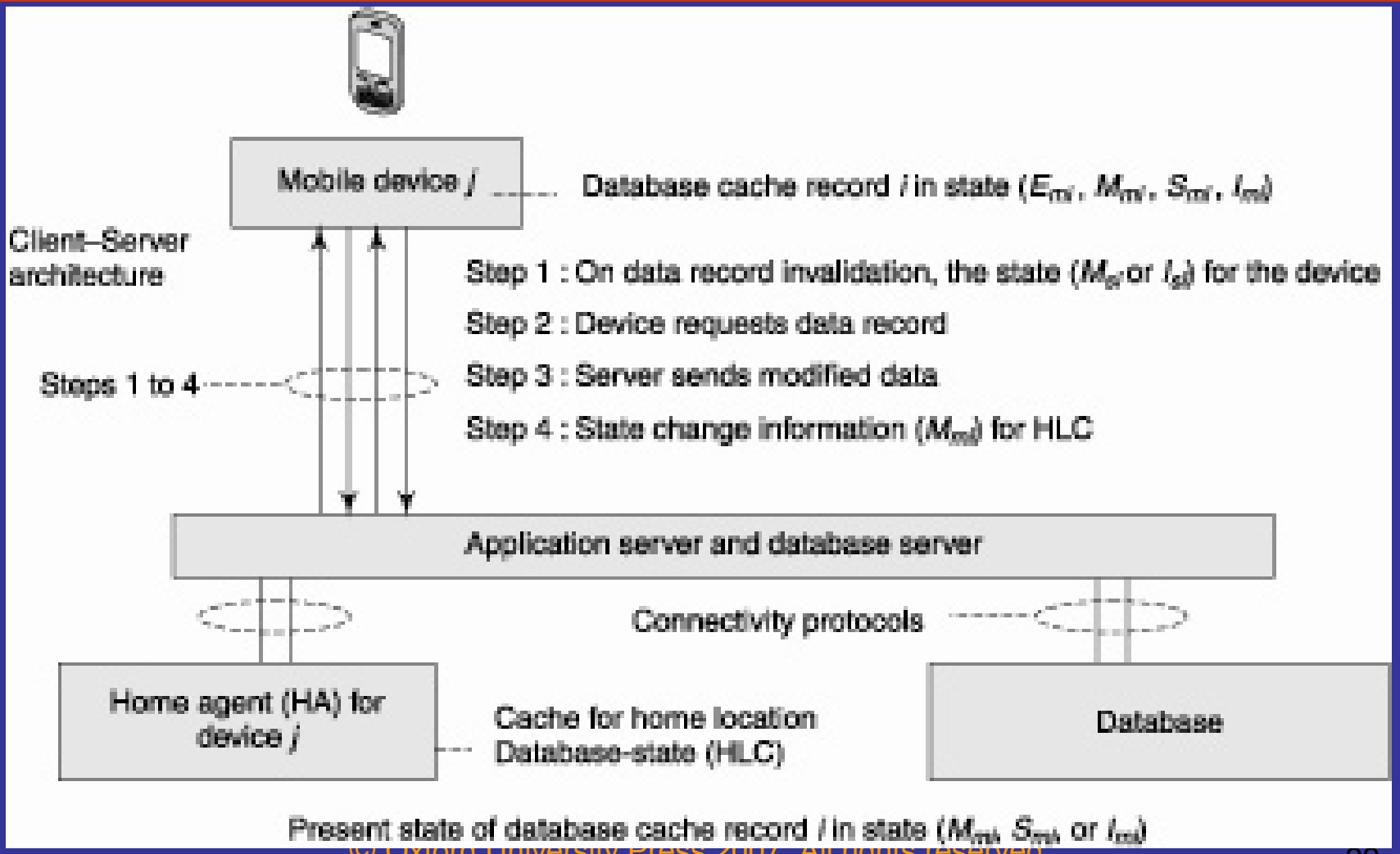
Four-step stateful asynchronous cache invalidation mechanism for cache consistency



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Advantage of the stateful asynchronous approach

- The stateful asynchronous mode is also advantageous in that only the affected clients receive the invalidation reports and other devices are not flooded with irrelevant reports

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Disadvantage of the Asynchronous stateful

- Client devices presume that, as long as there is no invalidation report, the copy is valid for use in computations.
- Therefore, when there is a link failure, then the devices use invalidated data

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Stateful synchronous

- Device cache states maintained at the server
- The server periodically transmits invalidation report to the concerned devices

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Stateful synchronous

- The client requests for new data on receiving the invalidation report, and sends its new state after caching the new data.
- If no report is received till the end of the period, the client requests for the report.

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Advantage of the stateful synchronous approach

- Reports identifying invalidity (and thus, indirectly, of validity) at periodic intervals and that the server also periodically updates the client-cache states stored in the HLC
- Enables to synchronize with the client device when invalid data gets modified and becomes valid.

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Advantage of the stateful synchronous approach

- Each client be periodically updated of any modifications at the server.
- When the invalidation report is not received after the designated period and a link failure is found at the device, the device does not use the invalidated data
- Instead it requests the server for an invalidation update.

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Disadvantage of the stateful synchronous approach

- High bandwidth requirement to enable periodic transmission of invalidation reports to each device and updating requests from each client device

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Web cache maintenance in mobile environments

- Mobile devices or their servers can be connected to a web server (for example, traffic information server or train information server)
- Web cache at the device stores the web server data and maintains it in a manner similar to the cache maintenance for server data

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Web cache maintenance in mobile environments

- Mobile devices or their servers connected to a web server— for example, traffic information server or train information server
- Web cache at the device stores the web server data and maintains it in a manner similar to the cache maintenance for server data

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Web cache maintenance necessity

- In a mobile environment to overcome access latency in downloading from websites due to disconnections

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Two methods for Web cache consistency maintenance

- Time-to-live (TTL) mechanism (client-initiated case)
- Power-aware computing mechanism (client-initiated case): Each web cache maintained at the device can also store the CRC (cyclic redundancy check) bits

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Power Aware Method

- Assume that there are N cached bits and n CRC bits and N >> n
- Server also stores *n* CRC bits
- Consistency between the server and device records, the CRC bits at both identical
- Else the corresponding CRC bits at the server modifies.

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Power Aware Method

- After the TTL expires or on-demand for the web cache records by the client API, the cached record CRC polled and obtained from the website server

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Power Aware Method

- If the *n* at server found to be modified and the change is found to be much higher than a given threshold (i.e., a significant change), then the modified part of the website hypertext or database is retrieved by the client device for use by the API

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Summary

- Four methods of Cache Invalidation based cache consistency maintenance mechanism
  - Stateless asynchronous
  - stateless synchronous
  - stateful asynchronous
  - stateful synchronous mechanisms

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Summary

- Polling and TTL methods for cache consistency maintenance for data cache
- Similar methods for Web Cache
- Power aware method– Poll for significant change in CRC

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End of Lesson 03

Data Cache Consistency Maintenance in Mobile and Web Environments

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Databases

Lesson 04

Client–Server Computing and Adaptation

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Two Network Based Computing Architectures

- Distributed Peer-to-Peer— designed each node distributed computing node of the system, each node on the network similar resources and the various nodes can depend on each other resources
- Client-Server— designed such that a node is either a client or a server

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Client-Server Architecture in Mobile Environment

- Client node has much less resources than server
- Client nodes depend on server resources

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Client-Server Architecture in Mobile Environment

- A client requests the server for data or responses
- The client can either access the data records at the server or cache these records through broadcasts or distribution from the server

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Client-server Computing

- An *N*-tier architecture (*N* = 1, 2, …)
- On the same computing system (not on a network), then the number of tiers, *N* = 1
- When the client and the server are on different computing systems on the network, then *N* = 2

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Server networks or connecting to other computing systems

- Connecting to other systems provide additional resources to the server for the client
- Then $N > 2$
- $N > 1$ means that the client device at tier 1 connects to the server at tier 2 which, in turn, may connect to other tiers, 3, 4, and so on

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Application server in two-tier client–server computing architecture

- Local copies 1 to j of database hoarding at the mobile devices) on client request
- Synchronization API enables running of the application independently on the devices without the need for a run-time retrieval

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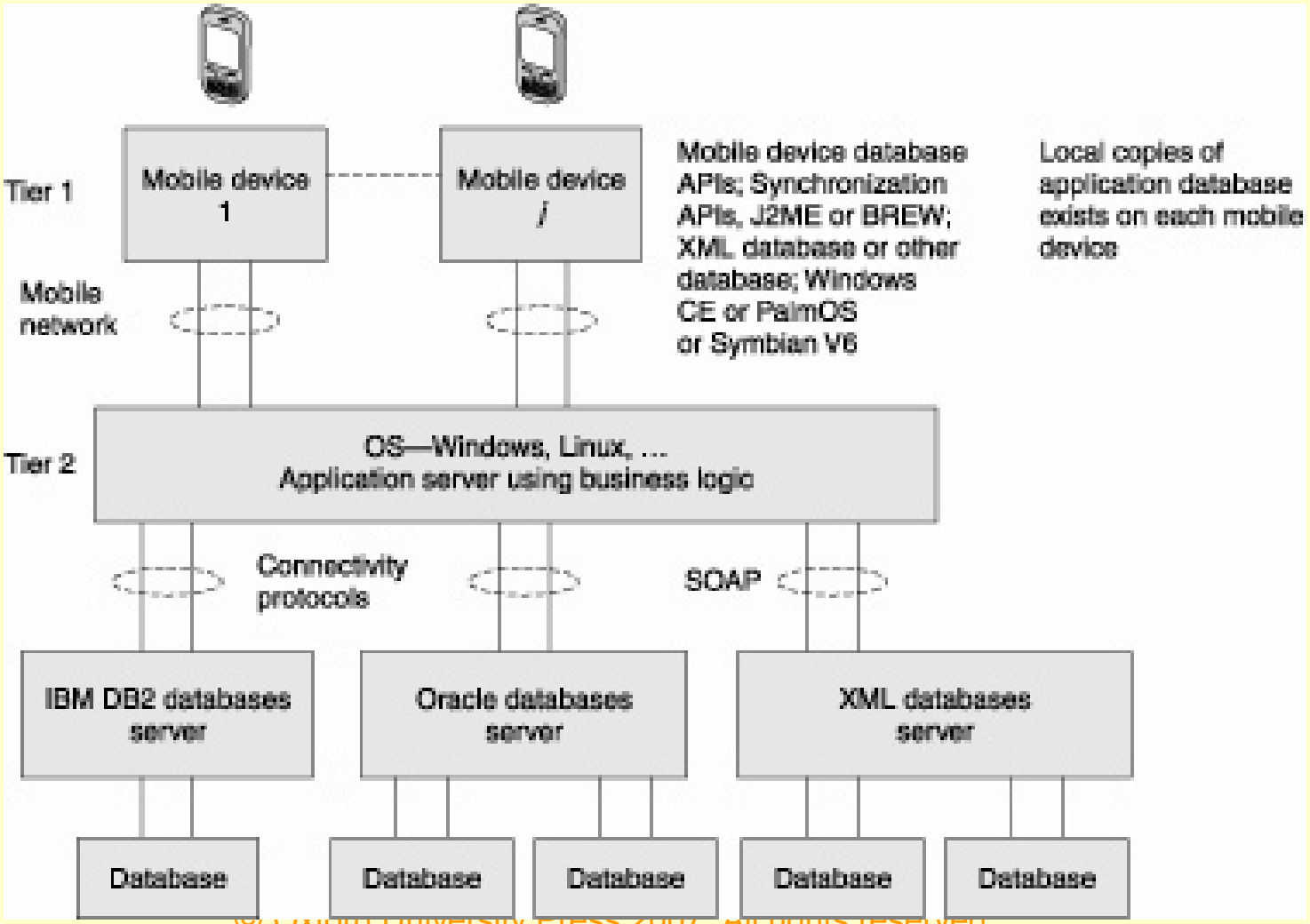
Two-tier Client–Server Architecture



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APIs and Synchronization API

- Various APIs synchronization with each other
- Synchronization– means that when copies at the server-end modifies, the cached copies accordingly modified
- The APIs designed independent of hardware and software platforms as far as possible as different devices may have different platforms

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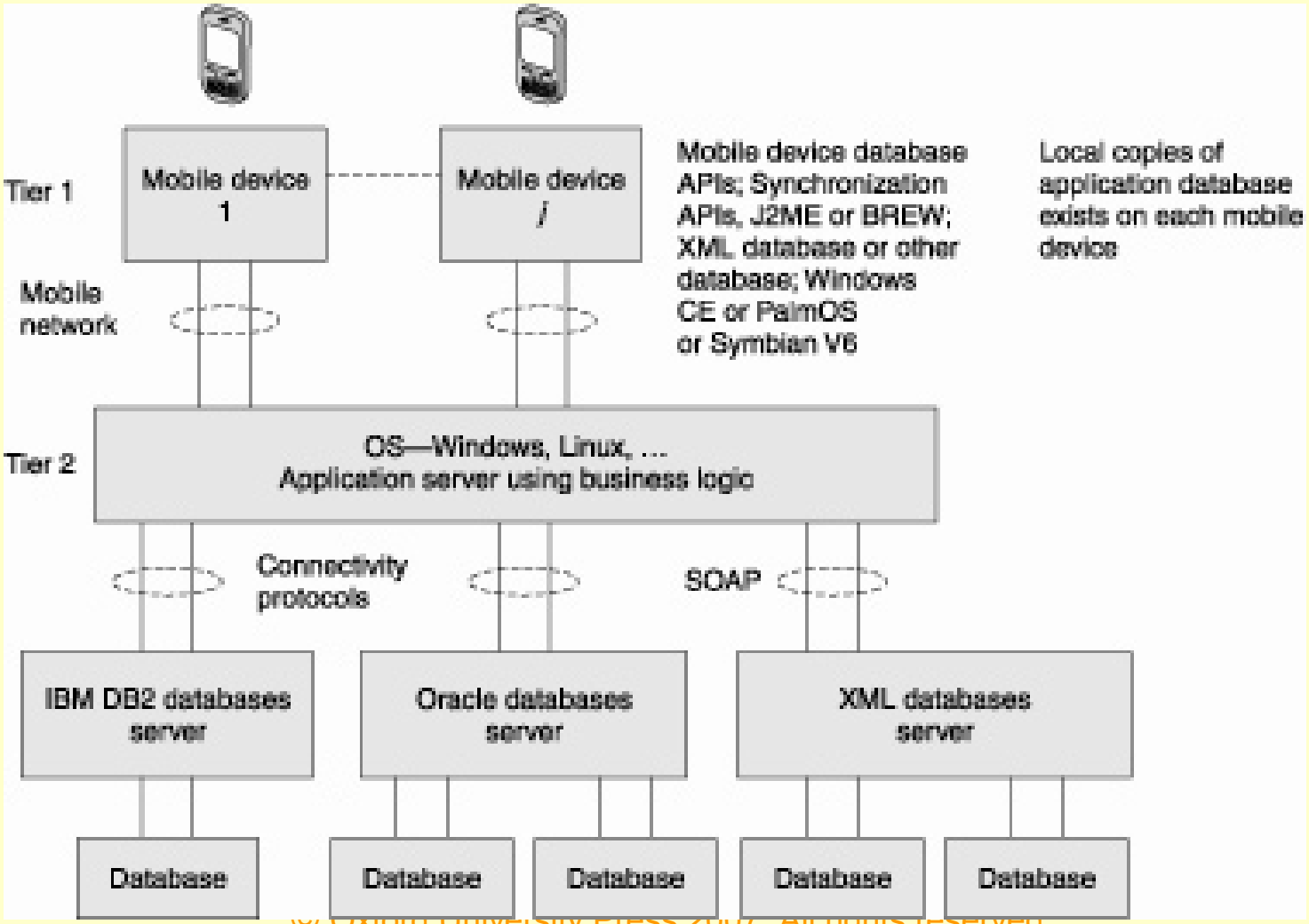
Two-tier client–server architecture using a multimedia files server



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Three-tier Client–Server Architecture

- The application interface, the functional logic, and the database are maintained at three different layers
- The database is associated with the enterprise server tier (tier 3)
- Only local copies of the database exist at mobile devices

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Three-tier Client–Server Architecture

- Database at the backend system of an enterprise (company) that holds IBM DB2, Oracle, and other databases
- Server at Tier 2 connects to the enterprise server through a connecting protocol. The enterprise server connects the complete databases on different platforms, for example, Oracle, XML, and IBM DB2

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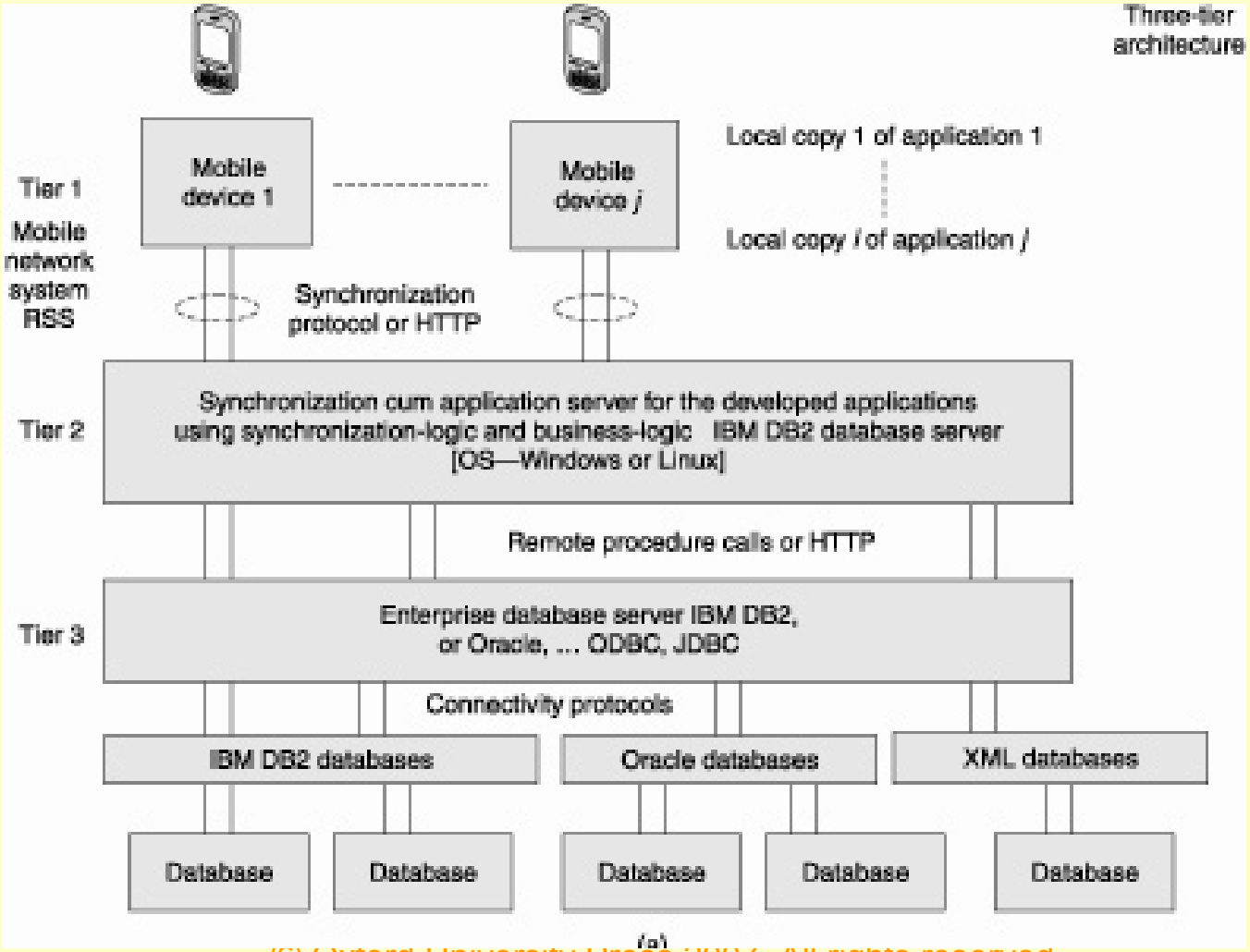
Database record Copies of database at the mobile devices using three tier architecture



(a)

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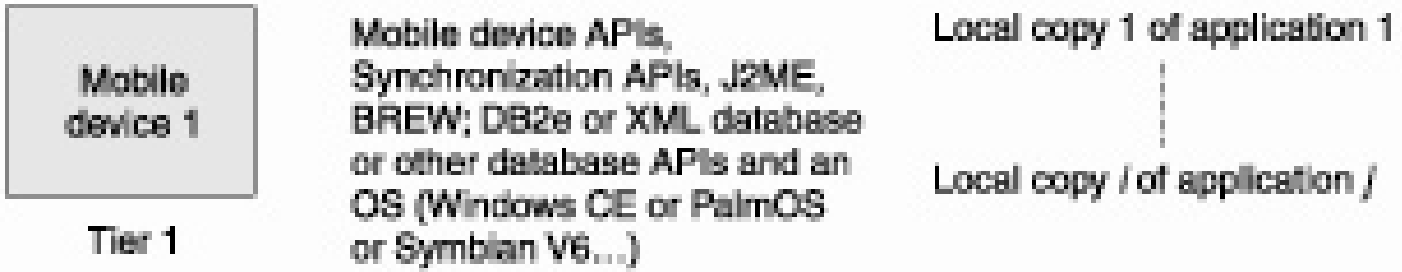
Mobile Device with J2ME or BREW platform, an OS and database having local copies



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Connectivity of the synchronization-cum-application server

- To the enterprise server is by RPC, RMI, JNDI, or IIOP protocols
- In case the application client at tier 1 connects to tier 2 using the Internet, the connectivity using HTTP or HTTPS

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N-tier Client–Server Architecture

- When N is greater than 3, then the database is presented at the client through in-between layers
- Four-tier architecture in which a client device connects to a data-presentation server at tier 2
- The presentation server then connects to the application server tier 3

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N-tier Client–Server Architecture

- The application server can connect to the database using the connectivity protocol and to the multimedia server using Java or XML API at tier 4

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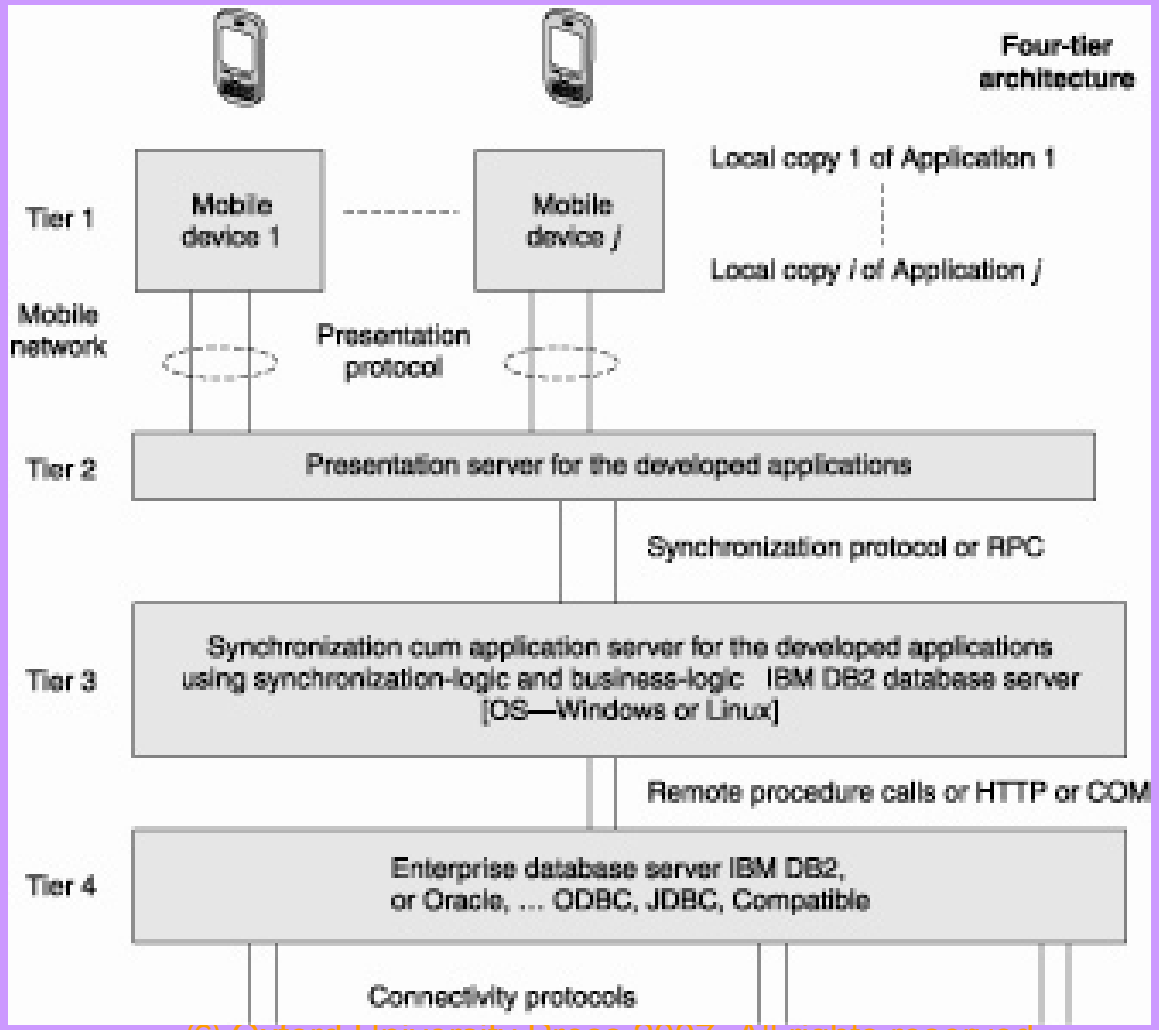
4-tier architecture in which a client device connects to a data-presentation server



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Mobile-device number of interfaces (APIs)

- PIM (personal information manager) interfaces for the **calendar, contacts**
- Microsoft Outlook or Intellisync Wireless e-mail
- Lotus Notes (5x and 6x)

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Mobile-device number of interfaces (APIs)

- Lotus Organizer (5x and 6x)
- APIs for IBM WebSphere Everyplace Access, BlackBerry Connect, Oracle Collaboration Suite, Secure Mobile Connections via VPN Client and Symantec Client Security 3.0, Fujitsu mProcess Business Process Mobilizer. report

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Necessity for Client Server Computing with Adaptation

- The data format differences in different cases for data transmitted from the synchronization server and those required for the device database and device APIs

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Client Server Computing with Adaptation

- Two adapters (adaptation software) at a mobile device
- An adapter for standard data format for synchronization at the mobile-device
- Another adapter for the backend database copy, which is in a different data format for the API at the mobile-device

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Adapter

- Software to get data in one format or data governed by one protocol and covert it to another format or to data governed by another protocol

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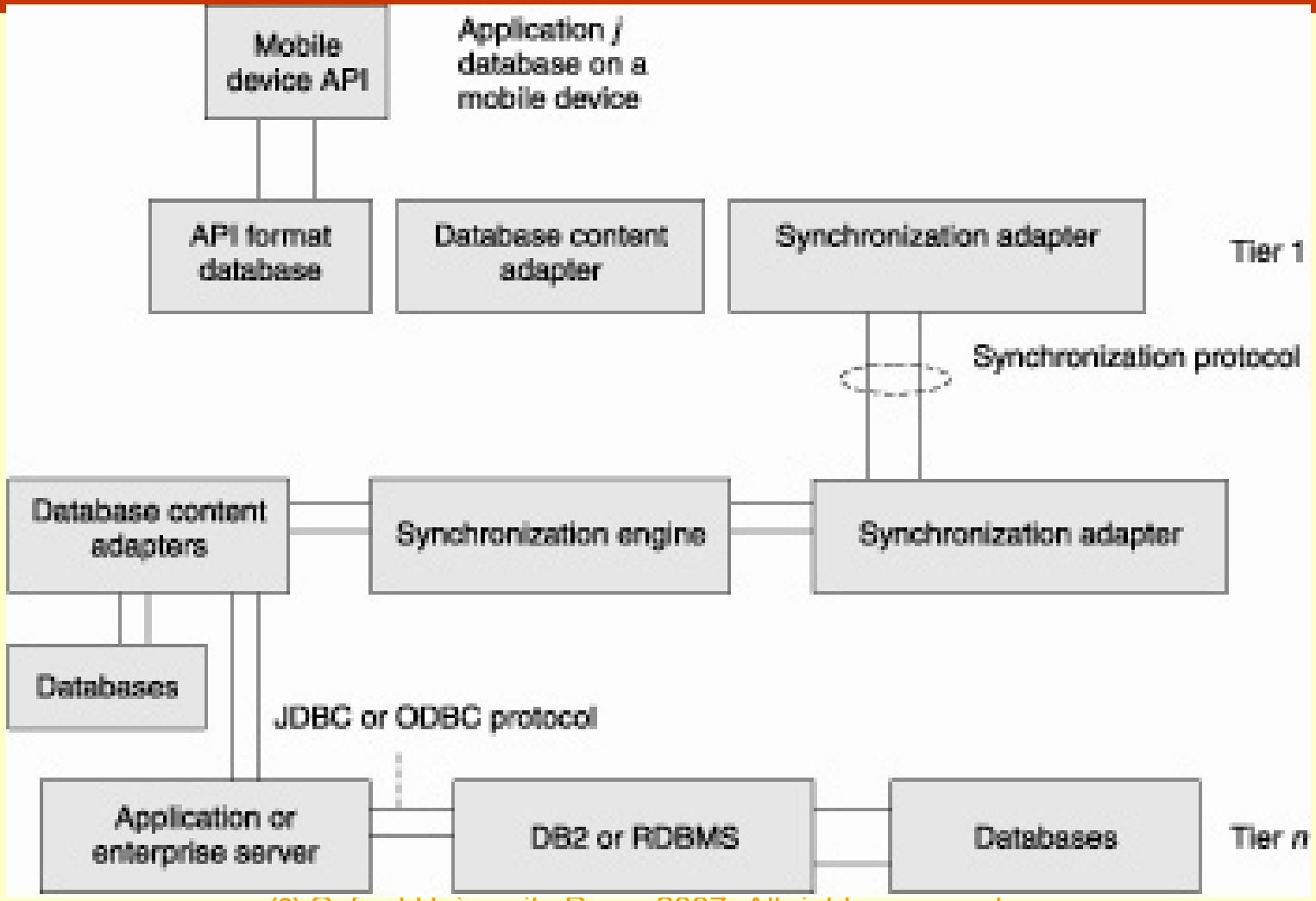
APIs, database and adapters at a mobile device and the Adapters for the server



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Adapters

- Used for interchange between standard data formats and data formats for the API
- IBM WebSphere Everyplace Access (WEA) provides adapters for synchronization objects (for example, XML format synchronization objects) and the objects of API databases (for example, for the PIM APIs)

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Summary

- Two methods in Network Architecture for computing
- Peer-to-Peer and Client Server
- 1 Tier in which server and API at the mobile device itself
- Two, three, four or N tier architecture
- Use of presentation, synchronization, enterprise database servers

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Summary

- Client-server computing with Adapters for interchange between standard data formats and data formats for the API

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End of Lesson 04

Client–Server Computing and Adaptation

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Databases

Lesson 05

Power and Context Aware Computing

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Power Aware Computing

- Computing processes must be energy efficient as the power resources at mobile devices limited due size constraints and mobility requirements
- Power-aware computing takes into account these constraints and devises methods to cut down the energy requirements of computing processes in mobile devices

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Power Aware Computing Methods

1. Data caching at the devices conserves power as multiple requests (for data) made by up linking need more energy
- The server's power not limited so the server can advertise the data records for the device caches

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Power Aware Computing Methods

2. The cache invalidation mechanism conserves power as compared to other cache consistency maintenance mechanisms
- The server advertises the invalidation reports to let the devices know about the invalidation of hoarded data

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Power Aware Computing Methods

3. Records aggregated at the server or at the mobile device before transmission
- Duplicate records can be suppressed and not transmitted
- The state-information (unmodified) for a group of records transmitted

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Power Aware Computing Methods

- When a record modified, only the addition or deletion in a previously transmitted record is transmitted
- The CRC information transmitted

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Power Aware Computing Methods

4. Data sent by the number of sensor-devices clustered and aggregated at a server-node
- The clustered data record server communicates the aggregated data to a base station.
- Aggregation reduces the power requirements as it reduces the number of packets or packet size

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Power Aware Computing Methods

5. Protocol optimization

- Optimized protocols use smaller size headers and need less frequent round trips than un-optimized protocols

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Context

- Dictionary meaning– the circumstances that form the setting of an event, statement, or idea, and in terms of which it can be fully understood
- Context refers to the interrelated conditions in which a collection of elements, records, components, or entities exists or occurs

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Context

- Each message, data record, element, or entity has a meaning
- But when these are considered along with the conditions that relate them to each other and to the environment, then they have a wider meaning

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Necessity of Context Aware Computing

- Understanding of the context in which a device meant to operate, results in better, more efficient computing strategies

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Context Aware Computing

- Context of a mobile device represents the circumstances, situations, applications, or physical environment under which the device being used
- For example, the context is *student* when the device used to download faculty lectures or PowerPoint slides

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Context Types in Context-aware Computing

- Physical context
- Computing context
- User context
- Temporal context
- Structural context

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Physical Context Aware Computing

- Assume that a mobile phone operating in a busy, congested area
- The device is *aware* of the surrounding noises, then during the conversation, it can raise the speaker volume by itself and when the user leaves that area, the device can again reduce the volume

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Physical Context Aware Computing

- When there is intermittent loss of connectivity during the conversation
- The device can introduce background noises by itself so that the user does not feel discomfort due to intermittent periods of silence

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Context-aware computing system

- Has user, device, and application interfaces such that, using these, the system remains aware
- Aware of the past and present surrounding situations, circumstances, or actions
- Aware of such as the present mobile network, surrounding devices or systems,
- Aware of changes in the state of the connecting network

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Context-aware computing system

- Aware of physical parameters such as present time of the day, presently remaining memory and battery power, presently available nearest connectivity, past sequence of actions of the device user, past sequence of application or applications, and previously cached data records, and takes these into account during computations

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Structural Context

- **C**onsider example of structural context
- Résumé — The fields for name, address, experience, and achievements of a person have an individual meaning. However, when put in a résumé, these fields acquire a significance beyond their individual meanings

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Context Significance

- This significance comes from the fact that data fields are now arranged in a structure which indicates an interrelationship between them
- The structure of the résumé includes the records and their interrelationship and thus defines a context for these records

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Structural context

- Context from the structure or format in which the records in a database are organized

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Implicit Context

- Implicit context provides for omissions by leaving out unimportant details, takes independent world-views, and performs alterations in order to cope with incompatible protocols, interfaces, or APIs by transparently changing the messages

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Implicit context in 'Contacts' Database

- Uses history to examine call history
- Manages omissions
- Determine recipients
- Performs contextual message alterations
- Provides for and manages transitions at the boundaries between world-views where contextual dispatches occur

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Implicit context in 'Contacts' Database

- The name, e-mail ID, and telephone number
- When a computing device uses a contact to call a number using a name record, the system takes independent view and uses the telephone number implicitly and deploys CDMA or GSM protocols for connecting to the mobile network implicitly
- Context CDMA is implicit in defining the records 'Contact'.

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Implicit context in 'Contacts' Database

- When a computing system uses a contact to send an e-mail using a name record, the use of the e-mail ID record implicit to the system and the use of SMTP (simple mail transfer protocol) or other mail sending protocol is also implicit
- The context of the mobile service protocol, mail transfer protocol, and use of specific interfaces and software also implicit

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Explicit Context for 'document'

- Contact or personal information is an extrinsic context
- In context to processing of a document, the existence of document author contact information extrinsic
- The *contacts* context is imported into the *document* context to establish interrelationship between document and *contact*

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Context-aware Computing

- Leads to application-aware computing
- This is so because the APIs are part of the context (implicit or explicit contexts)
- For example, when using an e-mail ID, a mail receiving or mail sending application software is used for computing

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Context-aware Computing

- An application can adapt itself to the context
- For example, if context is a contact, the phone-talk application will adapt itself to use of the telephone number from the 'contact' and to the use of GSM or CDMA communication

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Context-aware computing and pervasive or ubiquitous computing

- Consider the computing context during mobile device data-communication
- Computing context includes the existence of the service discovery protocol, radio-interface, and corresponding protocol

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Use of context in computing

- Helps in reducing possibility of errors
- Helps in reducing the ambiguity in the action(s)
- Helps in deciding the expected system response on computations

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Context-aware computing and pervasive or ubiquitous computing

- Suppose service discovery protocol senses the context and finds that communication protocol is Bluetooth then the device uses Bluetooth to communicate
- When it finds the protocol is 802.11 WiFi LAN, it uses the WiFi for communication

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Use of context in computing

- For example, if *name* is input in personal biodata context, then the *address*, *experience* and *achievements*, which correspond to that name, are also required for computations
- When *name* is input in telephone directory context, then the *address* and which one correspond to that name, are also required for computations

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Summary

- Power aware computing methods
- Data caching in place of pulls
- Cache Invalidation mechanism
- Aggregation, clustering, transmitting only changes or modifications

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… Summary

- Context aware computing
- Physical context
- Computing context
- User context
- Temporal context
- Structural context

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End of Lesson 05

Power and Context Aware Computing

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Databases

Lesson 06

Transaction Models, Query Processing and Data Recovery

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Transaction

- Means execution of interrelated instructions in a sequence for a specific operation on a database
- Database transaction models must maintain data integrity and must enforce a set of rules called ACID rules

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ACID Rules

1. Atomicity
2. Consistency
3. Isolation
4. Durability

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1. Atomicity

- All operations of a transaction must be complete
- In case, a transaction cannot be completed; it must be undone (rolled back)
- Operations in a transaction are assumed to be one indivisible unit (atomic unit)

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2. Consistency

- A transaction must be such that it preserves the integrity constraints and follows the declared consistency rules for a given database
- Consistency means the data is not in a contradictory state after the transaction

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Consistency

- The amount transferred must be subtracted from account *A* and added into account *B*
- Consistency means that the sum total of the balances in accounts *A* and *B* is the same as it was before the transaction

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3. Isolation

- If two transactions are carried out simultaneously, there should not be any interference between the two
- Further, any intermediate results in a transaction should be invisible to any other transaction

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4. Durability

- After a transaction is completed, it must persist and cannot be aborted or discarded
- For example, in a transaction entailing transfer of a balance from account *A* to account *B*, once the transfer is completed and finished there should be no roll back

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ADO.NET (ActiveX Data Objects in .NET)

- BeginTransaction: It is used to begin a transaction.
- Any operation after BeginTransaction is assumed to be a part of the transaction till the CommitTransaction command or the RollbackTransaction command

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Auto-commit mode

- Means that the transaction is finished automatically even if an error occurs in between
- set autocommit = 1

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Query Processing

- During a transaction with a database, queries sent to read and get the records from the database
- Contacts and SavedNumbers
- Contacts stores the rows of records consisting of first character (firstChar) of name, contact-name (cName), and contact telephone number (cTelNum)

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Query Processing

- Querying of Record in Contacts by firstChar, cName, or cTelNum
- DialledNumbers stores the rows of records consisting of dialling sequence number (seqNum), time of call (cTime), and dialled telephone number (dTelNum). A record in DialledNumbers can be searched by seqNum, cTime, or dTelNum

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SQL Query

- SELECT cName, cTelNum FROM Contacts, DialledNumbers WHERE Contacts.firstChar = “R” AND Contacts.cTelNum = DialledNumbers.dTelNum

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Query processing

- Efficient processing of queries needs optimization of steps for query processing
- Query processing means making a correct as well as efficient execution strategy by *query decomposition* and *query-optimization*. A relational-algebraic equation defines a set of operations needed during query processing

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Queries optimization

- Based on cost (number of micro-operations in processing) by evaluating the costs of sets of equivalent expressions
- Based on a heuristic approach consisting of the following steps: perform the selection steps and projection steps as early as possible and eliminate duplicate operations

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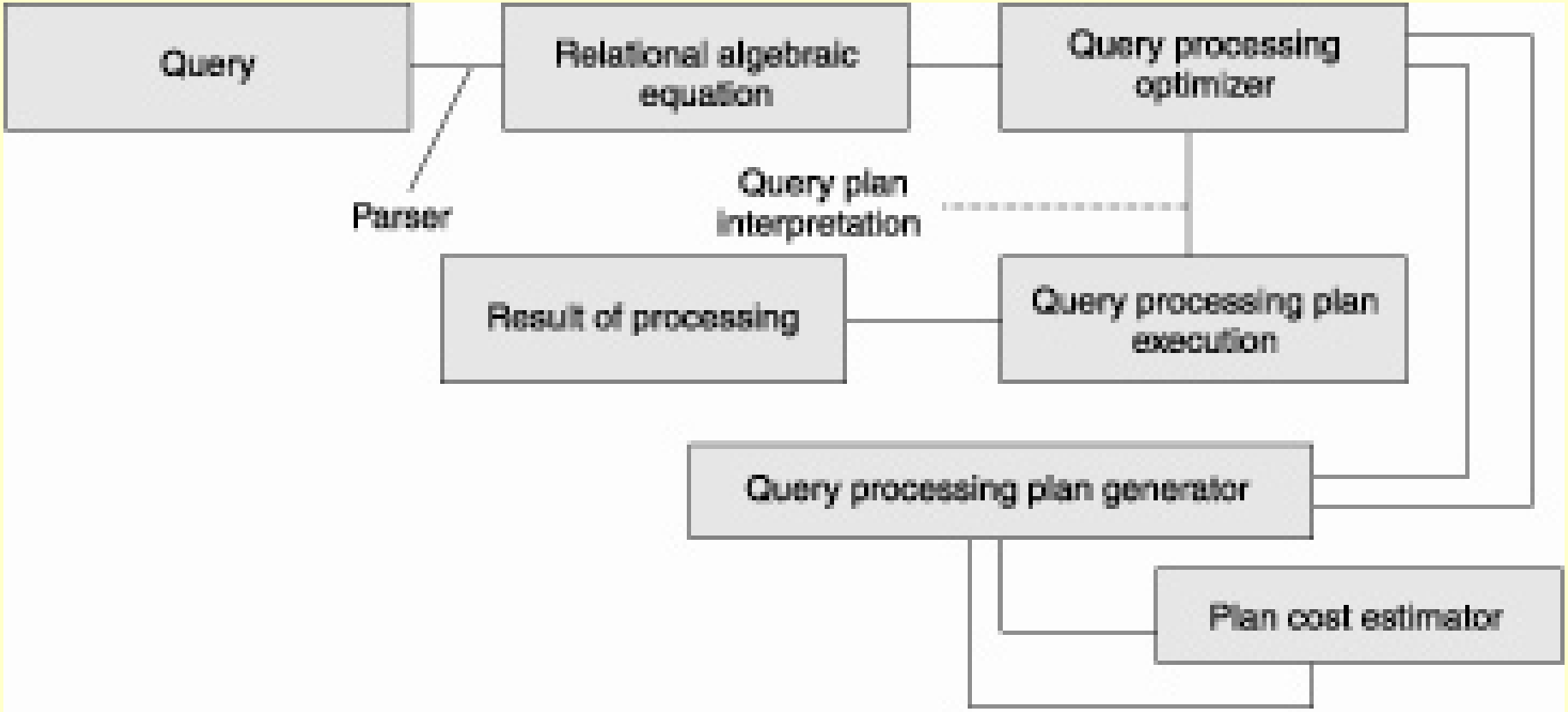
Query processing architecture



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Number of reasons warranting database recovery

- Media failure
- System failure
- Transaction abortion
- Data destruction due to intentional external attack or due to unintentional (due to careless handling) user carelessness

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Number of reasons warranting database recovery

- Data may also be destroyed due to destruction of the physical media hoarding the data
- Logical program errors and a transaction may not materialize
- Finally, there may be loss of main memory due to system errors (hardware or software)

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Non-recoverable Data

- In case of media failure, intentional attack on the database and transactions logging data, or physical media destruction
- However, data recovery possible in other cases

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Example

- Assume that transactions started at time t0 and system crash or failure occurs at *t*0 + *T*.
- Assuming that transactions *T*0 to *Tn*–1 are required to be completed in sequence *T*0, *T*1, *T*2 , ..., *Tn*–1, the following cases are possible

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Example

- Case 1: Last transactions incomplete
- Case 2: Initial and Last transactions incomplete

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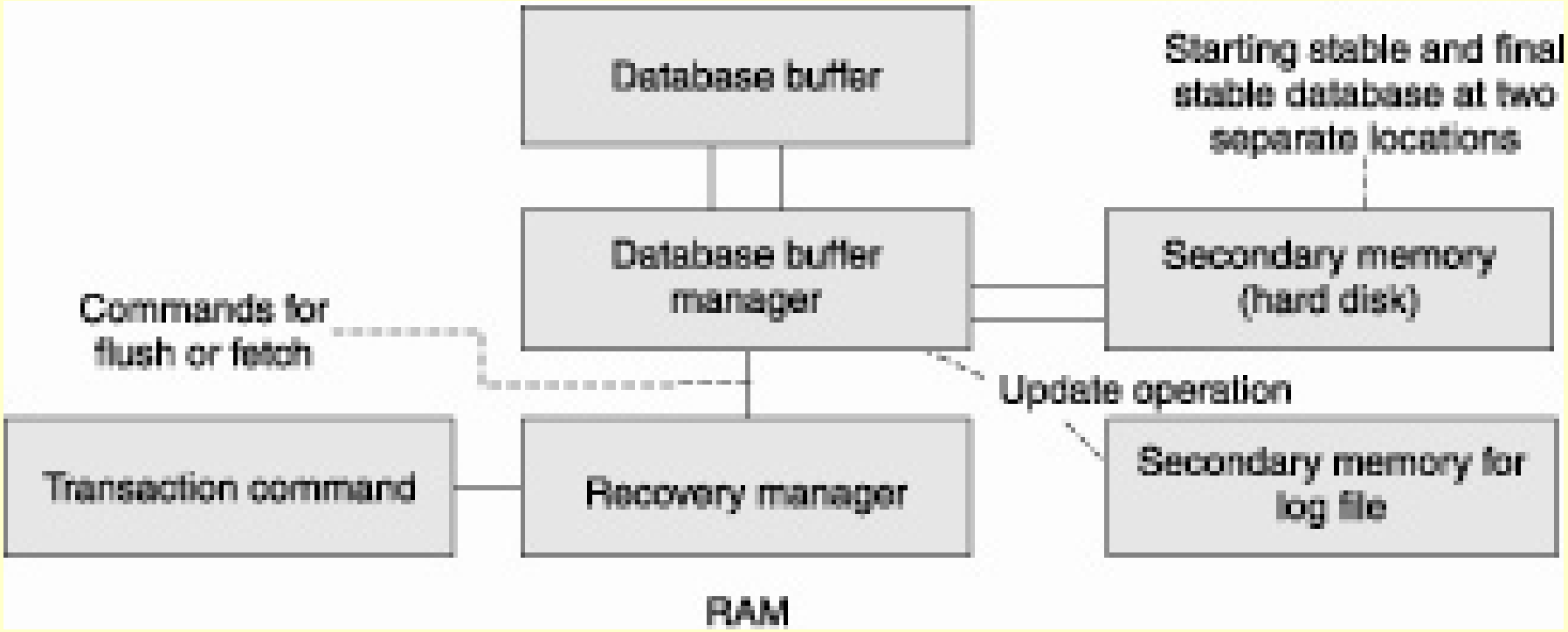
Recovery Management architecture



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Recovery Manager

- Recovers or aborts a transaction using the logged entries

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Recovery manager log file

- Each instruction for a transaction for update (insertion, deletion, replacement, and addition) logged.
- Database read instructions are not logged
- Log files stored at a different storage medium
- Log entries flushed out after the final stable state database is stored

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Logged entry Fields

- Transaction type (begin, commit, or rollback transaction)
- Transaction ID
- Operation-type
- Object on which the operation performed
- Pre-operation and post-operation values of the object

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Check Point based Recovery

- Uses the checkpoints for operations on the data during a set of transactions
- Recovery always made by back-scanning the logged records
- A checkpoint-based data recovery procedure defines the stage, up to which the back-scanning of logged operations in the secondary storage is to be done

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Recovery Models

- Full recovery model
- Bulk logged recovery model
- Simple recovery model

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Summary

- Atomicity in transactions
- Consistency in transactions
- Isolation in transactions
- Durability in Transactions
- Query
- Query processing
- Query Optimization

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… Summary

- Data recovery Model
- Recovery manager
- Check Points
- Logged Fields help in recovery

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End of Lesson 06

Transaction Models, Query Processing and Data Recovery

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Data Dissemination and Broadcasting Systems

Lesson 02

Pushed Based Data Delivery Mechanism

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Classification of Data-Delivery Mechanisms

- Push-based mechanisms (publish–subscribe mode)
- Pull-based mechanisms (on-demand mode)
- Hybrid mechanisms (hybrid mode)

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Push-based Mechanisms

- Server pushes data records from a set of distributed computing systems
- Examples of distributed computing systems– advertisers or generators of traffic congestion, weather reports, stock quotes, and news reports

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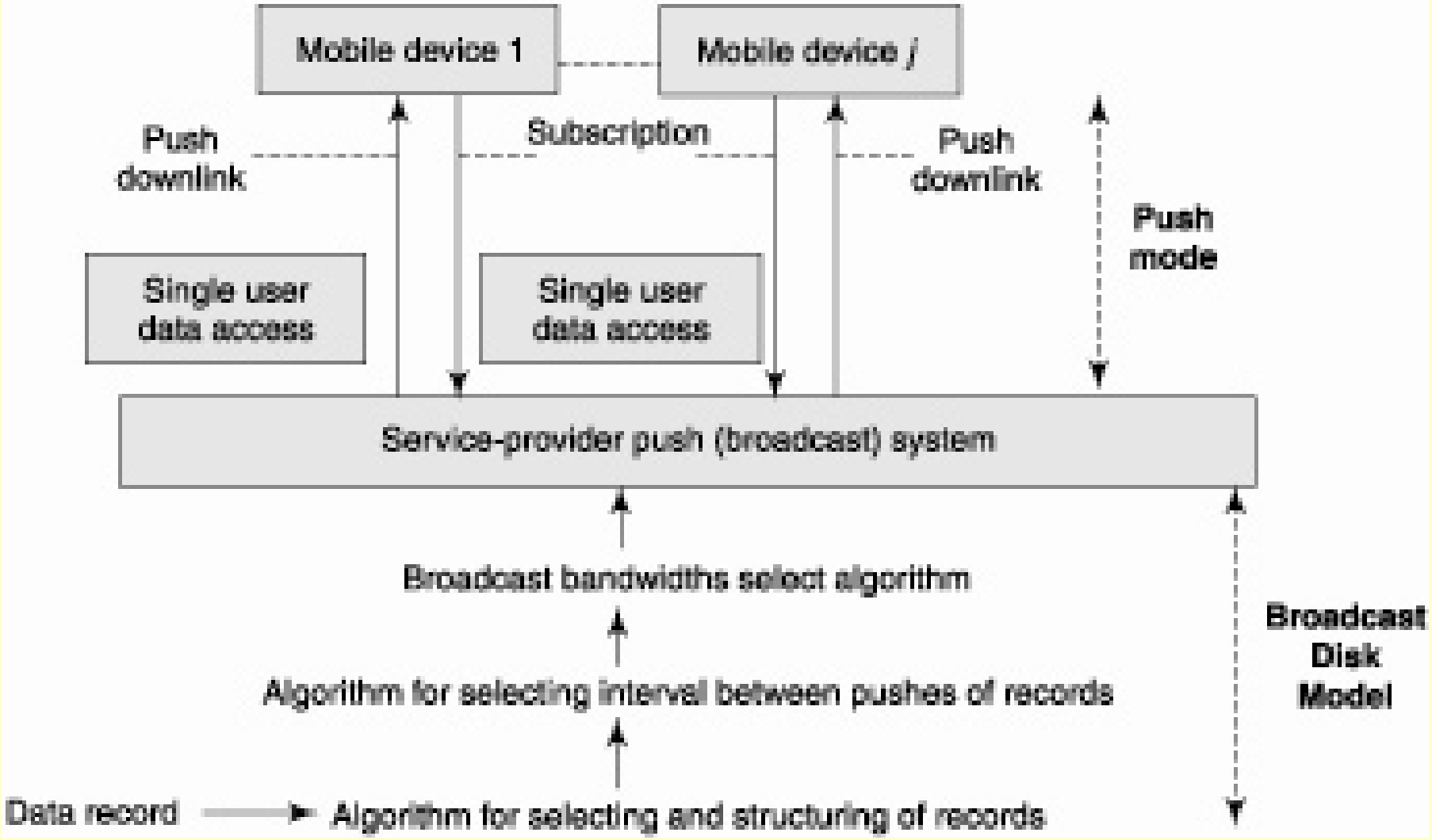
A server or computing system pushing the data records from a set of distributed systems



Publish–subscribe mode

- In which the data pushed as per the subscription for a push service by a user

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Pushing Algorithm

1. Select a structure of data records to be pushed
- An algorithm provides an adaptable multi-level mechanism that permits data items to be pushed uniformly or non-uniformly after structuring them according to their relative importance

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Pushing Intervals

2. Data pushed at selected time intervals using an adaptive algorithm

- Pushing only once saves bandwidth
- However, pushing at periodic intervals important because it provides the devices that were disconnected at the time of previous push with a chance to cache the data when it is pushed again

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Pushing Bandwidths

3. Bandwidths adapted for downlink (for pushes) using an algorithm

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Periods of Pushing and Stopping pushes

4. The same fixed periods can be used for pushing all records but usually higher bandwidth is allocated to records having higher number of subscribers or to those with higher access probabilities
5. A mechanism also adopted to stop pushes when a device is handed over to another cell

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Advantage of push-based mechanisms

- Enable broadcast of data services to multiple devices
- Server is not interrupted frequently by requests from the mobile devices
- Best option for the server as they prevent server overload, which may occur due to flooding of device requests

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Disadvantage of push-based mechanisms

- Dissemination of unsolicited, irrelevant, or out-of-context data
- User may not be interested in the disseminated data and may be inconvenienced

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Summary

- Server pushes data records from a set of distributed computing systems at intervals
- Server not interrupted frequently by requests from the mobile devices
- Dissemination of unsolicited, irrelevant, or out-of-context data

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Pushed Based Data Delivery Mechanism

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Data Dissemination and Broadcasting Systems

Lesson 03

Pull Based On-demand Data Delivery Mechanism

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Classification of Data-Delivery Mechanisms

- Push-based mechanisms (publish–subscribe mode)
- Pull-based mechanisms (on-demand mode)
- Hybrid mechanisms (hybrid mode)

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Pull-based Mechanisms

- User-device or computing system pulls the data records from the service provider's application database server or from a set of distributed computing systems

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Pull-based Mechanisms

- On-demand mode from a set of distributed computing systems, music album server, ring tones server, video clips server, or bank account activity server

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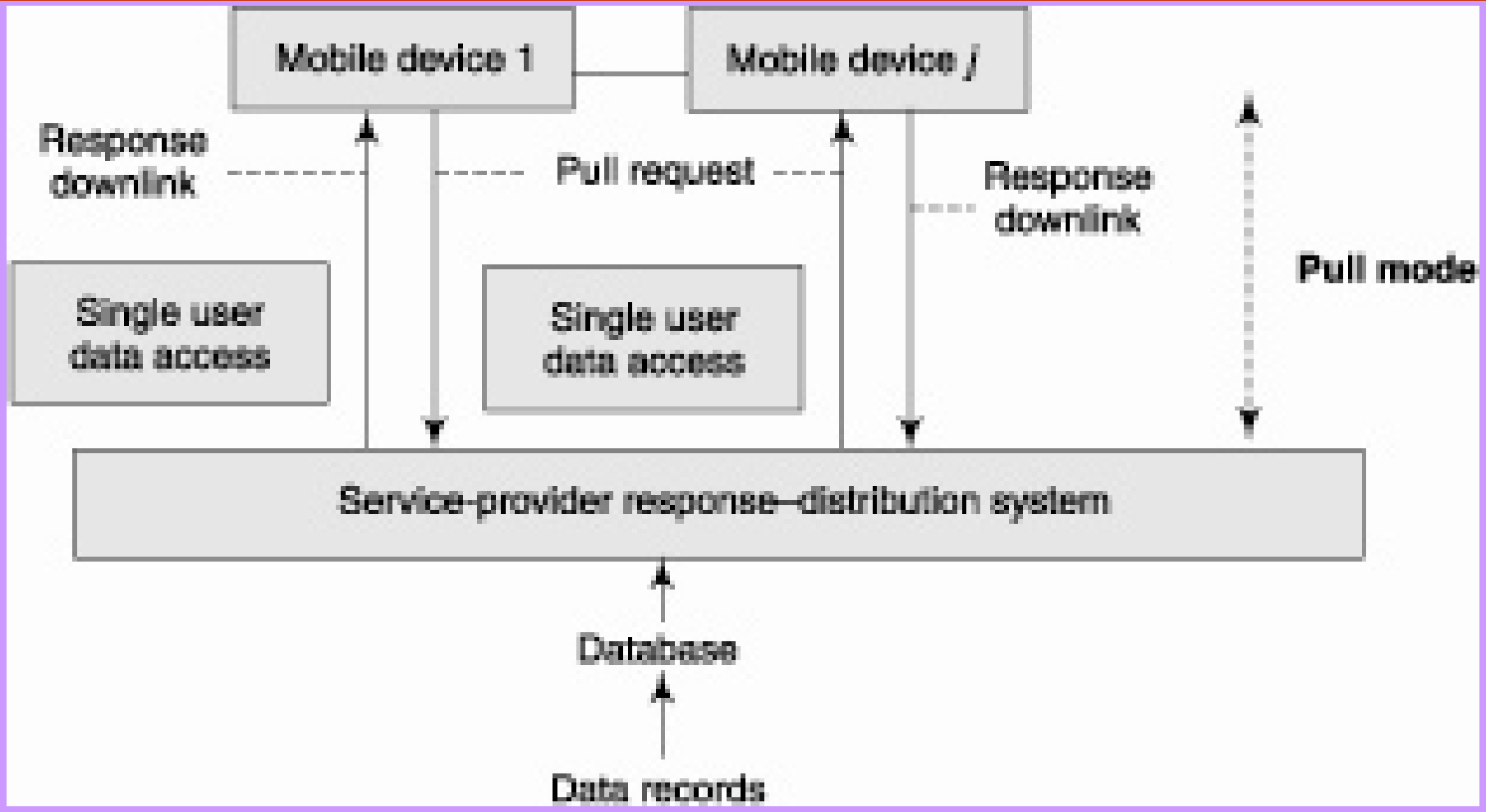
A mobile device Pulling the data records from a server or set of distributed systems



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Selective response from the server

- Records pulled and selective response to demand
- Server transmits data packets as response selectively
- After client-authentication, verification, or subscription account check

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Pulling Bandwidth

1. Used for the uplink channel depends upon the number of pull requests
- Assume that an uplink bandwidth of 19.2 kbps and service provider's application distribution system server accept 384 kbps
- Then only 20 pull requests can be used at 19.2 kbps

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Pulling Bandwidth

- Number of pull requests is larger, the link channel bandwidth lowered to 9.8 kbps or 4.8 kbps
- Similarly, the service provider's application distribution system adapting to the bandwidth required for serving the requests (downlink) in case the server is unable to deliver the response in a reasonable period

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Pull threshold

2. Threshold limits the number of pull requests in a given period of time
- Controls the number of server interruptions

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Prevent the device from pulling from a cell

3. A mechanism adopted to prevent access when handed over to another cell.
- On device handoff, the subscription cancelled or passed on to the new service provider system

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Advantage of Pull-based mechanisms

- No unsolicited or irrelevant data arrives at the device
- Relevant data disseminated only when the user asks for it
- Best option when the server has very little contention and is able to respond to many device requests within expected time intervals

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Disadvantage of Pull-based mechanisms

- Server faces frequent interruptions and queues of requests at the server may cause congestion in cases of sudden rise in demand for certain data records)
- The energy and bandwidth required for On-demand mode when sending the requests for hot items and temporal records (records changing with time) large

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Disadvantage of Pull-based mechanisms

- The number of server interruptions and uplink bandwidth requirement may increase a thousand times in the pull mode for hot records (e.g. World cup football score)
- A large number of devices making requests to the service provider choke the network
- The server is flooded with interruptions

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Summary

- User-device or computing system pulls the data records from the service provider's application database server or from distributed computing systems
- Relevant data disseminated when asked
- Server load when the number of server interruptions and uplink bandwidth requirement may increase a thousand times in the pull mode for hot records

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End of Lesson 03

Pull Based On-demand Data Delivery Mechanism

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Data Dissemination and Broadcasting Systems

Lesson 04

Hybrid Push-Pull Data Delivery Mechanism

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Classification of Data-Delivery Mechanisms

- Push-based mechanisms (publish–subscribe mode)
- Pull-based mechanisms (on-demand mode)
- Hybrid mechanisms (hybrid mode)

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Hybrid-based Mechanisms

- Integrates pushes and pulls
- Interleaved-push-and-pull (IPP) mechanism
- The user device or computing system pulls as well receives the pushed data records
- The devices use the back channel to send pull requests for records, which are not regularly pushed by the front channel

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Hybrid-based Mechanisms

- The front channel uses algorithms modelled as broadcast disks and sends the generated interleaved responses to the pull requests

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Hybrid-based Example

- A distributed computing system advertising and selling music albums
- The advertisements pushed and the mobile devices pull for buying the album

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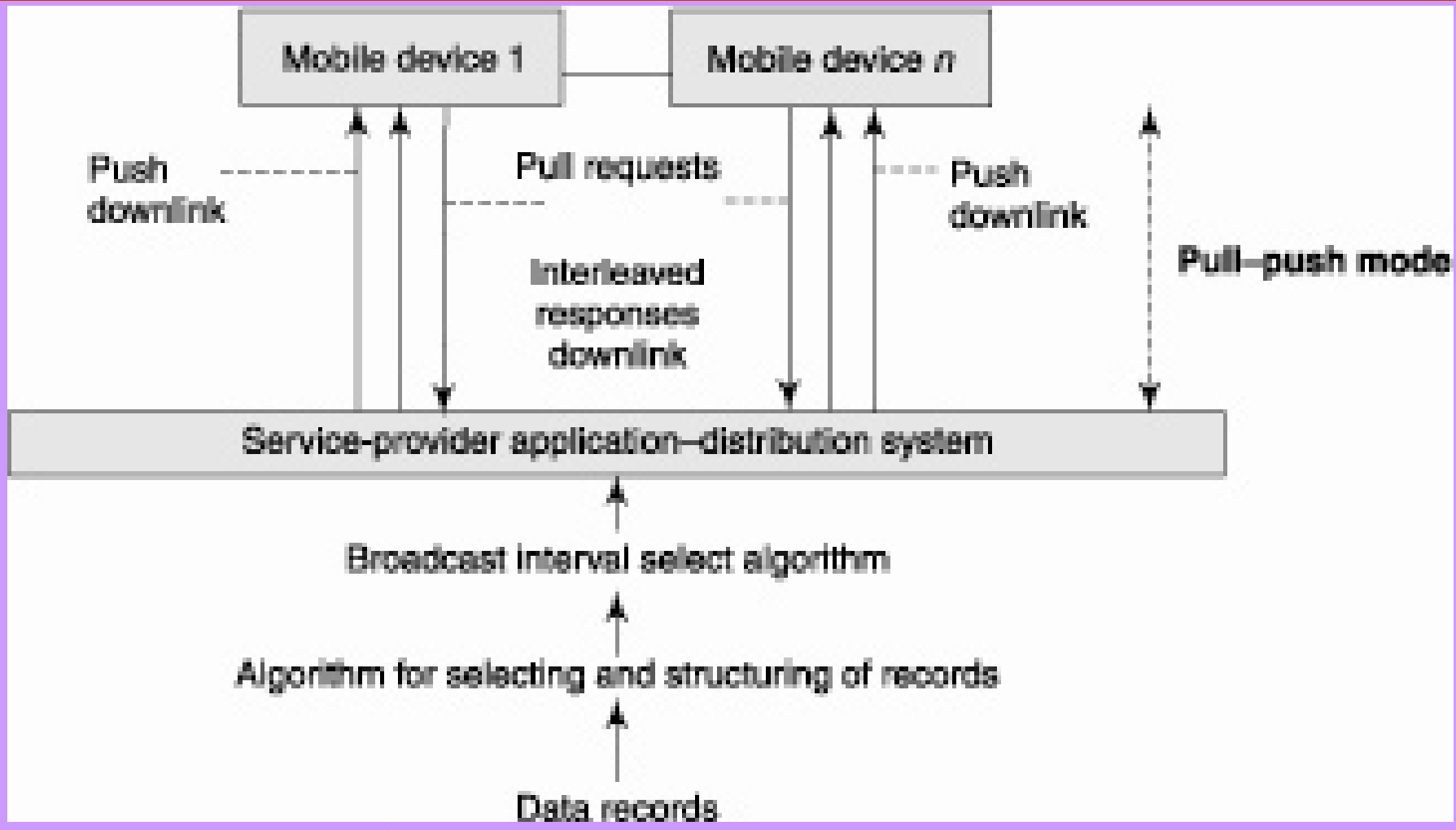
User device or computing system pulling as well receiving the pushed data records



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Two channels between devices and server

1. One for pushes by front channel and other for pulls by back channel
2. Bandwidth is shared and adapted between the two channels

- Adapted in downlink and uplink channels depending upon the number of active devices receiving data from the server and the number of devices requesting data pulls from the server

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Adaptive Algorithm for Push channel

3. An algorithm adaptively chop the slowest level of the scheduled pushes successively into larger number of pieces
4. Assume that at the slowest level, M data records each of length n bits are broadcast and pushed at successive interval of time, T_s each. The bandwidth used by these records is $M \times n \times (1/T_s)$ bps

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Advantage of Hybrid-based mechanisms

- The number of server interruptions and queued requests are significantly reduced

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Disadvantage of Hybrid-based mechanisms

- IPP, however, does not eliminate the typical server problems of too many interruptions and queued requests
- The adaptive chopping of the slowest level of scheduled pushes

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Summary

- Integrates pushes and pulls
- Interleaved-push-and-pull (IPP) mechanism
- Reduces number of server interrupts
- Two channels one for pushes and other for pull
- Bandwidth adaptable at a channel

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Hybrid Push-Pull Data Delivery Mechanism

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Data Dissemination and Broadcasting Systems

Lesson 05

Data Dissemination Broadcast-disk Models

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Disk models for Broadcast

- Presumed that all the *n* records to be broadcast are stored on a circular disk from 0°to 360°
- A hypothetical disk revolves and the angle changes from 0° to 360°
- The entire *N* bits in *n* records get pushed through a hypothetical reading-head over the disk.

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Broadcast Disk models

- The head continuously reads each bit of a record just beneath it and broadcasts it instantaneously on the wireless network
- During next revolution each bit in the records positioned from 0° to 360° broadcast once again in the same sequence as in earlier revolution

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Classification of Data-Delivery Mechanisms

- In case a device misses a record in first revolution, it can cache the same in next or any of the successive revolutions

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Broadcast bandwidth

- **Bandwidth means rate of bit transfer = $(t_s)^{-1}$** = Number of bits (N) stored between 0° and 360° divided by T_s
- T_s = the time taken for one revolution of the disk
- t_s = the time interval between successive bits transmitted from the disk

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Broadcast Time interval between transmission of successive bits

- Each bit in each record repeatedly broadcast at successive time intervals (= $N \times t_s = T_s$)
- Time interval between transmission of successive bits (T_s/N) [= *ts* = reciprocal of bandwidth]

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Number of adaptations and algorithms for broadcast

1. Circular Multi-disk Model
2. Flat Disk Model
3. Multi-disk Model with repetition rate proportional to priority
4. Skewed disk model

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Circular multi-disk model

- Each block of records pushed with a repetition rate proportional to its hierarchical level

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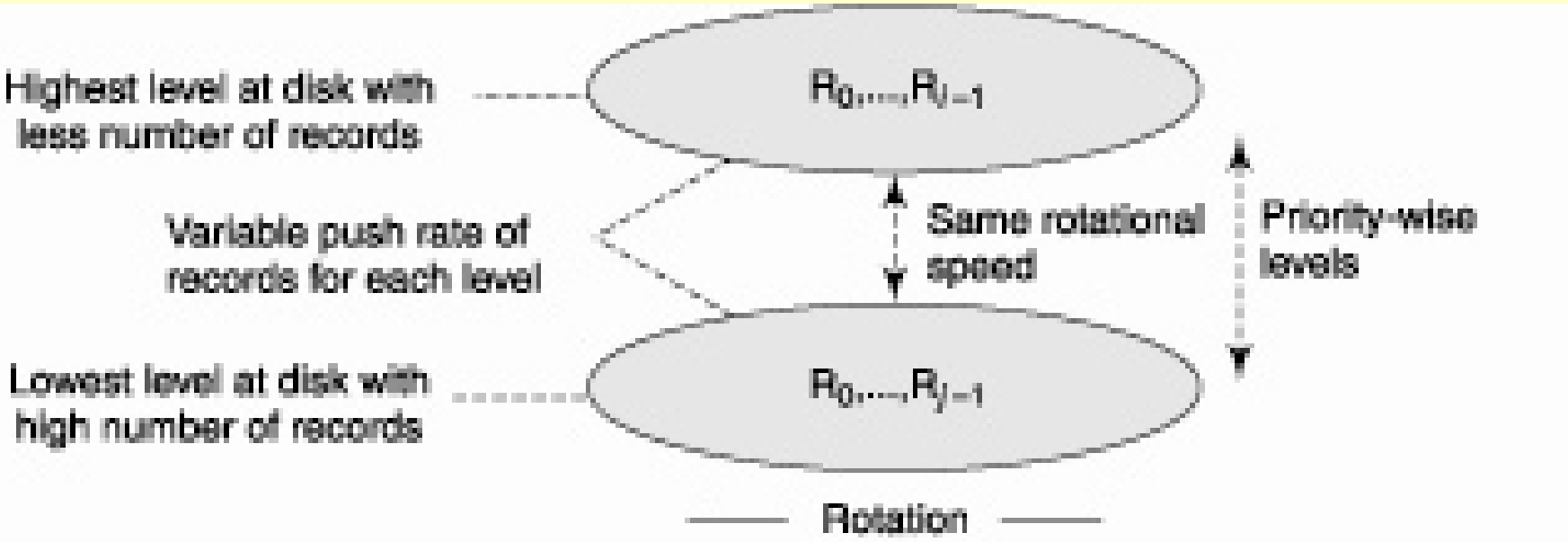
Circular multi-disk model



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Each rotating disk cycle

- Record blocks *R*0, *R*1, *R*2, *R*3, *R*0, *R*1, *R*2, *R*3, transmitted in a single broadcast cycle
- All record blocks have an equal priority level
- Using the flat-disk model, the server broadcasts the data as per cyclic requests (subscriptions)

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Multi-disk model

- Entails multiple levels of records on the broadcast disk

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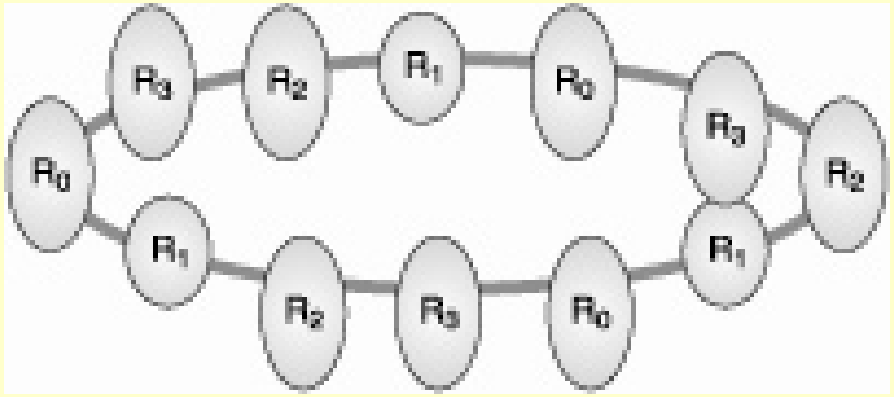
Flat Disk model



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Flat disk model

- The server broadcasts the data as per cyclic requests (subscriptions) without taking into account the number of devices that subscribe to a particular record

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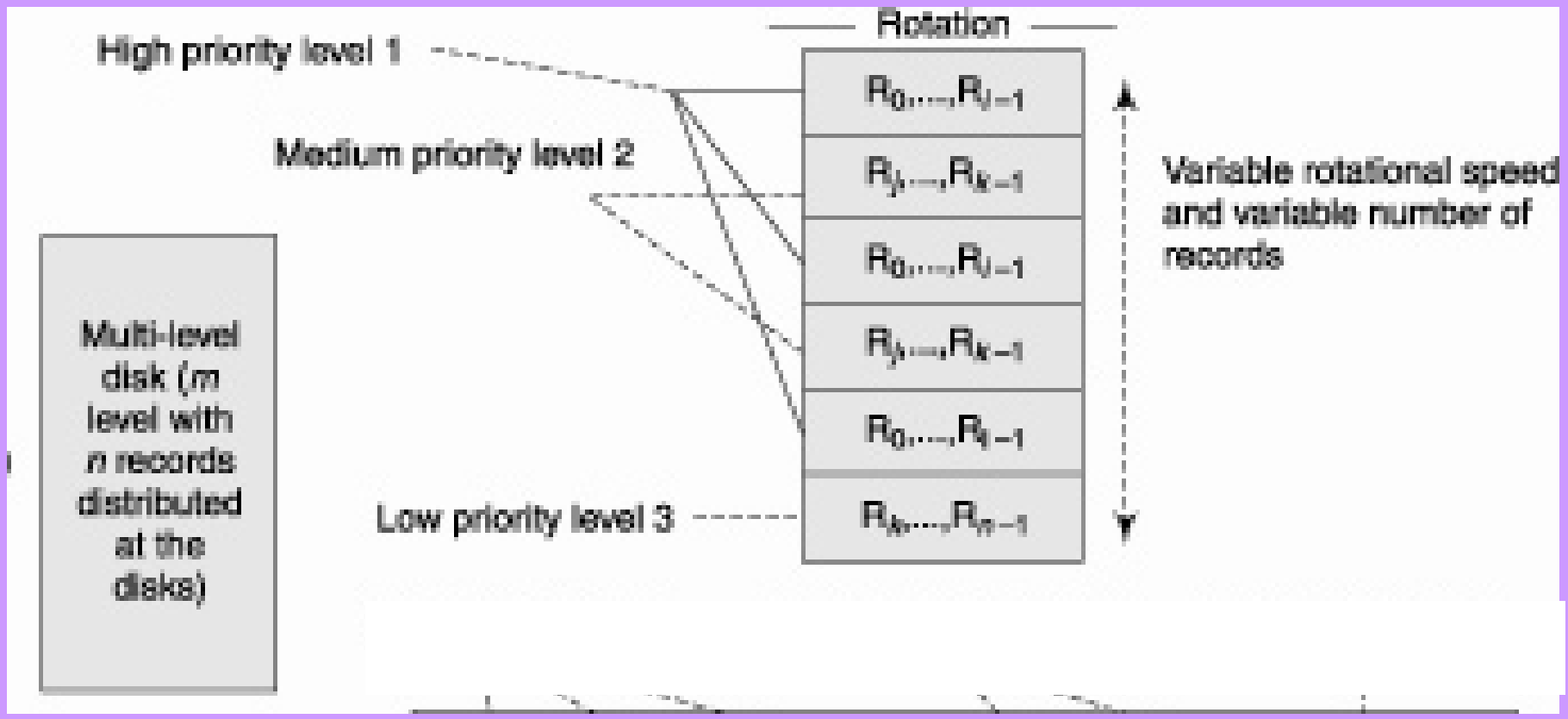
Multi-disk Model with repetition rate proportional to priority



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Number of levels assigned to a block of records as per its priority

- Priority can be as per the number of users subscribing to it
- Assume that the transmission rate at each level is same but the repetition rate of a block of records is proportional to the record's priority level

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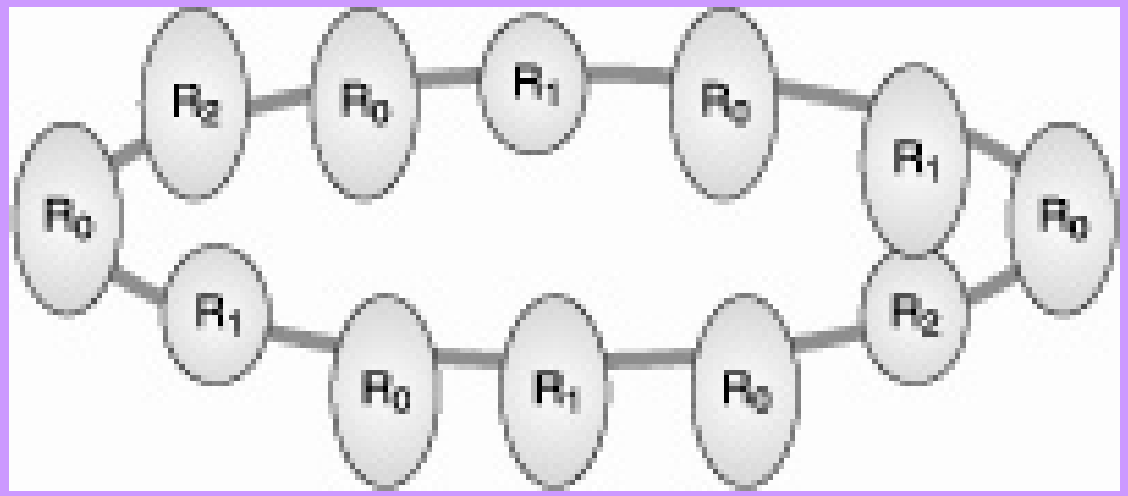
Multi-disk Model with repetition rate proportional to priority



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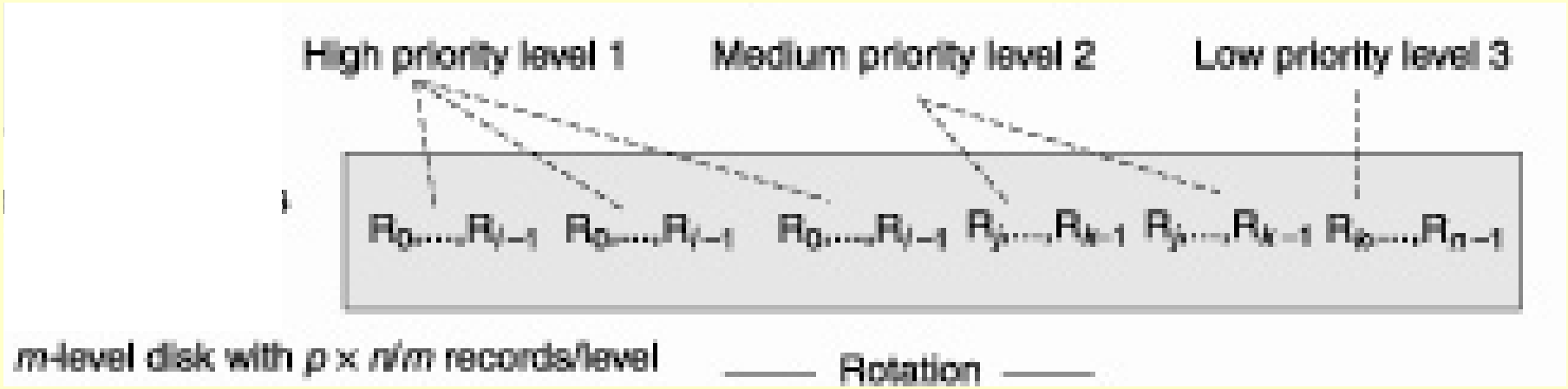
Skewed-disk model



m-level disk with $p \times n/m$ records/level

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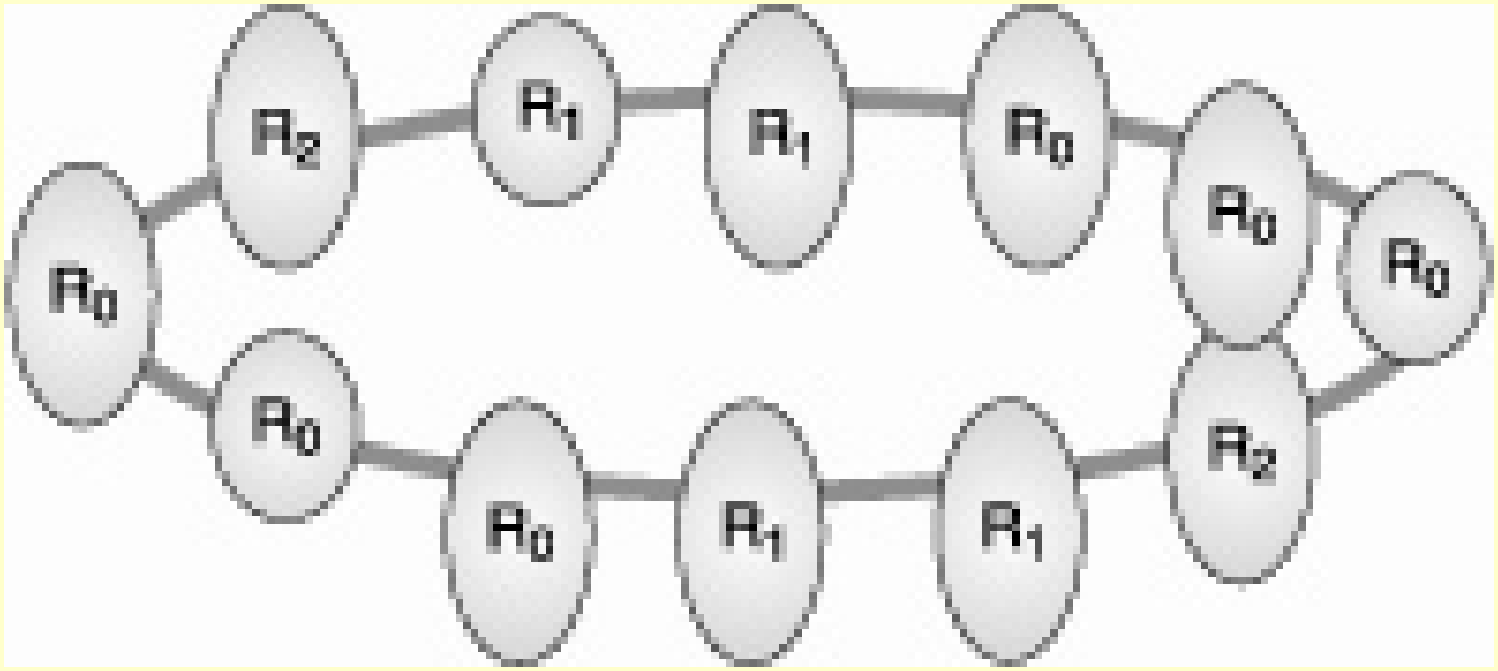
Skewed-disk model



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Skewed Disk Model

- The block of records repeated as per their priorities for pushing or as per number of subscribers of a given record
- However, unlike the multi-disk model, the skewed-disk model entails consecutive repeated transmissions of a record block, followed by consecutive repeated transmissions of another record block, and so on

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Skewed Disk Model

- High priority record blocks pushed more often than the low priority ones because these are repeated one after one more often

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Push–pull-based hybrid mechanism

- The server pushes the records through downlink and the devices send the requests to server through uplinks

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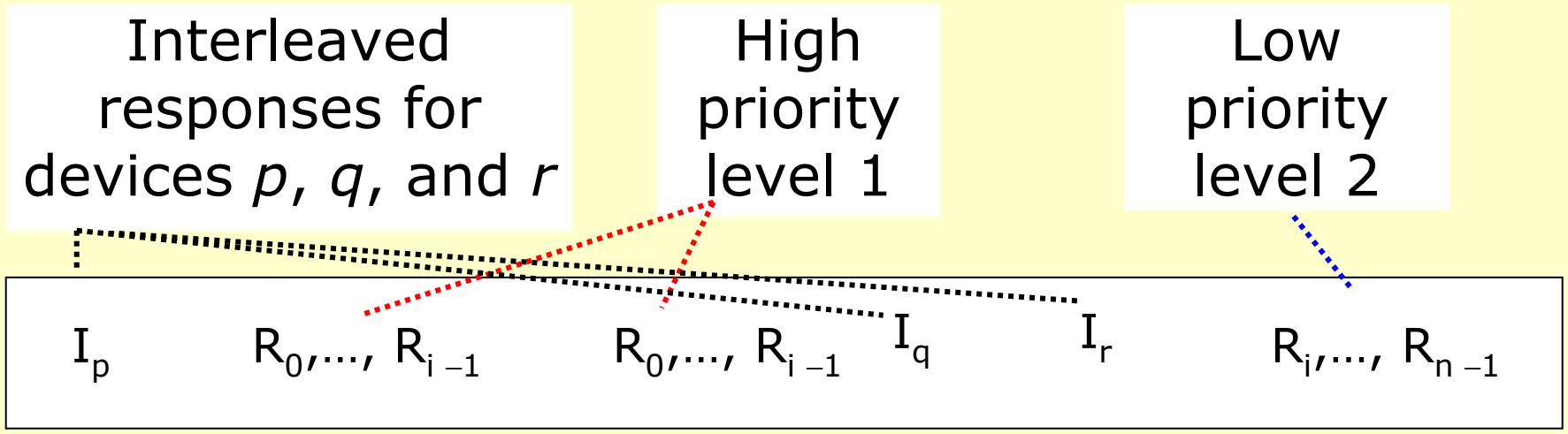
Hybrid mechanism Responses interleaving



m-level disk with p × *n*/m records/level with interleaved responses

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Real-time environment

- The records to be pushed in real time
- The instants at which a record pushed also matters
- Each data record (or each set of data records) represents an independent disk rotating at a speed inversely proportional to the time constraint associated with the record

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Real-time environment

- Independent disk rotating at different speed
- Facilitates the delivery of data records within a deadline in a real-time environment

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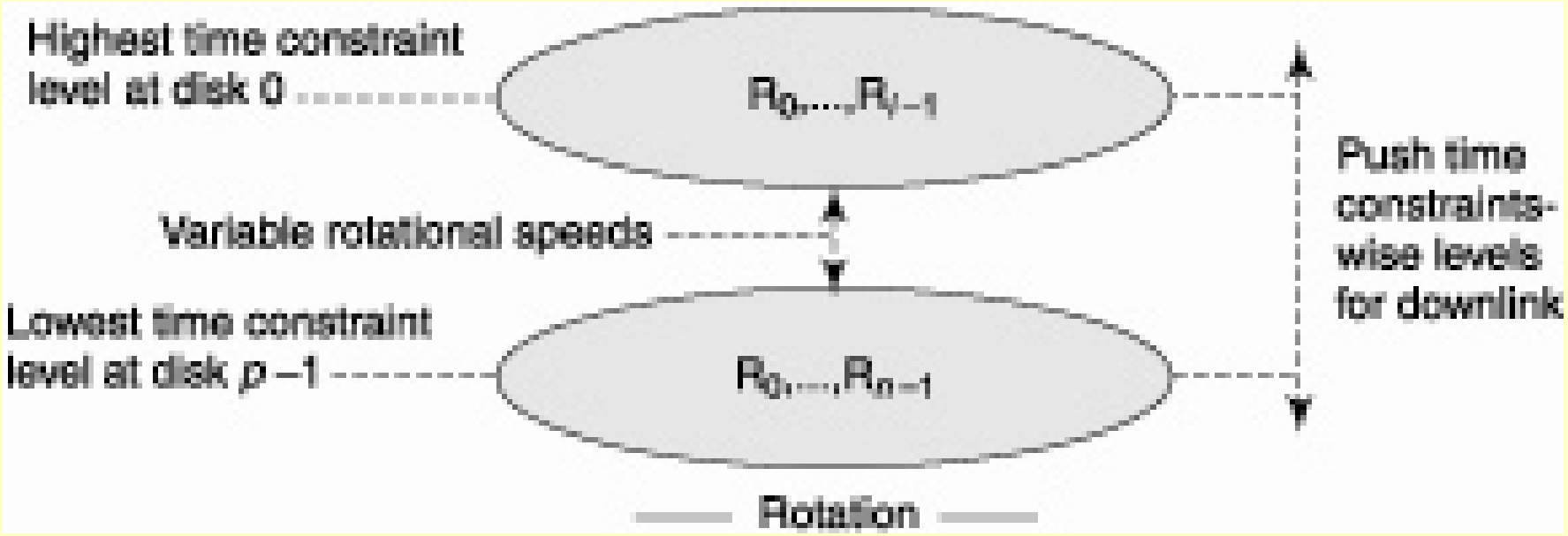
Broadcast Multi-disk Model for real time environment



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Summary

- Broadcast disk models
- A hypothetical disk (s) revolves and the angle changes from 0° to 360°
- The entire *N* bits in *n* records get pushed through a hypothetical reading-head over the disk (s)
- Circular multi disk model

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… Summary

- Flat disk
- Skewed disk
- Hybrid data delivery [Interleaving of responses]
- Real time environment disks

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Data Dissemination Broadcast-disk Models

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Data Dissemination and Broadcasting Systems

Lesson 06

Adaptive Dispersal Algorithms, Bandwidth allocation and Scheduling

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Functions of Information dispersal algorithm (IDA)

- To identify the duplicate or redundant parts of a file
- To make out the additions, deletions, or repetitions of a part, which can reconstruct the original file

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Example of using IDA

- Information consisting of record blocks *R*0 and *R*1 in a file is arranged as *R*0, *R*1, *R*0, *R*0, *R*0, *R*1, *R*1, *R*0, *R*1, *R*0, *R*1, and *R*0 in twelve parts.
- File when broken, AIDA algorithm can find two parts
- *x* and *y,* which correspond to *R*0 and *R*1*R*0

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IDA

- Using IDA, Transmit x, y, $2x$, $y - x$, $3y$ only in five record blocks on a broadcast disk.

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Adaptive IDA (AIDA) algorithm

- Aadapts the parts used for transmitting big sized information depending upon the requirements

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Algorithm based on the IDA or AIDA

- For data dissemination and push, file F_i partitioned into *k* parts
- Using algorithm, *j* parts selected using an IDA, pushed (dispersed, disseminated, or broadcasted) parts)
- All *k* parts *of* F_i reconstructed back at the client device from the algorithm

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Directory-based Data Dissemination

- Assume that a server gets updates of temperature, weather bulletin, and others for dissemination to the mobile devices
- All the records related to weather condition can be grouped into a directory
- Directory can hold a group of data records
- The records of each directory broadcast using a broadcast disk model

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Directory-based Data Dissemination

- Device can select the directory and tune and cache the weather records

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Advantage of Directory-based Data Dissemination

- The time, which would otherwise be spent by a device in first selecting and then tuning to the individual records needed by it in case of specific interests, for example, weather records, is saved

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Bandwidth

- Bandwidth refers to the number of bits transmitted per second from a server disseminating data by successive pushes
- Broadcast model bandwidth is t_s^{-1} where t_s is time interval between successive bits transmitted from the disk

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Bandwidth

- Assume l_{ii} = length of the i^{th} record, R_i, on a disk
- Then $N = \Xi\ l_{ii}$ where the sum extends over all records R_i with i varying from 0 to (n – 1) for n records on a disk
- Each bit in each record is thus repeatedly broadcast at successive time interval $N \times t_s = T_s$

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Bandwidth

- T_s is the time taken for one revolution of the disk
- Bandwidth = N = Ξ I_{ij} stored between 0°and 360° divided by time interval T_s between repeated transmissions in successive broadcast cycles

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Bandwidth allocation

- Means allocation of frequency $f = (t_s)^{-1}$, to the records in case of multi disks or multi-level disk
- It also means allocation of revolutionary speed $(t_s)^{-1}$ to given disk at a given level

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First **Bandwidth Allocation Strategy**

- A record allotted bandwidth in proportion to its length and its frequency of pushes (push rate = record repetition rate = *f*i)
- Assume that time interval between two pushes of record R_i is denoted by $t_s(i)$. Then f_i is $1 \div t_s(i)$
- Bandwidth allotted to i^{th} record (R_i) is proportional to $l_i \div t_s(i)$, where l_i is the record length

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Adopted allocation strategy and rate of pushes

- If p_i represents the subscription probability and f_i, the push rate [reciprocal of $t_s(i)$], then the average wait for i^{th} record (access latency), $t_{lat}(i)$ and average latency, $\overline{t}_{lat}$, for all records are given by two equations

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Square root rule

- $t_{lat}(i) = t_s(i) /2$
- $t_{lat} = (1/2) \Xi \ t_s(i) \times p_i$, where the summation goes from $i = 0$ to $n - 1$ for n records
- *Square root rule*, states that $\overline{t}_{lat}$ is minimum when $t_s(i)$ is proportional to $(l_i/p_i)^{1/2}$

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Equation for $t_s(i)$, p_i and l_i

- Assume that present time is t_p and t_s (i) is a previous instant when i^{th} record R_i was broadcast
- Consider a parameter $c(i)$ given by the equation
- $$c(i) = [t_p - t_s(i)]^2 \, p_i \div l_i$$

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$c(i)$

- It is proportional to the square of the time gap between present instant and previous instant when the R_i was scheduled for broadcast.
- $c(i)$ is useful in deciding whether R_i should be scheduled at this instant or later with the help of computations

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Online Scheduling Algorithm Steps

1. Compute $c(i)$ for all records.
2. Compute c_{max}, where c_{max} is the maximum value among the various values of $c(i)$.

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Online Scheduling Algorithm

3. Select the record for which *c* is maximum and call it record *q*. When more than one records show maximum *c*, then select any one of them as *q*
4. Broadcast using a broadcast service q^{th} record

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Bucket

- When the number of records is large, the computation of *c*(*i*) and *c*max, that is, steps 1 and 2 of the online scheduling algorithm, takes a longer time
- We define a bucket as the smallest logical unit of a broadcast
- Record can also be considered to be consisting of buckets during a broadcast

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Bucket Scheduling Algorithm Steps

1. Compute $c_b(j)$ for all bucket records (j = 0, 1, …, k –1), where k is the number of buckets in the records
2. Compute $c_b$max, where $c_b$max is maximum among the values of $c_b(j)$

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Bucket Scheduling Algorithm Steps

3. Select the bucket record for which c_b is maximum and call it q. When more than one bucket record shows maximum c_b, then select any one of them as q.
4. Broadcast the q^{th} bucket record.

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Off-line Scheduling Algorithm

- Subscription probability p_i and length of record l_i, do not change significantly
- Does not to warrant modifications in schedules of each broadcast cycle
- Thus continuous online computations involved in steps 1 and 2 are not required to be carried out at the server

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Off-line Scheduling Algorithm

- Initial stages require an online scheduling algorithm to compute the schedule steps 1–4 for one broadcast cycle such that each record is broadcast at least once
- For one broadcast cycle the sequences, repetitions, and schedule of broadcasting of each of the *n* records, once computed, are used for subsequent off-line schedules

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Summary

- Adaptively a file for data dissemination and push is partitioned into *k* parts and then, *j* parts are selected such that from the pushed parts, the mobile device can reconstruct all *k* parts and the file
- Directory based data dissemination
- Bandwidth allocation strategy

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… Summary

- Online scheduling of broadcasts
- Bucket scheduling
- Off-line scheduling

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Adaptive Dispersal Algorithms, Bandwidth allocation and Scheduling

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Data Dissemination and Broadcasting Systems

Lesson 07

Selective Tuning Methods

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Why selective tuning?

- Purpose of pushing and adapting to a broadcast model is to push records of greater interest with greater frequency in order to reduce access time or average access latency
- Mobile device does not have sufficient energy to continuously cache the broadcast records and hoard them in its memory

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Why selective tuning?

- Device dissipates more power if it gets each pushed item and caches it
- Therefore, it should be activated for listening and caching only when it is going to receive the selected data records or buckets of interest.

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Switching to idle power down mode

- Must during remaining time intervals, that is, when the broadcast data buckets or records are not of its interest to save energy

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Selective tuning

- A process by which client device selects only the required pushed buckets or records, tunes to them, and caches them
- Tuning means getting ready for caching at those instants and intervals when a selected record of interest is broadcast

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Enabling selective Tuning

- A structure and overhead placed over Broadcast data
- In addition to data, each broadcast cycle broadcasts a directory, hash-key, or index which is the overhead prefixed by server before the data

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Example of a Broadcasting Mechanism

1. *n* records *R*0 to R_n–1 interleaved and broadcast as in a multi-disk model
2. Only the records *Ri'* and *Rj'* are of interest and required by applications at a device
3. The broadcast disk broadcasts *Ri '* and *Rj '* thrice and once, respectively, as the subscription probability of *Ri '* is three times that of *Rj '*

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Example of a Broadcasting Mechanism

4. The record Ri' is partitioned into k buckets, bi_0 to bi_{k-1}
5. The record Rj' is partitioned into k' buckets, b_{j0} to $b_{j\,k'-1}$. Each bucket has equal length l_b, which means equal number of bits and the devices takes identical time $l_b \times t_s$ to cache each bucket data. [t_s the time interval between successive bits]

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Example of a Broadcasting Mechanism

6. In addition to data, each broadcast cycle broadcasts a directory, hash-key, or index which is the overhead prefixed by server before the data

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Selective tuning

- Device selects only the buckets of *Ri'* and *Rj '* which are of interest and receives the signals only during first, second, or third instances of *Ri '* or during instances of *Rj'* , that is, during the intervals Ti_0,… ,Ti_{k-1}, Tj_0, … ,$Tj_{k'-1}$ of broadcasting of bi_0 … bi_{k-1}, $bj0$ … $bj_{k'-1}$, respectively

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Selective tuning

- In the remaining intervals, where either the other records which are not of interest are being broadcast or when record of interest is already cached in an earlier broadcast cycle, the device remains idle.
- During this period it does not dissipate power and hence saves energy

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Access time (t_{access})

- The time interval between pull request from device and reception of response from **broadcasting or data pushing or responding system**
- Two important factors affect t_{access}

(i) number and size of the records to be broadcast (greater the n and N, the greater will be t_{access})

(ii) directory- or cache-miss factor

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Directory Method

- Broadcasting a directory as overhead at the beginning of each broadcast cycle
- If interval between the start of the broadcast cycles is T, then directory broadcasts at each successive intervals of T
- A directory can be provided which specifies when a specific record or data item appears in data being broadcasted

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Directory Method

- A device has to wait for directory consisting of start sign, pointers for locating buckets or records, and end sign.
- Then it has to wait for the required bucket or record before it can get tuned to it and, start caching it
- Tuning time t_{tune} is the time taken by the device for selection of records

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Hash-Based Method

- Entails that the hash for the hashing parameter (hash key) broadcasted
- Each device receives it and tunes to the record as per the extracted key
- In this method, the records that are of interest to a device or those required by it cached from the broadcast cycle by first extracting and identifying the hash key which provides the location of the record

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Index-Based Method

- Indexing is another method for selective tuning. Indexes temporally map the location of the buckets
- A broadcast cycle, a number called index can be first sent
- It specifies the location of the bucket or record

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Example

- Let index be 20 at the beginning of a broadcast cycle. It specifies that 20th bucket is of interest and is sent to the device in response to previous subscription

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Summary

- Selective tuning means device should be activated for listening and caching only when it is going to receive the selected data records or buckets of interest
- Selective tuning enables the device to remain idle till its records of interest reaches it from broadcaster

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. . . Summary

- Each broadcast cycle broadcasts a directory or hash-key, or index which is the overhead prefixed by server before the data to enable selective tuning

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Selective Tuning Methods

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Data Dissemination and Broadcasting Systems

Lesson 08

Indexing Techniques for Selective Tuning

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Indexing

- A method for selective tuning
- Indexes temporally map the location of the buckets

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Index-Based Methods

- Index be first sent
- It specifies the location of the bucket or record
- Consider a simple example. Let index be 20 at the beginning of a broadcast cycle. It specifies that 20th bucket is of interest and is sent to the device in response to previous subscription.

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Indexing

- A technique in which each data bucket, record, or record block of interest is assigned an index at the previous data bucket, record, or record block of interest to enable the device to tune and cache the bucket after the wait as per the offset value

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Indexing

- At each location, besides the bits for the bucket in record of interest data, an offset value may also be specified there
- While an index maps to the absolute location from the beginning of a broadcast cycle, an offset index is a number which maps to the relative location after the end of present bucket of interest

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Offset

- Offset means a value to be used by the device along with the present location and calculate the wait period for tuning to the next bucket
- All buckets have an offset to the beginning of the next indexed bucket or item

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Indexing

- The server transmits this index at the beginning of a broadcast cycle as well as with each bucket corresponding to data of interest to the device.
- A disadvantage of using index is that it extends the broadcast cycle and hence increases t_{access}

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Disadvantage of using index

- Extends the broadcast cycle and hence increases t_{access}

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(*I*, *m*) indexing

- An index *I* transmits *m* times during each push of a record
- An algorithm is used to adapt a value of *m* such that it minimizes access (caching) latency in a given wireless environment which may involve frequent or less frequent loss of index or data

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(*I*, *m*)

- Index format is adapted to with a suitable *m* chosen as per the wireless environment
- This decreases the probability of missing *I* and hence the caching of the record of interest
- If *m* is chosen small then the power dissipated by device is less

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(*l*, *m*)

- If *m* decreased, the chances that the cache be missed go up and the data access latency increases
- The value of *m* therefore needs to be optimized which can be done by employing an algorithm as stated earlier

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Distributed Index-based Method

- When Index *I* is repeated *m* times, the access latency increases significantly even though the cache-miss probability reduces drastically
- Distributed index-based method an improvement on the (*I*, *m*) method

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Distributed Index-based Method

- In this method, there is no need to repeat the complete index again and again
- Instead of replicating the whole index *m* times, each index segment in a bucket describes only the offset *I′* of data items which immediately follow
- Each index *I* is partitioned into two parts—*I′* and *I″*

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Distributed Index-based Method

- *I″* consists of unrepeated *k* levels (sub-indexes), which do not repeat and *I′* consists of top *j* repeated levels (sub-indexes)

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Flexible Indexing Method

- Provides dual use of the parameters (e.g., use of I_{seg} or I_{rec} in an index segment to tune to the record or buckets of interest) or multi-parameter indexing (e.g., use of *I*seg, *I*rec, or I_b in an index segment to tune to the bucket of interest)

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Temporal Addressing

- A technique used for pushing in which instead of repeating / several times, a temporal value is repeated before a data record is transmitted
- There can be effective synchronization of tuning and caching of the record of interest in case of non–uniform time intervals between the successive bits

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Broadcast Addressing

- A broadcast address similar to IP or multicast address
- Each device or group of devices can be assigned an address
- The devices cache the records which have this address as the broadcasting address in a broadcast cycle

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Summary

- A technique in which each data bucket, record, or record block of interest is assigned an index at the previous data bucket, record, or record block of interest to enable the device to tune and cache the bucket after the wait as per the offset value

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. . . Summary

- Index I based, (I, m) based, distributed index based and flexible indexing methods
- Temporal and broadcast address methods in place of the index

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Indexing Techniques for Selective Tuning

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Data Dissemination and Broadcasting Systems

Lesson 09

Digital Audio Broadcasting

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Digital Audio Broadcast System (DAB)

- OFDM carrier FHSS based technique for distribution (spreading) of data over large number of sub-carriers that are spaced at precise frequency intervals with the help of a coding scheme
- Multi-carrier transmission and multiplexing in each carrier facilitates single frequency networks (SFN) for multiple applications

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DAB

- OFDM enables separation of carriers in spite of the multi-path transmissions and interference of signals
- Multiplexing of stereo radios and radios for traffic reports
- Each carrier using mutually orthogonal codes
- Frequency spectrum in VHF Band III and UHF L band

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Frequency Spectrum and Bandwidth

- Eureka 147 protocol, VHF Band III (174 to 240 MHz) and UHF L band (1.452 to 1.492 GHz), bandwidth 1.5 MHz block (192 to 1536 sub-carriers) per carrier multi-carrier transmission

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Audio Coding

- MP2 (MPEG-1 layer-2) audio codec1 needs 192 kbps plus for good stereo audio, but at 192 kbps, only six DAB stations can multiplex
- 1.5 MHz block of the frequency band is used and 1.5 MHz block multiplexes six 192 kbps stations by frequency multiplexing

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DAB

- UK adopted DAB 128 kbps codec
- Dual rate codec (128 kbps and 192 kbps) protocols are being adopted
- DABv2 (DAB version 2, DAB-2) adopted in 2006

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DABv2

- Supports MPEG2, AAC (advanced audio coding), MPEG4, BSAC (bit slice arithmetic error resilient coding), AAC+ (only in new DAB+ standard), SBR2 (spectral band replication), and Windows Media audio codecs together with convolution coding and RS coding

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Multiplexing audio and text

- Dynamic label segment (DLS) multiplexes text with audio to provide radio text real-time information such as weather report, stock-quotes, and traffic congestion reports
- The text can be read on LCD screens

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Carriers and inter-symbol multiplexing

- OFDMA multiple carriers for broadcast from a single radio station
- For example, three short wave radios (SWR) of 192 kbps stereo, one 160 kbps stereo, two SWR services for traffic reports at 18 kbps use a SFN in Germany

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Broadcast transmission

- Needs lower power
- Same SFN of all stations in a country for same radio program network and using OFDM same frequency spread multiplexing
- Common interleaved frame (CIF) which transmits after the time–space interleaving of data fields in the frame

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Frame and Time–space interleaving and Modulation,

- Frame consists of main service channel (MSC), synchronization channel (SynC), and fast information channel (FIC)
- Time space Interleaving transmitted in different time slots t_s in sequence other than that in which generated
- Receiver rearranges the sequence and generates the original analog signals
- Differential QPSK (DQPSK)

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Guard interval t_g

- Period provided before synchronization of the transmitted bits takes place in the receiver

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CIF Frame Channels

- Fast information channel (FIC) carries control information and has 240 bits plus a 16-bit checksum
- interleaved in the frame along with the MSC and the synchronization channel
- The synchronization channel of the duration of the transmission time of two symbols [$2 \times (t_g + t_s)$] and is also interleaved with the MSC and the FIC

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OFDM Advantages

- Error bursts resulting from multi-path interference in a case of moving vehicle are averaged out over the time
- Effect of delay is felt only in time reference signals

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Delays

- Computation delay occurs due to this sequencing and re-sequencing
- The data buffering and other processing also contribute to delay, typically of a few seconds, between the studio source and the receiver

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Bit-error correction

- Viterbi method
- Based on forward error correction (FEC)
- Very low BER (bit error rate) in FEC for the control of critical features in the receiver (e.g., synchronization channel) and normal BER in FEC for traffic channel

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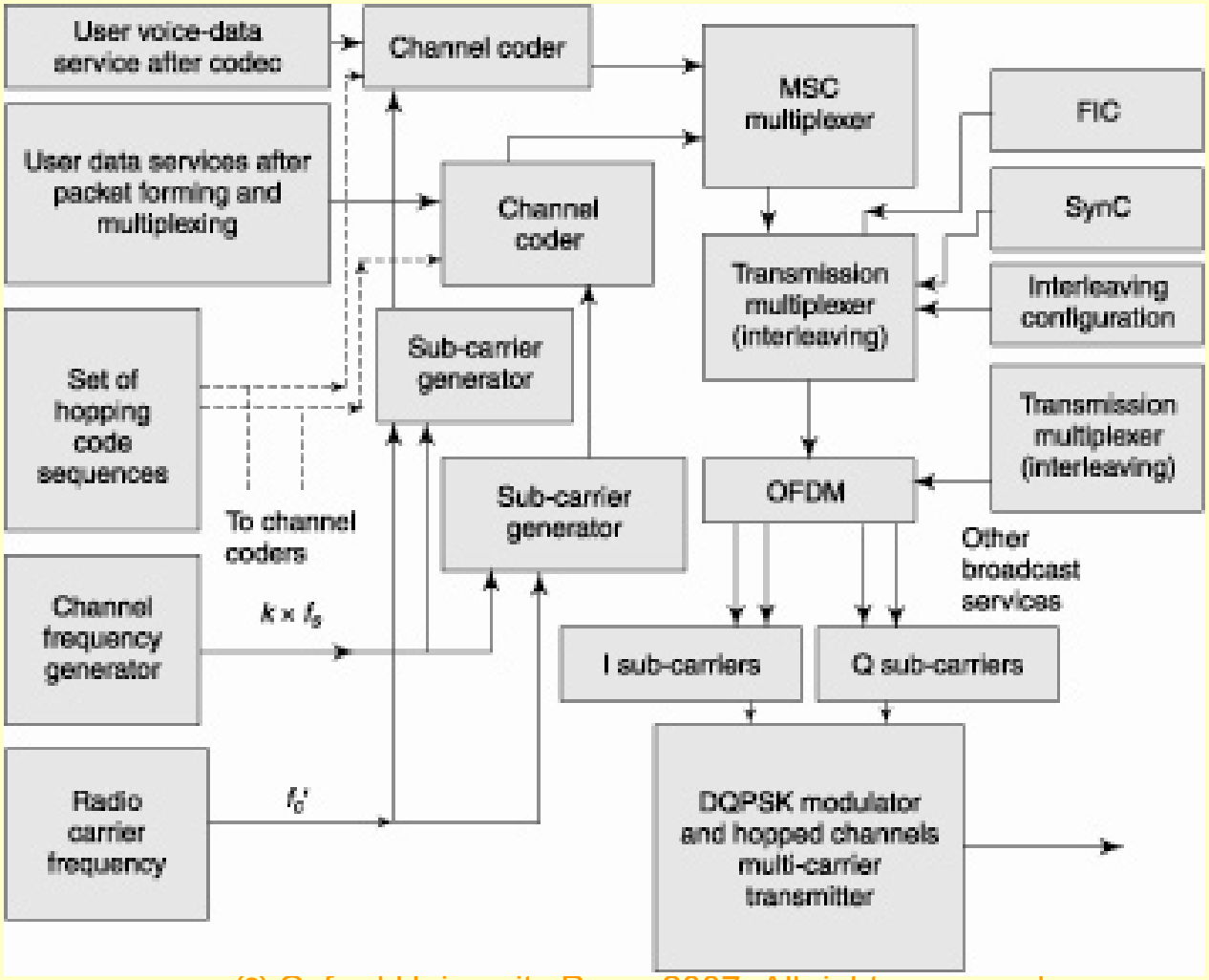
Architecture of a DAB transmission unit



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Object

- An object consists of a collection of logically bonded data fields and properties which define the state of the object and methods (functions) which manipulate the state of the object

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DAB Objects

- A DAB transmitter transfers the DAB objects with each object consisting of the data fields and services
- A device can be considered as receiving DAB objects in real-time environment and the server disseminating or broadcasting these objects to the devices

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Server (broadcaster) transmission of the objects

- The objects examples– Traffic reports, news as text, weather report, and stock quotes)
- Objects with high subscription (demand) can be repeated more often with defined push frequencies proportional to subscription probability

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Broadcasting interleaved segments of different objects

- Can broadcast such that only object header repeated
- Similar to index (*I*, *m*) technique in which index *I* repeats *m* times

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Multimedia object transfer (MOT) protocol

- A standard, which supports DAB and multimedia formats– JPEG, Java, HTML, GIF, BMP, ASCII, and HTTP)
- DAB receiver of various types
- For example, audio only, audio with colour graphic display, audio with multi-line text display, audio with single-line text display, audio with slide show, and audio with HTML web page

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MOT

- The DAB objects or interleaved segments form the body of the transferred data
- The body can have arbitrary data the content type of which is given in the header field

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MOT protocol

- Involves transmission of data with a core header, a header extension, and body
- The core has seven byte fields for header size, body size, and content type.

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The receiver using MOT

- Identifies the object as well as assess its resources
- For example, whether the data object received is a JPEG file, a text in ASCII, or an audio codec output

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MOT extension header fields

- After the core provide additional information
- Push frequency for a data file
- Priority of the data
- Segmentation and supporting caching mechanism (e.g., method to be used for selective tuning and caching of DAB objects or segments)

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Summary

- DAB Eureka 147 protocol, VHF Band III (174 to 240 MHz) and UHF L band (1.452 to 1.492 GHz), bandwidth 1.5 MHz block (192 to 1536 sub-carriers) per carrier multi-carrier transmission
- OFDM
- SFN of all stations in a country

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. . . Summary

- Common Interleaved Frame
- Frame consists of main service channel (MSC), synchronization channel (SynC), and fast information channel (FIC)
- DAB objects
- MOT protocol

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End of Lesson 09
Digital Audio Broadcasting

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Data Dissemination and Broadcasting Systems

Lesson 10

Digital video Broadcasting and Mobile TV

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Digital video Broadcasting (DVB)

- Analog TV— AM transmission for video component and FM transmission for audio component
- DVB— early 1990s
- Commercialized in 2000
- DVB-H for Mobile TV — commercialized since early 2006

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DVB systems

- Cable (DVB-C)
- Terrestrial TV (DVB-T)
- Satellite (DVB-S)
- Terrestrial TV for handheld mobile devices (DVB-H)
- DVB-H used in mobile TV

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DVB-T

- VHF (130–260 MHz) and UHF (430–882 MHz)
- OFDM– Multiple carriers with each carrier using mutually orthogonal codes
- Each carrier 8 MHz block
- FHSS
- Between 5 and 30 Mbps DVB receiver data rate for downlink at user

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DVB-T Broadcaster data rate

- Between 6 and 38 Mbps for downlink to high speed broadband Internet

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Multi-carrier transmission and multiplexing in each carrier

- Facilitates single frequency networks (SFN) for multiple applications
- Multiplexing of TV broadcaster, Internet service provider, mobile service provider channels, and service information tables

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Service information tables

- MPEG container in four tables for the set top boxes

1. Event (current status) information table
2. Service description table with broadcast service names, parameters, and multiplexed channels information
3. Network information table
4. Time and date information table

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DVB MPEG Encoding formats

- MPEG-2/DVB single channel HDTV (high definition TV) 1920 × 1080 pixel
- MPEG-2/DVB multiple channels EDTV (enhanced definition TV)
- MPEG-2/DVB multiple channels SDTV (standard definition TV) 640 or 704 ×480 pixel,
- MPEG-2/DVB multiple channels multimedia data broadcasting

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Modulation

- DVB-C uses 64-QAM or uses 256-QAM and DVB-T uses 16-QAM or 64-QAM (or QPSK)

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Additional Protocols of DVB

- DVB-VBI (vertical blanking interval) for conversion from DVB to analog TV
- Data connections DVB-DATA, return channels (for GSM, DECT, PSTN, ISDN, Satellite)

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Additional Protocols of DVB

- Protocol DVB-IPI, DVB-NPI (Network protocol independent) and DVB-Text for text and DVB-SUB for sub-titling on the video frames

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Multimedia home platform

- DVB-MHP (multimedia home platform) Java based
- For development of consumer video system applications, interfaces for network card control, application download, and layered graphics

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Encryption

- DVB-CA for conditional access system and DVB-CPCM for content protection and content management

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Mobile TV—DVB-H DVB-H broadcast downlink channel

- Used by mobile service provider
- DVB-T/DAB/IP data broadcaster with high rates
- Data broadcast rates 5 Mbps to the handheld devices

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Mobile TV—DVB-H DVB-H broadcast uplink channel

- Mobile TV devices also uplink and interact with mobile service provider network (enhanced telecommunication mobile GSM/GPRS network)

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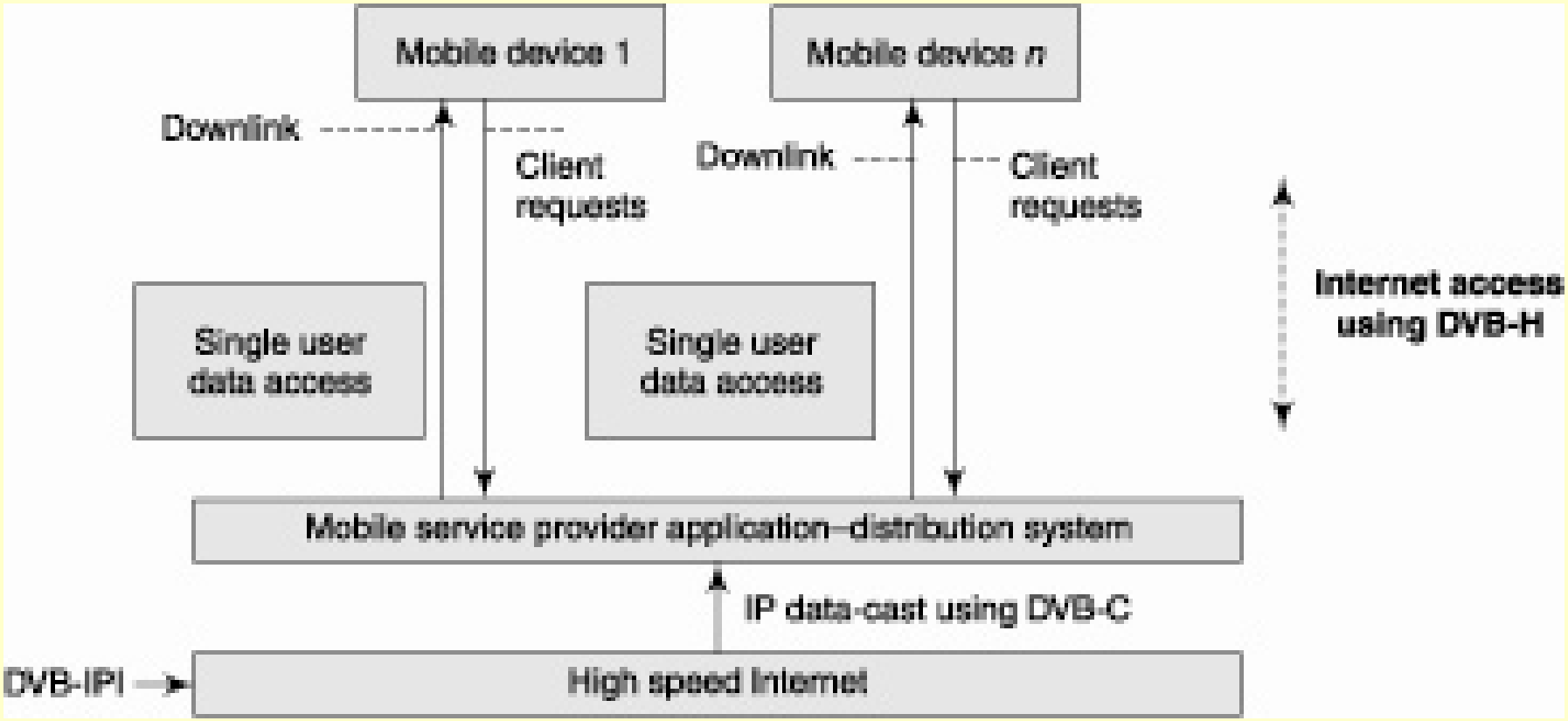
Mobile TV/DVB-H broadcasting architecture for downlink to handheld devices



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Commercial mobile TV started

- In early 2006 **in Oxford, UK**
- Participating companies Arqiva/O2 with content providers—BBC, ITV, Turner Broadcasting, Shorts International, Discovery, Eurosport, MTV, Channel 4, Five TV, and BSkyB
- Broadcast for receiving the signals on mobile TV as well for 16 popular TV programs

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Transmission

- TV services use OFDM DVB-T transmission standard
- Multiplexed data at second stage carried all over the globe using high speed Internet using IP datacast

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Transmission

- At third stage, the IP datacast networks to a mobile service provider application distribution system (MSPADS)
- This system finally provides service to handheld devices
- Only subscribed based service using DVB-H service

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Transmitter for Oxford SFN

- 9 Harris Semiconductor transmitters transmit and each employs SFN multiplexing
- ½ FEC
- QPSK modulation
- 10 Time-slices for 16-programs
- IP datacast Technique
- IPSec for security

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Standard broadcast frequency spectra

- Band IV (554 MHz), VHF Band III (174–230 MHz) or a portion of it
- UHF Band IV/V (470-830 MHz) or a portion of it
- Band L (1.452–1.492 GHz)
- DVB-H can coexist with DVB-T in the same multiplex DVB-H+ hybrid (satellite/terrestrial) architecture using S band

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Oxford SFN

- Uses H.263 video format

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Oxford SFN Data burst slots

- Within a data burst slot, the transmission of data at rate higher than the one used for display on the screen
- Data bursts store in a device-buffer
- From the device-buffer, the device either caches the application data or can play it live on its small LCD screen

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Oxford SFN Data burst slots

- Data bursts store in a device-buffer
- From the device-buffer, the device either caches the application data or can play it live on its small LCD screen
- The front end of the receiver device switches on only for those time intervals when the data burst of a selected BBC or discovery channel service is on air

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Development Tools

- Nokia N92
- Sagem my MobileTV DVB-H handsets
- DVB-H ESG Simulator

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Four Steps DVB for High-speed Internet Access

1. A handheld device transmits the device request through uplink channel to MSPADS
2. MSPADS passes the request to Internet through cable and to video channel through Internet

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Four Steps DVB for High-speed Internet Access

3. Video channel sends the response using DVB-IPI to high speed Internet.
4. The Internet service datacasts the data to MSPADS using DVB-C through a cable connection

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DVB for High-speed Internet Access

- IP datacasting enables high speed Internet access through Internet service provider (ISP)
- IP datacast then employed by DVB-H for connecting handheld devices
- Device accesses to high speed Internet and to a remote-networked video channel linked to Internet

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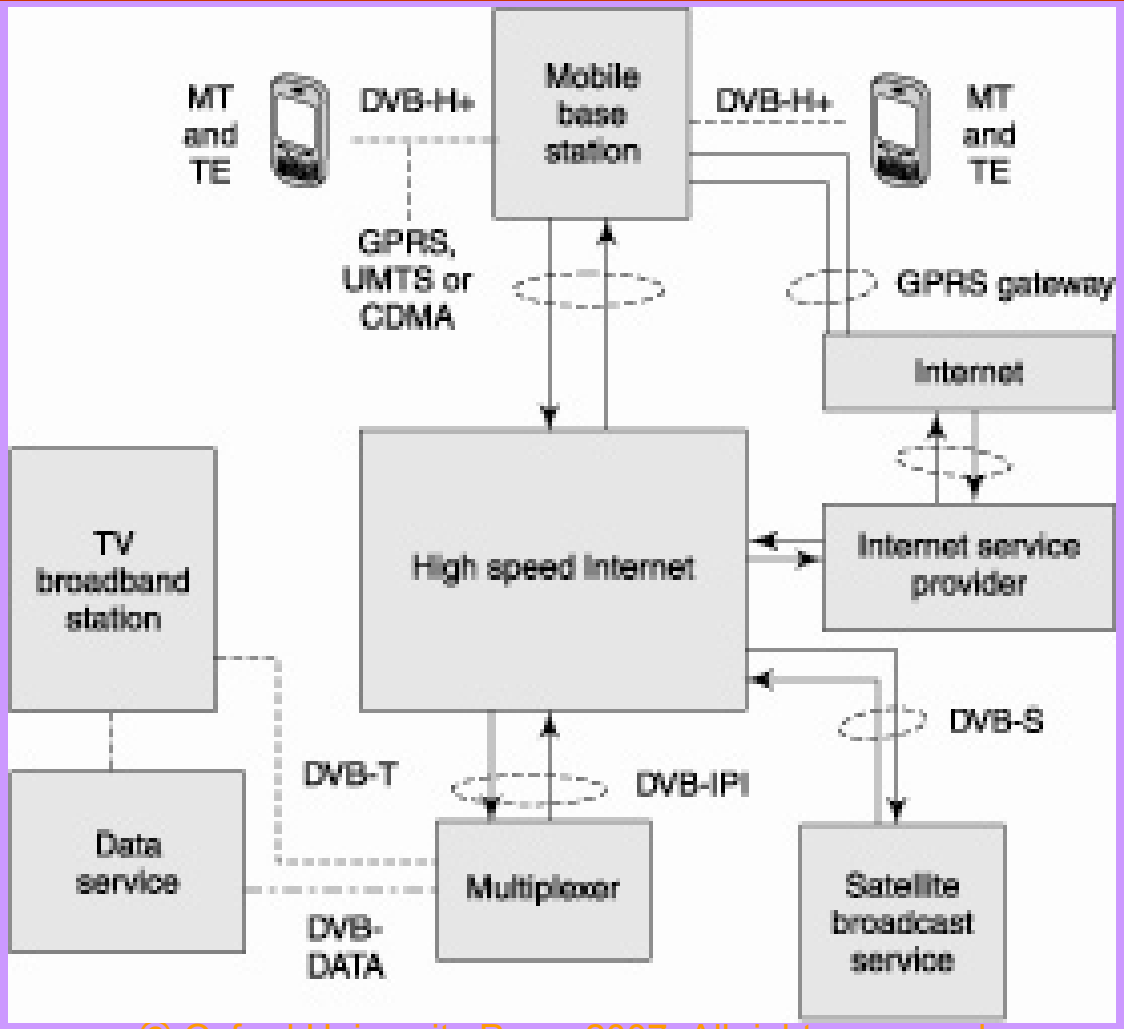
High speed Internet access architecture



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Convergence of Broadcasting and Mobile Communication

- A device accesses Internet IPv4, high speed Internet IPv6, and a remote networked data service, TV broadcast service, or video channel linked to Internet

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Convergence of Broadcasting and Mobile Communication

- DVB-H+ and convergence of mobile, Internet, and broadcasting network architecture
- DVB-H+ provides hybrid network

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Use of IP datacast

- Due to, it has become feasible to use DVB-H+ for accessing Internet, mobile telephone, and TV, audio, and satellite broadcast services

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Steps for convergence of mobile and Internet broadcasting and network

1. A handheld device transmits the device request through uplink channel to mobile base station
2. The base station functions as a MSPADS and connects to IPv4 Internet through GPRS gateway which networks the device to the IPv4 service provider

- The device is thus able to get Internet IPv4 service

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Steps

3. Base station passes the request for high speed Internet IPv6 access through cable using DVB-C
4. IPv6 Internet connects to a multiplexer using DVB-IPI

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Steps

5. The multiplexer connects to video channel or TV service through DVB-T and to data service using DVB-data
6. Data service, video channel, or TV station transmits the response to the multiplexer and multiplexer uses DVB-IPI protocol to communicate to high speed Internet using the IPv6 protocol

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Steps

7. The Internet IPv6 service datacasts the data to MSPADS using DVB-C through a cable connection
8. MSPADS transmits the response to the device request through a downlink using DVB-H+ to the handheld device

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9. The device receives DVB-H+ downlink using a mobile service provider GPRS, UMTS, or 3G system

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Summary

- DVB-H in mobile TV
- DVB-H+ in the mobile TV as wells as high speed Internet access
- VHF (130–260 MHz), UHF (430–882 MHz) and Band L (1.452–1.492 GHz)
- OFDM

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. . . Summary

- IP datagrams transmitted as data bursts in small time slots by TDMA by the Mobile service provider application distribution system
- Convergence of mobile and Internet broadcasting and network

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End of Lesson 10

Digital video Broadcasting and Mobile TV

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Data Synchronization in Mobile Computing Systems

Lesson 01

Data Replication and Synchronization in Mobile Computing Systems

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Data dissemination and replication at either remote or local location (s)

- Data replication may entail copying of data at one place after copying from another (i.e., recopying), copying from one to many others or from many to many others
- For example, videos of faculty lectures or music files get replicated at mobile phone

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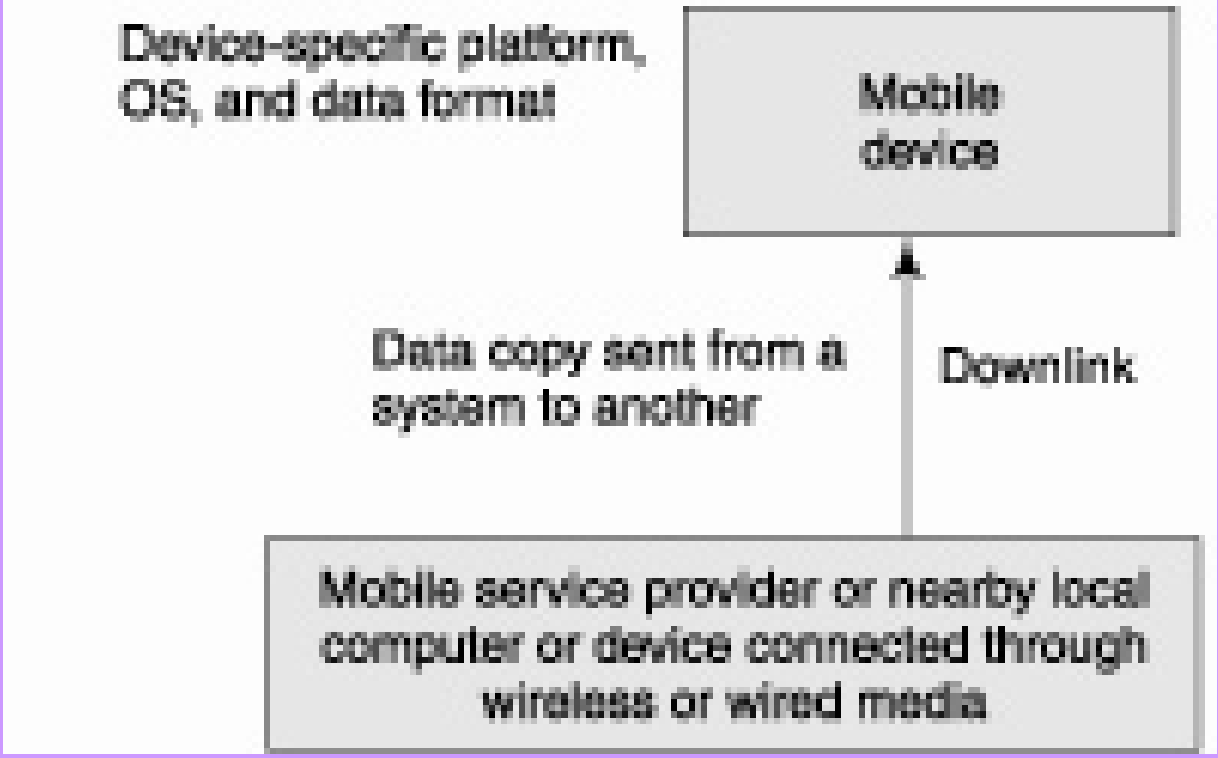
Data replication from data source and device



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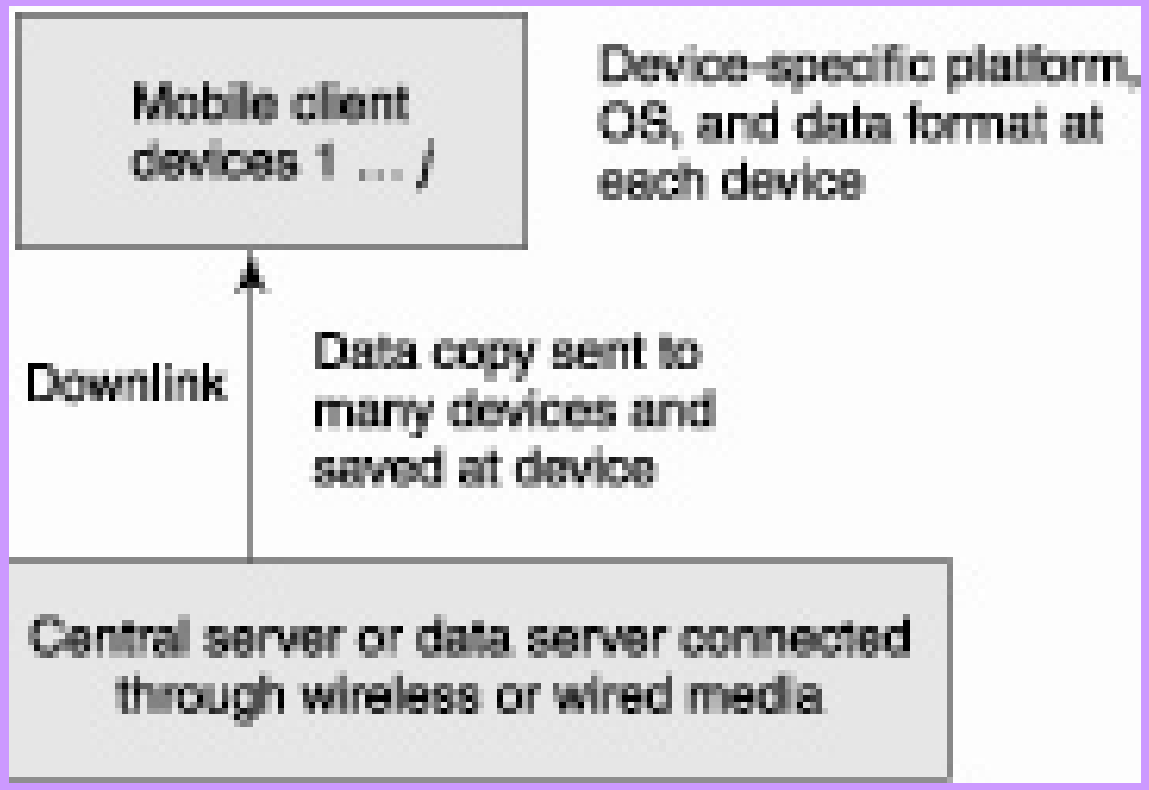
Data replication from data source server to many clients (devices)



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One to many synchronization

- Each system or device caches the data pushed from the server or sends a pull request to the central server and gets a response

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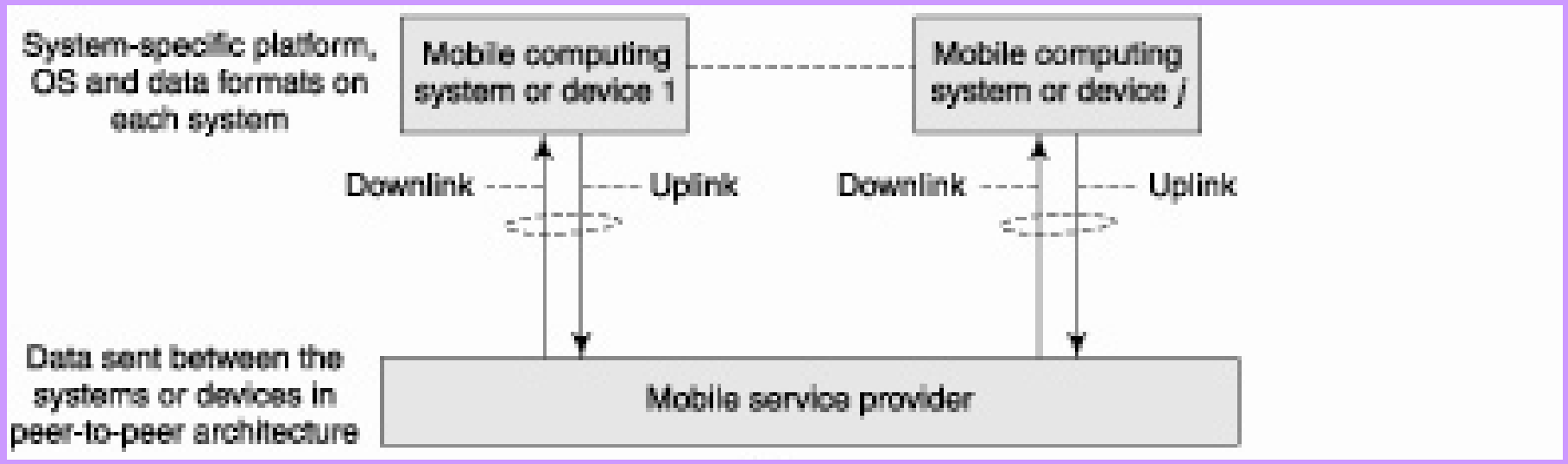
Data replication among systems and devices in peer to peer architecture



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Many-to-many synchronization

- Employs peer-to-peer architecture where each system is capable of sending pull requests and of pushing responses

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Full copy from a source

- Means that the full set of data records replicates according to certain domain-specific data format rules at the replicating devices or systems
- A server having a set of 8 images with resolution 640×640 pixels
- In the domain of a mobile device, it can replicate and hoard with 160×160 pixels
- When all 8 images copied, though with the different resolution, then it is known as full copy replication

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Full copy from a source Example

- A server having a set of 8 images with resolution 640 $\times$ 640 pixels
- In the domain of a mobile device, it can replicate and hoard with 160 $\times$ 160 pixels
- Full copy replication– when all 8 images copied, though with the different resolution

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Partial copying of data from the source

- A subset of the data set copied according to certain domain-specific rules at the devices or systems
- Assume that a server has a hourly data set of 24 temperature records with ± 0.1°C
- Partial copy replication In mobile device domain, assume that it replicates and hoards three hourly records with ± 1°C

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Data Synchronization

- Data replication precedes data synchronization
- The synchronization refers to maintaining data consistency among the disseminated or distributed data
- Data consistency— if there is data modification at the server then that should reflect in the data with the device within a defined period

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Data Synchronization in Mobile computing systems

- Defined as the process of maintaining the availability of data generated from the source and maintaining consistency between the copies pushed from the data source and local cached or hoarded data at different computing systems without discrepancies or conflicts among the distributed data.

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Consistent copy of data

- A copy which may not be identical to the present data record at the data-generating source, but must satisfy all the required functions and domain-dependent specific rules

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Domain Specific rules for consistency

- In terms of resolution, precision, data format, and time interval permitted for replication
- A consistent copy should not be in conflict with the data at the data-generating source

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Data synchronization for accessing data from server

- Helps mobile users in accessing data and using it for computing on mobile devices
- When a device not connected to a source or server, the user may employ data that is not in conflict with the present state of data at the source

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Data synchronization for caching data in and from personal area computer

- Helps mobile users in hoarding the device data at the personal area computer
- Also helps mobile users in hoarding the personal area computer data

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Data synchronization enhancing device mobility

- When initiated at frequent intervals enhances device mobility
- Ensures that device applications use the latest updated data from the source, even when the device is disconnected

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Data synchronization with enterprise server

- Helps storage at enterprise server a large chunks of information for the many devices connected to it and update partial copies of data at frequent intervals

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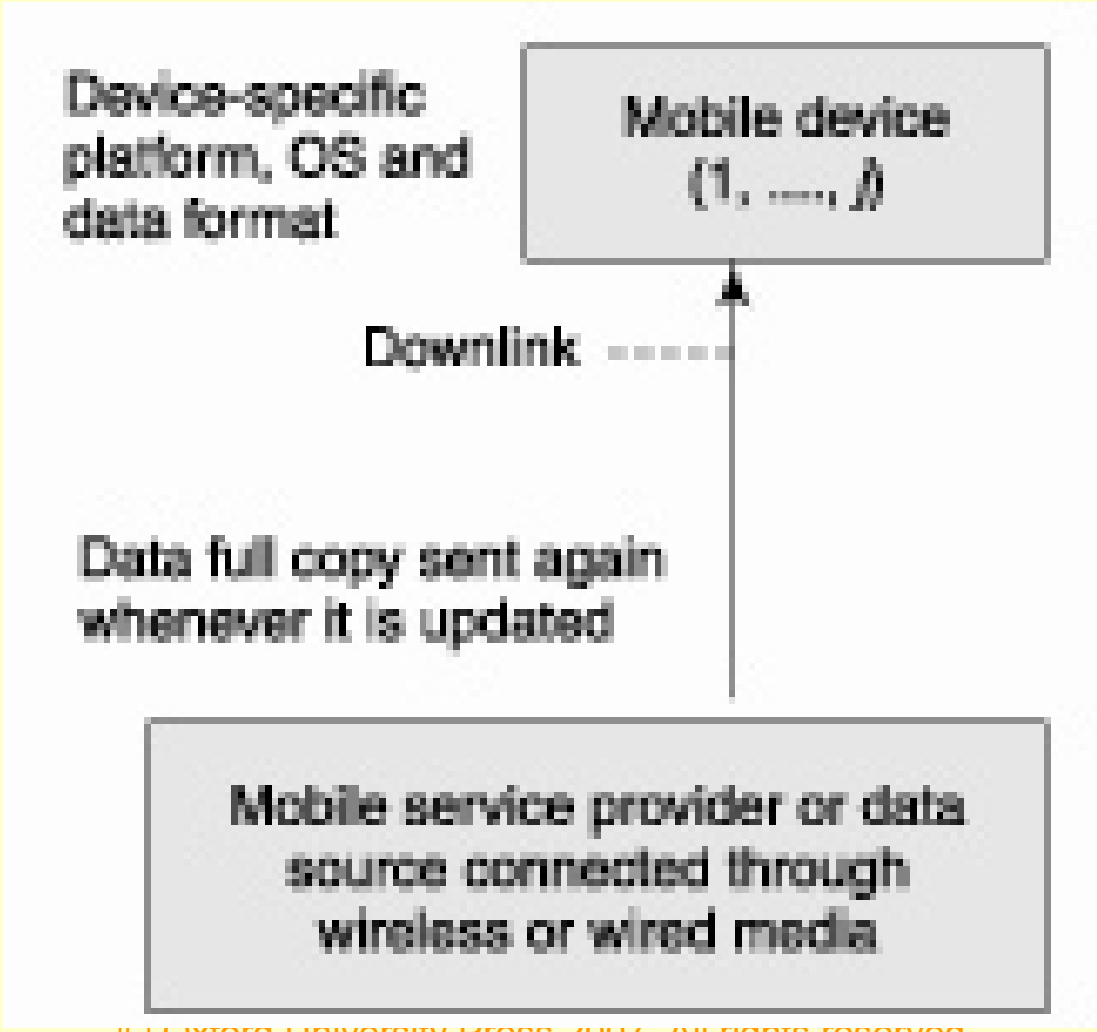
Full copy Synchronization at the device when the server sends data



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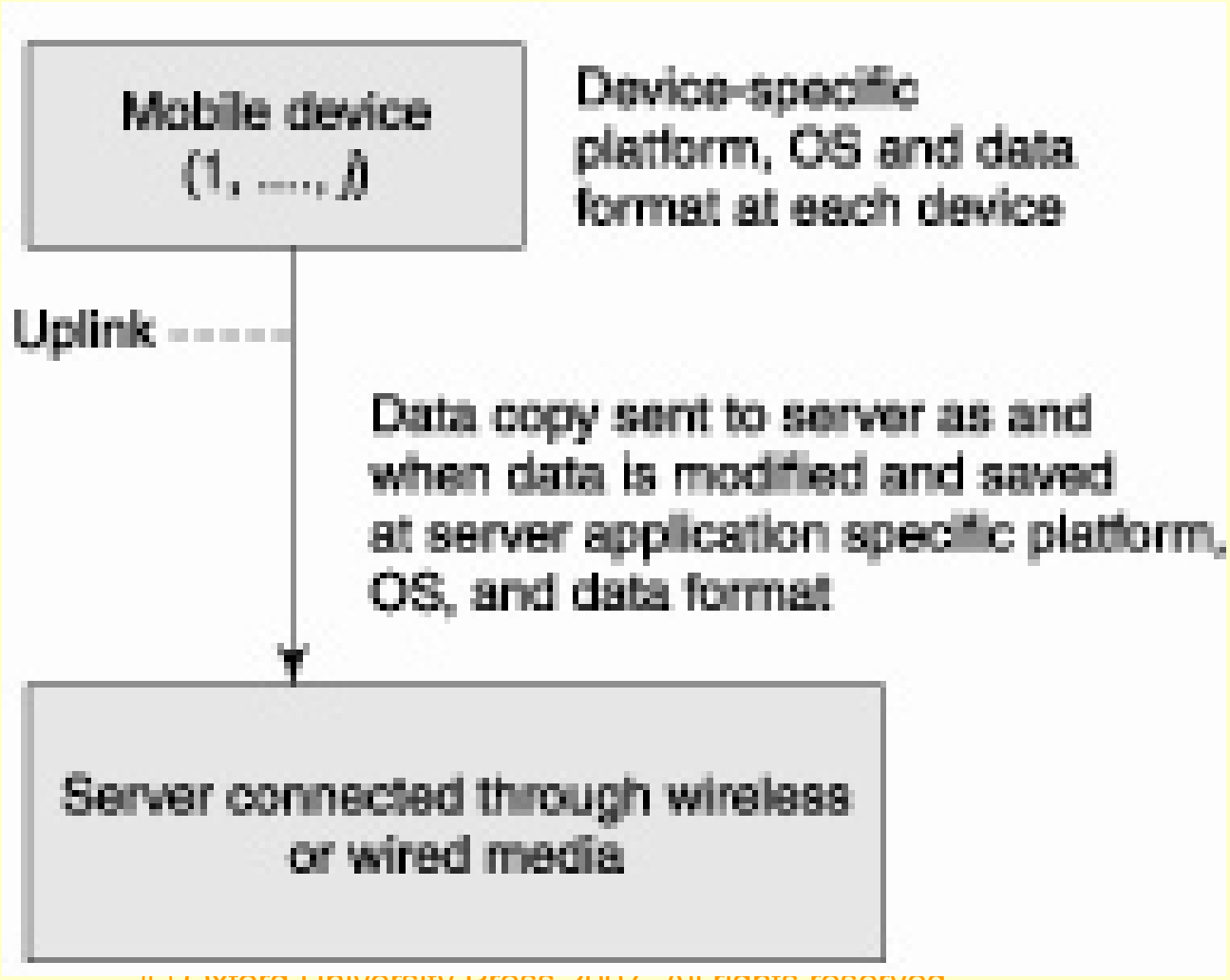
Full copy Synchronization at the server when the device sends data



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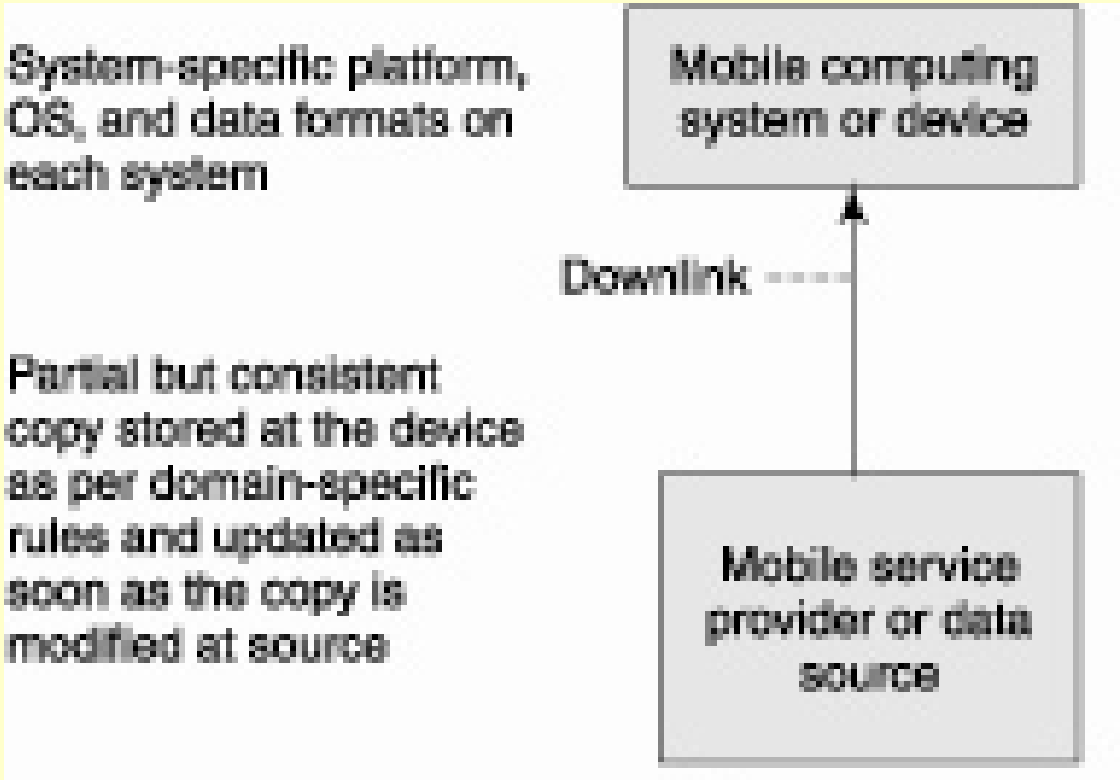
Partial copy Synchronization of consistent copy without the delays



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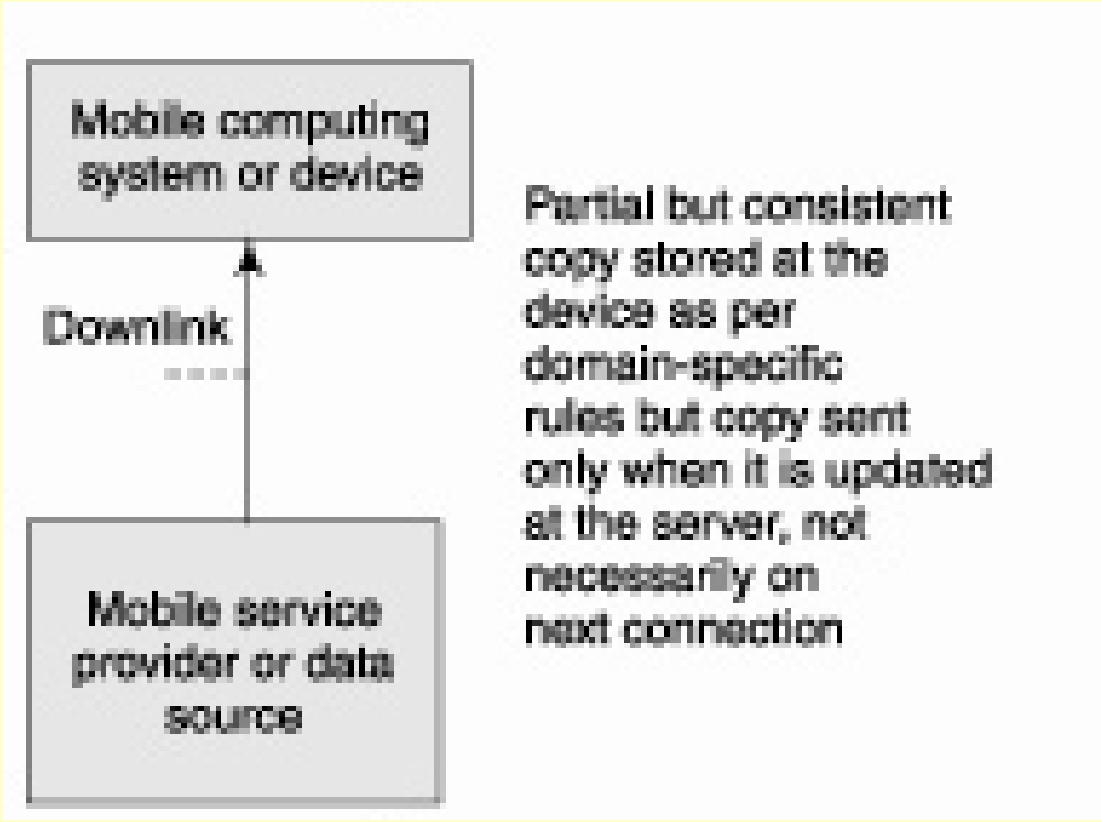
Partial copy Synchronization of consistent copy but after delays



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Summary

- Data replication after copying from another
- Data replication as per domain specific rules
- Full copy synchronization
- Partial copy
- Consistent copy with no discrepancy

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… Summary

- One to one Data synchronization
- One to many
- Many to many
- Synchronization at device from server
- Synchronization at server from device
- Delayed synchronization

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End of Lesson 01

Data Replication and Synchronization in Mobile Computing Systems

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Data Synchronization in Mobile Computing Systems

Lesson 02

Data Synchronization Types, Formats and Usage Models in Mobile Computing Systems

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Data synchronization Needs

- Required between the mobile device and service provider
- Between the device and personal area computer
- With nearby wireless access point (in WiFi connection)
- Another nearby device

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1. Two-way synchronization of partial or full copies of data

- Between mobile-device and personal-area computer
- For example, whenever the list of contacts and personal information manager data is modified at any of them, it is made consistent after synchronization

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2. Server-alerted synchronization

- The server alerts the client the data modification or additions
- The client synchronizes the modified or new data by pull request
- For example, alerting new e-mail and the device pulling that

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3. One-way server-initiated synchronization

- Server initiates synchronization of any new modification since communication of last modification
- Sends modified data copies to the client
- When a new email arrives at a server, it initiates the synchronization as and when the device connects to the server and pushes the mail

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4. Client initiated refresh synchronization

- The client initiates synchronization with the server for refreshing its existing data copies
- For refreshing the configuration parameters saved at the server for it

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4. Client initiated refresh synchronization– Example

- For example, a computer or mobile device initiates refreshing of the hoarded contacts and personal information data either at periodic intervals or as and when it connects

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4. Client initiated refresh synchronization – Example

- if the device configuration changes or a new device connects to a server, then the configuration parameters sent earlier refresh at the server

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5. Client-initiated synchronization

- With the server for sending its modifications, for example, device configuration for the services
- For example, a client mobile device initiates synchronization of the mails or new ring tones or music files available at the server either at periodic intervals or as and when it connects to it

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6. Refresh from client for backup and update synchronization

- The client initiates synchronization
- Sends backup to the server for updating its data
- For example, a computer or mobile device initiates refreshing of the hoarded contacts and personal information data either at periodic intervals or as and when it connects to the server

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7. Slow (full data copy and thorough) synchronization

- Client and server data compared for each data field and are synchronized as per conflict resolution rules
- Full copy synchronization usually takes place in idle state of the device
- Not immediately on connecting to the server, that's why called slow

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Formats of Synchronized Data Copies

- Can be different from each other at client and server
- When the data at a source synchronizes with the data at other end, it does so as per the format specified at that end

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Formats of Database records

- The records indexed enabling search by querying using the indexes, for example, the relational database records
- The database record retrieved by sending a query specifying the entries in these indexes
- Format DB2 at server and DB2e Every place at the mobile device

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Flat file Synchronization

- Data can be interpreted only if the file is read from beginning to end and that data cannot be picked from anywhere within the file
- For example, an XML or html file at the server synchronizes with the file at the device which is in text format or is a binary file depending upon the information format

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Flat file Synchronization– Example

- Information format in mobile computing XML document format
- For transmission it is WBXML (WAP Binary XML) content format
- Address book data at a mobile device with the data transmitted in WBXML format

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Device-specific storage Format

- AAC (Apple Audio Communication) files used for audio communication with an Apple iPhone
- A file in AAC format synchronizes with music files in some other format at a computer or remote website serving the music files

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Device-specific storage Format

- At a mobile device the *Contacts* information in vCard format
- Calendar, tasks-to-do list, and journal information are in vCalendar, vToDo, and vJournal formats, respectively

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Usage Models for Synchronization in Mobile Applications

- Four usage models employed for synchronization in mobile computing systems

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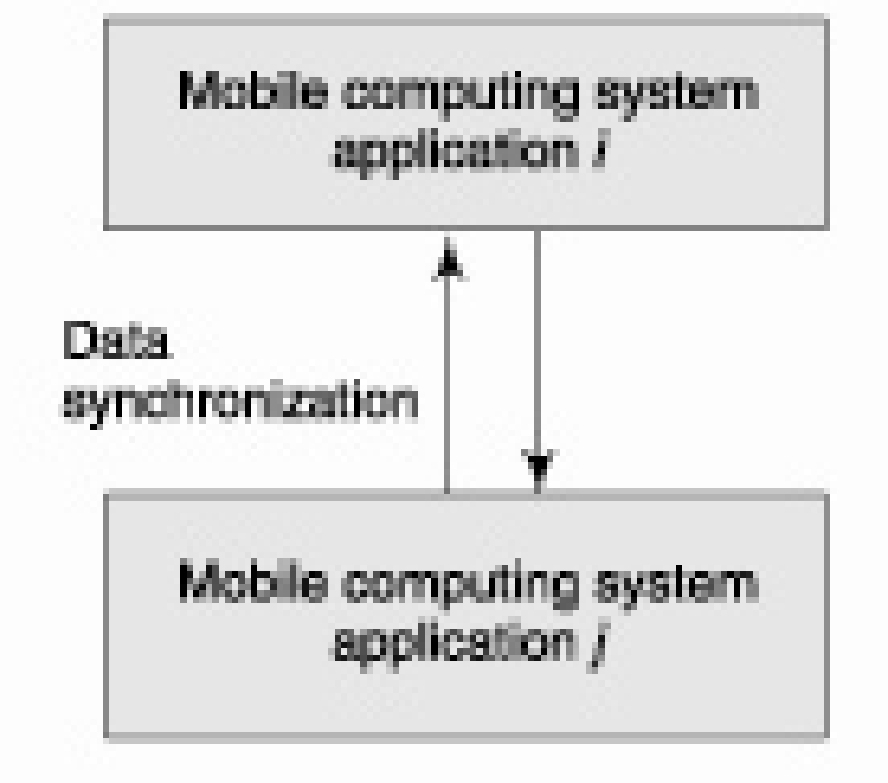
1. Synchronization between two APIs within a mobile computing system



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Synchronization between two APIs

- The data generated by an application synchronized and used in another application
- An API running at the device synchronizes data with another application on the same or another device or computer

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Example of synchronization between APIs

- Data records at personal information manager (PIM) API synchronized with the email API
- When email from a new source retrieves at the email API in the device, the name and email address data fields at the application saved as new data record at PIM API

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Example of synchronization between APIs

- When an email is to be sent to the same person, the email API uses the same data record from the PIM API

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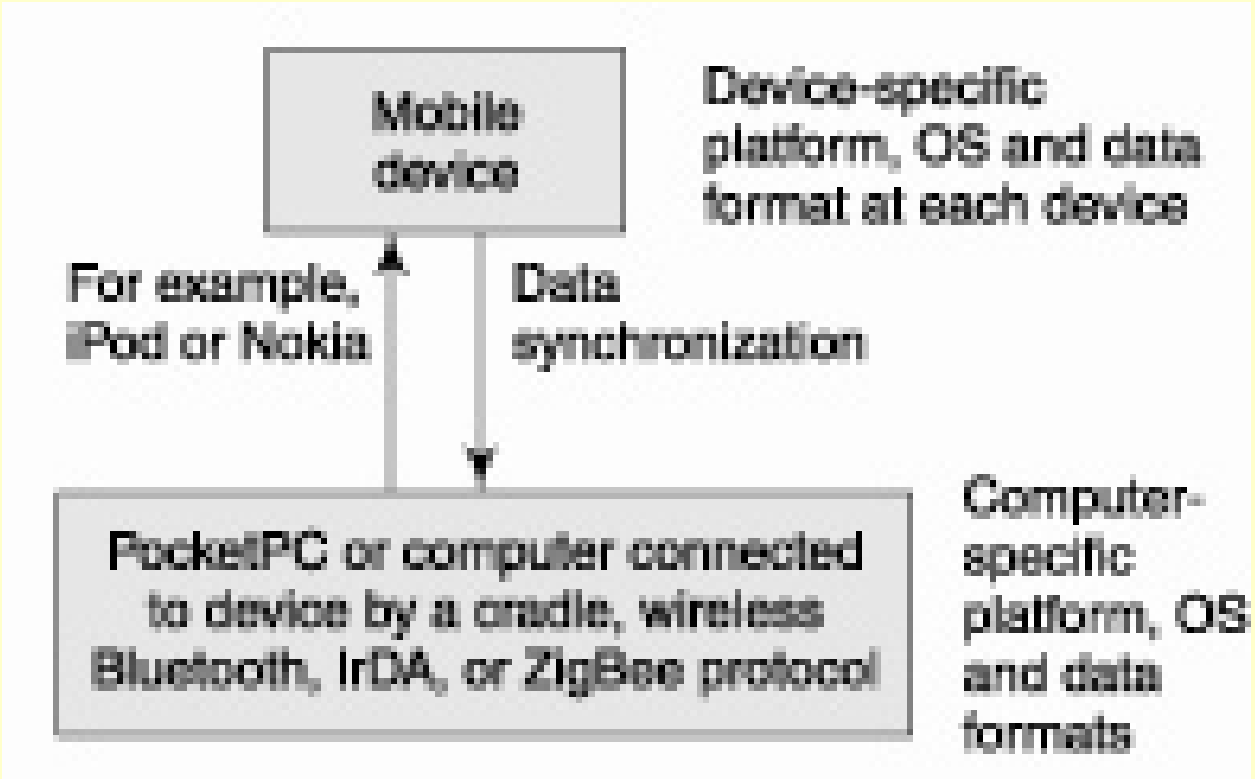
2. Synchronization between the device and nearby device



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Synchronization between the device and nearby device

- Device and computer synchronize their data
- Also called personal area synchronization (PAS)
- Using PAS software, for example, HotSync or ActiveSync

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Examples of PAS

- Synchronization with nearby PC through a serial port using a cradle and wired connection to PC through the cradle
- Synchronization with the nearby computer through a wireless personal area network (WPAN) using ZigBee or Bluetooth

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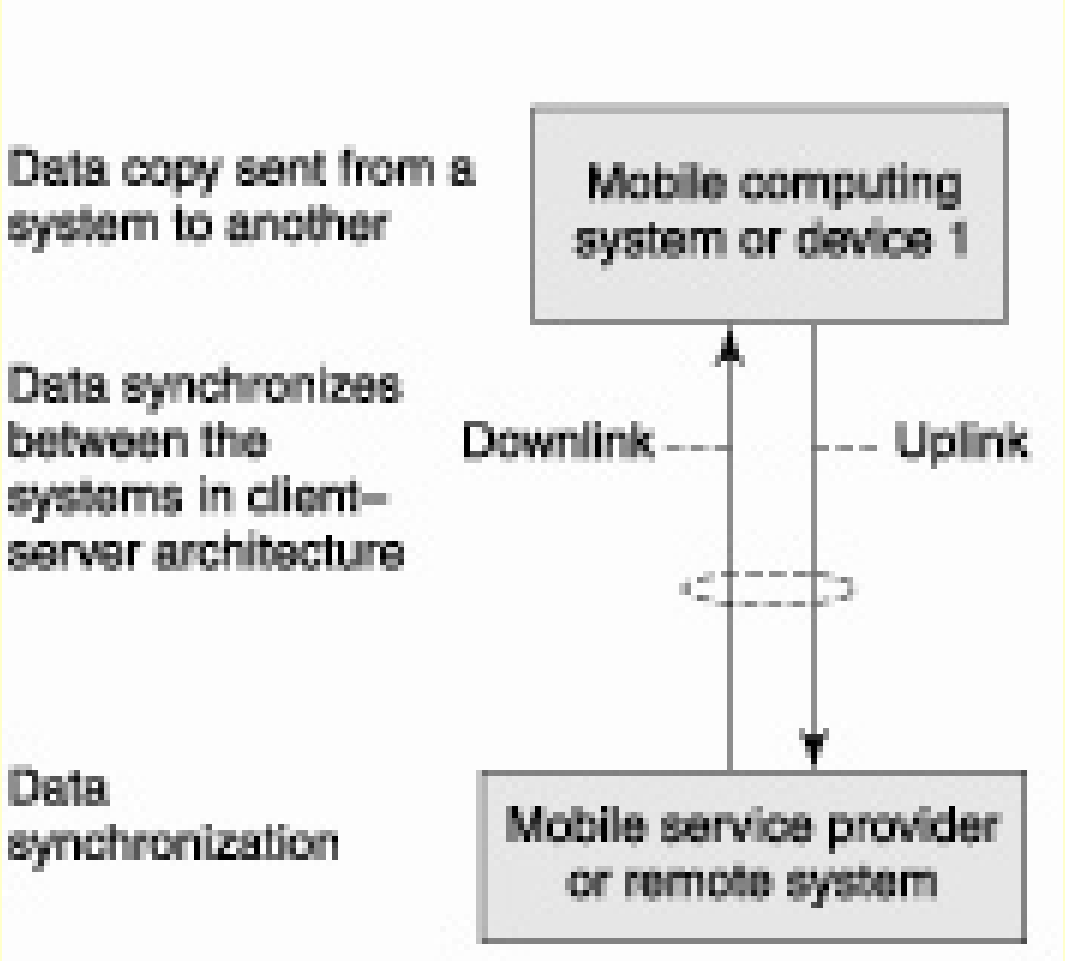
3. Synchronization between remote systems and device



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Synchronization between remote systems and device

- The device data records synchronize with the mobile service provider server records
- The remote server or systems synchronize their data with the mobile device
- The device connects to remote systems on Internet through the wired, wireless mobile service provider, or WiFi network

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Example of Synchronization between remote systems and device

- Wireless email synchronization using Intellisync between the device and remote server using SyncML language

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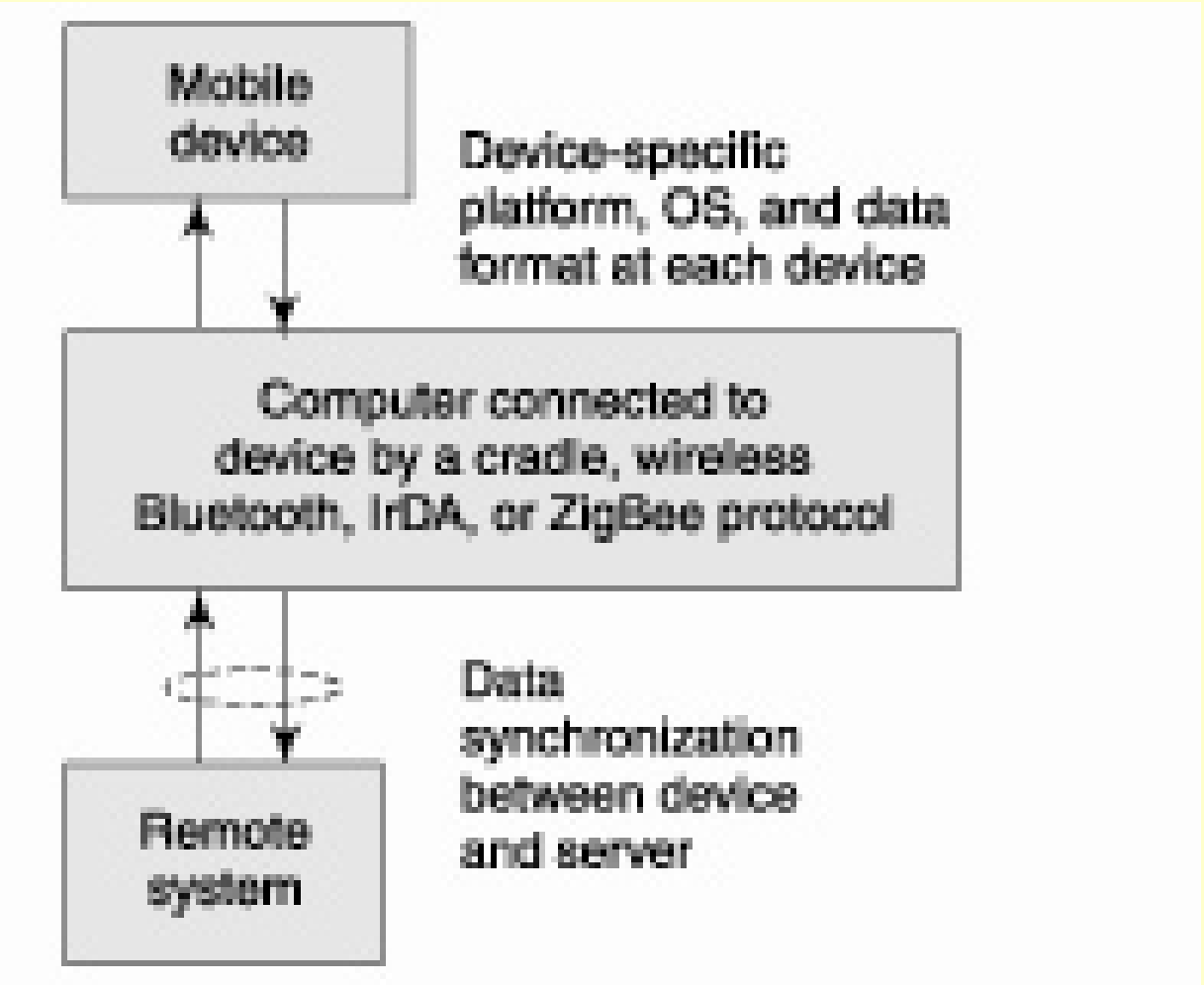
4. Synchronization through a local pass-through system



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Using local pass through computer or system

- Device data records synchronize with the records of remote system, for example, an enterprise server, through a local computer system

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Example of Using local pass through computer or system

- The device first synchronizes through ActiveSync or HotSync or Intellisync or Bluetooth to local computer connected by personal area synchronizer
- Then the computer synchronizes to Internet through WLAN, WiFi, or wired network

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Summary

- Two way synchronization
- Server alerted synchronization
- One way server initiated
- Client initiated Refresh
- Client initiated synchronization
- Refresh from client for backup and update

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… Summary

- Slow thorough synchronization when idle
- Database formats
- Flat files
- Device specific storage files
- Synchronization between two APIs
- Personal Area synchronization
- Remote direct or through local pass through system

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End of Lesson 02

Data Synchronization Types, Formats and Usage Models in Mobile Computing Systems

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Data Synchronization in Mobile Computing Systems

Lesson 03

Domain dependent Specific Rules and Conflict resolution Strategies

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1. Data synchronization in domain-specific platforms and data formats

- Data synchronization between data-generating domain and destined domain, both having different platform and data formats

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Examples of synchronization in domain-specific platforms and data formats

- A copy of database record at the device structured text or XML format and the device OS platform Symbian
- The record synchronized with the database record at the server where it is in DB2 or Oracle database format and the OS is Windows

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2. Domain-specific data-property-dependent synchronization

- Data synchronization between one domain with one property of data and another domain having different property

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Examples of Domain-specific data-property-dependent synchronization

- A data record at a device having an ID specified by a byte synchronizes with the record, which has an ID specified by 16-bit word at the server
- A device using 8-bit ASCII characters for an ID while the server using 16-bit Unicode characters

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3. Synchronization up to the last successful act of synchronization

- A domain-specific rule that data record considered to be synchronized if it was updated at the last connection

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Example of Synchronization up to the last successful act

- A phonebook records of missed calls, dialled numbers, and received calls
- Data record at the device synchronized with the record in the phonebook
- If it updated at the last connection, then it eventually updates again on the next connection

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4. Memory-infrastructure-dependent based synchronization at the domains

- A domain-specific rule that data records synchronized up to the allotted memory

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Example of Memory-infrastructure-dependent based synchronization

- A remote server maintaining full address book with allotted memory of 8 MB and a device allocated 128 kB for the address book
- Only a part of e-mail database, only 100 new email addresses synchronizes and saves in the device PIM (personal information manager)

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5. Synchronization with temporal properties of data

- Domain-specific rule that data records synchronized with data generated at source within specific time interval and at the time specified at the domain

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Example of Synchronization with temporal properties of data

- The flight time table data set of device synchronized every week and weather report once every day
- At the device weather report updated and synchronized up to the last day
- Eventually updates on a day if available at the server

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Synchronization with temporal properties of data

- May be periods of inconsistency when temporal properties of data being used for synchronization
- However, mobile applications remain unaffected if there are no temporal conflicts and unaccountable discrepancies

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Conflict in synchronization

- Arises when a data copy changed at one end but not simultaneously modified at other ends
- Therefore, the same data item at two ends, *P* and *Q*, in conflict during computation in the time interval between *t*1 and *t*2, where *t*1 and *t*2— the instants when *P* and *Q* get the modified data copy

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Synchronization and Conflict Resolution Strategies

- A conflict resolution strategy adopted in such cases to resolve conflicts
- The strategy specifies the rules that need to be applied for conflict resolution

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1. Priority-based resolution rule

- Data-server can be specified as dominant higher priority entity for conflict resolution of synchronized data records

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Example of Priority-based resolution rule

- Mobile-service-provider server S having a list of missed, dialled, and received calls for the device D
- D has a synchronised list of missed, dialled, and received calls
- When the list at D in conflict with the list at S, priority-based resolution rule specifies that the server priority is higher

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2. Time-based resolution rule

- Data node P specified as dominant entity when P always receives copies first from the server S

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Time-based resolution rule — Example

- S having the emails disseminated to the device D at an instant *t*1
- D connects to a personal area computer (PC) to which the device always synchronizes the mails at a later instant *t*2
- Time-based resolution rule— D dominant because it receives the mails earlier than the PC

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3. Information-based resolution rule

- Data node can be specified as dominant entity when information specific to it is synchronized with other nodes

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Example of Information-based resolution rule

- Server S having the device configuration record disseminated from the device D
- Information-based resolution rule specifies that since the information is for the device D hence D is dominant node
- For device-specific information, the device data accepted rather than the server data

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4. Time-stamp-based resolution rule Device-specific storage Format

- Time-stamp-based resolution rule necessitates that a time-stamp must be used while sending a data copy
- The copy found to be latest resolves the conflict

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Example of Time stamping rule for conflict resolution

- Server S having the flight information which it always disseminates at regular intervals with a time stamp over it to the device D and as well as to a PC
- Time-stamp-based resolution rule specifies that the node with flight information with latest time stamp dominant

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5. User-interaction-based resolution rule

- An API at a device allows a user to interact with the device
- Interaction resolves the conflict arising out of the duplicate or multiple entries
- The duplicate data entries permitted at the node when a receiver API later on resolves the conflict after interaction with user

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Example of User-interaction-based resolution rule

- Two phone number entries found for same name and address, the device prompts user to resolve the conflict
- User resolves the conflict by opting for one of it

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Summary

- Domain specific rules
- Data formats and platforms based synchronization
- Data property dependent synchronization
- Last successful action based synchronization

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… Summary

- Memory infrastructure dependent synchronization
- Temporal properties based synchronization

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… Summary

- Rules for resolution of conflict in synchronized data
- Priority Based
- Time Based
- information Based
- time-stamp Based
- User interaction Based

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End of Lesson 03

Domain dependent Specific Rules and Conflict resolution Strategies

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Data Synchronization in Mobile Computing Systems

Lesson 04

Personal Information Manager

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Personal information manager (PIM)

- Has APIs in Smart mobile phone devices for managing data copies for device user
- Manages the data record copies
- Data record copies for the multiple selections and options provided by the PIM APIs, for example, calendar, address book, and tasks-to-do

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Personal Information Manager

- Includes creation of copies
- Updating
- Replacement
- Addition
- Deletion of data records
- Responsible for sending a data record to an API, receiving it from another API, and sorting of the data records

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Sorting by Personal Information Manager

- Configurable according to first alphabet of the name
- As per calendar (entries in a list for tasks-to-do at current date first followed by entries for next date)
- As per last name in the names at the list of Contacts (entry of last name with first alphabet as A first and as Z last)
- As per priority

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Address book

- A list of contacts with their office, home, mobile, and fax numbers, home and office addresses, web addresses, and email IDs

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Task-to-do

- Tasks-to-do a list of tasks planned by the device user, which also provides along with each task the time at which to do the task
- Reminds the user of the tasks as per their planned time

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Record copies synchronization

- With the copies on a personal area computer, WPAN computer, a remote system, or another mobile device

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Backup Option

- For mobile device backup of the PIM data records to protect the user due to accidental deletion or battery power
- When the mobile device connects to a personal area computer, WPAN computer, a remote system, or another mobile device, the copies transfer completely to a selected directory
- The backup enables restoration later

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Restore option for synchronization

- Mobile device may loose the PIM data records, for example, due to accidental deletion or battery power loss
- Restore helps in restoring the copies at the device

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Restore option for synchronization

- When the mobile device connects to a personal area computer, WPAN computer, a remote system, or another mobile device, the copies synchronized with the copies at the latter and the computer copies the selected or whole data to the device

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‘Reports’ option

- Provides a device with the entries for added, deleted, or modified data copies at the other device or PC
- Not only specifies time and date of last synchronization but also gives reports of synchronization failures

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Configuration option and Setting Preference Options

- Configuration option
- Setting of preferences for synchronization– User Selection or Auto
- Setting the preferences of connection preference– Can be configured as Bluetooth, IrDA (infrared data association), USB, or COM port cable

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User Selection configuration

- Means synchronization done only when user selects the option ‘synchronize’

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Auto Configuration option

- Synchronization done automatically on connection between the device and computer

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Summary

- Personal Information Manager PIM
- PIM APIs for address book
- Task-to-do
- Calendar
- Contacts
- Backup
- Restore
- Configuration

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End of Lesson 04

Personal Information Manager

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Data Synchronization in Mobile Computing Systems

Lesson 05

Synchronization Engine and Mobile Agent for Synchronization

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Synchronizer (synchronization engine)

- Software tool for synchronization
- Resides at a host
- Called ‘Synchronization server’ synchronizer at the server

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Synchronizer Functions

- Configuring as per the specified domain-dependent and conflict resolution rules
- Finds the data item or record appended at the data set(s)
- Discovers modifications with respect to the last action of synchronization of the specified data copies which have been deleted, added, or modified

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Synchronizer Functions

- Makes changes in the copies accordingly
- In case of conflict, it resolves it as per resolution rule(s)
- Disseminates (propagates) the changes to other devices or systems so that others devices also incorporate the changes in their data copies

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A Synchronizer adopted Method for performing synchronization task

- More efficient compared to one in which the synchronizer directly retrieves the changed records
- First logs in the information about the records which have been changed and then retrieves the changed records

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Process of logging in the information about the changes

- Can be fast by just setting or resetting a flag called dirty or invalid flag

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Synchronizer 'invalid' flag

- When associated flag in set state (=1), record *R* state is modified or invalidated since previous synchronization
- When in reset state (=0), *R* is not modified or invalidated since previous synchronization
- Reduces the possibility of using conflicting entries at the server (or device) hosting the synchronizer

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Example of '*Contact*' in a PIM data of a mobile phone device *D*

- Assume that a Contact with name N_i exists
- A flag f_{nd} associated with N_i sets to 1 when N_i and associated data are entered for the first time at D
- Another associated flag ef_{nd} resets to 0 because data fields of contact N_i are not empty now and the data is valid

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Example of '*Contact*' in a PIM data of a mobile phone device *D*

- Additional data record containing personal information about office, home, mobile, default, and fax telephone numbers, address, email address, and web address also associated with N_i

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Example of '*Contact*' in a PIM data of a mobile phone device *D*

- Assume that fax number, email, and web fields in the records empty
- Further assume that a priority-based resolution adopted as the conflict resolution rule for the PIM data
- When the data at D and C are conflicting, the data at D has priority and is the dominant data

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Synchronizer actions

1. *Action 1* Assume that synchronizers Sy_c and Sy_d at a WAP computer C and D, respectively
- Both use the method of first logging in the information about the changed records

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Synchronizer Action 1

- When the device is placed on a cradle, connected to C, PIM data at the computer and the device synchronize at an instant *t*1
- When Sy_c synchronizes the N_i at D, it looks for the flags f_{nd} and ef_{nd} at D
- If $f_{nd} = 1$ and $ef_{nd} = 0$, the Sy_c synchronizes and replicates the N_i and associated data at C

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Synchronizer action 1

- On the other hand, if f_{nd} and ef_{nd} are both 0, the Sy_c ignores the synchronization of N_i data and does not copy it at C
- After the synchronization completes at C using Sy_c, the Sy_d at D resets f_{nd} to 0

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Synchronizer Action 2

2. *Action 2:* Now assume that device user at a later instant *t*2 has no changes in the contact Ni

- The N_i is not dirty now because it has not been modified
- Therefore, the dirty flag f_{nd} and invalidation flag ef_{nd} at the device remain reset to 0.

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Synchronizer Action 2

- When the device is placed on the cradle next time, it connects to C at *t*2
- The Sy_c at C synchronizes the contact data for N_i at D
- It looks for the flags f_{nd} and ef_{nd} at D
- Since both are found to be 0, the Sy_c ignores the synchronization of N_i data

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Synchronizer Action 3

3. *Action 3:* Now assume that the device user at a later instant *t*3 enters the email address at the contact Ni at D

- The N_i is now called dirty because it has been modified, f_{nd} at the device sets to 1
- The ef_{nd} still remains in the reset state, as data is not invalidated

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Synchronizer Action 3

- Again assume that when the device is placed on the cradle next time, it connects to C at the instant *t*3
- The Sy_c at C synchronizes the contact data for N_i at D and looks for the flag f_{nd} at D

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Synchronizer Action 3

- Since f_{nd} is found to be 1, the Sy_c synchronizes and copies the changes in N_i and associated data at C
- The Sy_d at D resets f_{nd} to 0 after synchronization

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Synchronizer Action 4

4. *Action 4:* Now assume that the device user at a later instant *t*4 deletes the contact Ni at D

- The Ni becomes empty because the data has been now invalidated
- Therefore, the invalid flag ef_{nd} sets to 1 at D

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Synchronizer Action 4

- When the device is placed on the cradle next time, assume that it connects to C at the instant *t*4
- The Sy_c at C synchronizes the contact data for N_i at D
- It looks for the flag ef_{nd} at D

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Synchronizer Action 4

- Since ef_{nd} is found 1, N_i and its associated data at C are deleted
- The Sy_d at D does not change ef_{nd} to 0 after synchronization as long as contact Ni is not restored at D using the Restore option

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Method Advantage

- Only the associated flags are retrieved by the synchronizers initially and, if necessary, the associated data record is retrieved later
- Thus the synchronization actions take very little time

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Mobile Agents for Synchronization

- Deployed for synchronization
- Recognizes inconsistency and conflict in data received at a client from the connected remote server, local server, or a device using resolution rules
- Mobile agent is present at a host which can be the client, an intermediate node, or the server

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Characteristic of mobile agent

- Can migrate from one node in a mobile computing system to another and if needed, to another host for data synchronization
- The host is one which is connected to the server
- The migrated mobile agent can function as proxy to a mobile device or computing system

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Example

- Assume that A_c is the agent for the synchronizer Sy_c at a computer C
- It hosts at the device D but does the work for Sy_c and Assume that a priority-based resolution is adopted as the conflict resolution rule for the PIM data
- When the data at D and C are in conflict, the data at D has a higher priority and is dominant

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Example of Agent A_c

- The hosted at D logs in the information about the records which have been changed so that the Sy_c can synchronize the changed records later whenever D connects to C
- The device connects to C for synchronization

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Example of Agent A_c

- The A_c communicates the status of the modified and invalid flags to C for use by Sy_c

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Agent and Synchronizer Actions

1. *Agent and Synchronizer Action 1:* When the device is placed on a cradle, connected to WAP computer C, PIM data at the computer and the device synchronize at an instant *t*1

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Agent and Synchronizer Action 1

- When C connects to D, the flag f_{nd} is communicated as 1 and ef_{nd} as 0 using A_c
- Sy_c synchronizes the contact data for N_i at D and copies data for Ni at C
- Once the synchronization at C completes, A_c at D resets the status of synchronization using Sy_c and thus resets f_{nd} to 0

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Agent and Synchronizer Action 2

2. *Agent and Synchronizer Action 2:* Now assume that device user has no changes at the contact Ni at a later instant *t*2.

- When the device is placed on the cradle next time, there is no communication from A_c when the device again connects to C at *t*2
- The Sy_c at C does not initiate the synchronization

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Agent and Synchronizer Action 3

3. *Agent and Synchronizer Action 3:* Now assume that device user enters the email address at the contact N_i at D at a later instant *t*3.

- When C connects to D, the flag f_{nd} is communicated as 1 and ef_{nd} as 0 using the A_c

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Agent and Synchronizer Action 3

- The Sy_c synchronizes the contact data for Ni at D
- Once the synchronization completes at C, A_c at D resets the status of synchronization using Sy_c making f_{nd} 0

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Agent and Synchronizer Action 4

4. *Agent and Synchronizer Action 4:* Now assume that device user deletes the contact Ni at D at a later instant *t*4.

- When the device is placed on the cradle next time, it again connects to C at the instant *t*4
- A_c at D communicates ef_{nd} as 1.
- Sy_d deletes the record of contact N_i at D.

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Agent and Synchronizer Action 4

- A_c at D does not change ef_{nd} to 0 after synchronization as long as contact N_i is not restored at D using the Restore option

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The agent A_c not at host at the device D but at intermediate Bluetooth device

- Bluetooth device placed between the computer C and the device D
- It can also be present at the computer C itself which is the client in the present case
- Migration action is one of the advantages of an agent

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The agent A_c periodically seeking the status of the flags from D

- Sy_c can then initiate the synchronization as per data state of A_c
- The synchronizers initiate action as per the data state communicated by the agent and take no action in case no communication is received from it

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An agent A_c need not send only the status but changed data directly

- An agent A_c need not send only the status as in the above actions 1 to 4
- It can communicate the changed record directly from the server to the client
- That is, from D to C in the above example
- The use of agents for synchronization proves to be beneficial

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Summary

- Synchronizer a software tool for synchronization
- Configurable
- Finds data
- Discover modifications
- Disseminate the changes to other devices

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… Summary

- A method that only the associated flags are retrieved by the synchronizers initially and, if necessary, the associated data record is retrieved later
- Synchronizer agent
- Characteristic of an agent is that it can migrate from one node in a mobile computing system to another

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End of Lesson 05

Synchronization Engine and Mobile Agent for Synchronization

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Data Synchronization in Mobile Computing Systems

Lesson 06

Synchronization Software— HotSync, ActiveSync and Intellisync

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Synchronization software

- A synchronizer used for data Synchronization as per configuration, domain-specific rules, and conflict resolution strategies
- Synchronizer is used for remote as well as local (personal) area data synchronization

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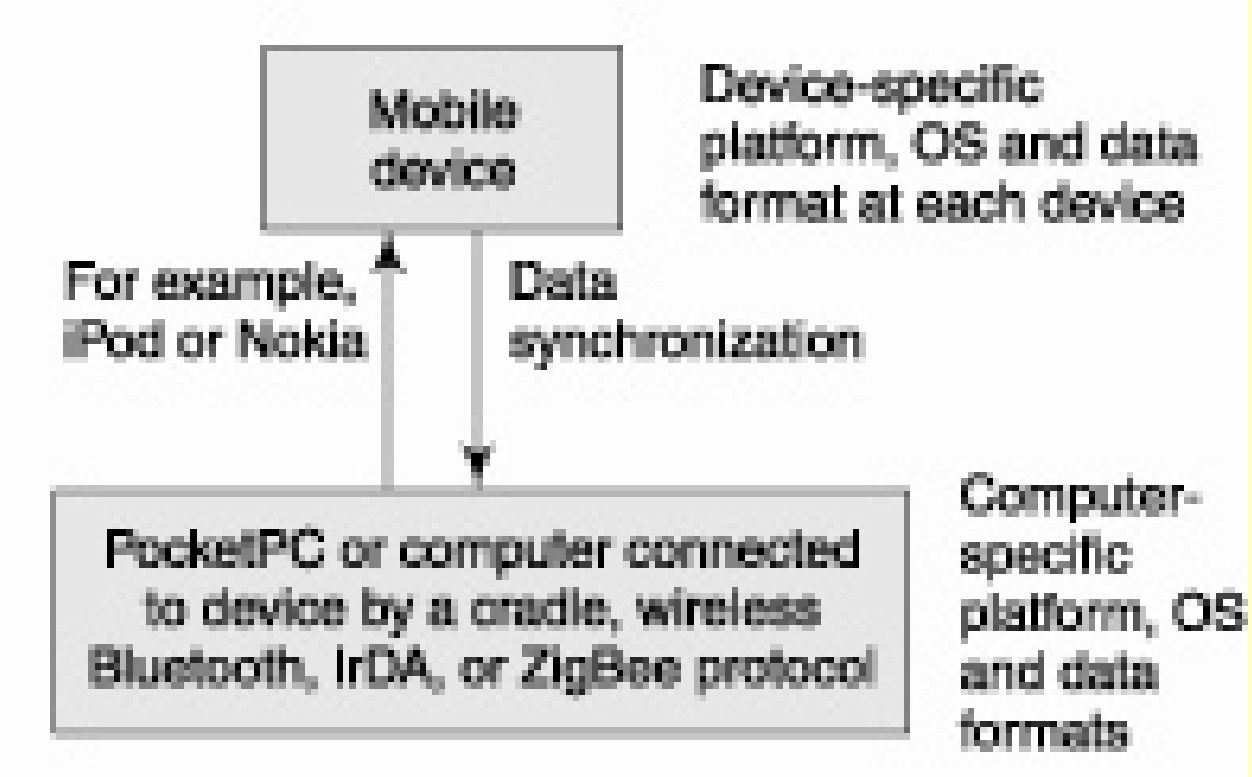
Synchronization between the device and nearby device using Synchronizer



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Synchronization software

- IntelliSync a synchronizer which provides synchronization with remote system as well as PAS

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Personal Synchronization (PAS) software

- Synchronizes the mobile data copies with data copies on PC in the WPAN
- HotSync used in a mobile device when device operating system (OS) is Palm OS
- ActiveSync used when device OS is Windows CE

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Personal Synchronization (PAS) software

- Connection through a USB (universal serial bus) port, serial port, or infrared port at PC
- The synchronizer can also connect to an Ethernet LAN

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HotSync

- Software used for synchronizing handheld devices based on Palm OS with Windows- or Mac-based personal computers in a synchronizing architecture
- Organizes data and most programs in the device based on Palm OS
- Copies of the device data also listed at the PC in a backup list, so that these can be restored

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HotSync

- An attribute bit (similar to dirty, invalid, or modified flags) at each copy (file) that sets when there is a change in the copy at the PC
- A backup program at the device, using the attribute, copies those copies from the PC, which have their attribute bits set. After copying is complete for a copy, the attribute bit is removed at the PC

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Conduits in HotSync

- Each task which is synchronized uses a conduit program
- Auxiliary software for HotSync installed in PCs
- The auxiliary software can also be used to transfer photos, music, and other multimedia objects to the handheld device

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HotSync

- It enables saving of settings, preferences, synchronize memos, tasks-to-do list, calendars, contacts, and data files
- Enables favourites, call history, and speed-dialling. The data can also be tuned with Microsoft Outlook
- Can be used to install new applications on the device

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Palm OS device and HotSync

- Connects to the PC through a cable called HotSync cable or using a wireless connection which could be WiFi, Bluetooth, or infrared IrDA
- It also enables synchronization with remote systems

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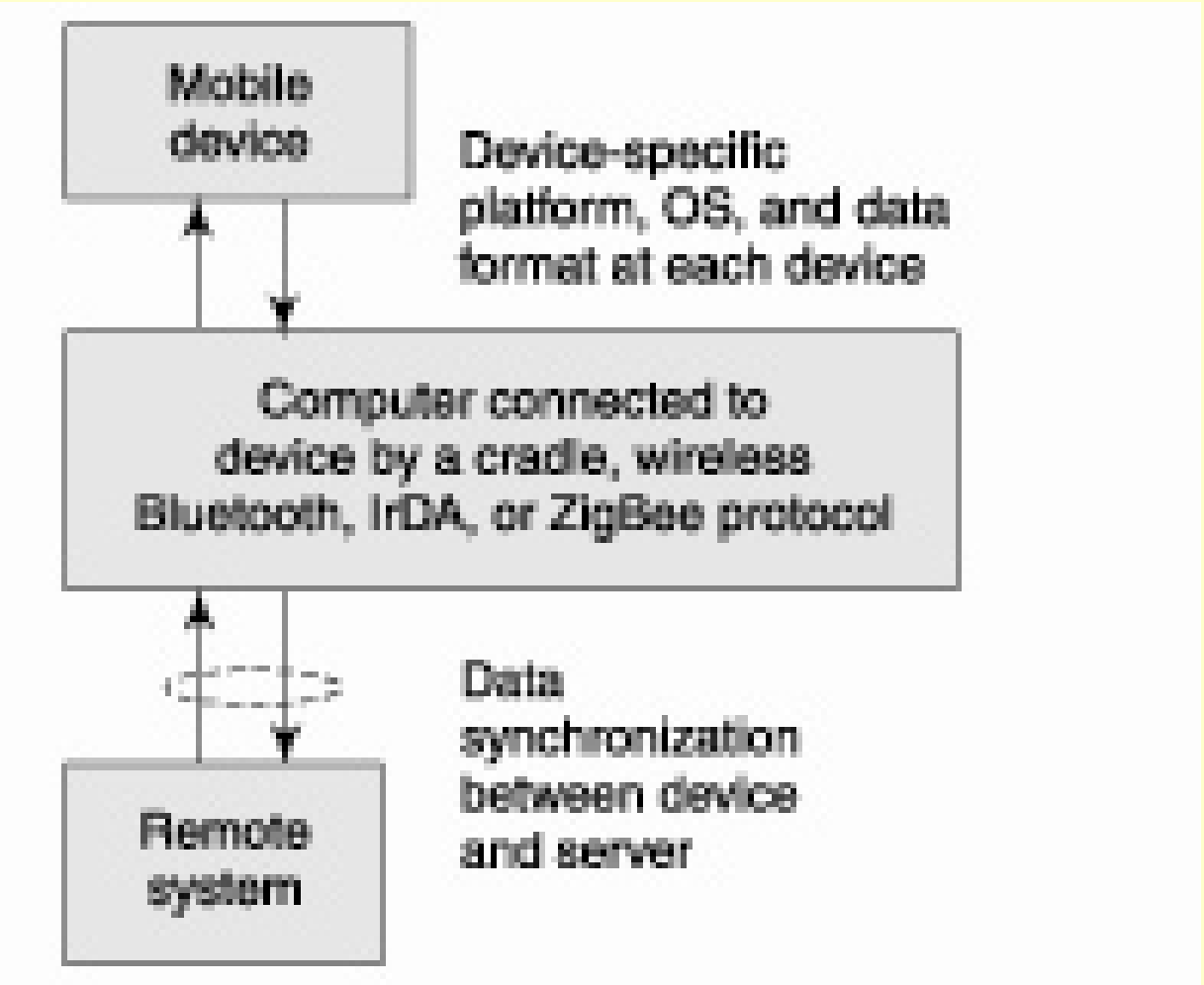
Remote System Synchronization through a PC with Palm device



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ActiveSync

- Software from Microsoft for synchronizing mobile devices with Windows-based PCs
- ActiveSync 4.1 synchronizes data at the PC with devices based on Windows Mobile 5.0 or Windows CE.
- Also available for the Symbian OS platform

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ActiveSync

- Synchronizes personal information (email, calendar, and contact information) on the mobile device even when the device is away from the PC

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ActiveSync

- Also functions as personal sync server (PSS)
- PSS enables a mobile user to synchronize the PIM data set, which consists of address book, calendar, and tasks-to-do list, on the handset with PIM data on a PC or a laptop

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ActiveSync PSS

- Integrates with Microsoft Outlook and Outlook Express on the PC, enabling email in Outlook to be transferred to the mobile device even when the user is on the move

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ActiveSync

- ActiveSync synchronization between mobile devices and PCs is not restricted to communication through serial or USB ports or through the Bluetooth or IrDA protocols
- A serial port may also be configured to support non-encrypted or encrypted (using secure connection configuration) communication

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Bluetooth ActiveSync partner

- PC can be configured as a Bluetooth ActiveSync partner
- Bluetooth communication sets a virtual COM port, which is utilized by ActiveSync for synchronizing with the PC, thus allowing the device to synchronize with the PC using Bluetooth

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ActiveSync 4.x synchronizer

- PC with mobile devices with Windows Media, videos, pictures, music, and MS Office files
- Has a partnership wizard to help device users set up a synchronizing partnership easily

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Conflict Resolution in ActiveSync

- Between different versions of files during data exchange and uses multiple service providers and service managers

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Internet through a wired network or a wireless WiFi network

- Using PC connects to Internet the in a synchronization architecture
- The PC then stores copies of the data for synchronization with the device
- For example, the PC downloads music files and videos and synchronizes them with the mobile device

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ActiveSync 4.x

- ActiveSync 4.x does not allow synchronization through direct Internet connection (TCP/IP connections using WiFi, WLAN, or dial-up telephone line)
- This is to prevent any external system from accessing the device and accessing the device data directly

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Device and remote system synchronization through PC

- Using ActiveSync in conjunction with Microsoft Exchange Server
- Microsoft Exchange 2003 Service Pack 2 with devices running the Messaging and Security Feature software for Windows Mobile 5.0 enables direct push

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Intellisync

- Developed at the Intellisync Corporation (now acquired by Nokia)
- Synchronizes PIM data between mobile devices and the Internet
- Open architecture and can, therefore, be integrated with enterprise architecture

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Intellisync

- Synchronizes email, calendar, Microsoft Outlook, and Lotus Notes
- Remote server Intellisync Wireless Email Express saves inbox, contacts, tasks-to-do list, calendars, personal travel information, weather forecasts, driving directions, etc. for each client, which can be updated while the mobile user is on the move

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Intellisync

- Also supports meeting requests and viewing attachments with emails. It also provides wireless email and push email features on a mobile device, just as in a Blackberry mobile
- Push email has push latency of 30 minutes

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Intellisync

- Enables enterprise connectivity features
- Provides security—it supports end-to-end encryption and password protection

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Intellisync Desktop synchronizer

- Supports Microsoft Windows Mobile-based smartphones
- Supports most mobile device platforms and handheld devices based on Palm OS, Pocket PC, Symbian, BREW, and other mobile device operating systems

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Intellisync

- Supports email, PIM synchronization, email accelerator, device management and file distribution using Systems Management/File Sync software, and synchronization with Microsoft Exchange Server

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Summary

- Synchronizer is used for remote as well as local (personal) area data synchronization
- HotSync for Palm OS using device
- Active Sync for Windows as well as Nokia device synchronization
- Saving of settings, preferences

...

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… Summary

- Synchronize memos, tasks-to-do list, calendars, contacts, and data files
- Enables favourites, call history, and speed-dialling
- E-mail Synchronization
- PC downloads from Internet music files and videos and synchronizes them with the mobile device

…

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… Summary

- Intellisync now from Nokia synchronizes local as well as remote
- Synchronizes PIM data between mobile devices and the Internet
- Open architecture and can, therefore, be integrated with enterprise architecture
- Enterprise data synchronization
- Security

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End of Lesson 06

Synchronization Software— HotSync, ActiveSync and Intellisync

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Data Synchronization in Mobile Computing Systems

Lesson 07

Synchronization Protocols– Bluetooth, IrDA and WAP

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Synchronization Protocol

- Protocol used for communication of data between two nodes of a computing system
- Also at each layer of communication, a distinct protocol can be used when communicating data between two layers of a computing node

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Synchronizer

- Can also use the different protocol layers for communicating to the personal area and remote area devices and computers

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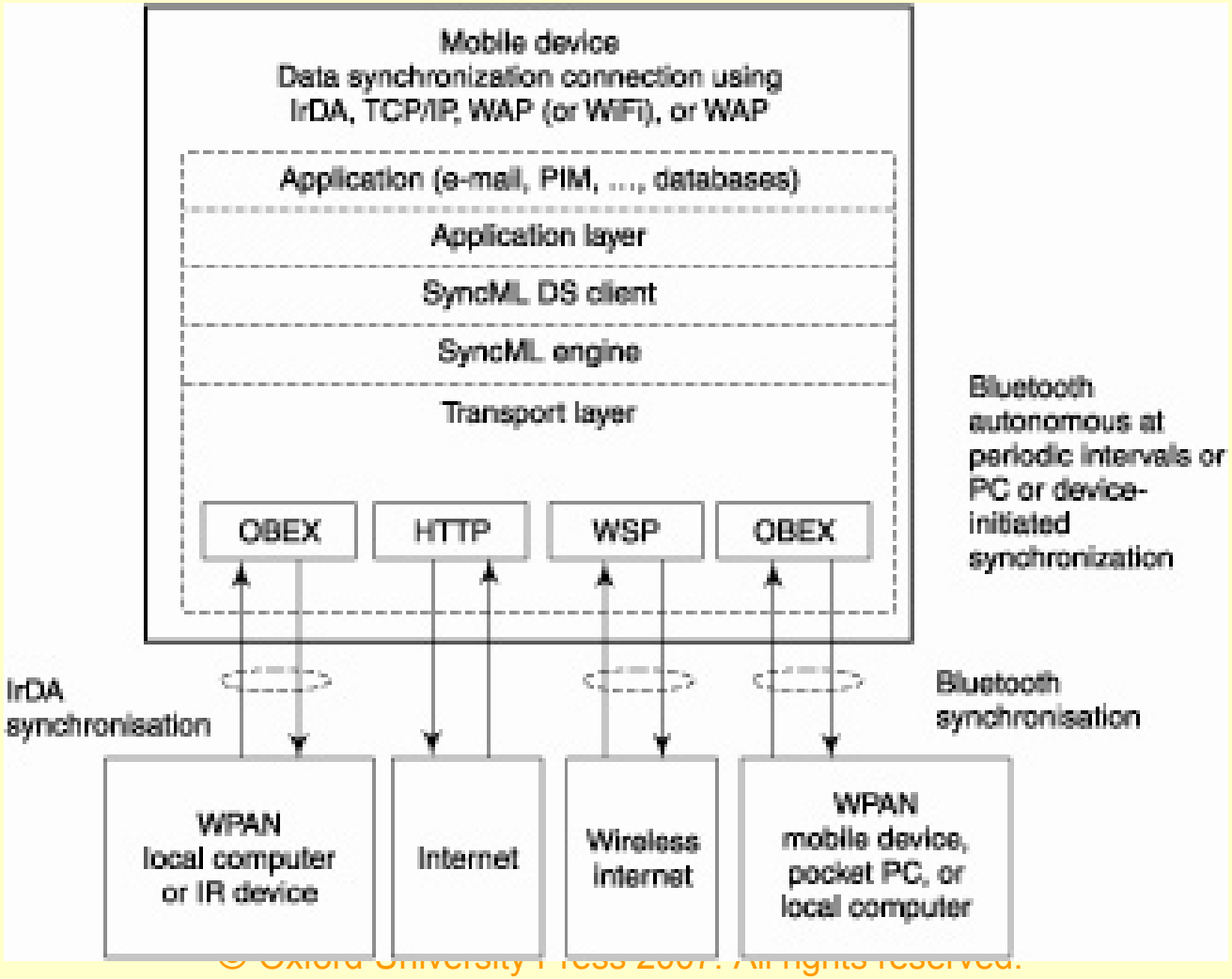
Synchronization protocols for the PIM, email and application data



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Bluetooth protocol

- Used for synchronization among mobile devices and Bluetooth-enabled PCs in a wireless personal area network

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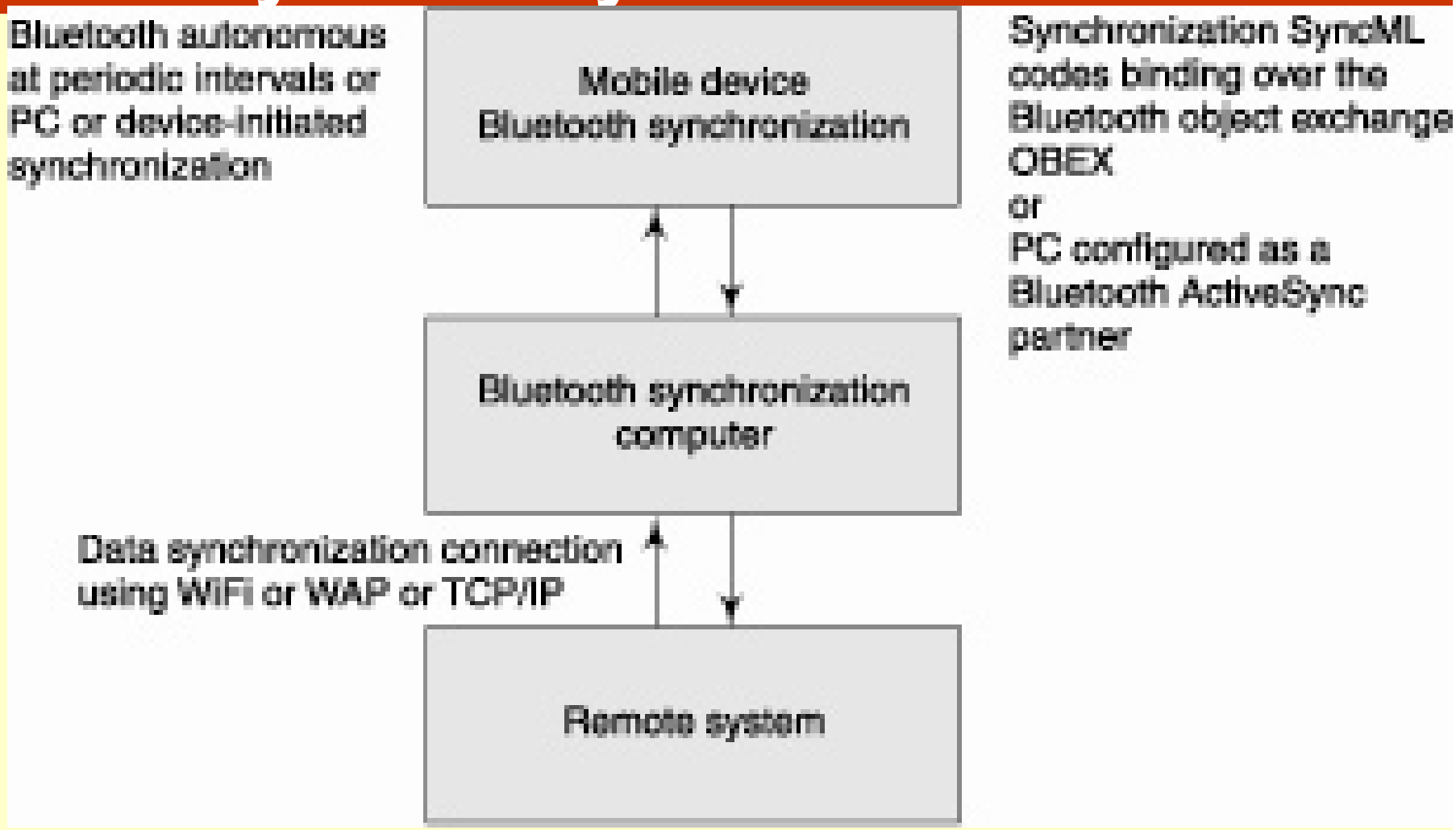
Bluetooth-enabled computing systems Synchronization



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Bluetooth protocol

- A connection-oriented protocol using Bluetooth object exchange OBEX (a protocol for transport layer in Bluetooth)

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Bluetooth protocol

- Can be used for one-to-one or one-to-many communication over short distances
- A self-discovery protocol
- Discovers whether nearby personal area device a Bluetooth-protocol-based communicating device
- A Bluetooth enabled device sets up an ad hoc network with the Bluetooth enabled devices and computing systems

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APIs for the PIM, email, and customized device applications

- Deploy a client (software for sending requests for response from the other node, computer, or device) and an engine (software for driving the requests of the client and receiving responses from the server for the client)

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Synchronization between the client and server

- Carried out through SyncML codes at the SyncML client and SyncML engine by sending the messages in the given sequence

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Sequence of Messages

1. *CONNECT*
2. *PUT* (to put the response to the request) or *GET* (to get the response to the request)
3. *ABORT* (to abort the connection)

- The term *message* used for describing information encapsulated in the header, commands, and associated accompanying data

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Alternative way of synchronization

- Configuring a Bluetooth ActiveSync partnership
- In this kind of partnership, the device uses Bluetooth protocol synchronization and the PC uses ActiveSync

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Bluetooth ActiveSync partnership

- For establishing the partnership for synchronization, the Bluetooth device port is first configured as a virtual COM port because the connected server for data is not a Bluetooth device but an ActiveSync PC port
- Later the Bluetooth device and PC synchronize through ActiveSync

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Bluetooth device

- Synchronizes PIM data (calendar, email, business card, text messages, and phonebook) with the ActiveSync device or a device which is not Bluetooth enabled through the virtual COM port
- Similarly, a virtual USB port can be configured at the Bluetooth device

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Infrared data association (IrDA) Protocol

- Infrared-based synchronization of mobile devices and computers within the same room

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IrDA

- Specifications include connection-oriented or connectionless protocols. IrDA specifies five levels of communication—minimum, access, index, sync, and SyncML (levels 1 to 5)
- Synchronization can be used to synchronize PIM data (calendar, email, business card, text messages, etc.)

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Wireless application protocol WAP 2.0

- A protocol for wireless synchronization of WAP client computers and WAP servers
- Synchronization through SyncML codes binding over the WAP application layer client or server

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WAP gateway

- Connects WAP client to HTTP servers which serve Internet websites
- The HTTP layer in TCP/IP protocol suite is an application layer protocol used when connecting to Internet in a wired network

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WSP (wireless session protocol) layer in WAP 2.0

- An application layer protocol when connecting to the Internet in a wireless network
- SyncML codes bind with WSP for Internet connectivity

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Summary

- Protocol for synchronization
- Bluetooth a self-discovery protocol, discovers whether nearby personal area device a Bluetooth-protocol-based communicating device
- IrDA
- WAP 2.0

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End of Lesson 07

Synchronization Protocols– Bluetooth, IrDA and WAP

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Data Synchronization in Mobile Computing Systems

Lesson 08

SyncML Language Features

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A mobile computing system

- Consists of (i) mobile device, (ii) personal area computer in a WPAN, a computer connected by WLAN, or Internet, (iii) nearby devices, for example, printer, and (iv) mobile service provider connected by wireless

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A mobile computing system

- In general, each of the devices can use different platforms
- One device may use Symbian OS, another Palm OS, and the computer on WLAN Windows OS
- Also, each one can use different languages
- For example, a device may use Java and the computer C/C++

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Use of SyncML Language

- Database connector for SyncML-based mobile application synchronizes data at the device with any relational database
- SyncML-based software synchronizes data for PIM (email, calendar, memo, tasks-to-do list, or contacts list)

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JCF (Jataayu client framework)

- A client framework to enable functioning of the software on different platforms

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Use of SyncML client and SyncML engine

- APIs for PIM, email, and customized device application can deploy SyncML client and SyncML engine
- SyncML server for sending response to the requests from the other node, computer, or device
- Sends the messages which accompany the data and the operational results as per the messages

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SyncML (Synchronization Markup Language)

- A data synchronization language based on XML (Extensible Markup Language)
- In other words, it is a markup language used for writing the codes for interfaces used for synchronization between the mobile devices and the server

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XML Base of SyncML

- A language for marking up a given text with tags and attributes and it is extensively used in mobile computing

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Example of XML codes

- <search_list>
- …
- <!- - Contact information about contacts identified by first alphabet as R - - >
- <alp_name first_character = “R”>
- <contact_name>
- Raj Kamal
- <address> ABC Street, …. </address>
- <telnumber> 9876543210 </telnumber>
- </contact_name>

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Example of XML codes

- <contact_name>
- Raveena
- <address> XYZ Street, …. </address>
- <telnumber> 9848543210 </telnumber>
- </contact_name>
- </alp_name>
- …
- </search_list

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Comments in XML

- Comments are not used in parsing (processing) of the codes.
- XML comments start with <!- - (less than sign, ! sign and two dashes) and ends with - - > (two dashes before the greater than sign)

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Start and last tags for writing the text of a search list in between the tags

- The start tag starts with < sign
- Followed by a tag name which is search_list in this case
- ends with > sign
- The last tag starts with <, followed by a slash sign, the same tag name as at the start, and > sign

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Inner tag with attributes

- For example, alp_name with attribute specification first_character = “R”
- The coding format is < sign, tag name, tag attribute or attributes, > sign, followed by text associated with the given tag and attributes, < sign, slash sign, tag name and > sign

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Data type definitions (DTD) file

- For an XML document, there is a data type definitions (DTD) file which specifies the rules
- For example, for the document given, it specifies that search_list is the root element and that contact_name contains the address and telephone number

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XML

- A platform independent processing language
- This implies that it can be used for processing not only by Java but also by any other language
- Tags, attributes, and metadata formats in XML are standardized so that they can be universally interpreted on different platforms, machines, or networks

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SyncML and Voice XML

- *SyncML* an open standard based on XML. It has revolutionized mobile application-development, services, and devices
- *Voice XML* another language based on XML and is used for communicating voice messages

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SyncMLML based Information Exchange

- Between a client and server in form of an envelope representing a message
- Term message describes information
- A tag and its attributes define an envelope of a text message
- Each envelope has a header followed by body

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SyncML Header and Body

- The header exists between header start and end tags
- The *body* which includes the *commands* is present between body start and end tags
- The *envelope* exchanged between client and server by request and response messages

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SyncML Header and Body

- SyncML message has two components—(a) a header which starts with the start tag <SyncHdr> and ends with the end tag </SyncHdr> and (b) a body which starts with <SyncBody> and ends with </SyncBody>

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SyncHdr

- Consists of DTD, protocol, and data (message or session) identifications
- Includes target and source information
- Carries initialization information which is required before synchronization
- The initialization information enables device authentication and includes information on available device functions

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Example of SyncML Header

```
<SyncML>
 <SyncHdr>
  <VerDTD>1.0</VerDTD>
  <VerProto>SyncML/1.0</VerProto>
  <SessionID>session01</SessionID>
  <MsgID>message09</MsgID>
  <Target><LocURI>http://www.syncml.org/sync-
server</LocURI></Target>
```

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Example of SyncML Header

<!- - LocURI means local URI. URI means Universal Resource Identifier - - >

<Source><LocURI>IMEI:49……800 </LocURI></Source> < - - IMEI is International Mobile Equipment Identity represented by a number - ->

…

</SyncHdr>

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Use of SyncBody

<SyncBody>

...

</SyncBody>

</SyncML>

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SyncML used between client and server

- The accompanying data (payload) is placed between a start tag and the corresponding last tag
- SyncML can be used between client and server for sending messages and data and for synchronization as it has standard defined tags, commands and protocol for exchange

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Definition of the term Data store

- A term used in SyncML codes for persistent data storage
- It is also written as DataStore
- Refers to storage of data in a file system or database or in any other way in which persistency is maintained

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Data store

- In the context of mobile devices, persistency means that the data remains intact till deleted even if the device power is interrupted
- Implies that a change in data during an operation is simultaneously stored and reflected at all related files in file system, database, or any other record

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Example of DataStore

- Suppose a telephone number is stored in a mobile device
- The flash memory file stores it persistently and it is used in call operations

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Example of DataStore

- When user modifies the telephone number in *Contacts* at PIM using an API, it is also stored and modified at the flash storage and will be available any time on next call
- When user deletes the telephone number in *Contacts,* only then the number looses persistency

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Use of DataStore

- APIs, for example, PMI or email, use a *Data store* mechanism
- For synchronizing data using different *Data store* mechanisms at the nodes (client, database, file system, or server), with each one, in general, using different platforms and languages, is a difficult task

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SyncML

- Can be used for sending messages of the APIs and data using the Data store mechanism at both the client and server ends

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Parsing of SyncML message

- A SyncML *message* from SyncML client or server is used after parsing the tags, attributes and the text
- A SyncML *message* parsed similar to an XML document
- For example, the search list—an XML document, in Sample

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Example of Using Parser

- The parser also able to retrieve the data for the contact name, telephone number, and address
- An API at the device or server can save the data using the *Data store* mechanism
- An API can use the data for synchronization with another API in personal area network or at server

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Parse use by an API

- Assume that an API uses a parser and parses for contact names, then firstly the parser will parse for alphabet tag, then first character “ R”
- As a result, the parser gets the contact names with first character as the alphabet ‘R’
- A parser program associated with PIM API can be used to get a list of contact names

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Parser

- Using the document in Sample Code, an item in the list of items will be—first line: Name Raj Kamal, second line: Address ABC Street, …, and third line Phone 9876543210

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Sync ML Data Type Definitions

- SyncML, like XML, uses DTDs
- These include device information DTD, service information DTD, meta information DTD (for metadata), and main SyncML DTD
- Service information DTD represents the functional capabilities of the data objects supported by client or server

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Two-way synchronization

- If a client supports vCard version 2.1 for two-way synchronization, the server must also have this capability; otherwise the synchronization session for the vCard data object cannot proceed

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SyncML DTD

- Also exchanged with the message
- SyncML defines a universal data synchronization format DTD, which is exchanged with a SyncML message

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Metadata in Data Type Definitions

- Metadata is information regarding the stored data or it is information about information
- Like XML document, the SyncML metadata is structured data that describes various characteristics of information-carrying elements

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Data store info

- Whether Data store mechanism is database-based or file-based

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Device info

- Has information about the device capability for synchronization
- Device info consists of device type, model number, manufacturer, device hardware version specification, device software specification, and device capabilities for maintaining data copies and synchronization

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Metadata

- Helps in discovering and locating data or in its assessment
- The metadata data helps in the identification or management of data in the subsequent text data in the document
- Metadata considered as information about data or as information about information

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Open Standard Acceptability by OMA

- Initiative for universal acceptability of SyncML is a project of the Open Mobile Alliance (OMA)
- The OMA SyncML initiative came from IBM, Motorola, Nokia, Palm, Ericsson, Lotus, Starfish, and Psion
- Later many organizations joined

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Summary

- SyncML is a standard XML based language for mobile application development
- Parsing similar to XML
- DataStore
- SyncML DTD
- Metadata

...

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… Summary

- Tags and attributes
- Envelope
- Header
- Body

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End of Lesson 8

SyncML Language Features

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Data Synchronization in Mobile Computing Systems

Lesson 09

SyncML Client and Server Framework

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Synchronization Client and Server Framework

- Seven types of synchronization—(a) two-way synchronization, (b) server-alerted synchronization, (c) one-way server-initiated synchronization, (d) refresh synchronization at client, (e) client-initiated synchronization, (f) refresh synchronization from client for backup and update, and (g) slow (full data copy) synchronization

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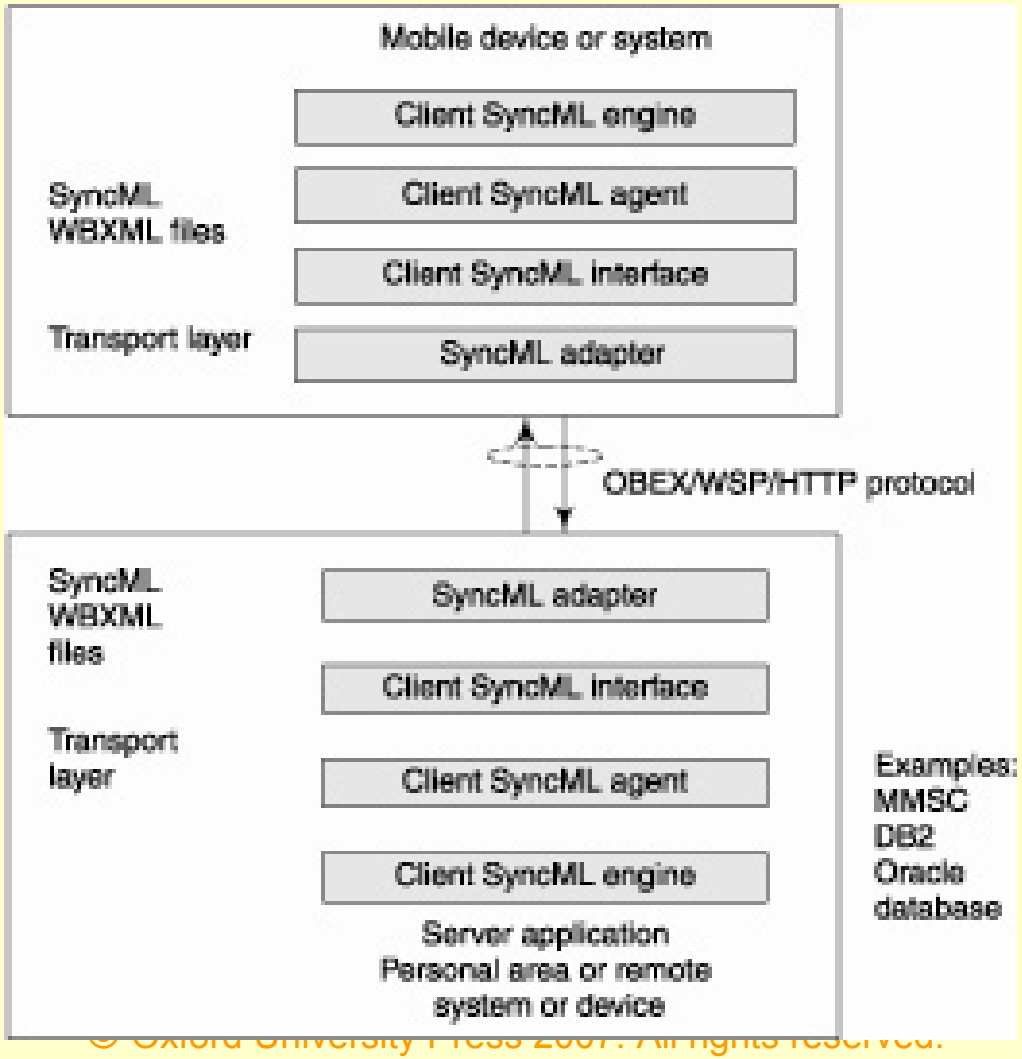
Framework for client and server synchronization using SyncML



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SyncML client framework

- Provides portability and interoperability
- It may be ported on single or multiple platforms—J2ME, BREW, Windows Mobile, PalmOS, Symbian, and others

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SyncML agent in Framework

- Performs data synchronization in association with a SyncML engine
- The agent employs a SyncML interface to send and receive SyncML WBXML format data to and from a SyncML adapter

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Adapter

- WBXML makes the SyncML data compact
- SyncML adapter is a piece of software that maintains transfer of SyncML data using OBEX, WSP, or HTTP protocols

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MMS Server

- Consider an MMS server which provides SyncML interface for data synchronization servers
- Consider that a device has an MMS and a database client
- An MMS server provides a feature rich range of multimedia messaging and also provides essential core of the MMS environment for the MMS clients

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SyncML adapter

- Provides the SyncML interface for the MMS server data
- The interface provides the SyncML transport using OBEX, WSP, or HTTP protocol
- The MMS client at device receives the MMS data from the SyncML adapter at the device

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Adapter for database clients

- DB2 and Oracle database servers provide interfaces for SyncML data synchronization servers
- Interfaces synchronize the database records with database clients at the devices
- A SyncML adapter enables SyncML transport over OBEX , WSP, or HTTP to the database clients

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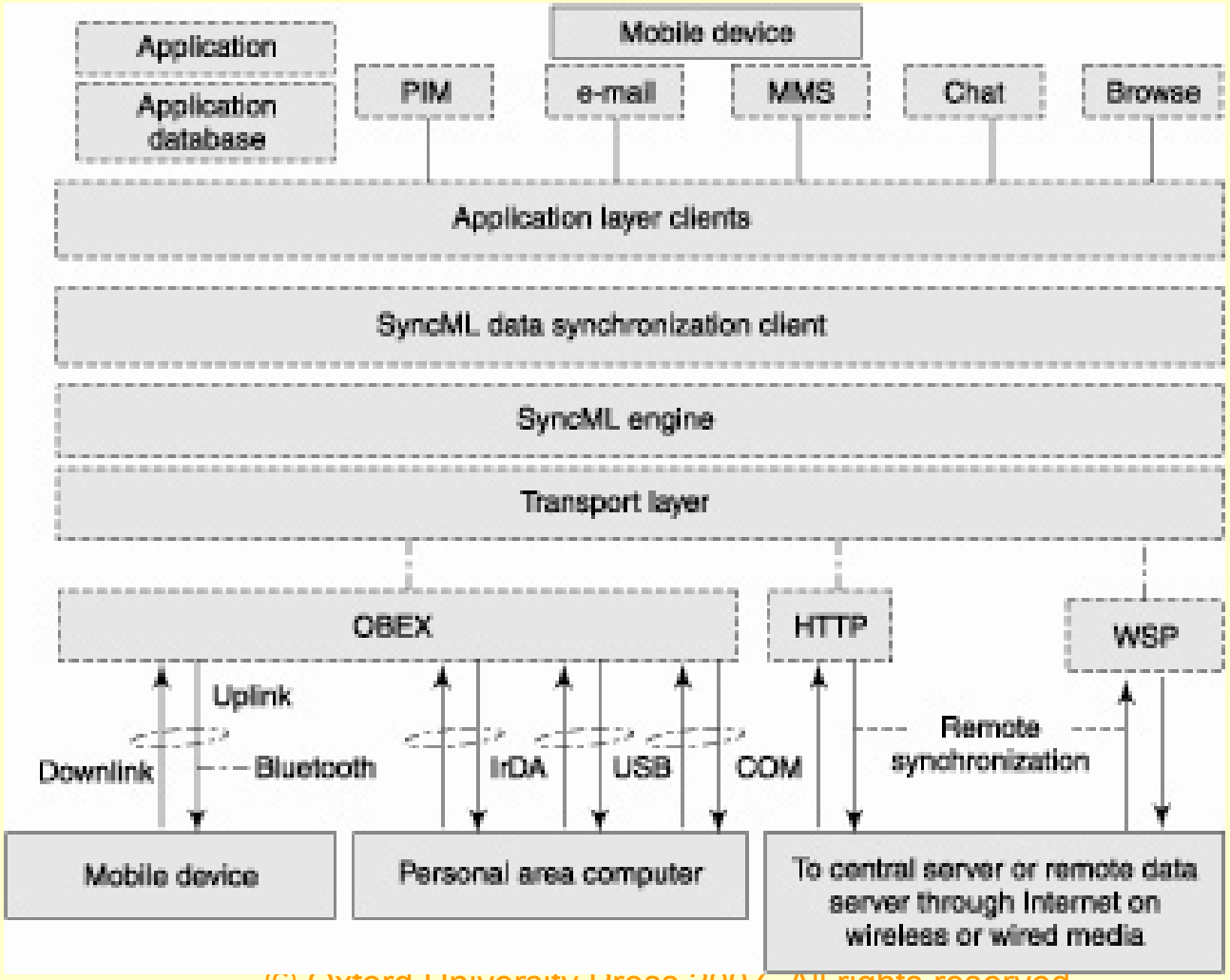
Synchronization of a mobile device in SyncML protocol architecture



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Device synchronization

- Device synchronizes with a personal area network computer or remote server using SyncML data synchronization (SyncML DS) client, SyncML engine, and binding with OBEX/WAP/HTTP

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Application layer

- Executes the application and provides extensible adapters for different applications and multimedia interfaces for device user interactions

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Example of Application

- An application software is an IMPS (instant messaging and presence service) client used for online chatting
- Other applications include browsing, using HTML or WAP 2.0, MMS client, email, and Sync client

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Example of Application

- IMPS is a Wireless Village protocol compliant software
- Used to provide an instant messaging client
- IMPS chat client (in Nokia) for chatting employs the *My Presence* protocol

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SyncML DS client

- Executes SyncML commands for applications, PIM, and email
- Encodes and decodes PIM data

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SyncML DS client

- Encodes the PIM data that is received from the SyncML DS server and decodes the PIM data that is sent to the SyncML DS Server
- It generates status codes and communicates these to the SyncML protocol engine

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SyncML data engine

- Performs SyncML code generation, parsing of received SyncML data, validation of DTD in WBXML and XML format data, base-64 encoding/decoding and notification message parsing, credential checks, security operations, and HMAC data integrity check

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Application layer API

- Uses HTTP and WSP
- Transport layer functions are provisions of object-exchange adapters using OBEX for synchronization through Bluetooth, IrDA, COM ports, and USB ports

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Transport layer function

- A method of communication for remote synchronization
- It receives notification buffers over OBEX or WAP PUSH receiving and sending SyncML Package data to and from the DS server

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Summary

- SyncML client Frame work provides portability and interoperability
- It may be ported on single or multiple platforms—J2ME, BREW, Windows Mobile, PalmOS, Symbian, and others
- SyncML Engine
- SyncML adapter

...

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… Summary

- OBEX for object exchange with mobile device, Personal area computer using Bluetooth or IrDA or USB or COM
- HTTP or WSP to exchange messages with
- SyncML DS client synchronization gives a APIs development platform

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End of Lesson 9

SyncML Client and Server Framework

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Data Synchronization in Mobile Computing Systems

Lesson 10

SyncML Protocols

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SyncML provisions for an open standard

- Representation protocol
- Synchronization protocol
- Ways of formatting the document
- Ways of description of architecture for synchronization

– Ways for binding an application with the well known transport protocols

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Ways of binding

- SyncML codes bind the WAP, Bluetooth, or IrDA protocols and a mobile application run for synchronization and synchronize with Bluetooth, WAP 2.0, or IrDA level 5 connection using a SyncML client and engine

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SyncML provisions for an open standard

- Interfaces for binding the programming languages which are very common, for example, Java, C, and C++.
- Prototype implementation for using the SyncML

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SyncML programming

- Based on two protocols—the SyncML representation protocol and the SyncML synchronization protocol
- The SyncML representation protocol defines the representation format of SyncML messages which are in XML
- It gives details about the inner working of the SyncML framework

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SyncML Message

- SyncML protocol specifies that a *message* has SyncHdr and SyncBody, with meta info as well as device info present within SyncHdr
- Meta info is placed between the start and end tags <MetInf> and </MetInf> and device info between <DevInfo> and </DevInfo>

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Universal Resource Identifier (URI)

- A full path specification for a device resource
- Assume a PIM data structured like a tree

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Universal Resource Identifier (URI)

- The parent PIM data object is the root object
- At the branches of the root object, there are objects called daughter data record copies, these are *calendar*, *address_book*, and *tasks_to_do*

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Address_book object

- Has the branches having the contacts. Each of the contacts object has branches and daughter objects which may be leaves
- The leaves are name, office, home, mobile and fax numbers, home and office addresses, web addresses, and email IDs

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Root object of device PIM data dev_PIM_data

- Assume that the root object of device PIM data dev_PIM_data
- Server PIM data PIM_data
- The root PIM_data hierarchy at the server— PIM_data → address_book → contacts → Raj Kamal → telNum_RK

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PIM data object address_book branches

- Further has the object Contacts
- Contacts has the object Raj Kamal
- Raj Kamal object has a leaf, the resource telephone number, telNum_RK

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PIM data object address_book

- telNum_RK contains the telephone number data in digits, where resource refers to an entity used in the computations or for synchronization
- For an API, the resource is at the leaf during computations using the telNum_RK

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Protocol specification of the URI

- Used to identify any resource at the object
- PIM_data/address_book/contacts/Raj Kamal is URI for identifying a resource at the Contacts at the server
- PIM_data/address_book/contacts/Raj Kamal/telNumRK is URI for the resource at the leaf telNum_RK

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Protocol specification of the URI

- If the object Raj Kamal has two branches, telNum_RK and address_RK, then the URI for the leaf object address_RK will be PIM_data/contacts/Raj Kamal/address_RK, where address_RK has the text of address

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Commands

- Create, Delete, Add, Update, Sync, Alert, Atomic, Search, Read, Get, Exec, Put, Copy, Results, Map, and Status
- Refer Table 9.1 for the meaning of the commands
- Alert command is a special SyncML feature by which the server alerts the client

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Sample Code

```
<SyncBody>
  <Status>
   <Cmd>SyncHdr</Cmd> <CmdRef>0</CmdRef>
     <MsgRef>1</MsgRef>
   <TargetRef> IMEI:49……800</TargetRef>
   <SourceRef> http://www.syncml.org/sync-server
     </SourceRef>
  <Data>212</Data>
  </Status>
```

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Sample Code

<Status>

<Cmd>Alert</Cmd> <CmdRef>1</CmdRef>
<MsgRef>1</MsgRef>

<!- - Assume that Device contact data object at the device is dev_contacts, which was the target defined at the header and assume that new contact added at the server is URI ./contacts/Raj Kamal and Alert is sent to client device - - >

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Sample Code

```
<TargetRef>./dev_contacts</TargetRef>
  <SourceRef>./contacts/ Raj Kamal
     </SourceRef>
   <Data>200</Data>
  </Status>
</SyncBody>
```

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Security

- For secure synchronization of messages between source and destination, a message *M* sent from a source to destination needs verification of its integrity and authenticity of the source

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keyed hash message authentication code (*HMAC*)

- $HMAC_{source}$ of message *M* sent along with *M*
- Generated after computations at the source
- At the destination, the $HMAC_{dest}$ is regenerated

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Keyed hash message authentication code (*HMAC*)

- If the $HMAC_{dest}$ computed at the destination matches with the received $HMAC_{source}$, the integrity of *M* stands verified

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Computations for HMAC

- Done using M, a secret key S and an iterative hash function
- Iterative function is a function repeatedly operated on the operand
- Two of the several iterative hash functions can be used
- SHA-1 (secure hash algorithm-1) and MD-5 (message digest algorithm-5)

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Handling Large Objects Using <MoreData> tag

- Wireless transmission, there are interruptions
- Therefore, a large data object should be broken into many chunks
- <MoreData> tag for transmitting large object data in chunks

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Handling Large Objects Using <MoreData> tag

- Using <MoreData> tag, a large object can be exchanged by dividing it into data chunks. Each chunk has a start tag <MoreData> and an end tag </Moredata>

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Handling Large Objects Using <MoreData> tag

- This indicates that next chunk expected in next session
- The receiving objects join the chucks to recreate a large object

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Use of status codes in case of Errors

- SyncML protocol defines error codes in the event of data conflict, incomplete document, and other errors that occur during synchronization
- Status codes between 500 and 599 are received for response from the receiver
- For example,Code 511 which implies server failure

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Example of status codes

- For example, assume that a status code sent by the receiver of SyncML message is error code 501
- This implies that the command could not be implemented at the receiver because the SyncML client or server did not support it for any of the resources

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Setup and Synchronization phases

- SyncML DM protocol specifies a standard method for set up and synchronization
- Device management– one-way synchronization of the device from the server

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Setup and Synchronization phases

- The server sets and updates the data on the client device
- It also requests for the device data, for example, data for enabling device authentication by it

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Setup and Synchronization phases

- Data exchange occurs in phases using packages 0–4
- A *package* is a SyncML message containing XML document
- Phases of data exchanges in packages 0–2 are called setup phases
- Phases of data exchanges in packages 3 and 4 are called synchronization or management phases

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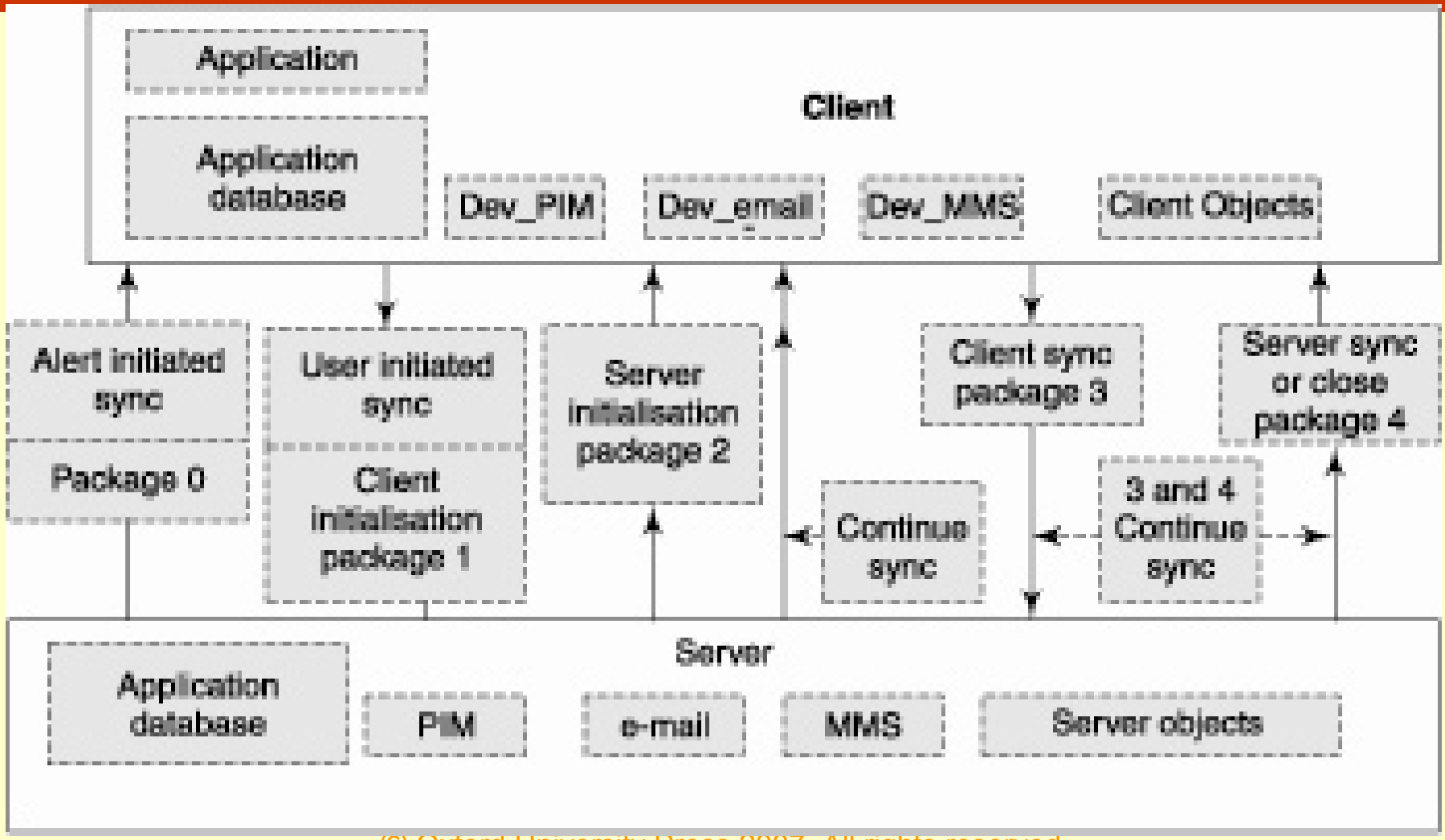
Setup and Synchronization phases



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Summary

- Representation protocol
- Synchronization protocol
- Ways of formatting the document
- Ways of description of architecture for synchronization
- Interfaces for Binding
- Prototype implementation

...

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… Summary

- Universal resource Identifier by full path from root to leaf
- Commands for message exchanges for synchronization and client-server exchanges
- HMAC security

…

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… Summary

- <MoreData> for handling large objects
- Four phases for set-up and synchronization

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End of Lesson 10

SyncML Protocol

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Data Synchronization in Mobile Computing Systems

Lesson 11

Funambol

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Sync4J called *Funambol*

- Provides an open source standard for Java-based processing of SyncML messages and synchronization formats

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Examples of Java Based Processing

- SyncML message contains a command for specifying the maximum display time (MAXDT). <Item><Data>MAXDT = 15></Data></Item>
- A parser parses the SyncML messages and the parser program can be in Java. After parsing, the commands are to be executed

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Examples of Java Based Processing

- The parser parses MAXDT and its data = 15
- A program then has to implement the parsed command
- That program can also be in Java

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Examples of Java Based Processing

- Initially named Sync4j, Funambol provides Java-based synchronization using SyncML messages. Funambol is an open-source mobile application server software

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Sync4j (Funambol)

- Initially named Sync4j, Funambol provides Java-based synchronization using SyncML messages
- Funambol– an open-source mobile application server software

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Sync4j (Funambol)

- First, a SyncML message containing XML document is parsed using either Java and DOM (document object model) or SAX modelled APIs
- Then the appropriate commands are implemented

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Funambol

- Implements *itemized commands—Alert, Put, Get, Modification,* and *Response*
- Also implements *Atomic, Map, Search,* and *Sequence* commands

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Funambol server for mobile application

- Includes a suite of tools
- The tools enable programmers to develop, deploy, and manage mobile applications

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Funambol server for mobile application

- Funambol implements SyncML OMA data synchronization
- Device management commands
- Data synchronization server

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Funambol server for mobile application

- Open source DBConnector (database connector)
- Push email and Microsoft Outlook functionality
- iPod

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Summary

- Funambol provides Java-based synchronization using SyncML messages

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End of Lesson 11

Funambol

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Data Synchronization in Mobile Computing Systems

Lesson 12

Synchronized Multimedia Markup Language (SMIL)

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Language required to specify the multi-modal multimedia communication

- Mobile devices not only have to synchronize data but also multimedia (music, video clips, images, and slide shows)
- The transmitted text shown onto the display of the video clip
- The text also rendered with the voice
- The displayed text, images, and audio needs to be synchronized

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Language required to specify the multi-modal multimedia communication

- To specify the synchronization messages in order to enable appropriate synchronization and for integration of multi-modal multimedia communication

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Multi-modal

- Usage of different modes—text, image, video, or audio
- Multi-modal communication integrates and synchronizes multimedia.

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SMIL

- Used for text, speech, or multimedia integration for multi-modal communication
- Like SyncML, the SMIL based on XML
- SMIL version 2.1 enables coding of messages for interactive audio–visual presentations
- The coding of SMIL messages needs a simple text editor

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SMIL

- SMIL specifies the standard ways and tags which integrate text, images, and streaming audio and video
- SMIL– a W3C council (World Wide Web Consortium)

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Coding for a text-to-speech synthesis (TTS) engine

- TTS deployed in automobiles and many other applications
- If the driver of an automobile attempts to read a text message, his attention may get diverted
- TTS engine converts text messages to voice messages
- SMIL can be used for coding the TTS engine

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SMIL features

- Just as SyncML refers to objects by URIs, SMIL refers to multimedia objects by URLs ((universal resource locators)
- SMIL provides the commands for Multimedia objects sharing between presentations and may be required to be stored on different servers for load balancing the actions

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SMIL features

- SMIL provides commands for Different media objects required to be transmitted at different bandwidths
- SMIL document has two components—(i) a header between start and end tags, <header> and </header> and (ii) a body between start and end tags, <body> and </body>

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SMIL Features

- Due to multimedia synchronization, the <body> section also provides the timing information

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Sample Code 9.4

```
<smil>
 <SyncHdr>
     ...
</SyncHdr>
<SyncBody>
  ...
</SyncBody>
   </smil>
```

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SMIL Tags within the <SyncBody>

1. <layout> within the header element to specify layout of SMIL document
2. <seq> for sequential operations within the body element. The specified operations should be performed in sequence

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SMIL Tags within the <SyncBody>

3. <par> for parallel operations within the body element. The specified operations should be carried out in parallel.
4. <switch> for a different set within the body element for presenting multimedia contents

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Sample Code

1. <SyncBody>

<seq>

<!- - Source of WBXML text file is my.wml,

maximum period 10 s, duration is 1 s,
repetition is 5 times- - >

<text src = “my.wml” max= “10s” dur = “1s” repeatCount =”5”/>

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Sample Code

```
<!- - Source of video file is my.mpg, identifier
    is my_vid and end duration = 10s. - - >
     <video src = “my.mpg” id = “my_vid” end
    = 10s/>
</seq>
</SyncBody>
```

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Sample Code

2. <SyncBody>

<!- - Assume that all operations image and audio begin in parallel and begin at 2s" - - >

<par begin = "2s">

<!- - Source of image file is myimage.jpg, end is 2s and freeze on display for 2s - - >

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Sample Code

```
<img src = “myimage.jpg” begin = “2s” end
    myimage.end – 2s” fill = “freeze”/>
<!- - Source of audio file is myaudio.wav, id
    is “my_id”, begin at t = 0s for 10s
    duration. - - >
<audio id = “my_id” src = “myaudio.wav”
    begin = “0s” dur = “10s” />
    </par>
</SyncBody>
```

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Multimedia messaging service (MMS)

- MMS is the video and picture equivalent of SMS, is a subset of SMIL
- It can be implemented on handheld computers and mobile devices

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SMIL messages

- Can be structured as in a document object model (DOM) tree
- DOM tree specifies a tree-like structure of the tags

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SMIL messages

- Tree-like structuring of objects as in URI specifications
- In a DOM tree, a manager is the root and SMIL messages are the branches and leaves
- SMIL messages scheduled using SMIL scheduler software

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SMIL Parsing

- Just as an XML document or SyncML message, SMIL message needs to be parsed
- A DOM interface specifies the parsing and layout

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Summary

- Funambol provides Java-based synchronization using SyncML messages
- SMIL enables coding of messages for interactive audio–visual presentations
- SMIL specifies the standard ways and tags which integrate text, images, and streaming audio and video

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End of Lesson 12
Synchronized Multimedia Markup Language (SMIL)

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Mobile Devices: Server and Management

Lesson 01

Mobile Agent

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Mobile agent

- Consists of software with data, which can move from one computing system to another autonomously
- Functions for a device or system on the present host

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Mobile agent

- Described as an autonomous software which runs on a host with some data
- Dynamically moving software to another host (which has other required data) as and when required

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Mobile agent

- A powerful tool for distributed applications and retrieval of remote host information
- Has dynamic software that runs on different hosts at different times
- Makes available the resources of its host to the resource-scarce devices, discovers new resources, and monitors the distribution of resources

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Mobile agent

- Also manages the network and the distributed computing systems
- Very effective alternative to the use of application-specific server(s) and device middleware for retrieving information and messages

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Example of a Mobile agent-based architecture

- Agent moves at instants T1, T2, and T3 to process a request, get email, and get records from a database, respectively
- When a mobile agent moves at instant T1, T2, or T3, it saves its own state at the host and transmits this saved state to the next host in order to resume execution of the codes starting from the saved state

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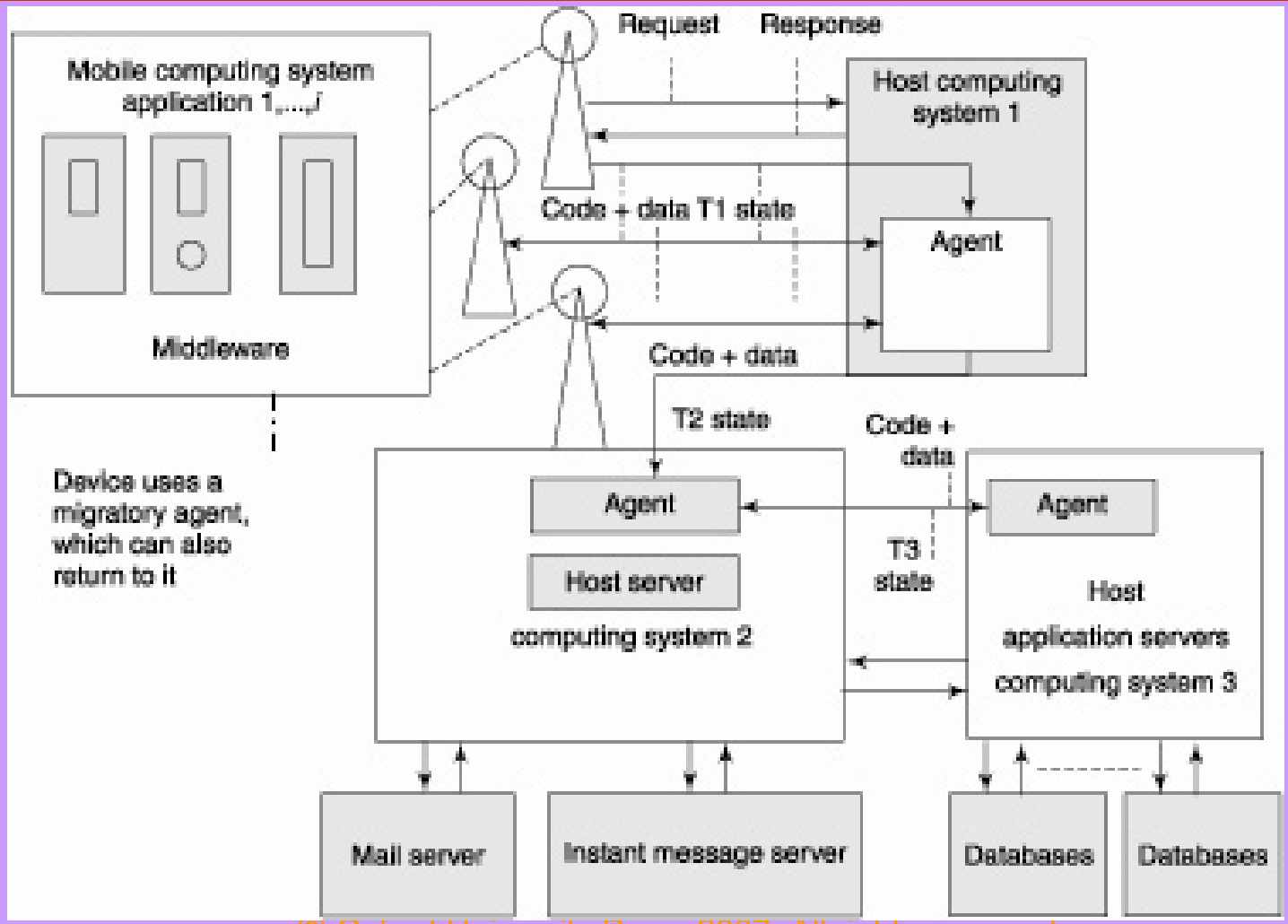
A mobile agent-based architecture



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AgentOS, an operating system

- Developed in 2006
- Provides application virtualisation environment
- Allows automatic thread migration (ATM)
- The threads running on the host being independent of the OS

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AgentOS Application virtualisation environment

- An application instead of running in its own environment provided by the OS and the system hardware actually runs at a host OS and host system hardware of the mobile agent of that system
- To a user, the application appears to be running at the system environment while it is actually running at the host environment, which is host to the agent

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Characteristics of a mobile agent

1. Mobility of code and data from one computing system (host) to another
2. Ability to learn in order to adapt code and data to the host computing system
3. Ability to clone, extend, or dispose itself after its role finishes
4. Compatibility to the hosts

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Characteristics of a mobile agent

5. Ability to continuously and autonomously process requests and send responses and alerts
- An alert– an unsolicited message, record, or information

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Advantages of a mobile agent

1. Asynchronous running of codes on diversified heterogeneous hosts
2. Reduced computational and data requirements on the devices with limited resources
3. Tolerance to connection failures

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Advantages of a mobile agent

4. Only the agent source (for example, device middleware, which sends the agent) needs to be modified in order to redefine the functions expected from the agent
- There is no need of a centralized or an application-specific server

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Advantages when deploying an agent in a computing system

5. An agent can send the requests to a computing system as well as generate responses for requests from the system. An agent thus has certain similarities to peer-to-peer architecture
6. The connection protocol and the connecting network between host and source are immaterial

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Peer-to-peer architecture

- Each system or device can send a request to and get a response from the other
- Each device can have access to databases or database servers

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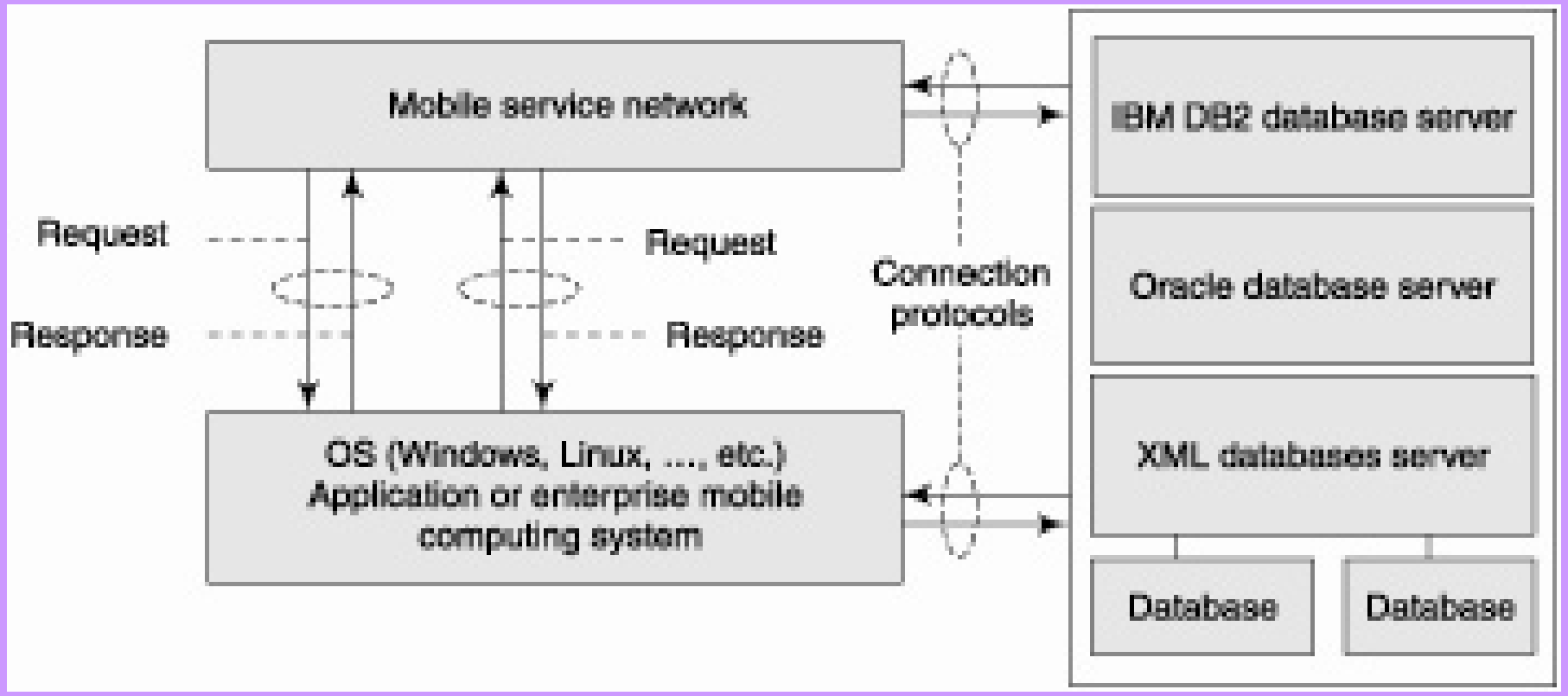
Peer-to-peer architecture



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Latency Issues in use of the agent

- Migration latency means waiting period in migrating from one host to another
- Collaboration latency means waiting period in start of collaboration between the application server and the service-requesting system
- An agent possess migration and collaboration latencies

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Environment- and platform-specific and security Issues in use of the agent

- There can be environment- and platform-specific difficulties in implementing adaptability and compatibility at diversified hosts
- In addition, security-specific issues related to an agent moving from one host to another

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Mobility Issues in use of the agent

- Agent may have strong or weak mobility

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Summary

- Mobile Agent– an autonomous software which runs on a host with some data for the device or system
- Dynamically moving (migrating) software to another host (which has other required data) as and when required
- No need of a centralized or an application-specific server when using agent

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End of Lesson 01
Mobile Agent

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Mobile Devices: Server and Management

Lesson 02
Application Servers– Part 1

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Application server

- Software, which executes at a server and serves the application-level logic of the business functions

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Application-level logic

- The logic commands or instructions which an application server uses for sending and receiving the logic results from a computing system

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Business functions

- The logical way in which transactions (business) carried out between server at one end and application at the other

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Examples of transactions involving mail application-server

(a) Establishing connection between mail APIs (application program interfaces) and mail server

(b) Updating mails by inserting, adding, replacing, or deleting

(c) Querying for the mails

(d) Terminating the connection between the API and the mail server

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Responses to Requests by an application server

- The server Gets from the collaborating or independent mobile devices of an enterprise
- From a distributed mobile computing system
- The server processes these requests
- Generates responses

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Enterprise Server

- A server that connects to enterprise centralized data server in an enterprise
- The centralized server holds most of the information about the enterprise
- Responds to the requests that are only from authenticated and authorised clients

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Application server additional functions

- Also handles presentation services to the devices or computing systems
- Employs records at the server database(s) for this purpose
- Also integrates itself with the backend databases
- Integrates with systems, for example, an enterprise system

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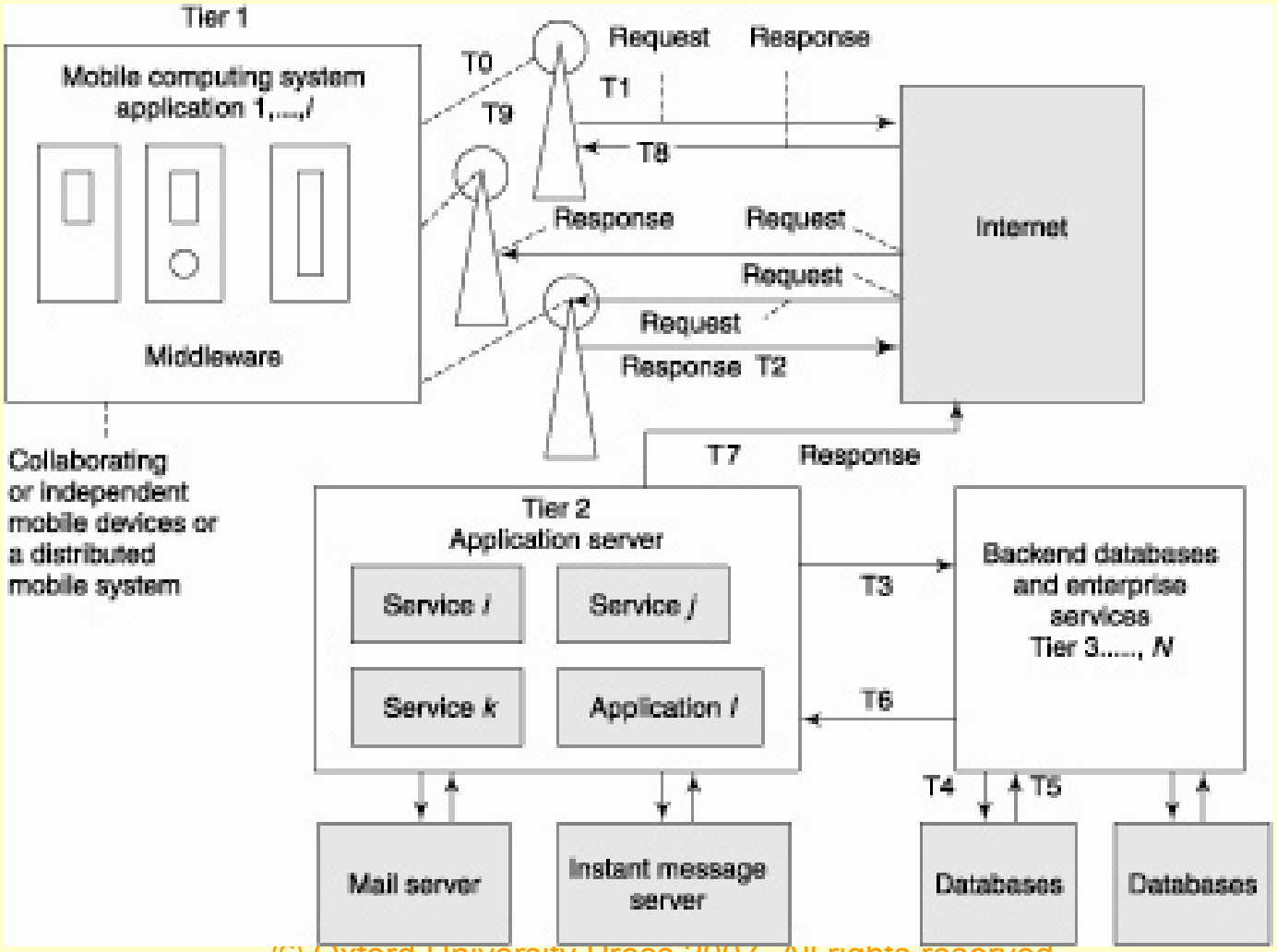
An application-server-based *N*-tier architecture ($N \geq 3$)



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Application-server-based *N*-tier architecture (*N* ≥ 3)

- Requests processed at the application server using backend database(s) and systems
- Assume that there are *j* clients which can request to the server
- A client 1 … or *j* sends the request from collaborating or independent mobile devices of an enterprise or from a distributed mobile computing system

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The stages of data transmission requests at instants from T0 to T4

- Requests are processed through tiers 1–*N*
- Responses sent from the backend system to tier 1 at instants from T5 to T9

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Services provision at the application server at Tier 2

1. Service *i*: application logic processing at the server
2. Service *j*: presentation services for device responses and decoding the device requests (e.g.; presentation service of a middleware application server for universal device access)

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Services provision at the application server at Tier 2

3. Service *k* : transaction services with support to pervasive computing model of mobile applications
4. Application *l*: system integration service for backend services and database at Tiers 3, …, N

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Examples of web database and enterprise application servers

1. IBM DB2 database server—IBM DB2 is an RDBMS (Relational Database Management System) data server from IBM

- DB2 EveryPlcae version run on handheld devices
- Enterprises application logic processing at the server

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Examples of web database and enterprise application servers

2. Oracle 9i database Server— RDBMS Oracle9i server has a large number of features and it supports XML documents and has an option for cluster database

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Application servers

- Web Generic application servers for Java-based web applications (Microsoft, Sun, and Netscape) with additional support for wireless network and mobile devices

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Application servers

- IBM WebSphere Application Server with specialized mobile Web computing application server (it supports J2EE Web applications and XML databases)
- IBM Domino Application Server for workgroups, email applications, and support for handheld and Windows CE devices

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Application servers

- Microsoft Mobile Information Server (e.g., for messenger and email)
- Oracle 9i Application Server for database services with mobile support
- Puma and Synchrologic iMobile Suite for data-synchronization services

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Application servers

- Nokia WAP (Wireless Application Protocol) Server for wireless Internet WAP applications
- BlackBerry Enterprise Server (BES)
- BES– a middleware software for BlackBerry wireless devices

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Funambol (Sync4J) provisions for mobile application server

- For PIM (personal information manager, for example, for the push email, address book, and calendar)
- For open source DB Connector
- For data synchronization services

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Client plug-ins in Funambol (Sync4J)

- For iPod
- Outlook
- Windows Mobile
- BlackBerry
- Palm

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Funambol

- Also provides device management and has a number of applications for wireless devices.

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Summary

- Application server, which is executed on a server and serves the application-level logic of the business functions
  Attenuation in obstacles in the path of the signal greater in size than the wavelength
- Processing stages of client requests in N≥ 3 tier architecture

...

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… Summary

- Enterprise server
- Application servers Examples

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Application Servers– Part 1

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Mobile Devices: Server and Management

Lesson 03
Application Servers– Part 2

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Sun Java System Web Server 6

- For large business applications
- Compatible with a number of operating systems
- Access manager provides a secure access to Web-based resources
- Include email service, security, file system, and session management

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Application services of Sun Web Server 6

- Session management entails starting a session, carrying out transactions during the session, and closing the session
- Runtime environment means a platform for running CGIs, Java Servlets, Perl or PHP

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Sun Java System Web Server 6

- Allows deployment of Cold Fusion
- Servlets
- JSPs (Java server pages)
- ASPs (active server pages)

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PHP

- A language for processing the text and preparing it in hypertext format and enables dynamic web pages

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Cold Fusion software

- To create pages by joining different entities, elements, and databases before a web server sends the response to the client

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Servlets

- Java classes at server side for processing the web page

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JSP

- A web page which connects to the databases and deploys codes, JavaScript codes, and Java components and directives and generates the response in HTML for the requesting clients

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ASP

- A web page which connects to the databases and deploys the JavaScript and Visual Basic scripts, codes, and directives and generates the response in HTML for the requesting clients

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Sun Java System Web Server 6 content engine

- A software layer (in between software component)
- For publishing the Web application response
- Uses the content sources at a server and drives them to the destination

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Sun Java System Web Server 6 content engine

- Driving means sending, publishing, or generating response in a web application so that the client gets the required contents at the destination
- The engine three components— search engine, content management engine, and HTTP engine

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Sun Java System Web Server 6 content management

- Maintains integrity of the client contents with the server. For example, a client has submitted a user ID, a password, and other client information to the server to enable it to get response contents. Integrity means the client information is used for client-specific application only.

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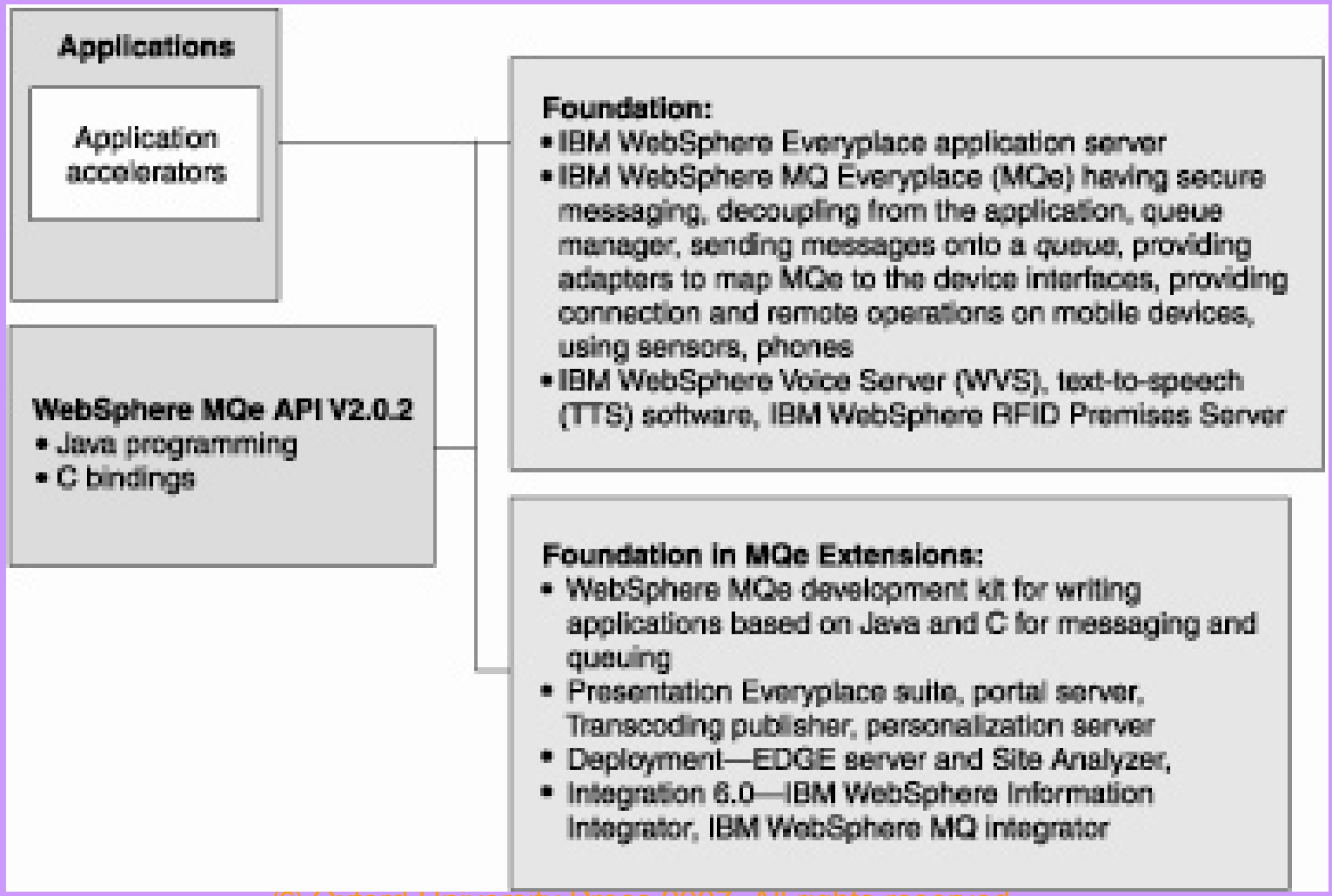
IBM WebSphere application server for mobile devices



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IBM WebSphere MQe

- Used for writing applications for messaging and queuing for mobile devices
- e stands for Everyplace
- Means for mobile devices at all places including sensors, phones, PDAs, IBM WebSphere Voice Server, text-to-speech (TTS) software, and IBM WebSphere RFID Premises Server

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IBM WebSphere MQe for mobile device

- MQe refers to an added set of features for secure messaging, decouples from the application, and uses a queue manager
- Application accelerator accelerates the running of an application so that results are obtained faster

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IBM WebSphere MQe

- Queue Manager messages onto a *queue*
- Provisions for *adapters* to adapt itself to device interfaces
- MQe enables connection and remote connection to mobile devices, for example, sensors, phones, and PDAs

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Presentation Everyplace suite

- Portal, transcoding, and personalization servers
- Deployment and integration are two other functions of the WebSphere

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Transcoding

- Means transformation-cum-coding
- A web portal or server deploys data formats and codes which are different from the ones at a mobile device
- For example, characters may be in ASCII format at device and in Unicode at the server
- Database may be in XML format at the device

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Transcoding

- Transcoding means adaptation, conversions, and changes using software which renders the web responses, messages, or records in formats and representations required and acceptable at a device
- Transcoding software adapts the device requests, convert, and chang into the required formats acceptable at the server

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IBM WebSphere Everyplace services and functions

- Three *basic services—Configuring service*, *directory service*, and *networking protocols*
- A basic service of this software is configuring of the server and operations

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IBM WebSphere Everyplace services and functions

- Second basic service is directory services
- It deploys JNDS (Java naming and directory service) and LDAP (lightweight directory access protocol)
- IBM WebSphere Everyplace also has an HTTP server which functions as website server. SyncML and WAP are used for website server and applications

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Services of IBM WebSphere Everyplace

- Device management and management of subscriptions for the applications
- Provides the devices with connectivity protocols, TCP/IP, CDMA, GSM, and WAP
- Provides a synchronization engine
- Maintains consistency without discrepancies or conflicts

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Services of IBM WebSphere Everyplace

- Provides for device caching
- Enables load balancing which means distribution of time between multiple client requests

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Oracle Application Server

- Most popular RDBMS
- Application server (AS) enables Web-based transactions with the databases
- Oracle Application Server 10g version
- The last character g stands for grid computing feature
- Grid computing means a number of computers forming a grid for computing

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Oracle Application Server 9i (9iAS)

- Windows as well as UNIX platforms
- It includes the Oracle XML Parser
- OracleJSP (Oracle Java Server Pages)
- Two components—HTTP server and 9iAS portal with OC4J (Oracle AS containers for J2EE 1.4 specification EJBs)

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9iAS

- The HTTP server responds to the SQL (simple query language and HTTP requests from the clients
- A client sends requests and gets responses through an in between web cache called 9iAS Enterprise Web Cache
- The HTTP server interfaces to 9iAS portal

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9iAS

- AS portal has a parallel page engine (PPE)
- Enables retrieving of pages in parallel at the portal
- The SQL calls received at the HTTP server connect to database schema and database providers

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9iAS

- 9iAS has OC4J J2EE EJBs (Java 2 Enterprise Edition Enterprise JavaBean) in a container

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9iAS J2EE

- J2EE provides web applications
- The EJBs establish the sessions with the client and connectivity with portal through which the pages are rendered using PPE. 9iAS integrates business logic, management, security, e-business, and portal functions

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Summary

- Sun Web Server 6
- Deployment of CGI (common gateway interface) scripts
- Content management
- IBM Web Sphere MQe for writing applications for messaging and queuing for mobile devices

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Summary

- Oracle Application server (AS) enables Web-based transactions with the databases

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End of Lesson 03
Application Servers– Part 2

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Mobile Devices: Server and Management

Lesson 04
Gateways and Portals

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Gateway

- Connects two networks, each using different protocols in its network layers

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Gateway between GPRS and data network for packets

- A GPRS mobile service network deploys SGSNs (serving GPRS support nodes)
- A SGSN interface to BSCs (base station controllers)
- The SGSNs on the other hand interfaces to GGSNs (Gateway GPRS support nodes)
- On the other hand, GGSNs connect to a packet data network like Internet

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Protocol Conversion Gateway

- Connection gateway— software which is used to connect two application layers using two different protocols
- Connects client application and application server

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WAP or IBM SecureWay Wireless Gateway

- Between wireless devices, the Internet, and application-server-based *N*-tier architecture ($N \geq 3$)
- Requests processed at the application server using backend databases and system

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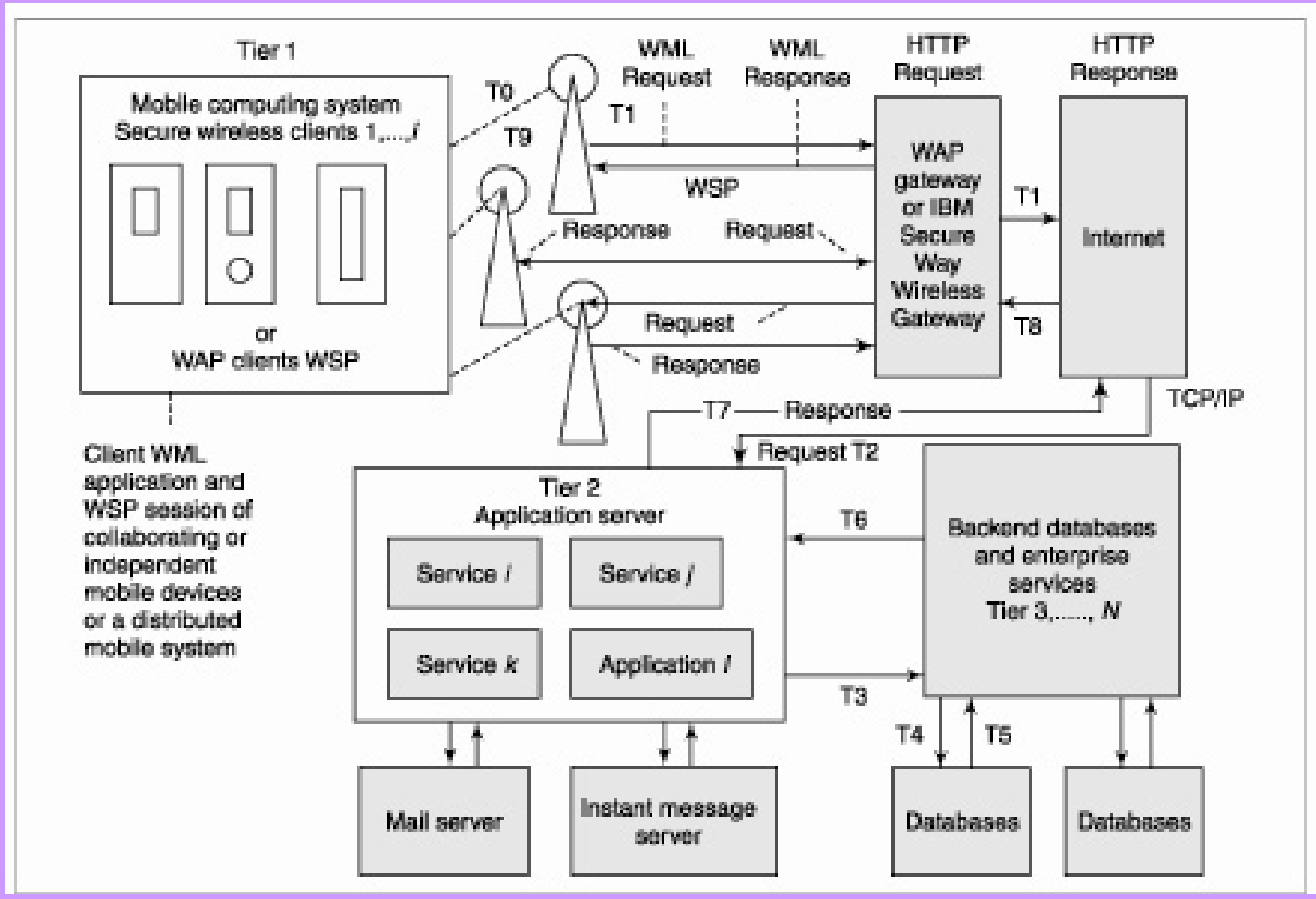
WAP or IBM SecureWay Wireless Gateway



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Tier 1

- A client sends requests for the service required by collaborating or independent mobile devices or a mobile computing system
- The client sends the application service request and obtains the responses

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Tier 1 (client)

- Uses WML (wireless markup language)
- WSP (wireless session protocol) establishes session between the application server (AS) at the Internet and the client(s)

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Tier 2 Application Server (AS)

- Connects to tier 1 through the Internet
- The Internet end uses TCP/IP, while the wireless device ends use WAP or other protocols
- When the protocol used is WAP, a gateway which connects tier 1 to Internet which has the AS is called WAP gateway

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IBM SecureWay Wireless Gateway

- A WAP gateway which connects these two tiers— 1 and 2
- The connection establishes through WSP

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Use of Funambol for developing the mobile computing applications

- The connector objects provide the gateways
- The gateways connect to the file systems, databases, email systems, and applications
- Used for two-way synchronization with existing data assets

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Connector objects in Funambol

- Also provide gateways for datastores (databases, files, and email systems)

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IBM WebSphere Partner GateWay

- Used for the connections and transcoding between the tiers

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Transcoding Gateway

- A gateway when it adapts its response to the content format of the client device and requests to it in the format required by the application running on the application server

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Transcoding proxy

- Conversion, computational and analyzing capabilities, while a gateway has conversion and computational capabilities only
- A proxy can execute itself on the client system or application server

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Transcoding gateway applications

- Format, data, and code conversions from one end to another when the multimedia data transferred from a server to the mobile TV, Internet TV, WAP phone, and Smart Phone as the client devices

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Transcoding gateway applications

- Filtering
- Compression
- Decompression
- Configurable transcoding gateway to provide authoring and deployment

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Transcoding Gateway applications

- Used for converting XML style sheets to WML or HTML
- Video to images
- Image to hyperlink
- One image format to another
- Scaling, mapping, and colour adaptation

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TTS and STT Transcoding gateway

- Facilitates TTS (text-to-speech) conversion and STT (speech-to-text) conversion

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Home Network

- Home — Number of systems—Cable TV or set-top box, personal computer, laptop, digital camera, iPod, home theatre, iPhone or mobile phone, and Bluetooth-enabled appliances

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Outside world

- Typically consists of Internet, enterprise server, backend database servers, and application servers
- Consists of high speed Internet IPv6

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Residential Gateway

- A wireless device which provides connectivity through a service provider
- The network also connects to application servers and backend server through the Internet
- Residential gateway a gateway between a network of home devices and the outside world

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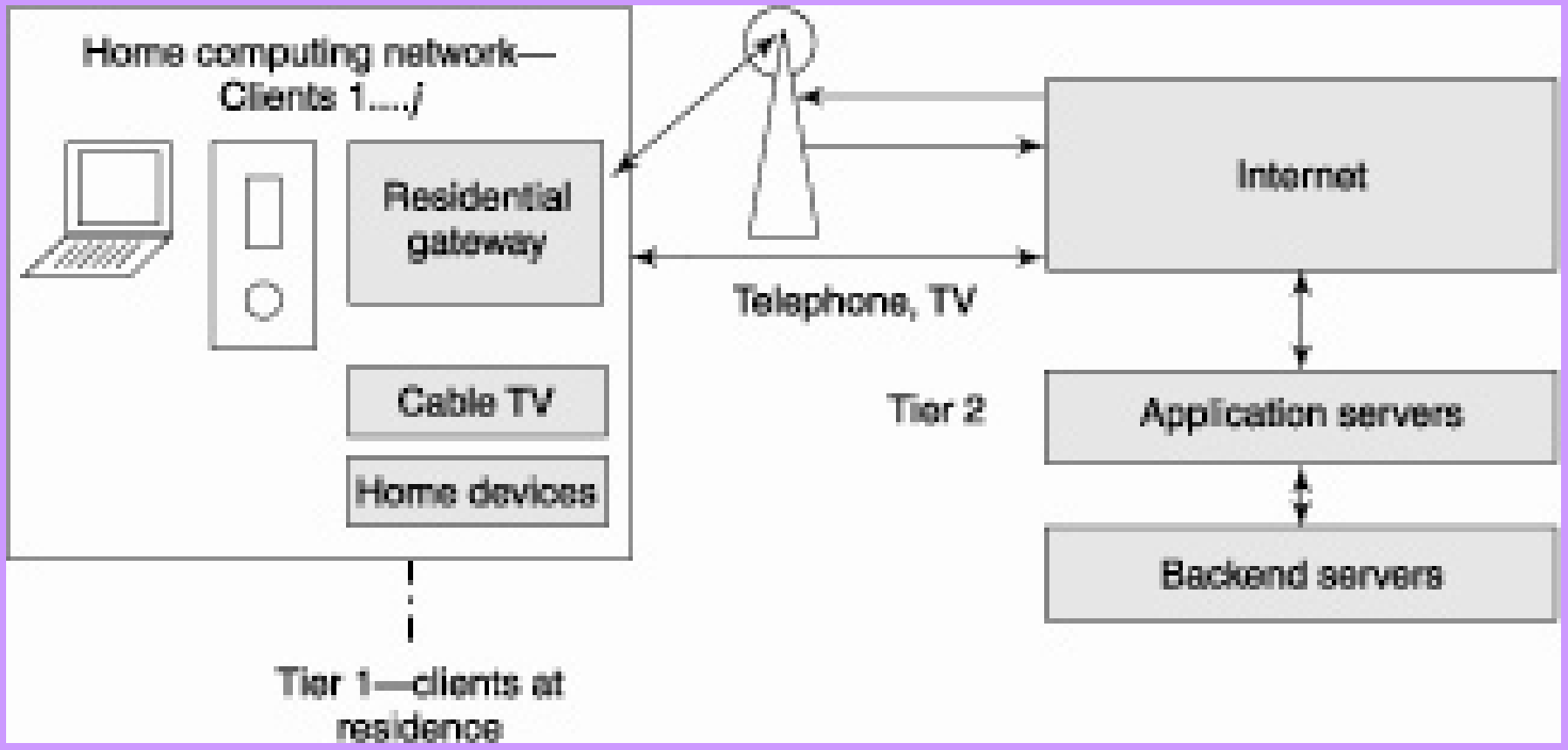
Residential Gateway Architecture



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Web Portal

- A website that provides application-specific programs and personalized capabilities like business transactions to client device(s) or computing systems
- A portal may have the PPE, for example, in 9iAS
- Has portlets (application-specific small portals), e.g., mail (POP3) portlet

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Web Portal

- Provides a path to other content related to the portal personalization criteria and enables running of distributed or collaboration applications
- Collaboration application example—business transactions through an enterprise portal

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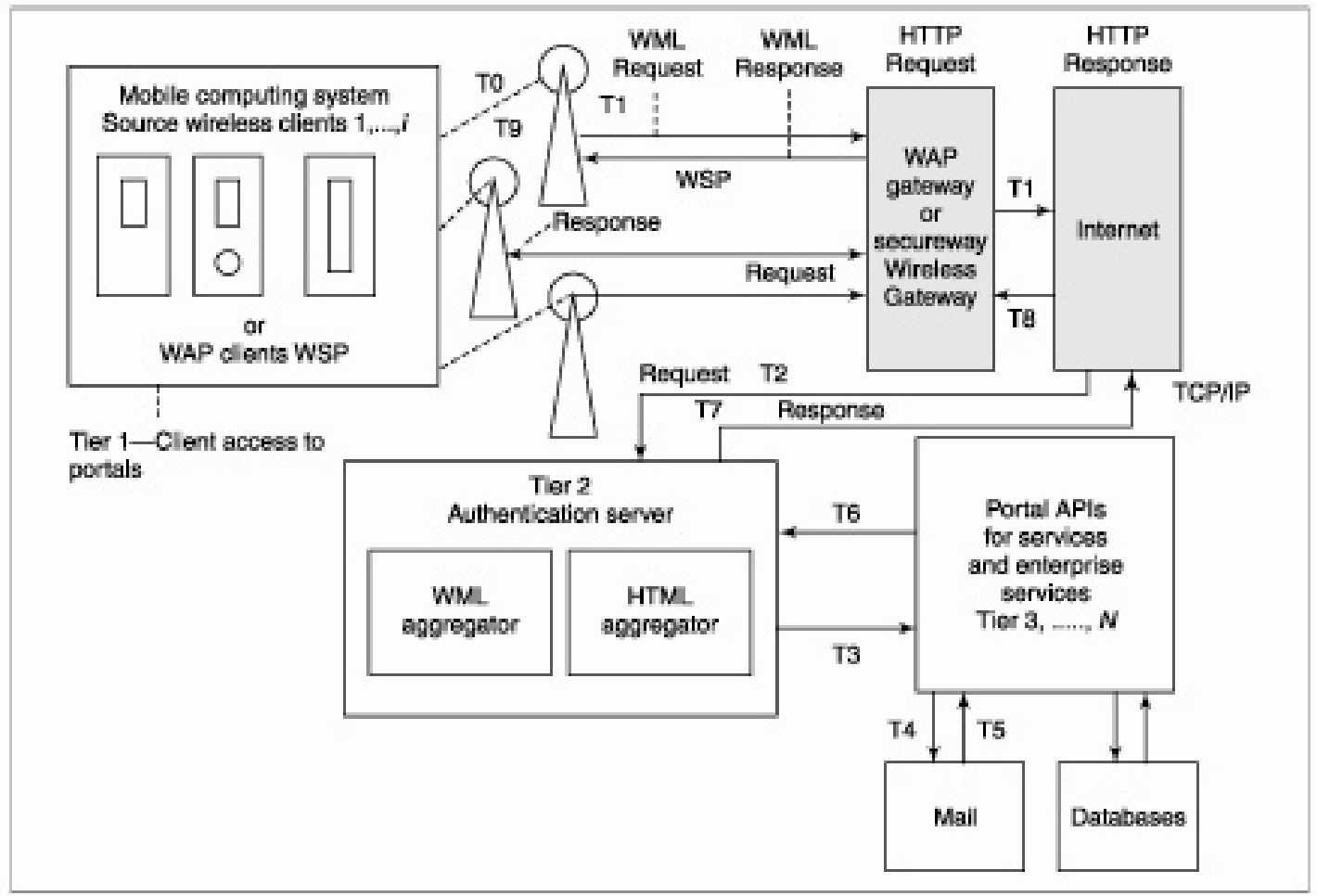
Portal based Client Server Architecture for mobile clients



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Portal

- Provides services available from a number of websites
- Enables them using diversified middleware
- Provides services to PCs as well as mobile devices

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IBM WebSphere Portal

- Provides a software architecture for the applications and business transactions
- Has scalability of any size organization
- Has an extension for voice-based applications

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IBM WebSphere Portal

- The extension deploys IBM voice tool kit. It gives voice-based access to the IBM WebSphere portal
- Interfaces with Voice Gateway which connects to a network of mobile service providers

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WSRP (Web services for remote portlets)

- Software for content aggregators (e.g., Web portals)
- Accesses and displays content sources which are at remote sites or portals

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Java Portlet

- Specifies a contract between the portlet container and portlets
- Programmers deploy JSR (Java Specification Recommendation) 168

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Summary

- Gateway enable access of client using one protocol to application server using another protocol
- Enables transcoding
- Transcoding for Filtering
- Compression
- Decompression

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… Summary

- Configurable transcoding gateway to provide authoring and deployment
- Residential gateway connect home and outside world networks
- Portal provides services available from a number of websites

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… Summary

- Portal enables them using diversified middleware
- Provides services to PCs as well as mobile devices

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End of Lesson 04
Gateways and Portals

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Mobile Devices: Server and Management

Lesson 05
Service Discovery

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Service discovery

- An adaptable middleware in a device (or a mobile computing system) that dynamically discovers services
- Bluetooth Service discovery protocol
- JINI
- SLP (service location protocol)
- UPnP (Universal Plug and Play) service discovery functions

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Steps for Service discovery

1. Lets nearby service network (or device or system) recognize that device
2. Lets the nearby network know of device service(s)
3. Searches and discovers a new service(s) at the network
4. Interacting with nearby network using discovered service(s)

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Self-administration

- Software for starting the operating system
- Allocating network and system access addresses
- Initiating accesses

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Self-administration

- Establishing and terminating the connections
- Making secure connections by the provisions by a system on its own without using network administration software when connecting to a network

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Service discovery middleware

- Features of self-healing and self-configuring

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Self Configuration

- Means establishing and modifying the route information for the connections by a system on its own

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Self-healing network

- Means that the network can establish an alternative route when a connection or enroute node breaks
- The discovery of the neighbouring devices and server and interactions done without administering the device

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JINI enabled printer

- When placed close to the camera, the latter discovers the former and starts interacting with it
- Prints the selected pictures

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Using Bluetooth self discovery protocol (SDP)

- Enable camera placed near a Bluetooth enabled PC discovers that the PC is Bluetooth enabled
- The camera exchanges information with the PC, which downloads the pictures or video clips onto it

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Bluetooth enabled PC discovering WiFi LAN

- Downloads MP3 files from the broadband Internet

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Service discovery in iPod

- When placed near it, the PC transfers the media files to iPod
- The user can now listen to selected music when mobile
- The iPod can also download photo albums and iTunes form the PC or network

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JINI

1. Sun Microsystems open architecture network technology
2. Responsibility now transferred to Apache
3. enables the programming for the distributed computing system environment, for example, mobile devices and server, and for developing modular and cooperating services as it enables the download of classes for the service components. JINI provisions for not only service discovery but also for the lookup for the databases, RMIs (remote method invocations), and the joining (binding) of APIs and programs of a device with those of other devices discovered using the lookups

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JINI

- Sun Microsystems open architecture network technology
- Responsibility now transferred to Apache
- Enables the programming for the distributed computing system environment, for example, mobile devices and server

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JINI

- Enables developing modular and cooperating services
- Enables the download of classes for the service components
- JINI provisions for service discovery

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JINI

- Provisions for the lookup for the databases
- RMIs (remote method invocations)
- Joining (binding) of APIs and programs of a device with those of other devices discovered using the lookups

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Scattering of signals

Jini core protocols for the service discovery, join, and lookup

Core Services:

- Lookup for databases of all devices and their services to make available the service of a newly connected device to all other devices. The *device querying* is by using attribute and value pair. Lookup protocol at client searches service by database lookup using discovery protocol.
- Remote Method Invocation (RMI) to enable invocation (calling) of objects at the other devices for collaborative and distributed computing.
- *Discovery* to enable a device to become a part of Jini system by using a discovery protocol. Discovery protocol uses lookup service to register the new device.
- *Discovery* provides a service object to lookup service to *join* the service. Joining to the lookup service enables not only uploading of descriptions by a client device, but also the Java classes, and downloading of the other device descriptions. Java classes enable use of other device services. Join enables the interaction of API and programs of a device with those of other devices.

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JINI JavaSpaces Technology

- A simple and powerful high-level tool — Used for programming collaborative and distributed applications
- Share network-based object space(s)

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JINI JavaSpaces Technology Object space

- Associates memory for the distributed objects on the network
- Used both for object storage and as exchange area
- Communicating nodes use the space indirectly
- It creates a simple API for use by source and destination nodes

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JINI

- Also includes extensible remote invocation (JINI ERI)
- Enables programming and dynamic computing in a device and provides a platform to create adaptable, scalable, evolvable, and flexible network-centric services

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JINI

- Highly adaptive to changes in software and hardware
- Provides spontaneous interactions between devices and network
- A discovery protocol may or may not provide the facility of device querying but JINI makes it possible using the pairs

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Service Location Protocol (SLP)

- Enable client device dynamically discover a service
- SLP stack– consists of SLP header and SLP service URL (universal resource locator)
- A URL is a universally accepted unique identifier for resource and thus a location
- SLP URL enables other devices to use the service of the client device

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Service Location Protocol (SLP)

- SLP URL provides the location of the device in the network
- SLP advertises its service needs in multicast mode and does not use directory service

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Multicast transmission using SLP

- Multiple nodes get to a service directory, service catalogue or service database/descriptions
- Client uses a multicast message to discover a service

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Multicast transmission using SLP

- Multiple nodes get to a service directory, service catalogue or service database/descriptions
- Client uses a multicast message to discover a service

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SLP

- An alternative to lookup service database in JINI or a service catalogue
- It provides Java classes (program codes) to a client device

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SLP diffferences from JINI

- SLP just provides the lookup for the URLs and description of other devices during discovery phase
- Does not provide for database lookup, join, and spaces as JINI

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Description

- Specifies a service
- Device textual description at a lookup database service or service catalogue enables a new device to use a service of a specific device

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Description

- It is uploaded at the database when a new device joins a network and is downloaded to the new device to let the device discover the services
- It can be in XML

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Unicasting service discovery

- Unicast using TCP/IP or any other SDP means that the service discovery is directly by connecting to the lookup service (database/descriptions)
- Each device as well as lookup service has a URL
- These interact through unicasting

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Multicasting service discovery

- Means service discovery by a broadcast of the descriptions of the service to a group of devices
- The directory, service catalogue or service database/descriptions multicast and enables service discovery

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Multicasting service discovery

- Each device can use a multicast message to discover a service
- Multicast permits dynamic service discovery
- A device receiving a multicast message for a new service uses it to discover that new service

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Advertisement for service discovery

- Means a device need not discover a service
- A new device establishing a connection to a network advertises its services
- A device disconnecting from the network advertises its disconnection
- In this way, each device maintains the database or descriptions of the services presently available

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Universal plug and play (UpnP)

- A Microsoft solution for service discovery
- For service and device descriptions
- For use of control points
- For Control for registering the subscription events and withdrawal after subscribed interval
- For Presentation and event notifications (called venting)

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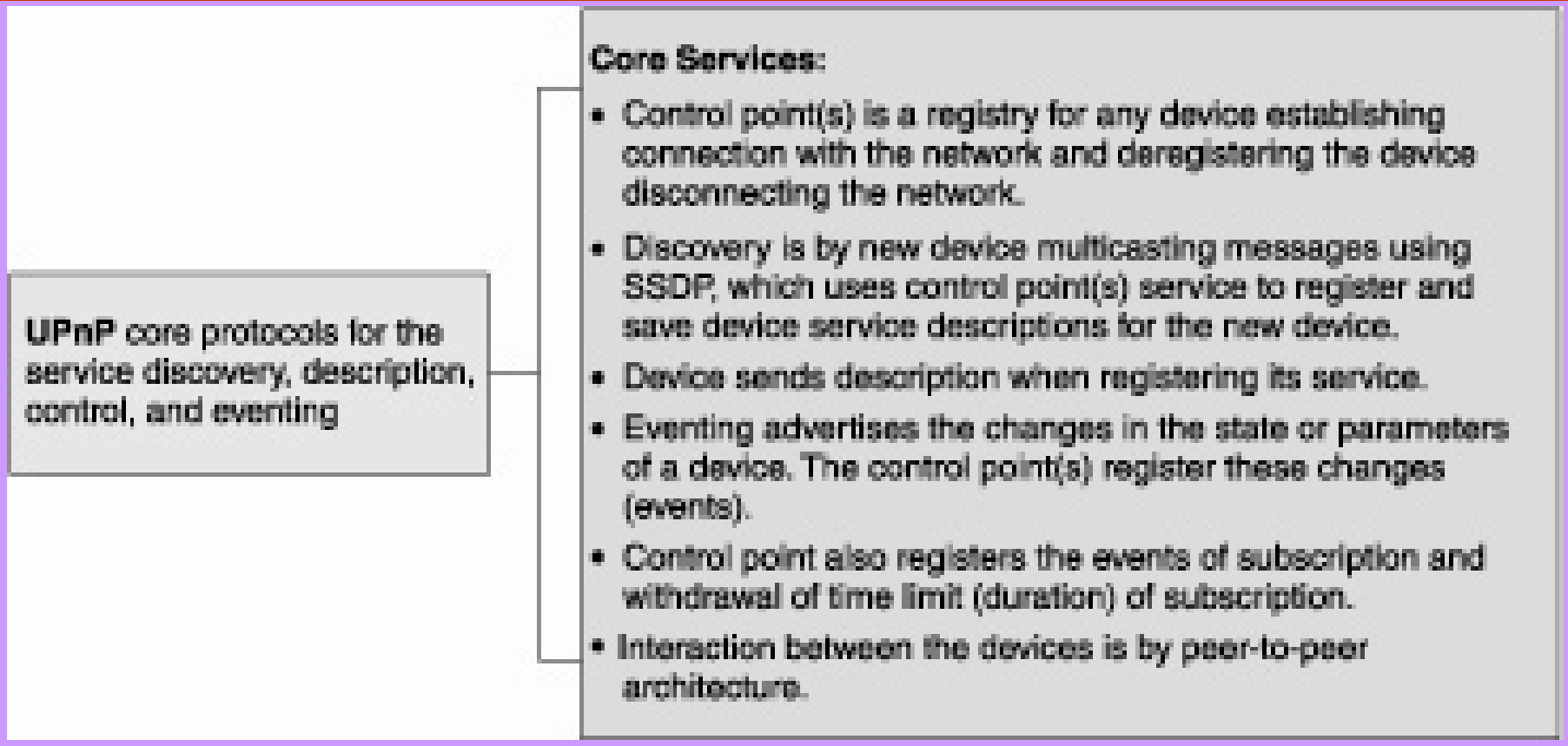
UpnP core protocols for the service discovery, description, control, and eventing



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Control Point– A registry

- For any device establishing connection with the network or disconnecting from the network
- Provides descriptions and URLs of all devices presently connected to the network and makes available the service of a newly connected device to all other devices

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Control Point– A registry

- Does not allow device querying
- Provides only descriptions of device service

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Not a part of UpnP– Discovered Device providing the APIs

- For querying
- downloading
- uploading of classes
- A device itself has to be programmed for dynamic computing and adaptability using the descriptions and URLs provided by the control point(s)

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Summary

- Service discovery
- Service discovery self-administered, self-configured and self-healing
- Bluetooth SDP
- SLP
- Unicasting, multicasting and advertisement for service discovery

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… Summary

- JINI
- Provisions for the lookup for the databases
- RMIs, Joining (binding) of APIs and Spaces

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… Summary

- UpnP
- UpnP Provides descriptions and URLs of all devices presently connected to the network
- Does not provide for for querying
- downloading
- uploading of classes

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End of Lesson 05
Service Discovery

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Mobile Devices: Server and Management

Lesson 06
Device Management

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Device Management (DM)

- Many types of devices in a mobile network
- Managed by a mobile service provider
- DM means configuring at initialisation (bootstrapping), monitoring current configuration, processing maintenance requests, and taking care of location and handover of each device

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Device Management in pervasive computing environment

- Means managing the infrastructure of a large number of networks at the same time
- Each device can have applications downloaded from different sources in an enterprise
- The service provider has to manage and serve the applications

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Device Management

- Each device may subscribe to different types of services for different durations
- For example, a device may subscribe to specific gaming applications for a month
- The account and authentication of each device is managed

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Device Management

- Managed invisibly without system administrator
- Self-administered
- Device boots up
- Starts the operating system

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Device Manager

- Initiates accesses
- Establishes and terminates the connections
- Makes secure connections on its own without using a network administration software when connecting to a network

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Device manager

- Runs through a setup phase
- Exchanges packages to get the allocated network and system access addresses
- Each device in a mobile computing system interacts with the other
- Features of self-healing and self-configuring network

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Tivoli Device Support Infrastructure (DSI)

- IBM software
- Used for ATMs, handheld devices, set-top boxes, and cable modems
- A Device Gateway has a device management agent to connect devices at one end with the gateway at other end

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Tivoli DSI Device Gateway

- The Gateway includes Tivoli Management Gateway
- Connects to device management server of the service provider

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DSI device manager

- Assigns a unique ID to a device
- Also local ID to the device which is supported by the support infrastructure.
- Unique ID remains fixed
- Assigned once
- Local ID can be reassigned when the device moves from one personal area network to another

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DSI device manager

- Saves Device information
- When a number of devices are of identical types, for example, Smart Phones type, then a group object can be used by assigning the same type of devices to a group
- The object then manages large number of devices of same type

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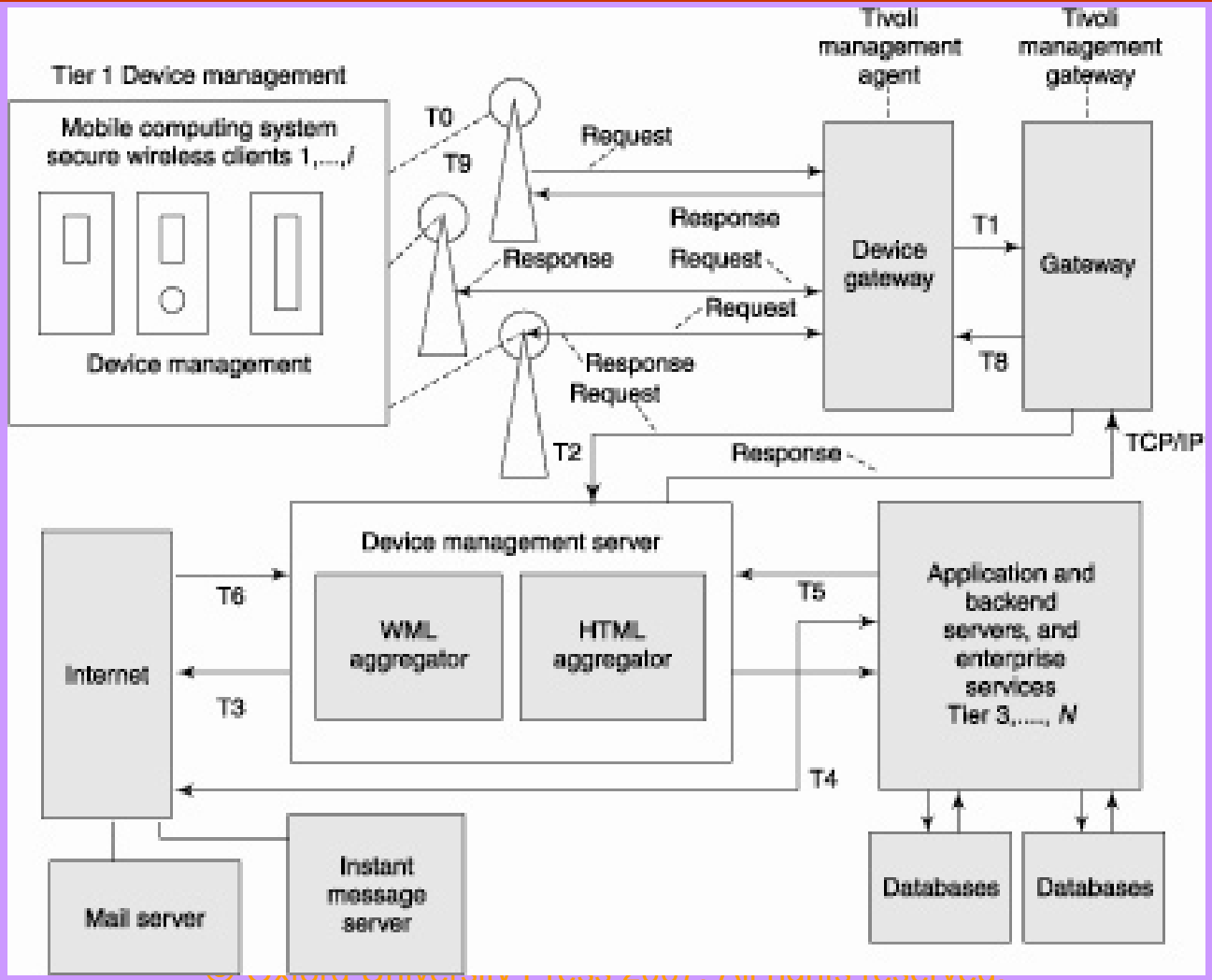
IBM Tivoli device support infrastructure architecture



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Profiles

- Profiles provide a specification for the use of software such as Device manager or Device management server
- Device management requires profiles for the user, device, and network

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Mobile information device profile (MIDP)

- Provides a specification for the mobile devices such as mobile phone to enable the use of Java microedition programming framework

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User profile

- Consists of user password and ID
- A user can also add PIM data, individual preferences, and security credentials to the profile
- Facilitates Device management by system access to user profile

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Device profile

- Device profile includes a unique ID, local ID, individual preferences, and available resources
- Accessed by Device manager

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Network profile

- Accessed by Device manager
- Network profile specifies the current location address of the device and networked devices and the description of the network services

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Information provided by profiles

- Includes specification of groups, services, names, and objects
- A profile may give descriptions of the types of the devices which can group and be managed concurrently
- A profile may give descriptions of the services at the devices in the network. A profile may include the names (services and object names)

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Directory

- An efficient way of storing and accessing data
- Has a tree-like structure with entries at the tree-leaves and nodes representing the printers, documents, persons, organizational units, groups of persons, or anything else which may represent a given entry or multiple entries at the tree

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Directory Service

- A service means a software or protocol for specifications and provisions for a set of operations with the given objects or entries
- Directory service means a service protocol which specifies and provisions for the set of operations with the given objects or entries in a directory

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A child object or leaf object

- Each one Identified by a URI (universal resource identifier) in a function (method)
- For example, assume that A is root object and it has child objects B1, B2, and B3. B1 has children C1 and C2 and assume that C1 is a leaf object.
- URI for C1 is A.B1.C1

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URI

- Specifies the hierarchy position of a node under consideration with respect to the root
- Used when referring to an object in a function or method.

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Relative URI

- Means specification relative to a present node not necessarily from the root
- An object accessed by its Name and attributes
- Name is referred to as DN (distinguished name) for the object
- Each attribute is also named

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LDAP (lightweight directory access protocol)

- An open source networking protocol for accessing, modifying, and querying TCP/IP directory services
- Its current version is LDAPv3
- Lightweight means that the protocol does not depend on OS and system resources

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LDAP (lightweight directory access protocol)

- Accessing, querying, or modifying an object in LDAP can involve a tree of directory entries, each of which consists of a set of named attributes with values
- Some attributes are mandatory and some optional

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LDAP Basic Operations

- Most services use LDAP as a simple starting point for their database organization
- bind, start TLS (transport layer security) protocol, add entry, delete an entry, modify DN, abandon to abort an earlier request, search, compare, extend, and unbind

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Bind

- An operation (function or method) to link an accessing object with the acccessed object
- Without successful bind operation, the directory entries (objects) cannot be accessed, modified, or queried

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OMA DM (Open Mobile Alliance Device Management)

- OMA DM objects most used standard in mobile device computing system
- DM defines a description framework and has hierarchical structure in which there is a management object tree

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DM

- Based on SyncML Data Synchronization (SyncML DS) specifications
- In a hierarchical structure for the management objects, the OMA DM protocol (standard) provides for specifying how many times (how many children of a parent) an object node can occur in the hierarchy

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Examples

- ClientUserName (user name of client which server recognizes) and clientPW (password using which server authenticates a client before providing the service) specified in OMA DM as having zero or one occurrences

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Example

- Parent node of a management object for data synchronization is DSAcc (data synchronization account) (one or more occurrences)
- The child objects (nodes) and leaves (objects for DSAcc) of the parent object DSAcc with specifications for their occurrences and functions (methods) required for their accessibility

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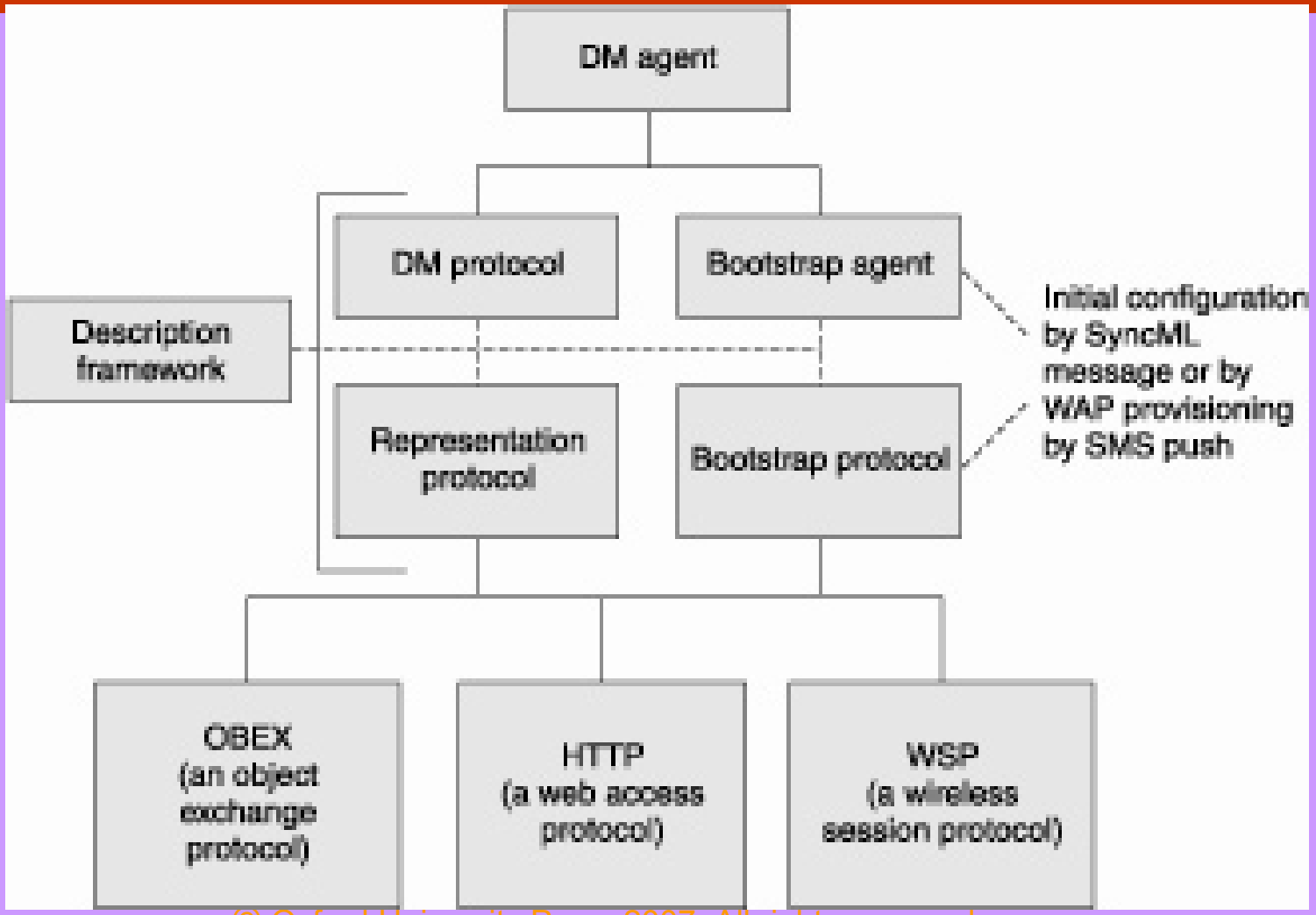
SyncML DM stack



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Summary

- Device management
- Configuring at initialisation (bootstrapping)
- Monitoring current configuration
- Processing maintenance requests
- Taking care of location and handover of each device
- IBM Tivoli Device management Support Infrastructure

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… Summary

- Profiles of user, device and networks required for device management
- Directory service
- LDAP
- OMA DM for device management

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End of Lesson 06
Device Management

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Mobile Ad-hoc and Sensor Networks

Lesson 01

Introduction to Mobile Ad-hoc Network (MANET)

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Fixed infrastructure network

- Networking using switches, hubs, routers, access-points, base stations, or gateways networked
- Switches, hubs, or routers locations fixed
- To connect to and access the network a mobile device or wireless sensor has to be moved in the vicinity (connectivity range) of an access-point
- Example– a cellular network

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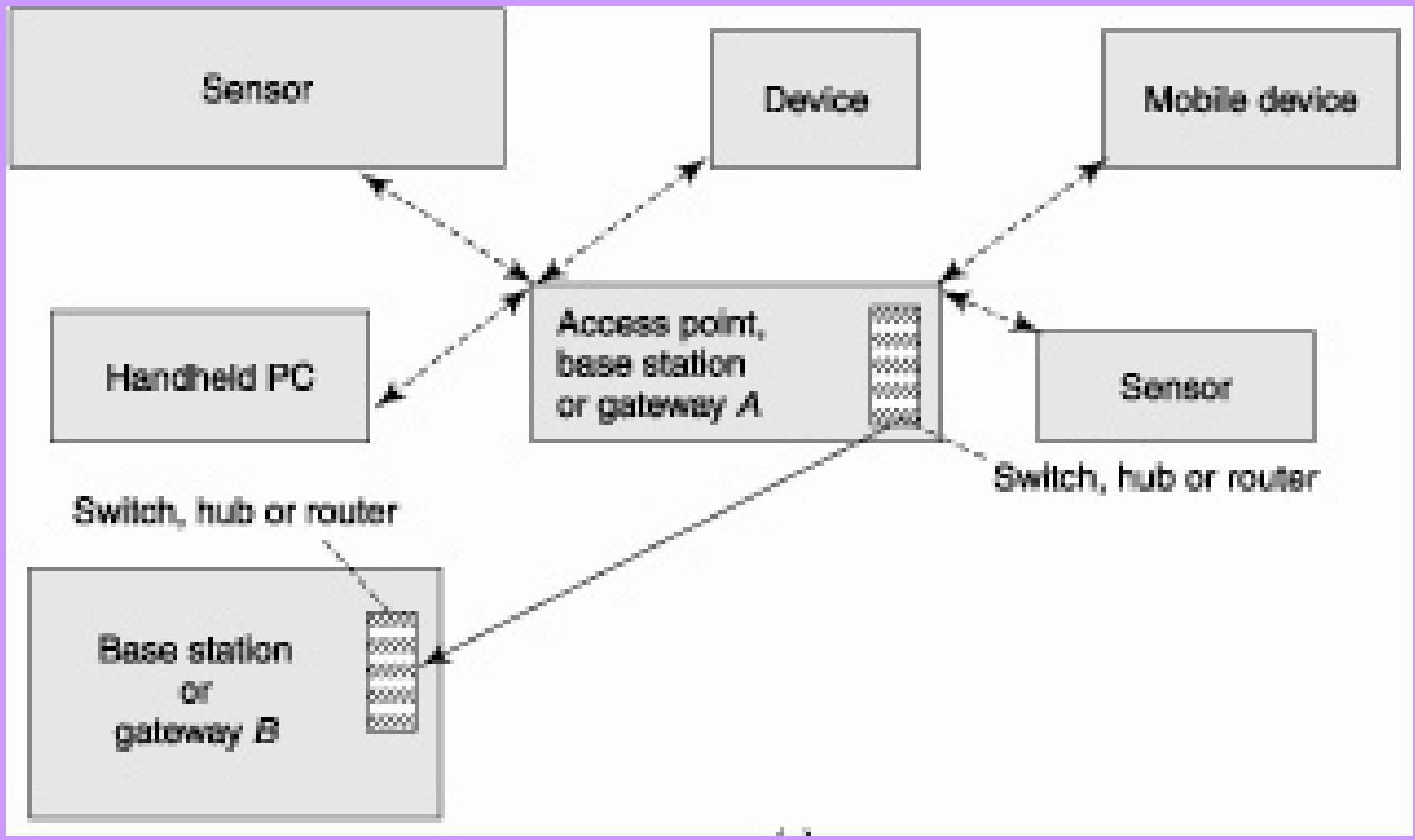
Fixed Network Infrastructure architecture



Fixed Infrastructure

- Each mobile device or sensor connects to an access-point, base station, or gateway with a switch, hub, or router *A*

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A Switch in fixed infrstructure

- Provides connectivity between the two, a hub functions as a central switching exchange

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A router in fixed infrastructure

- Provide two or more paths to route a message or packet so that the available path can be used at an instant
- They function as the nodes of the network
- A mobile device or sensor has to acquire an access-point or node of the fixed infrastructure network before being able to connect to another

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GSM Cellular phones in a fixed infrastructure network

- GSM system— A three-subsystems architecture consisting of radio subsystem (RSS), network subsystem (NSS), and operational subsystem (OSS)
- Each cellular phone has to first connect to a RSS of GSM public land mobile network

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Cellular phones in a fixed infrastructure network

- The connectivity between two cellular phones is ensured through GSM public land mobile PSTN, ISDN, or PSPDN networks

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Problem with fixed infrastructure network

- Disconnection from the network and thus unable to communicate through the network when a wireless sensor or mobile device moves out of the range of access-point, base station, or gateway having the switch or router
- Even though there may be another wireless device in its vicinity connected to network

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Problem with fixed infrastructure network

- Network not usable in operations like disaster relief

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Mobile ad-hoc network (MANET)

- A network in which the locations of the switches, hubs, or routers can be mobile
- The number of routers available at an instant can increase or decrease, and the available routing paths can change
- The mobile devices or wireless sensors as well as the access-points can have switches or routers

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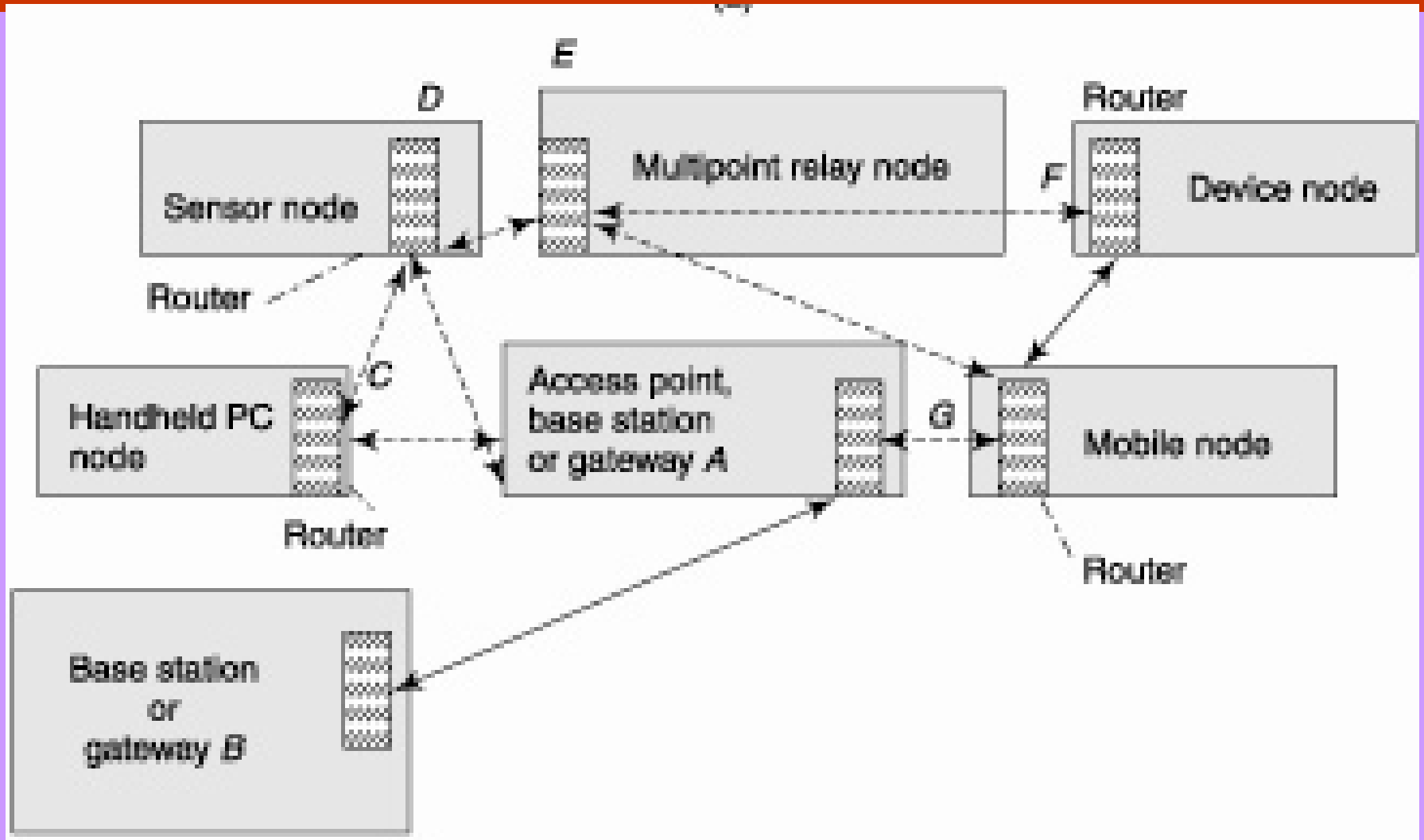
Mobile ad-hoc network (MANET) architecture



MANET Organization

- The ad-hoc network formed by the nodes *A*, *C*, *D*, *E*, *F*, and *G*
- Each mobile device or sensor functions as a node with a switch or router

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The network organization

- Change if *D* and *E* move away from each other such that they reach out of the range of wireless coverage
- Two new ad-hoc networks will then be formed by (i) *A*, *C*, and *D* and (ii) *A*, *G*, *F*, and *E*
- The devices on two networks can still connect to each other through the common node *A*

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MANET Organization

- An important characteristic of ad-hoc network architecture is that its organization can change due to movement of a device or sensor
- In other words, the ad-hoc networks are self-organizing

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MANET

- The routes available to the mobile devices or wireless sensors can thus change at any time
- Depend on presence and locations of other wireless devices in their vicinity (connectivity range)

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MANET organization

- Depends upon the location of the nodes, their connectivity, their service discovery capability, and their ability to search and route messages using nearest node or nearby nodes

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Example of network of mobile device, home computer and printer at office

- A Bluetooth-enabled mobile device, a Bluetooth-enabled computer, and Internet with WiFi connection at home
- Assume that there is a Bluetooth-enabled computer connected to TCP/IP Internet and also to JINI client printer at office

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Example of network of mobile device, home computer and printer at office

- Through intermediate nodes— WiFi, Internet, and office computer, an ad-hoc network establishment between the mobile device at home and printer at office when the user carrying the device moves from office to home and handheld PDA mobile device reaches near the home computer

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Network of mobile device, computer and printer Using service discovery

- A MANET establishes after the services of JINI, TCP/IP Bluetooth, and WiFi discovered
- When the user of same mobile device goes to an airport with WiFi connectivity, a MANET again established with the office printer

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Summary

- To connect to and access the network a mobile device or wireless sensor has to be moved in the vicinity (connectivity range) of an access-point in fixed infrastructure network

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… Summary

- Connection depends upon the location of the nodes, their connectivity, their service discovery capability, and their ability to search and route messages using nearest node or nearby nodes in Mobile Ad-hoc network (MANET)

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End of Lesson 01

Introduction to Mobile Ad-hoc Network

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Mobile Ad-hoc and Sensor Networks

Lesson 02

Mobile Ad-hoc Network (MANET) Properties and Spectrum needs at the nodes

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MANET Properties

- Seamless interaction and ubiquitous mobile computing environment
- Seamless connectivity maintained between the devices when they move with the nearby wireless nodes, sensor nodes, and embedded devices in automobiles

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MANET Properties

- Neighbour discovery— One of the important characteristics of a MANET node
- Data routing abilities — data can be routed from a source node to a neighbouring node

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MANET Properties

- Flexible network architecture and variable routing paths — to provide communication in case of the limited wireless connectivity range and resource constraints

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MANET Properties

- Flexibility— enables fast establishment of networks
- When a new network is to be established, the only requirement is to provide a new set of nodes with limited wireless communication range
- A node has limited capability, that is, it can connect only to the nodes which are nearby and thus consumes limited power

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MANET Properties

- Using a service discovery protocol, a node discovers the service of a nearby node and communicates to a remote node in the MANET
- Peer-to-Peer connectivity

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MANET Properties

- Computations decentralization—independent computational, switching (or routing), and communication capabilities

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MANET Properties

- Limited wireless connectivity range—require that a node should move in the vicinity of at least one nearby node within the wireless communication range, else the node should be provided with the access-point of wired communication

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MANET Properties

- Weak connectivity and remote server latency
- Unreliable links to base station or gateway — failure of an intermediate node results in greater latency in communicating with the remote server

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MANET PROPERTIES

- Resource constraints– Limited bandwidth available between two intermediate nodes
- Node may have limited power and thus computations need to be energy-efficient

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MANET PROPERTIES

- No need of access-point
- Only selected access-points provided for connection to other networks or other MANETs

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MANET PROPERTIES

- Need to solve exposed or hidden terminal problem
- Diversity in nodes– iPods, palm handheld computers, Smartphones, PCs, smart labels, smart sensors, and automobile-embedded systems

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MANET PROPERTIES

- Protocol diversity— Nodes can use different protocols, for example, IrDA, Bluetooth, ZigBee, 802.11, GSM, or TCP/IP
- Data caching, saving, and aggregation at node

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Bandwidth of an access-point-based fixed infrastructure network

- Large number devices connects to a centralized server
- The bandwidth requirement too high
- N devices using FDMA in duplex transmission, then the required bandwidth will be $2 \times N \times f_{bw0}$, where f_{bw0} is the bandwidth allotted to one device for sending a packet to its access-point

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Bandwidth of an access-point-based fixed infrastructure network

- Using TDMA and SDMA, the bandwidth (spectrum) requirement is reduced

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Spectrum requirement at Nodes in MANET

- Each MANET node has much smaller frequency spectrum requirements than that for a node in a fixed infrastructure network

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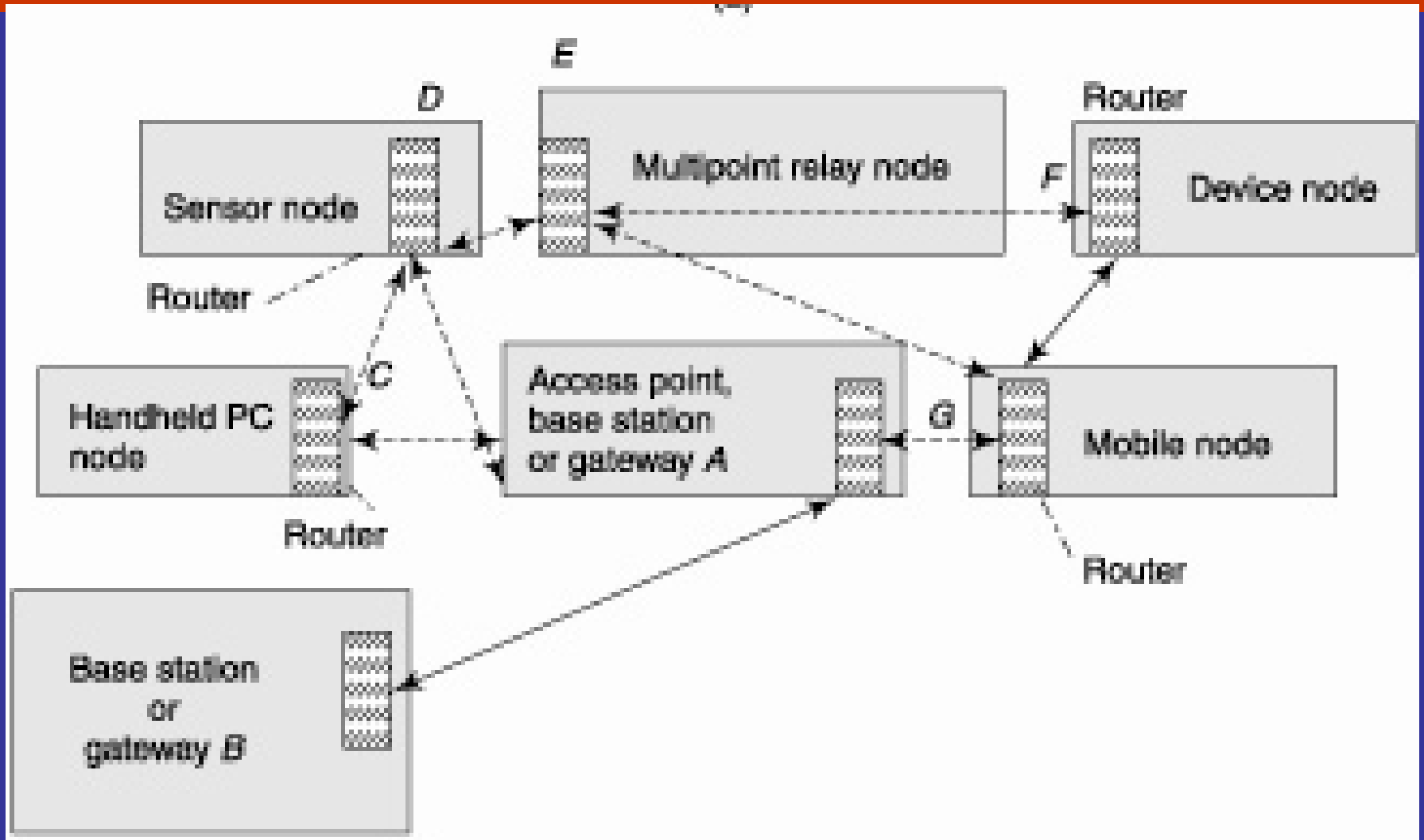
Mobile ad-hoc network (MANET) Nodes A to G



Spectrum requirement at Nodes in MANET

- A node itself — a router for all the packets coming from or going to the other nodes
- Node *D* at a given instant— Can get incoming packets from *E*, *F*, *G*, and *A* and can send packets to *C* and *A* or vice versa

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Spectrum requirement at Nodes in MANET

- Nodes are themselves mobile
- Therefore, bandwidth available to any node at any instant is variable
- MANET enables spectrum reuse

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Spectrum requirement at Nodes in MANET

- Each wireless link provides a limited bandwidth
- MANET communication is multi-hop
- When node *D* transmits to *G*, it is through the three hops—(i) *D*—*E*, (ii) *E*—*F*, and (iii) *F*—*G*.

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Each node has low and adaptable transmission power

- Optimized to have signal strength just sufficient to carry the signal up to single hop
- Hops can therefore occur simultaneously using the same frequency band

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Each node has low and adaptable transmission power

- There is spatial reuse of bandwidth
- Also, the bandwidth depends on surrounding environment

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Bandwidth Need computations

- Assume FDMA mode access by a node
- The bandwidth depends on the number of next hop neighbours
- The node with higher number of next hop neighbours require higher bandwidth in FDMA
- The nodes *D*, *E*, and *G* shall need higher bandwidth compared to *C* and *F*

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Bandwidth Need computations

- Bandwidth required will be $2 \times 3 \times f_{bw0}$ when three nodes *D*, *E*, or *G* can transmit in full duplex mode to all the nodes
- Will be $2 \times 2 \times f_{bw0}$ for two nodes *C* or *F*
- When each node path and each direction hop scheduled to operate at different instants, as in TDMA, then the bandwidth required will be just f_{bw0}

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Summary

- MANET node's Neighbour discovery
- Data routing abilities
- Flexible network architecture
- Variable routing paths to provide communication
- Limited wireless connectivity range and resource constraints

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… Summary

- Protocol diversity
- Nodes diversity
- Weak connectivity
- Limited spectrum requirements
- Multi-hop transmission

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End of Lesson 02

Mobile Ad-hoc Network (MANET) Properties and Spectrum needs at the nodes

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Mobile Ad-hoc and Sensor Networks

Lesson 03

Mobile Ad-hoc Network (MANET) Applications

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Content Distribution and Synchronization

- In an enterprise, there are a number of Bluetooth-enabled mobile handheld devices, PCs, laptops, and WiFi access-points
- MANET used for content-distribution, PIM, other information dissemination, information fusion, and file sharing in the enterprise

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MANET nodes in multicast tree topology

- Ddisseminate data packets and form a multicasting network
- Clusters of the nodes used to give a multicast tree topology in a MANET

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Mesh Networking and Mobile Service Provider Network

- Mesh-based mobile networks offer highly dynamic autonomous topology segments for the robust IP-compliant data services within the mobile wireless communication networks
- Inexpensive alternatives or improvement to infrastructure-based cellular CDMA or GSM mobile service provider

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Mesh Network

- A multicast tree network differs from mesh as it provides only a single path between a sender and a receiver
- Mesh network many paths

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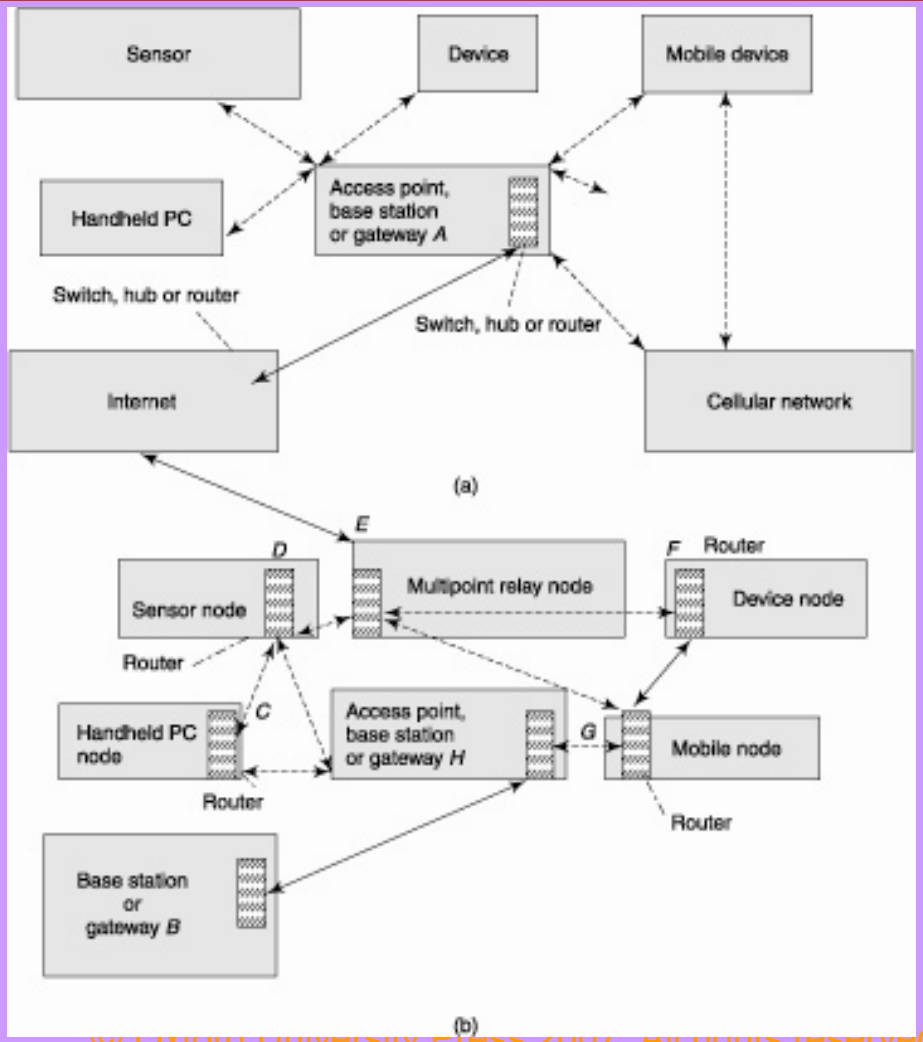
Mesh Network of interconnected MANETs and fixed infrastructure network



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Protocol for unified multicasting through announcements (PUMA)

- A protocol that builds a mesh that connects MANET nodes with each other
- On the other mesh provides multiple paths between sender and receiver nodes

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Needs for PUMA

- MANETs have nodes which may be mobile and the wireless links are error-prone
- Certain packets may not be delivered to receivers through a multicast tree topology
- PUMA which send packets from senders to receivers through multiple paths may thus have a greater packet delivery ratio

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Needs for PUMA

- However, in benign conditions (low mobility and traffic load which leads to lesser collisions), sending packets is not needed and is a waste
- In such situations PUMA is able to reduce the redundancy
- PUMA adapts the amount of redundancy in the network depending on need

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Image Acquisition, Processing and Distribution using MANET

- Number of imaging devices forming a MANET—low cost digital still camera with a wireless network interface, Wireless WebCam, mobile device connected to a digital still camera, mobile phones, and pocket PCs equipped with an image acquisition sensor

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Applications of Image Acquisition using MANET

- Remote viewfinder by security personals in an office
- Remote processing on a computer for a video stream from wireless WebCam and other devices

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Applications of Image Acquisition using MANET

- Image file transfer
- Messaging and data transmission to remote devices using 802.11b (Section 1.1.5)
- Remote controlling.

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IPv6 Integration and Wireless Sensor Networks

- IPv6 is a new generation Internet and is used for Internet radio and real time video over the Internet
- IPv6 can be integrated with MANET and wireless sensor networks
- CDMA handsets and Apple iPhone are the examples of integration of the mobile phones with IPv4 and IPv6

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Summary

- Content acquisition and distribution
- Multicasting
- Mesh networking
- PUMA
- Image acquisition
- IPv6 and IP4 integration

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End of Lesson 03

Mobile Ad-hoc Network Applications

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Mobile Ad-hoc and Sensor Networks

Lesson 04

Mobile Ad-hoc Network (MANET) Routing Algorithms– Part 1

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Ad-hoc networks deployment

- For routing, target detection, and service discovery
- Routing protocols used for routing by MANET nodes

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Dynamic Source Routing (DSR) Protocol

- Deploys source routing
- Source routing means that each data packet includes the routing-node addresses also

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Reactive protocol feature of DSR

- Reacts to the changes and dynamically maintains only the routing addresses from source to destination, which are the active paths to a destination at a given instant
- Performs unicast routing
- Unicast means routing packets to a single destined address

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DSR Nodes

- Each node *caches* the specified route to destination during source routing of a packet through that node
- This enables a node to provide route-specification when a packet source routes from that node

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DSR Nodes

- Each node *deletes* the specified route to destination during routing of error packet in reverse path to the source in case of observing a disconnection during forward path to destination
- The deletion of link shown in a table or cache is called link reversal

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Phase 1 in DSR Protocol

- Source node initiates a route discovery process
- It broadcasts the packets, each with a header
- It then expects return of acknowledgement from each destination
- The packets are called route request (RREQ) packets

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Phase 1 in DSR Protocol

- DSR uses flooding (sends multiple RREQs
- A header for each route request packet has the unique request number and source and destination addresses
- This enables identification of request at each intermediate node in the request and acknowledged packet(s)

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Phase 1 in DSR Protocol

- When the process starts, initially only the source address is given in the header
- When the packet reaches a neighbour, that is, any intermediate node, the node adds its own address in the header if it is able to successfully send the packet to its next neighbour

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Phase 1 in DSR Protocol

- When the packet reaches the destined address, its header therefore has all addresses of the nodes in the path

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Example

- Assume that node *D* is a source and *G* is a destination and the path *D—E—F—G* is not known. In such a case the path cannot be placed in the header.

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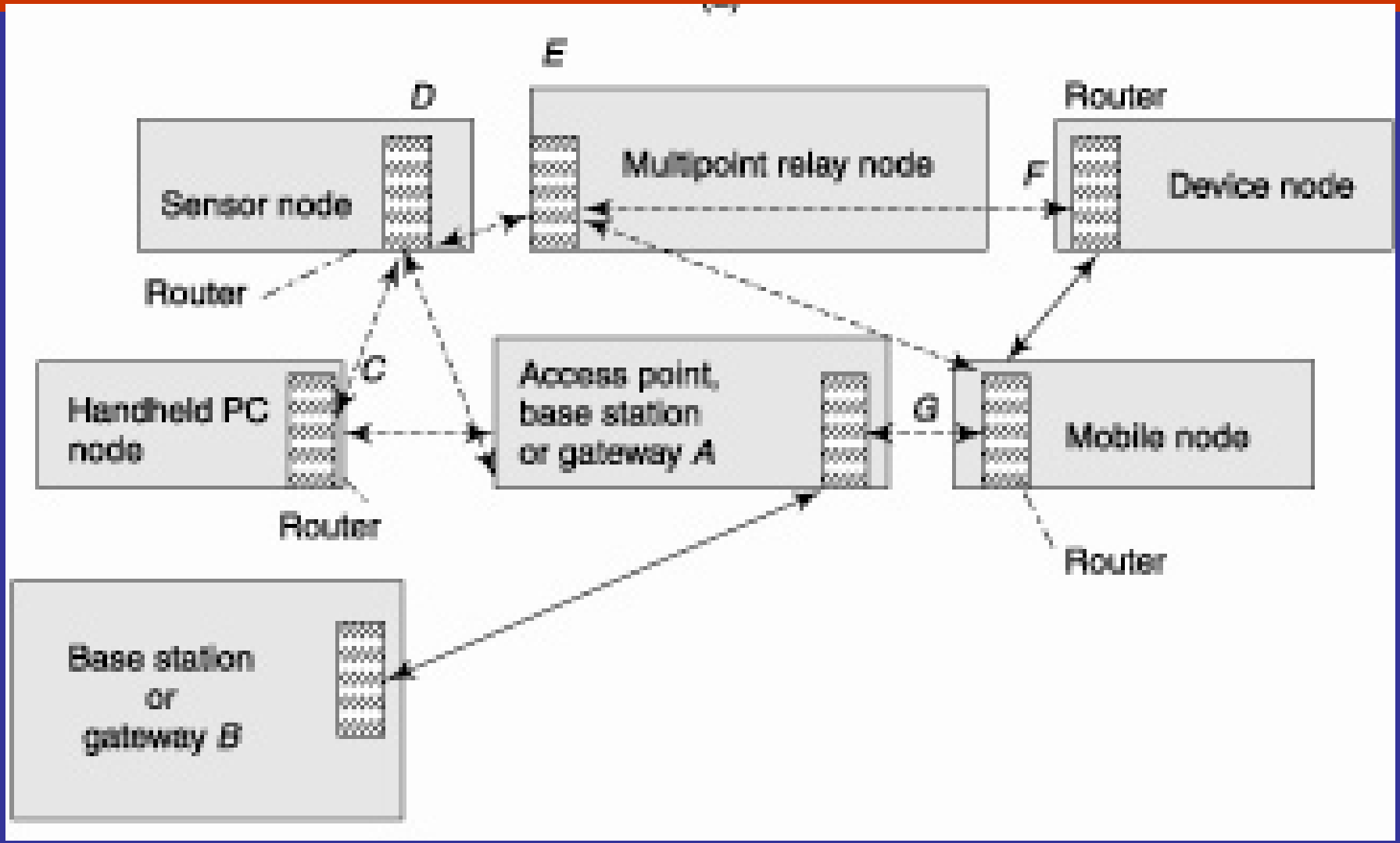
Example of MANET



Source Route Discovery Process

- Source header from *D* puts the sequence number *q* and source address *D* in the packet header and sends the packet to its next neighbour. When the packet reaches *E*, its header is (*q*, *D*)
- Assume that no route error packet bounced back from neighbour *E*

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Source Route Discovery Process

- The packet is then transmitted to *F*
- When the packet reaches *F*, its header is (*q*, *D*, *E*). Assume that no route error packet bounced back from neighbour *F*

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Source Route Discovery Process

- The packet is transmitted from *F* to *G*. Assume that no route error packet bounced back from neighbour *G*.
- When the packet reaches *G*, its header is (*q*, *D*, *E*, *F*)

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Domain Specific rules for consistency

- When packet reaches the destination, a route reply (RREP) for the sequence used in RREQ is generated
- On return path, the route cache builds up at each intermediate node for deployment at a later instant of phase 2

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Phase 2 in DSR

- When any source node desires to send a message, it first looks at its route cache
- If the required route is available in cache, the source node puts all the addresses of the nodes for the path to destination in the header

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Source routing addresses in DSR

- Assuming that there is a message from a MANET node *D* in the network

Node	Destination	Cached Path
D	*A*	*D—C—A*
D	*B*	*D—C—A—B*
D	*F*	*D—E—F*
D	*G*	*D—E—F—G*

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Ad-hoc On-demand Distance Vector (AODV) Routing protocol

- A reactive protocol
- Reacts to the changes and maintains only the active routes in the caches or tables for a pre-specified expiration time
- Routes that are found that are available at a given instant

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AODV

- Performs unicast routing
- Distance vector means a set of distant nodes, which defines the path to destination

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AODV

- *D—E—F—G* is a distance vector for source-destination pair *D* and *G*
- In AODV, a distance vector is provided on demand during forwarding of a packet to destination by a node in the path and not by the route cache providing path through the header in the source data packet [phase 2]

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AODV

- Every node keeps a next-hop routing table, which contains the destinations to which it currently has a route
- A routing table entry expires if it has not been used or reactivated for a pre-specified expiration time
- AODV adopts the destination sequence number technique

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AODV

- Does not deploy flooding (multiple RREQs)
- Stores the next hop routing information of the active routes in the routing caches (tables) at each node
- Therefore, has small header size and thus reduces the network traffic overhead

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Phase 1 in AODV Protocol

- A node uses hello messages to notify its existence to its neighbours
- Therefore, the link status to the next hop in an active route is continuously monitored

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Phase 1 in AODV Protocol

- When any node discovers a link disconnection, it broadcasts a route error (RERR) packet to its neighbors, who in turn propagate the RERR packet towards those nodes whose routes may be affected by the disconnected link
- Then, the affected source can be informed

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Phase 2 in AODV Protocol

- Source node initiates a route discovery process if no route is available in the routing table
- It broadcasts the demand through the RREQ packets

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Phase 2 in AODV Protocol

- Each RREQ has an ID and the addresses of the source and destination in its header
- It expects return acknowledgement from destination
- A node identifies the last observed sequence number of the destination from the ID

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Phase 2 in AODV Protocol

- Each RREQ starts with a small TTL (time to live) value [Number of attempts]
- If the destination is not found during the TTL, the TTL is increased in subsequent RREQ packets
- The node also identifies sequence number of source node

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Phase 2 in AODV Protocol

- Sequence numbers ensure loop-free and up-to-date routes.
- Loop-free means free from bouncing of a packet to a node after intermediate hops

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Phase 2 in AODV Protocol

- Each node rejects the RREQ which it had observed before
- This reduces flooding which means it reduces too many RREQs present in the network at a given instant.

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Route table in AODV

- Keep entries for a specified period and each node maintains a cache
- The cache saves the received RREQs
- Only the RREQ of highest sequence numbers are accepted and previous ones are discarded

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Route table in AODV

- The cache also saves the return path for each RREQ source
- When a node having a route to the destination or the destined node receives the RREQ, it checks the destination sequence number it currently knows and the one specified in the RREQ

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Route table in AODV

- RREP packet is created and forwarded back to the source only if the destination sequence number is equal to or greater than the one specified in RREQ
- It guarantees the up-dation of routing cache information

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Summary

- DSR
- Deploys source routing
- Reacts to the changes and dynamically maintains only the routing addresses from source to destination, which are the active paths to a destination at a given instant

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…Summary

- AODV reactive protocol
- Routes that are found that are available at a given instant
- Every node keeps a next-hop routing table
- A routing table entry expires if it has not been used or reactivated for a pre-specified expiration time

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…Summary

- AODV adopts the destination sequence number technique

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Mobile Ad-hoc Network (MANET) Routing Algorithms– Part 1

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Mobile Ad-hoc and Sensor Networks

Lesson 05

Mobile Ad-hoc Network (MANET) Routing Algorithms– Part 2

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Temporally ordered routing algorithm (TORA)

- A reactive protocol
- Reacts to the changes and link reversals
- Employed for highly dynamic MANETs and provides an improved partial link reversal process

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TORA

- Discovers the network portions showing the link reversal(s)
- Has a feature that it stops the non-productive link reversals in a given portion of the network

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TORA

- Assumes addresses of the routers in the path and of source and destination for one set of input route
- Each node provides only one set of subsequent route addresses

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TORA

- Possesses network capacity such that many nodes can send packets to a given destination
- Guarantees loop-free routes and supports multicasting (from one source to multiple destinations)

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TORA

- Unlike AODV, but similar to DSR, TORA supports unidirectional links and also provides multiple routing paths
- It does not exchange hello messages periodically to listen to disconnected links as done by AODV

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TORA

- Phases 1, 2, and 3 in TORA are route creation, route maintenance, and productive (useful) link reversal(s) (vector discarding)

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Cluster-head gateway switch routing (CGSR)

- A hierarchical routing protocol
- proactive protocol
- When a source routes the packets to destination, the routing tables are already available at the nodes
- A cluster higher in hierarchy sends the packets to the cluster lower in hierarchy
- Each cluster can have several daughters and forms a tree-like structure in CGSR

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CGSR

- Forms a cluster structure
- The nodes aggregate into clusters using an appropriate algorithm
- The different clusters can be assigned to different band of frequencies in FDMA or different spreading CDMA codes

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CGSR algorithm

- Defines a cluster-head, the node used for connection to other clusters
- Also defines a gateway node which provides switching (communication) between two or more cluster-heads

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Three types of nodes in CGSR

1. Internal nodes in a cluster which transmit and receive the messages and packets through a cluster-head

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Three types of nodes in CGSR

2. Cluster-head in each cluster such that there is a cluster-head which dynamically schedules the route paths. It controls a group of ad-hoc hosts, monitors broadcasting within the cluster, and forwards the messages to another cluster-head

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Three types of nodes in CGSR

3. Gateway node to carry out transmission and reception of messages and packets between cluster-heads of two clusters

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Cluster structure

- A higher performance of the routing protocol as compared to other protocols because it provides gateway switch-type traffic redirections and clusters provide an effective membership of nodes for connectivity

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Phases 1, 2, and 3 of CGSR

- Routing path discovery and caching, maintaining update, and distribution, respectively
- The basic processes of CGSR are cluster definitions and selection of clusters for routing
- Algorithms are used for both the processes

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Flat Routing Table Driven Protocol

- Routing cache table used earlier was a routing table which builds by caching the RERP and RERR packets
- Flat routing table driven protocol is a proactive protocol
- This means that routing table will be available in advance at a node

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Flat Routing Table Driven Protocol

- In the proactive protocol, the routing table is available at each node shows available routes from itself to target destination node, is dynamically modified to show available routes, and has rows for all destined targets irrespective of whether they will eventually be needed or not

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Flat Routing Table Driven Protocol

- The packet does not specify route in the header and the routes need not be discovered after the demand is raised

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Optimized Link State Routing Protocol (OLSR)

- Characteristics similar to those of link state flat routing table driven protocol, but in this case, only required updates are sent to the routing database
- Reduces the overhead control packet size and numbers
- Further, there are multi-point nodes for relay of data

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Optimized Link State Routing Protocol (OLSR)

- A node selects independently a multi-point node which also relays the route tables
- The node provides bi-directional links such that the routes provided by the multi-point relay routing neighbouring node is also taken into account

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Summary

- TORA– A reactive protocol, Reacts to the changes and link reversals, Employed for highly dynamic MANETs and provides an improved partial link reversal process

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…Summary

- CGSR —A hierarchical routing protocol, proactive protocol, When a source routes the packets to destination, the routing tables are already available at the nodes

…

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…Summary

- Flat Routing table based protocol
- Optimized Link State Reversal

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Mobile Ad-hoc and Sensor Networks

Lesson 07

Wireless Sensor Networks

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Example of a library with smart labels on each book

- A set of wireless access-points in the library
- Also wireless Internet connectivity to a central server computer
- Smart labels network together to a central reading server through wireless access-points, Internet, and a centralized server

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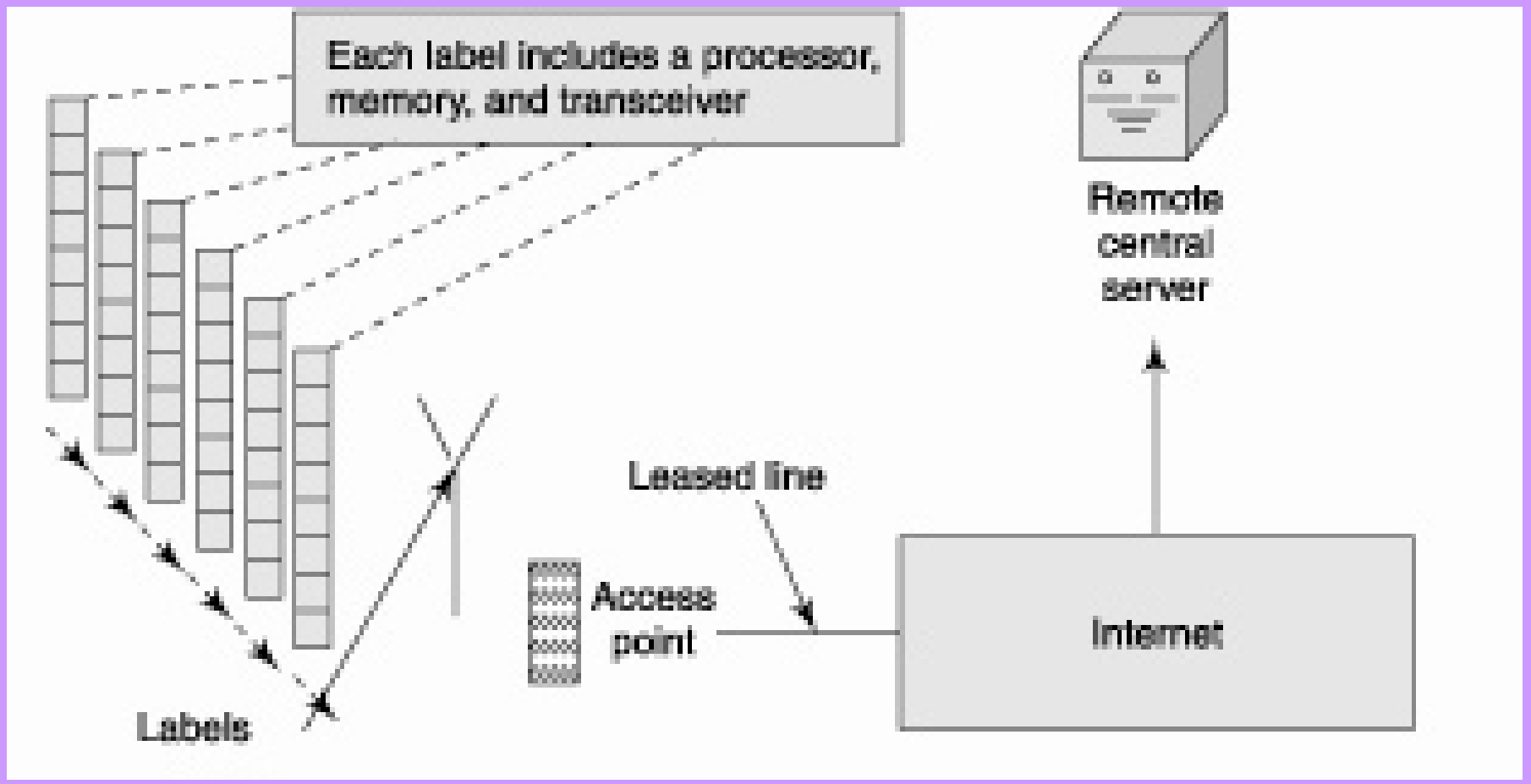
Example of wireless sensor network in a library with smart labels



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Example of a library with smart labels on each book

- Cluster of labels form a MANET similar to a LAN network and the MANET connects to central server through wireless access-point and Internet

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Example of a library with smart labels on each book

- When a labeled book is removed from the shelf, the smart label on the neighbouring book discovers service through another neighbouring label and MANET is reorganized and establishes connection to central server is established

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Example of a library with smart labels on each book

- Smart labels are sensors of radiation from wireless access-points
- Therefore, the MANET of smart labels is also called wireless sensors ad-hoc network

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MANET Sensor nodes

- Sophisticated hardware, software and features
- Each node has an analog sensor with signal conditioner circuit
- Sensing can be of the light level, temperature, location shift, time stamps of GPS satellites , vibration, pressure, weather data, noise levels, traffic density, and nearby passing vehicles

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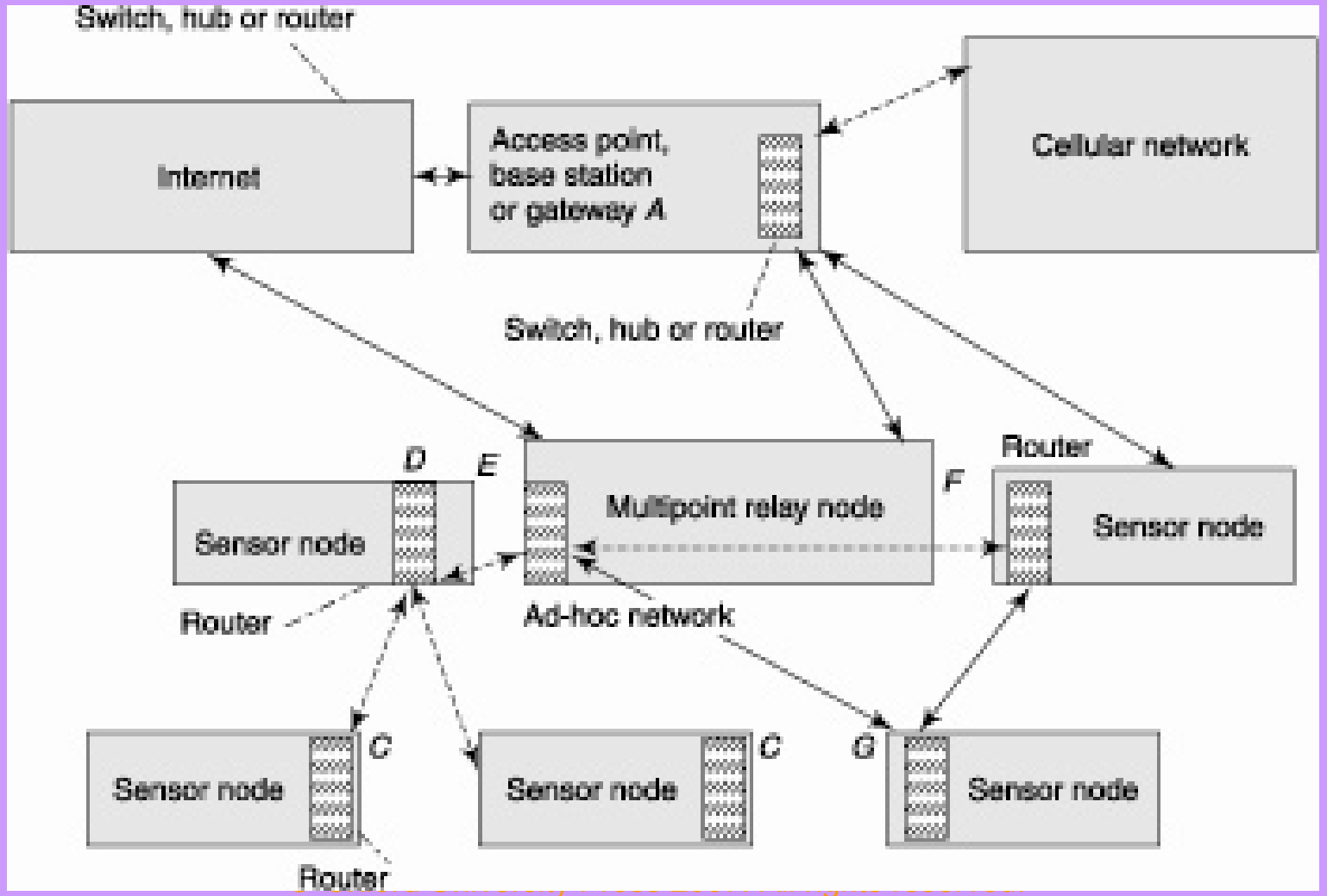
Wireless sensor network



MANET Sensor nodes

- The smart sensors have computational, communication, and networking capabilities but are constrained by their small size, limited energy availability, and limited memory
- Since greater computational speed needs greater energy, these sensors operate at limited computational speed
- Moreover, these have limited bandwidth

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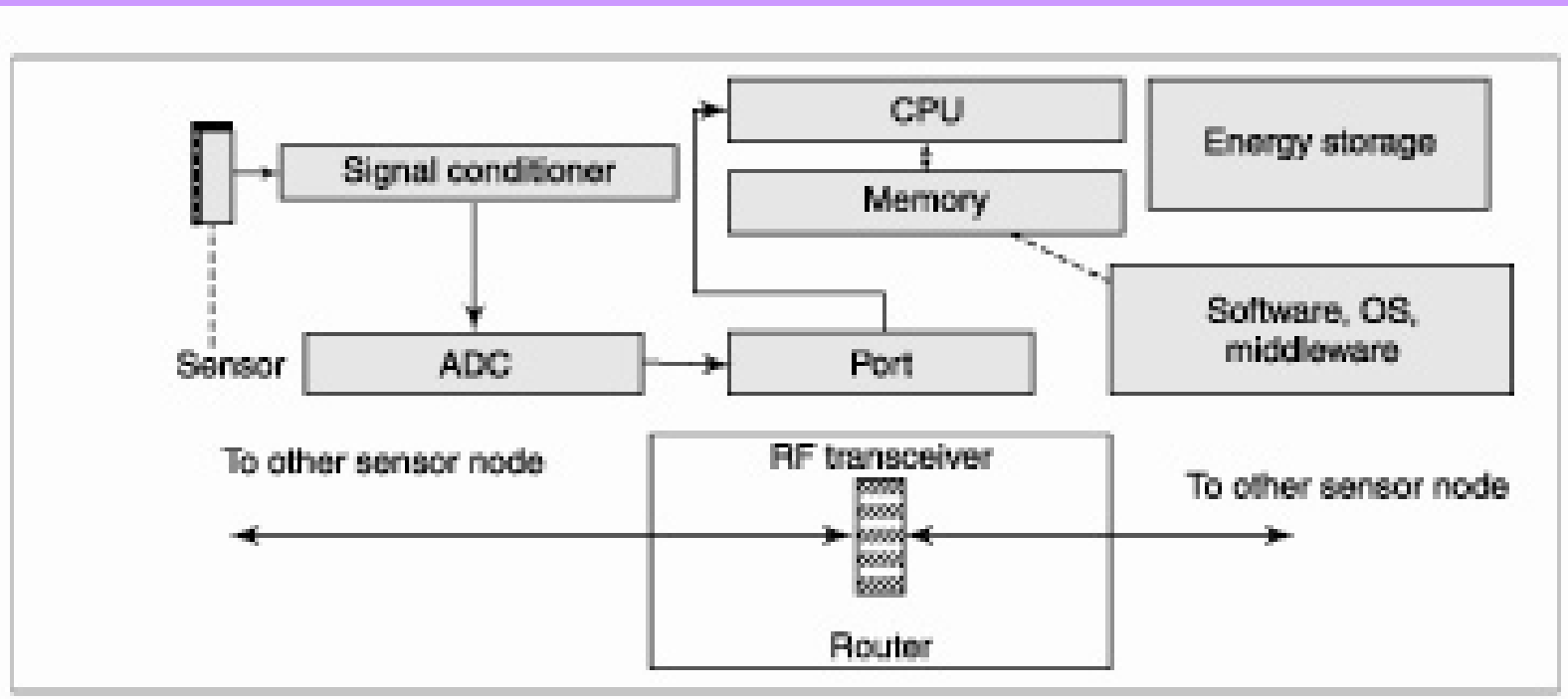
Smart wireless sensor node architecture



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A smart wireless sensor architecture

- Consists of an RF transceiver for communication, a *microcontroller* [CPU, memory, and ADC (analog-to-digital converter)], and an *energy source* or a power supply

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A smart wireless sensor architecture

- A charge pump traps the charge from the radiations (for example, from WiFi transceiver or an access-point)
- Alternatively, an energy-harvesting module can be used to trap solar radiation and store the energy

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A smart wireless sensor architecture

- The *RF transceiver* enables a node to receive data packets from nearby nodes and route these to next hop of the packet
- A wireless sensor node disseminates information to the network, central computer, or controller

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Data Dissemination after Aggregation

- Aggregation refers to the process of joining together present and previously received data packets after removing redundant or duplicate data

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Data Dissemination after Compaction

- Compacting means making information short without changing the meaning or context, for example, transmitting only the incremental data so that short information sent

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Data Dissemination after Fusion

- Fusion means formatting the information received in parts through various data packets and several types of data (or data from several sources), removing redundancy in the received data, and presenting the formatted information created from the information parts in cases when the individual records are not required and/or are not retrievable later

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Distributed Network and Characteristics

- A wireless sensor network can be considered as a MANET of autonomous devices, which are spatially distributed
- Sensor devices cooperate with each other to disseminate the sensed or other data in the network

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Distributed Network and Characteristics

- The characteristics are energy constraints, probability of node failure, mobile network topology, and nodes using heterogeneous protocols with no maintenance during their operation it is known as full copy replication

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IEEE 802.15.4-2003 ZigBee Protocol

- A Standard protocol for wireless sensor networks
- ZigBee — a set of communication protocols used by small-sized low power digital radio embedded in the sensors and home devices

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6lowpan **Protocol**

- 6lowpan (IPv6 over low power wireless personal area network which permits communication of IPv6 packets in sensor network)

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Software

- Software once embedded into the sensor node is for lifetime
- Should be robust, fault tolerant, and should provide maximum features and middleware
- Software should have features of security, self-healing, and self-configuration

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Few specific operating systems

- tinyOS and CORMOS (communication oriented runtime system for sensor networks)

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Examples of a few specific middleware (agent or database adapter)

- tinyDB, SensorWare, and GSN (global sensor networks) application-oriented middleware

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Router

- Sensor networks deploy special routing protocols such as CGSR, DSR, or AODV

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Applications of Wireless sensor network

- Industrial plant wireless sensor networks—Industrial plants use large number of sensors in instruments and controllers

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Applications of Wireless sensor network

- **Pervasive computing networks**—Mobile pervasive computing means *a set of computing devices*, sensors, or systems or a network having the characteristics of *transparency*, application-aware adaptation, and environment sensing

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Applications of Wireless sensor network

- Traffic monitoring using traffic density wireless sensor networks
- Traffic density information aggregated at a central server
- The server relays this information to motorists on wireless Internet
- A traffic control server sends the traffic reports on Internet

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Applications of Wireless sensor network

- The automobile owner can subscribe to a traffic control service provider which provides SMS messages about traffic slowdowns and blockades at various city points
- Enables a driver to select the roads with the least hurdles
- TTS (Text to speech) converters can also give voice messages to the drivers

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Applications of Wireless sensor network

- Medical applications of wireless sensor networks— patients can be monitored by the sensors attached to them
- When a patient moves, the sensors form a MANET

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Applications of Wireless sensor network

- Military applications of wireless sensor networks—The voice of a person can be sensed by a wireless sensor network deployed in remote border areas
- This monitors the enemy troop and machines movements

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Applications of Wireless sensor network

- Smart labels and RFID-based wireless sensor network—It is used worldwide for monitoring movement of goods, movement of books in library, and supply chain management systems

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- Environmental monitoring wireless sensor network—Environmental parameters like temperature, pressure, light, rainfall, and seismic activity
- Home automation—including security using a wireless sensor network

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Summary

- Sensing of the light level, temperature, location shift, time stamps of GPS satellites vibration, pressure, weather data, noise levels, traffic density, and nearby passing vehicles
- Smart sensors have computational, communication, and networking capabilities

...

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… Summary

- Constrained by their small size, limited energy availability, and limited memory
- Operate at limited computational speed
- Limited bandwidth
- RF transceiver for communication, a *microcontroller* [CPU, memory, and ADC (analog-to-digital converter)], and an *energy source*

…

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…Summary

- Data Dissemination after Aggregation, Compaction and Fusion
- Distributed Network and Characteristics
- Applications of wireless sensor networks and MANETs

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End of Lesson 07
Wireless Sensor Networks

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Wireless LAN, Mobile Internet Connectivity, and Personal Area Network

Lesson 01

Wireless LAN Architecture

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Local area network (LAN)

- A set of computers, computational systems, units, and devices, for example, mobile phones, printers, laptops, smart sensors, and smart labels, networked using a standard suite of protocols
- Local refers to some defined area or a set of nearby or distant stations

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Wireless LAN (WLAN)

- Also called WiFi (Wireless fidelity)
- IEEE 802.11a, 802.11b, … 802.11g standards recommended for WLAN in mobile communication and for establishing communication between mobile devices and Internet or other networks

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Two service sets in the WLAN architecture

- Basic Service set (BSS)– Set *A* has nodes which connect to an access-point
- Independent basic service set (IBSS)– Set *B* do not connect to any access-point
- IBSSs do not connect among themselves

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Basic Service set (BSS) *A*

- BSS devices in each set interconnect to the access-point using 802.11
- Form a single station STA_A of WLAN using same frequencies for radio
- The BSS station interconnects to other stations through access-points

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IBSS Set *B*

- Set *B* has several stations STA_B, STA_C, ….

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Standard basic feature of 802.11

- Supports both access-point-based fixed infrastructure WLAN network using BSSs
- Ad-hoc peer-to-peer data routing network using IBSS stations

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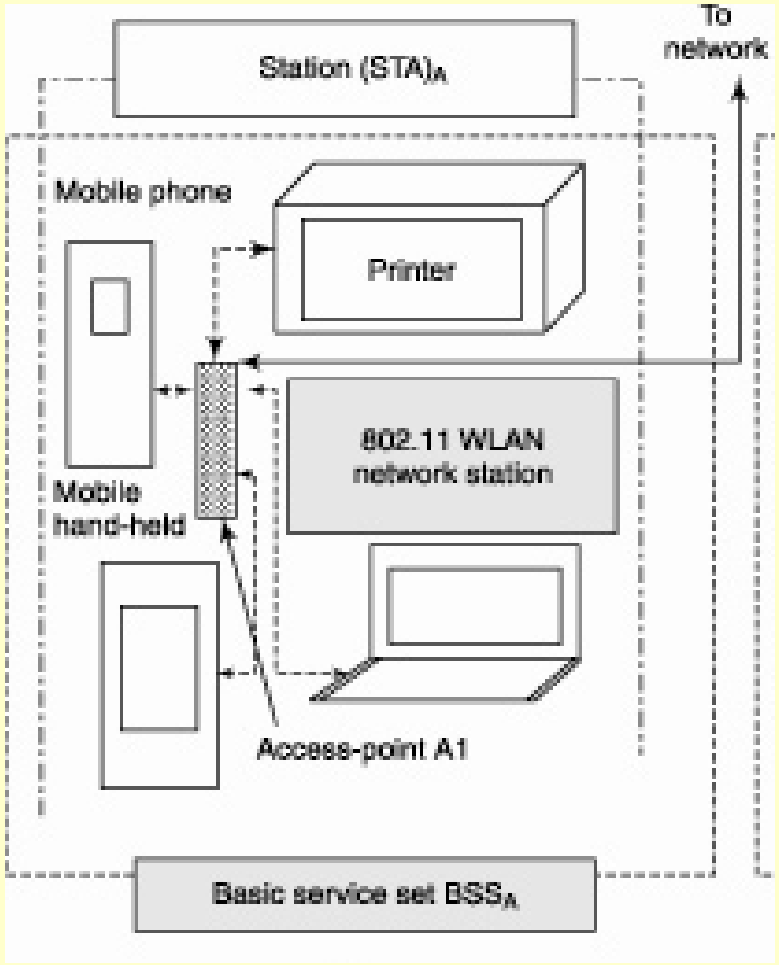
BSS, which also has an access point for connectivity



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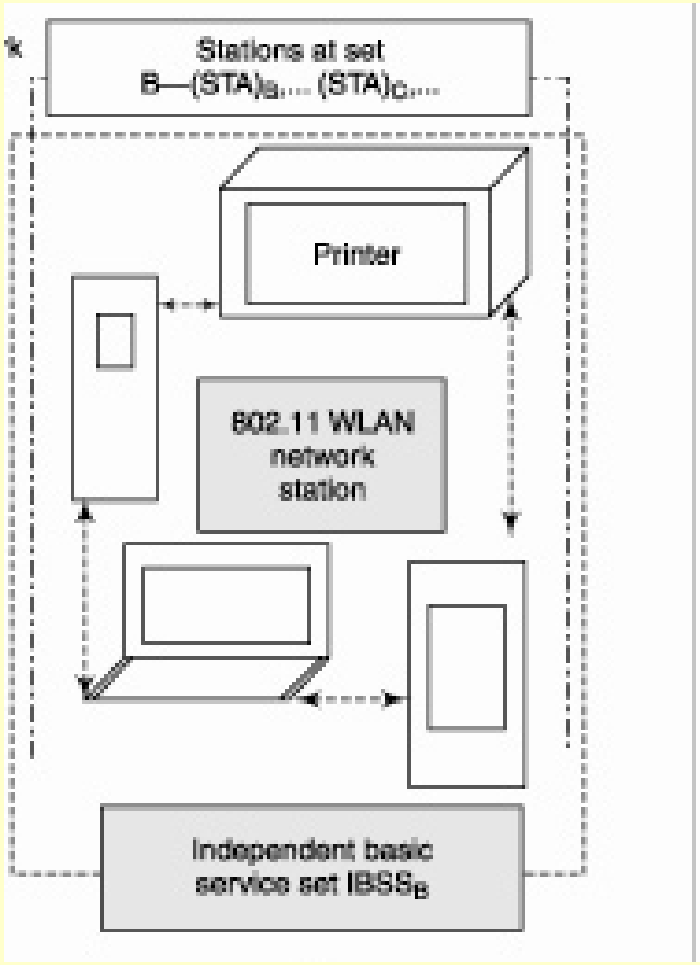
IBSS, which has no access point for connectivity to other IBSS



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Node in WLAN

- Each node of a station uses the same frequency band if it is at a distance from another station or a distinct frequency band if it is not distant enough from another station

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Node in WLAN

- Node at a station can communicate directly to an access-point (in BSS)
- To another node at another station through the access-point
- Communicate among themselves after forming an ad-hoc or any other type of network (for example, Bluetooth) using same frequency band for each node

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802.11 protocols suite

- Does not specify the protocols for the nodes for data routing, exchanging, or supporting exchange of network topology information
- Thus, there can be Bluetooth exchanges between the nodes or the nodes can be the ZigBee devices

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WLAN and Internet Access

- IEEE 802.11a, 802.11b, and 802.11g standards
- WLAN also called WiFi (Wireless Fidelity)

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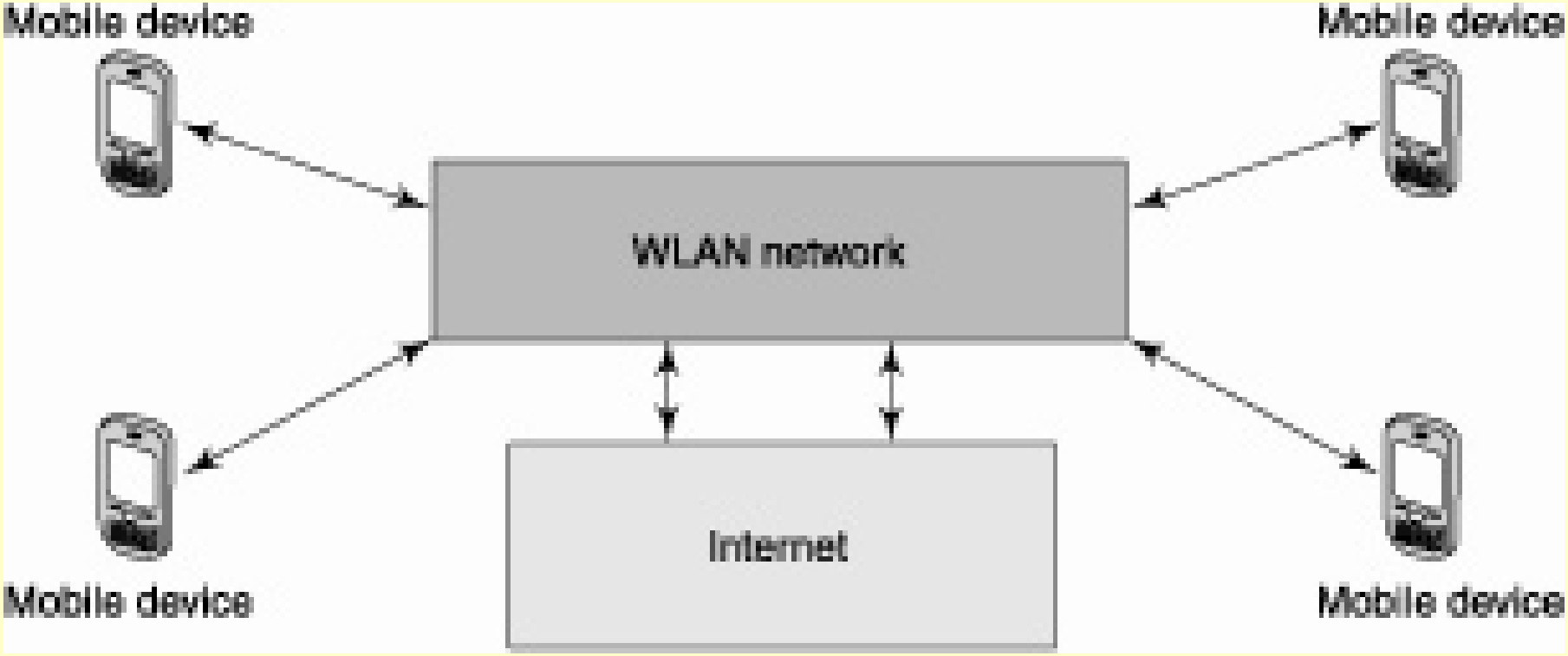
Mobile communication using an 802.11 WLAN standard



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IEEE 802.11 based standards for WLANs

- 802.11a– MAC layer operations such that multiple physical layers in 5 GHz (infrared, two 2.4 GHz physical layers)
- Infrastructure based architecture as well as Mobile ad hoc network (MANET) based architecture

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802.11a

- OFDM at data rates of 6 Mbps, 9 Mbps,…
- Data rates supported are from 54 kbps to a few Mbps

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802.11b

- 54 Mbps and at 2.4 GHz.
- Modulation DSSS /FHSS
- Supports short-distance wireless networks using Bluetooth (IEEE 802.15.1) based applications and the HIPERLAN2 (HIPERformance LAN 2)

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802.11b

- OFDMA physical layer
- Provides protected Wi-Fi access
- The data rates are 1 Mbps (Bluetooth), 2 Mbps, 5.5 Mbps, 11 Mbps, and 54 Mbps (HIPERLAN 2)

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802.11g

- Operates at 54 Mbps and at 2.4 GHz
- Used for many new Bluetooth applications
- Compatible to 802.11b
- Uses DSSS in place of OFDMA

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Extended Service Set (ESS)

- Functions as a distribution system possessing an ID, called ESSID
- The 802.11 provides the definition for ESSID, but the distribution system network protocols are not defined within 802.11
- Internet can be deployed by WLAN distribution system

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Example of access points, A, B, C, D, E, F, and G form the ESS

- Access-points exist at the base stations or gateways *J and H*
- An access-point also present at a multi-point relay node, *E*

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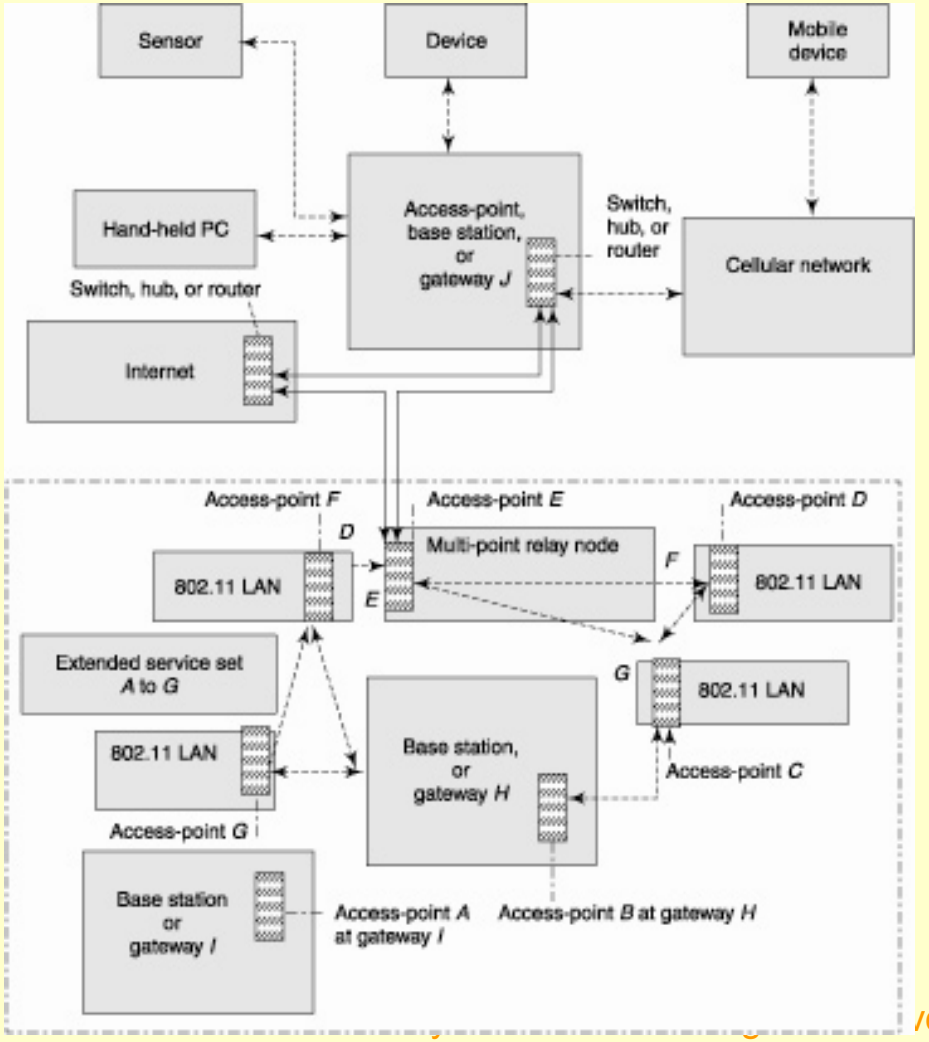
802.11 station access-points *A* to *G* networked together forming ESS



ved.

Stations in a given IBSS

- A mobile phone, TV with a set-up box, security system, and computer at home
- Form a WLAN station and can use the same frequency band for radio

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Stations in a given IBSS

- Since it does not have an access-point to a distribution system or ESS, the station is a part of an IBSS
- These devices can also have Bluetooth OBEX exchange between mobile phone and computer

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Example

- Consider the mobile phones, computers, and printers at a company office having independent workspace for each set of a mobile phone, a computer, and a printer
- Each set forms a WLAN station

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Example

- Each station uses same frequency band for radio if the frequencies do not interfere and distinct frequency band if the frequencies are too close to each other
- All stations together form an IBSS, which is distinct from the IBSS at home

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Protocols

- Depend on how the BSSs interoperate in a service provider servicing set up
- These protocols may or may not be TCP/IP or IPv6
- Also a node can be mobile and can move from one BSS to another such that its service access-point becomes different on moving (roaming

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Standard basic feature of 802.11

- Supports BSSs and Ad-hoc peer-to-peer data routing network using IBSSs

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WLAN network having stations at the BSSs in an ESS

- The mobile phones, computers, and printers at the company office having independent workspace for each set of a mobile phone, a computer, and a printer

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WLAN network having stations at the BSSs in an ESS

- Each workspace has a wireless access-point for connecting to Internet in each office
- The frequency- band used by each device at the office for connecting to the access point is same

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WLAN network having stations at the BSSs in an ESS

- The mobile phones, computers and printers form a WLAN station
- The station is a part of the BSSs of the company offices at the distant locations

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WLAN network having stations at the BSSs in an ESS

- Each BSS of the company connects through a distinct access point in an ESS of the company
- All BSSs of the ESS form a WLAN network
- Each BSS uses an ESSID to communicate with the other BSS and may or may not use Internet as a distribution system

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Roaming in a WLAN network

- Assume that there are the BSSs of the mobile phones, computers, and printers at the company offices and homes of the employees

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Roaming in a WLAN network

- A mobile phone can roam between home and company offices
- It forms an ad-hoc network when it moves from one BSS station to another and gets connectivity to the WLAN network through the access-points

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Summary

- Basic Service set (BSS) has nodes which connect to an access-point
- The mobile phones, computers and printers form a WLAN station
- The station is a part of the BSSs of the company offices at the distant locations
- ESS consisting of interconnected BSSs using Internet or any service provider network

…

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…Summary

- Independent basic service set (IBSS)—Set *B* do not connect to any access-point
- IBSSs do not connect themselves
- A mobile phone, TV with a set-up box, security system, and computer at home
- Form a WLAN station and can use the same frequency band for radio

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End of Lesson 01

Wireless LAN Architecture

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Wireless LAN, Mobile Internet Connectivity, and Personal Area Network

Lesson 02

Wireless LAN Protocol layers

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Physical layer

- The layer which transmits or receives the signals through wireless communication or through wire, fibre, or microwave after formatting or multiplexing

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Multiple layers in a communication network

- Each layer has specific protocols to send the bits to next layer
- Open System interconnection (OSI) model

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Layers 1- 7 in OSI Model

- Physical (layer 1) layer
- Data link (layer 2)
- Network (layer 3)
- Transport (layer 4)
- Session (layer 5)
- Presentation (layer 6)
- Application (layer 7) layer

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Signals in transceiver

- Reception In the order—layer 1 to layer 7
- Transmission in the reverse order—layer 7 to layer 1
- Each layer adds additional headers (messages) in specific formats so that at the receiver, these headers are stripped and the actions and operations specified by the header fields take place

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Number of Layers and Sublayers in a transceiver

- May not have all the 7 layers
- Some layers functions may be assigned the functions of the neighbouring layer(s)
- The functions of a layer can also be divided amongst sublayers

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IEEE 802.x set of protocols defined for networking

- **802.1** [x =1] gives specifications for bridging of sublayers LLC (logic link control) and MAC (medium access control)
- For management of layers 1 and 2

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IEEE 802.x set of protocols defined for networking

- *x* = 2 gives specifications for LLC sub-layer at layer 2
- *x* = 1 and 2 specifications common to all standards in 802.x for *x* = 3 and above
- *x* = 3 gives the specifications for MAC sub-layer of layer 2 and physical layer for wired LAN, called Ethernet

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IEEE 802.x and 802.x.yset of protocols

- Upper layers common in protocols 802.x
- *x* = 10 gives the security specifications for layers 2 and above and is common in protocols 802.1y
- *x=1; y* = 1 means 802.11
- *x=1; y*= 5 means 802.15
- *x=1; y*= 6 means 802.16

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802.11 standard– a suite of WLAN protocols

- For the MAC sub-layer of layer 2 and physical layer (layer 1), which includes security 802.10 specifications

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Physical layer

Physical layer (PMD)

- Three options: FHSS/DSSS/Diffused IR
- 802.11a OFDM 5 GHz (infrared, two 2.4 GHz physical layers), 6 Mbps to 54 Mbps
- 802.11b 2.4 GHz DSSS, supports 5.5 Mbps and 11 Mbps using CCK, 54 Mbps HyperLAN2
- Supports 802.15.4 ZigBee, 802.15.1 Bluetooth FHSS

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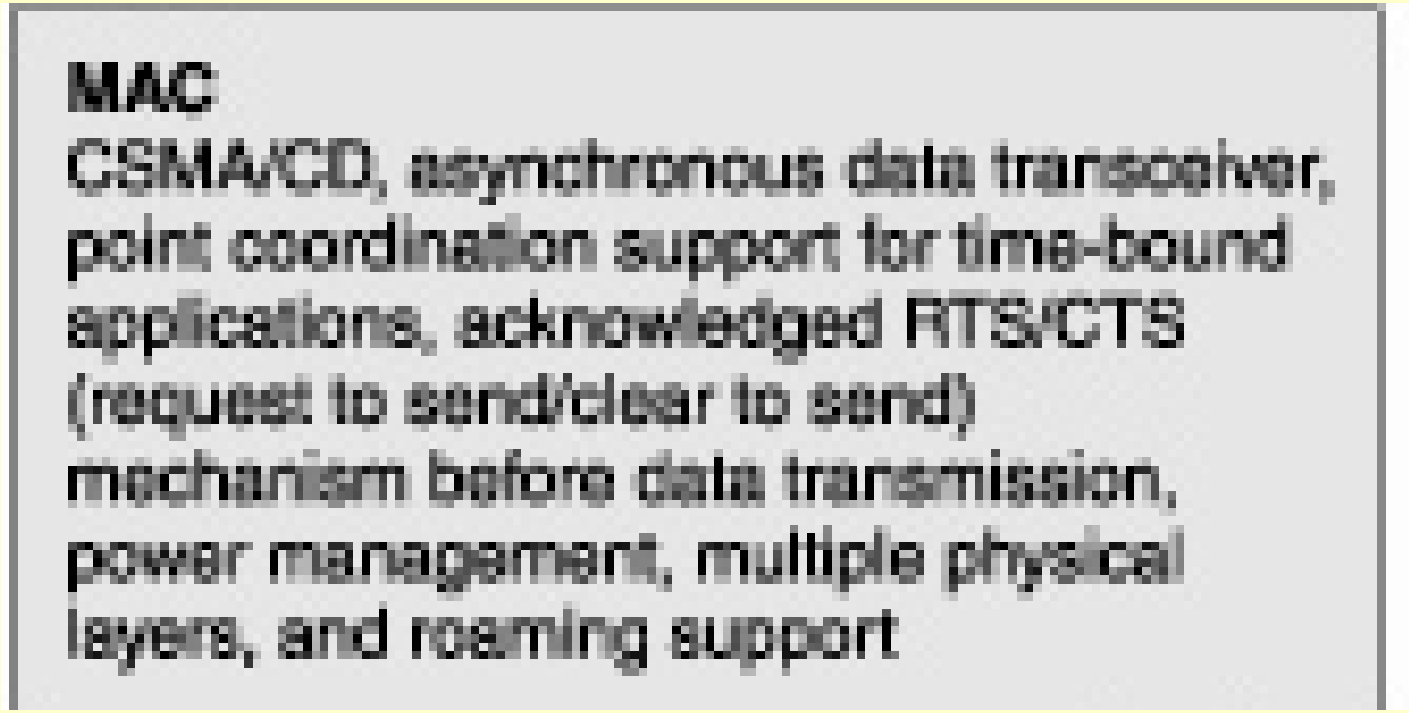
MAC sub-layer of layer 2 (data link layer)



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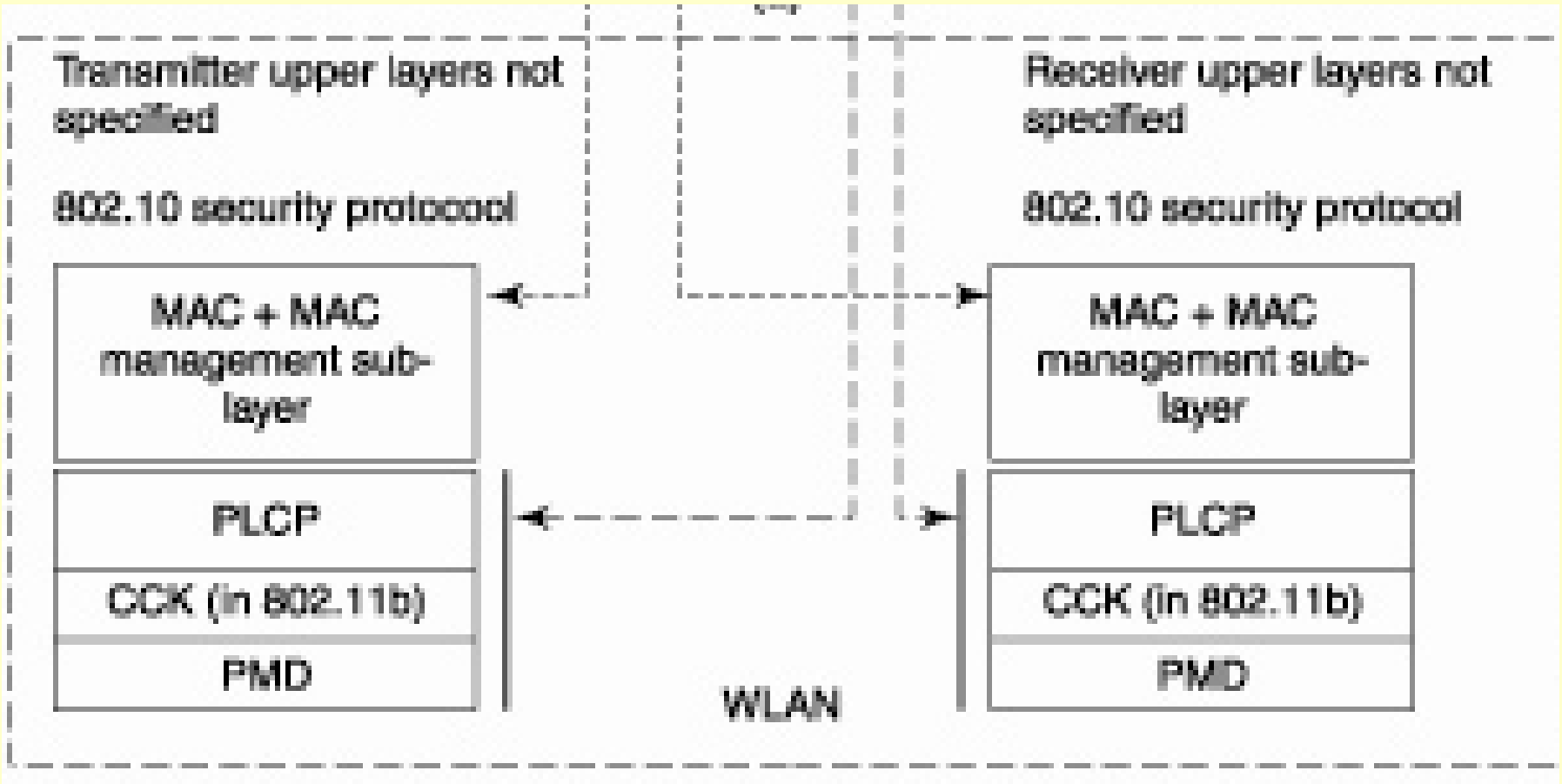
Basic protocols layers in IEEE 802.11



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Physical layer two sub-layers

- PMD (physical medium dependent) sub-layer
- PLCP (physical layer convergence protocol) sub-layer
- There is an additional sub-layer in 802.11b—CCK (complementary code keying) for data rates of 5.5 Mbps by QPSK to map 4 bits and 11 Mbps 8-QPSK to map 8 bits simultaneously

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PMD protocol specifications of the modulation and coding methods

- Service access-point with 1 Mbps or 2 Mbps data rate to MAC layer

1. FHSS—radiated at 10 mW, 100 mW, and 1 W as per country-specific restrictions

- Modulation 1 Mbps Gaussian BPSK or 2 Mbps Gaussian QPSK

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PMD protocol specifications of the modulation and coding methods

2. DSSS—using 11-bit Barker code radiated at 10 mW, 100 mW, and 1 W as per country-specific restrictions and 1 Mbps or 2 Mbps data rates (symbol rates)

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PMD protocol specifications of the modulation and coding methods

- DSSS transmission characteristics—negligible interference and multi-path delay spread
- Modulation— DQPSK, 11-bit code—11 Mchip/s, Scrambling done by a polynomial $G_Q = z^7 + z^4 + 1$

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PMD protocol specifications of the modulation and coding methods

3. PPM (Pulse Position Modulation)—a modulation method. 16-PPM is used for 1 Mbps and 4-PPM for 2 Mbps data rate

- 16-PPM means that a code is transmitted for each quad of 4 bits and is positioned in one of the 16 slots (a slot is a 16-bit long sequence of bits, each slot-bit separated by 250 ns)

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PMD protocol specifications of the modulation and coding methods

- PPM method involves 250 ns pulses of diffused infrared (IR) for 10 m range within a room
- IR does not pass through walls and thus provides isolation from neighbouring room nodes

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Examples of PPM of a quad of 4 bits

- Assume positioned in a 16 bit long slot with each slot-bit separated by 250 ns

(i) Consider a quad of 4 bits as 0000b = 0d. It means that at 0th position (counting positions from 0, 1, 2, …), there will be 1

- Hence the 16 bit sequence will have 0th slot-bit or lsb as 1. The transmitted bits after PPM will therefore be 0000 0000 0000 0001

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Examples of PPM of a quad of 4 bits

(ii) Consider a quad of 4 bits as 0100b = 4d

- It means that at 4th position (counting positions from 0, 1, 2, …), there will be 1
- Hence the 16 bit sequence will have the 4th slot-bit as 1
- The transmitted bits after PPM will therefore be 0000 0000 0001 0000

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Examples of PPM of a quad of 4 bits

(iii) Consider a quad of 4 bits as 1111b = 15d

- The transmitted bits after PPM in this case will be 1000 0000 0000 0000

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PLCP Sub-layer

- Specifies sensing of the carrier at the receiver and packet formation at the transmitter
- The different transmission and reception protocols (FHSS, DSSS, and diffused IR) specified for the PMD
- Thus a convergence protocol sub-layer required in between the PMD and MAC sub-layers

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PLCP Sub-layer

- PLCP sub-layer protocol prescribes the standard procedure for convergence of PMD to MAC at receiver and from MAC to PMD at transmitter
- Refer details in Section 12.1.2.2

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MAC and MAC Management sublayers

- MAC sub-layer specifies CSMA/CD (CSMA/CollissionDetect), RTS/CTS, and PCF mechanisms
- Sub-layer specifies MAC management

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MAC layer for medium access control features

- CSMA/CD
- Point coordination support for time-bound applications
- Acknowledged RTS/CTS (request to send/clear to send) mechanism before the data transmission

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MAC frame format of 802.11

- Refer Section 12.1.2.3

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Functions of MAC management sub-layer

1. Roaming management

- The access-point registers or deregisters the devices after the scanning
- New device registration provisions for device association at new access-point when it roams into the new area from another access-point area

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Functions of MAC management sub-layer

2. Internal receiver clocks are synchronized, which is necessary
- Generation of beacon signals is also part of management functions.
- A BSS periodically sends beacon signals, which contain—(i) time stamp for synchronizing node clock and (ii) power management and roaming data

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Functions of MAC management sub-layer

3. Transmitter switches to power-save mode after each successful data transmission for power management periodically activating the sleep mode
- Buffering by a receiver and starting processing after enough data received in buffer also saves power

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Summary

- WLAN 802.11.x specifications a suite of protocols for the MAC sub-layer of layer 2 and physical layer (layer 1)
- Includes security 802.10 specifications
- Physical layer— PMD (physical medium dependent) sub-layer
- Physical layer— PLCP (physical layer convergence protocol) sub-layer

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…Summary

- Data link layer – MAC sublayer
- Data link layer – MAC management sublayer

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End of Lesson 02

Wireless LAN Protocol layers

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Wireless LAN, Mobile Internet Connectivity, and Personal Area Network

Lesson 03

Wireless Application Protocol (WAP1.1 and 2.0) Architecture

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Wireless Application Protocol

- Offers open development platform for applications
- WAP 2.0 and WAP 1.1

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Hypertext Transfer Protocol (HTTP)

- Hypertext means a text which can embed the links to any other text, image, audio clip, or video clip through the URLs and hence enable navigation through these URLs
- HTTP transfers a hypertext, text, data, or voice tagged using HTML
- Similarly, WAP transfers a text written in WML (wireless markup language)

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WAP 1.1

- Two sets of software

1. WAE (wireless application environment)
2. WAE services

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Wireless Application Environment (WAE) 1.1

WAE 1.1

- WML(wireless mark-up language)
- WMLScript
- WBXML (WAP binary XML)
- WTA (wireless telephony applications)
- User agent profile
- Data formats [vCard 2.1, vCalendar 1.0, address book, pictogram, pictures (jpg, gif, ...)]
- Remote service provider pre-configuring of the device for provisioning the services

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WAE in WAP 1.1

- WML [Refer Lesson 5 for details]
- WBXML
- WTA
- WMLScript
- Data formats– vCard 2.1, vCalendar 1.0, address book, and pictures (jpg, gif, …)
- User agent

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WBXML

- WAP 1.1 provides for communication of client with gateway or proxy using WBXML
- XML and WML page document are not compact
- WBXML specification in binary representation so that XML or XML-based language– transmitted and received in compact format

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WBXML

- A binary number can represent a tag in place of characters
- Another binary number can represent an attribute in place of characters
- For example, attribute ID needs two characters
- It is represented by a single byte
- Attribute title needs five characters
- It is also represented by a single byte

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Wireless Telephony Application (WTA) Protocol

- Call set up
- call accept
- call forwarding
- caller line ID
- connected line ID
- closed user group
- multiparty groupings

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Wireless Telephony Application (WTA) Protocol

- call waiting
- call barring
- operator restrictions
- call charge advice
- contacts entry in phone book
- call hold

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Wireless Telephony Application (WTA) Protocol

- conferencing
- ring tones
- speed dial
- telephone/fax
- SMS up to 160 characters
- emergency number, MMS—gif, jpg, wbmp, teletext, and videotext access

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WATI (WTA interface)

- WATI provides the interfaces the features using WML browser
- A WTA URI can be wtai://wap.mcard: followed by a telephone number
- Identical to port number specifications provided in the URL

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WTA URI

- Example: wtai://wap.mcard: followed by a telephone number
- Identical to port number specifications provided in the URL

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Wireless Telephony Application (WTA) Server

- Server can push the WMLScript or deck contents

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Wireless Telephony Application (WTA) event handler

- A WTA event handler can handle WTA events
- Example of an event– change in data-field content

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Wireless Telephony Application (WTA)

- A persistent storage interface helps in storing the data on device when the content is modified. WTA also provides security interface
- Only authorised gateway or proxy can access the data at the server

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User Agent

- Software used by the user to give input using VUI (voice user interface)
- GUI (graphic user interface)
- To interact with mini browser (browser with limited screen size)
- Executes the WMLScript at the client and displays the results
- Displays the WML decks received as response from the server

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User Agent Profile

- Provides small screen device characteristics, font, and display capabilities
- Enhances the input capabilities, for example, the use of T9 keypad, stylus, and touch screen is enabled

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Data formats for data displayed on a mobile device

- vCard 2.1 is the format for visiting card
- vCalendar 1.0 is the format for calendar
- Also a mobile device provides pictogram which is a small picture of very low resolution that cannot be split and can be placed along with the text
- Pictogram used for displaying logo

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WAE 2.0

- WAE 1.1
- XHTML-MP
- HTTP
- HTML Browser

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WAP 2.0

- Wireless protocol for synchronization of WAP client computers and WAP or HTTP server
- Derived from the architecture of the synchronization between HTTP client (browser) and the HTTP server (web server) in wired Internet
- WAP 2.0 has backward compatibility and supports WAP 1.1 devices

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WAP2.0

- Wireless Session layers and Wireless Transport protocol layers not required in case of WAE XHTML-MP or HTML

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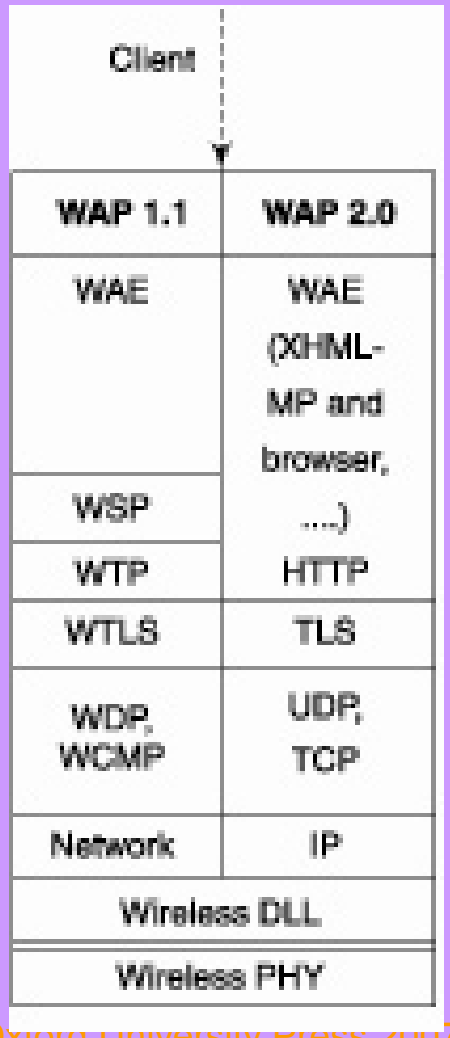
WAP 1.1 and WAP 2.0 Protocol Layers



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Synchronization in WAP 1.1 and WAP 2.0

- Remote service provider pre-configuring of the device for provisioning of services
- Used for data synchronization between server and mobile devices
- WAP 2.0 uses SyncML for Remote service provider pre-configuring of the device for provisioning of services
- WAP 2.0 uses SyncML for data synchronization between server and mobile devices

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WAP 1.1 Gateway

- Required for protocol conversions between two ends—mobile client device and HTTP server
- Required for iWMLScript (Internet WML script) compilation into CGI script which runs at the HTTP server to get HTML response which is sent to the client application

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WAP 1.1 Gateway

- Gateway converts WAE 1.1, WSP, WTP, WTLS, and UDP layers encoded data packets into the HTTP, TLS (in HTTPS), and UDP layers encoded data packets when the device transmits data to server
- Does decoding when the server sends data to client through the gateway

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WAP 2.0

- WAP 1.1 gateway encoders and decoders not required in WAP 2.0
- A WAP gateway connects WAP client to HTTP servers
- HTTP server serves the websites on the Internet
- HTTP layer in TCP/IP protocol suite acts as application layer protocol when connecting to Internet on a wired network

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WAP Push-Proxy Gateway

- WAP 2.0 uses XHTML-MP (Extensible Hypertext Markup Language Mobile Profile) in place of WML
- Therefore encoding and compilation is not required and only a WAP 2.0 proxy suffices

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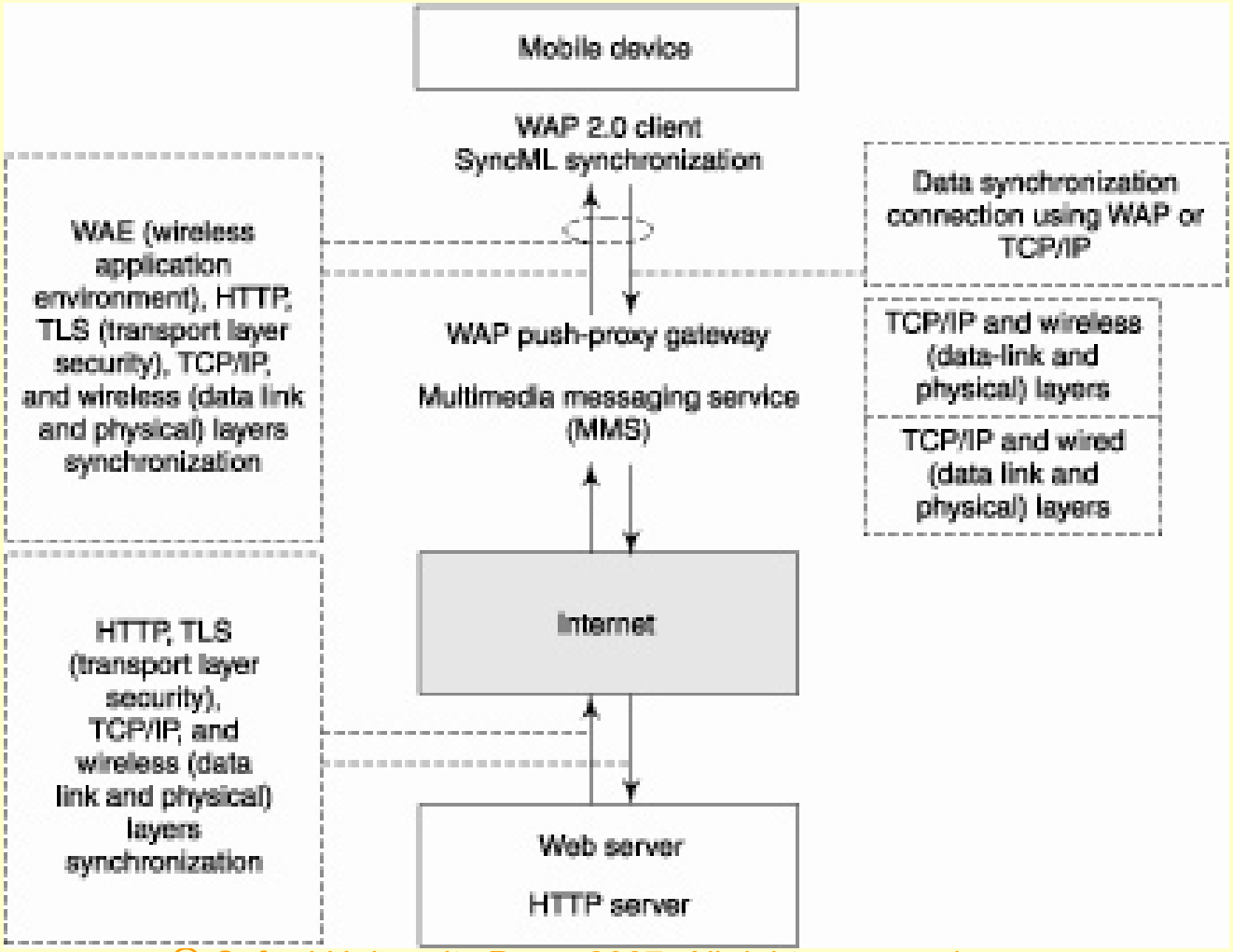
Architecture for communication between a WAP client and HTTP



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Running of application in a Mobile device WAE

- A WML card containing a client-request is transmitted and is decoded at the gateway
- After decoding, the gateway communicates the request to the server in HTML format
- The server generates an HTML response by employing the method(s) which run at the server

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Running of application in a Mobile device WAE

- The response is encoded in WML form at the gateway
- The gateway transmits the WML response to mobile-device client which runs an application after parsing the WML
- The application uses the methods which run at the client

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WAP Push-Proxy Gateway

- HTTP web servers function in pull mode
- That is, an HTTP client application sends a request to the server and the HTTP server sends the response
- Mobile device applications require data dissemination by server in push mode, pull mode, and push-pull hybrid mode

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WAP Push-Proxy Gateway

- A WAP 2.0 proxy is required for pull mode
- A push-proxy gateway is used to exchange data packets between a mobile device through wired Internet and Web servers. The role of WAP 2.0 gateway is restricted to provisioning for push and pull mode services from the servers

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WAP 2.0

- Have three important features over WAP 1.1

1. SyncML synchronization
2. WAP push service
3. MMS service

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SyncML Synchronization in WAP 2.0

- Remote service provider pre-configuring of the device for provisioning of services
- Used for data synchronization between server and mobile devices

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WAP 1.1 architecture

- Does not provide HTTP-TLS-TCP-IP layers at the WAP client for interacting with the WAP gateway
- TLS (transport layer security)— a security protocol

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WAP 1.1

- WAP gateway, therefore, uses a decoder for sending request to web HTTP server and an encoder for sending response to WAP client

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WAP gateway

- WAP gateway provides access to the wireless and wired networks and also builds caches due to frequent disconnections in the wireless environment
- Ensures security in wireless and wired networks

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WAP gateway

- An HTTP server environment provides only pull mode service but WAP gateway has provisions for both push and pull mode services from the servers
- Pull mode means client sends a request and pulls the data from server as a response

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Summary

- WAP 2.0 and WAP 1.1 application development platforms
- WAP transfers a text written in WML (wireless markup language)
- WAP gateway required for protocol conversions and iWMLScript (Internet WML script) compilation into CGI script
- WBXML

...

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…Summary

- WTA
- User Agent
- Special data format for WAP
- WAP 2.0 uses XHTML-MP (Extensible Hypertext Markup Language Mobile Profile) in place of WML
- Encoding and compilation not required and only a WAP 2.0 proxy suffices

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End of Lesson 03

Wireless Application Protocol (WAP1.1 and 2.0) Architecture

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Wireless LAN, Mobile Internet Connectivity, and Personal Area Network

Lesson 04

WAP Protocol Layers

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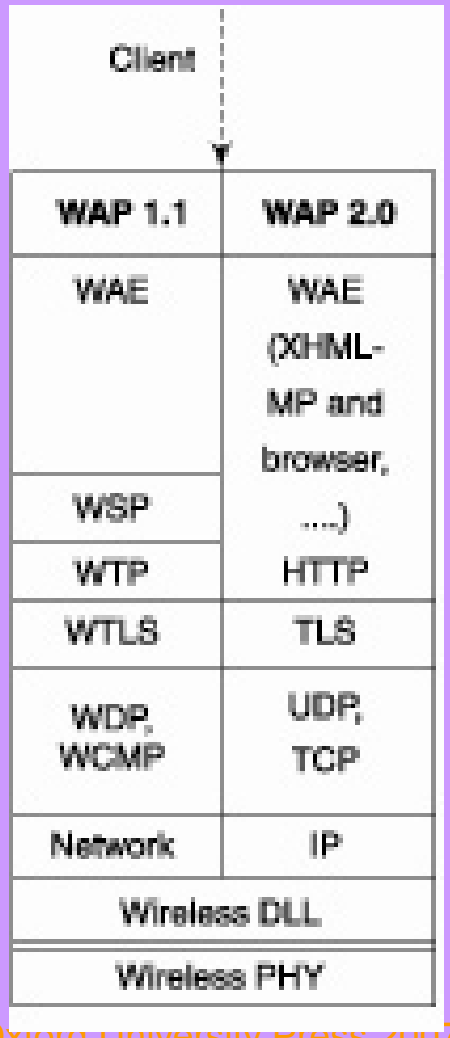
WAP 1.1 and WAP 2.0 Protocol Layers



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WAP transmission physical layer

- Can be HSCSD
- SMS
- GPRS in GSM
- CDPD
- 3G bearer (SMS, MMS, …) services

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Networking Layer Protocol WDP (wireless datagram protocol)

- A datagram gives independent information and is stateless
- The data of a datagram is sent by a connectionless protocol
- WDP (wireless datagram protocol) a connectionless information
- Similar to UDP in TCP/IP suite
- Used for multicasting a datagram on the network

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Networking Layer Protocol– WCMP (wireless control message protocol)

- Similar to ICMP
- WCMP employs a datagram with a WCMP header when sending the messages for querying to find information, reporting errors, making route address advertisement, and for a router seeking (soliciting) messages

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Networking Layer Transmitted WDP datagram

- A header and then user data which is received from upper layers at the device
- Consists of a source port, a destination port (optional), source address (an identifier IP address or telephone number), destination address (optional), length of data, and checksum bytes for the header (to check erroneous receipt of header)

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Networking Layer

- An error-code as per the error is also reported to the upper layer, for example, in case the datagram could not reach its destination

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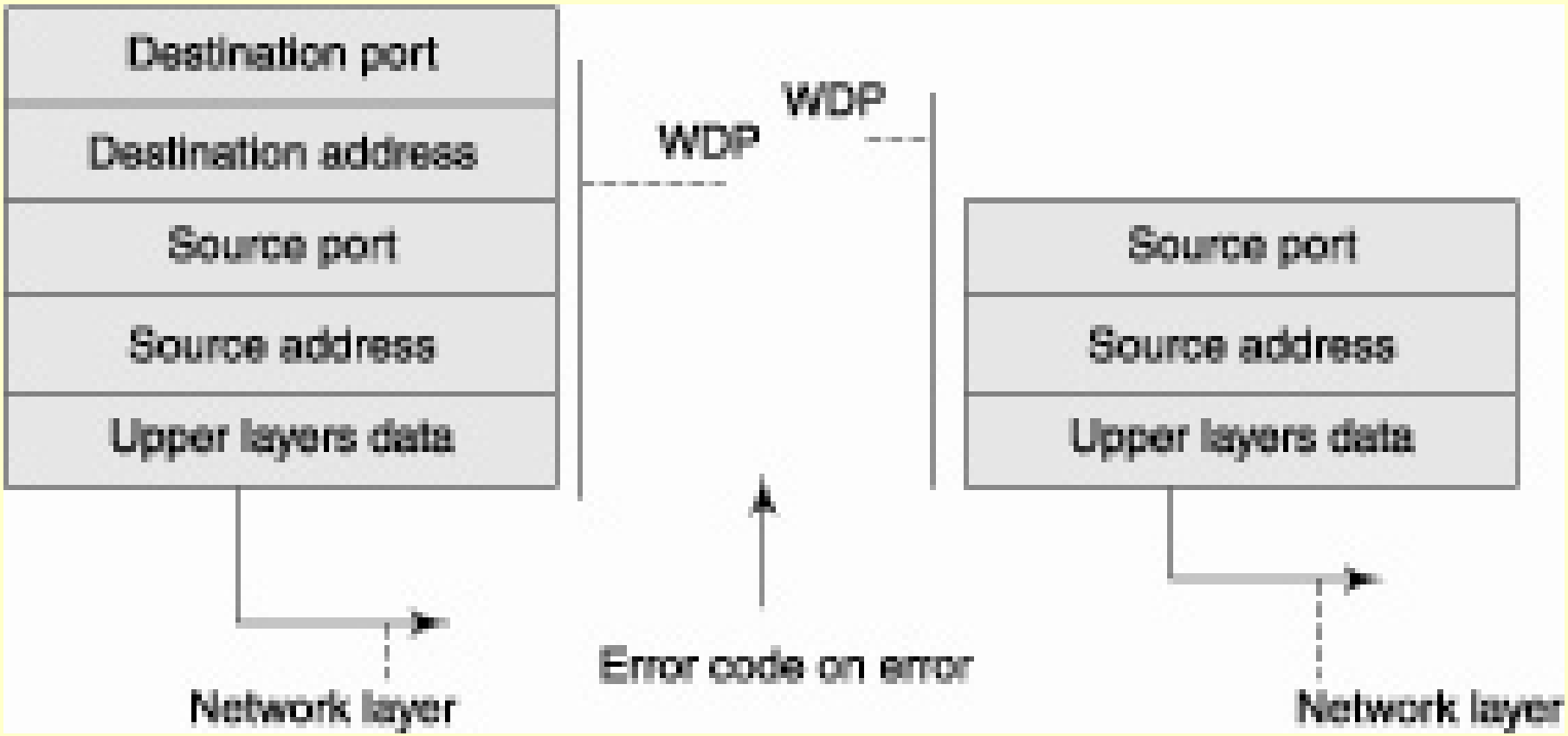
Networking Layer header



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Secure session establishment

- Must before the data from upper layers (WAE, WSP, and WTP) that are above the WTLS layer is transmitted through gateway or proxy to other end peer and received through gateway or proxy to the upper layers (WTP, WSP, and WAE)

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Wireless Transport Layer Security (WTLS) protocol

- Data transaction occurs between client device and gateway
- Assures integrity and privacy in transactions and device authentication

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Wireless Transport Layer Security

- WTLS layer maps to SSL (secure socket layer) in HTTPS
- SSL is also called TLS (transport layer security)
- WTLS supports TCP (transport layer protocols), WDP, and WCMP

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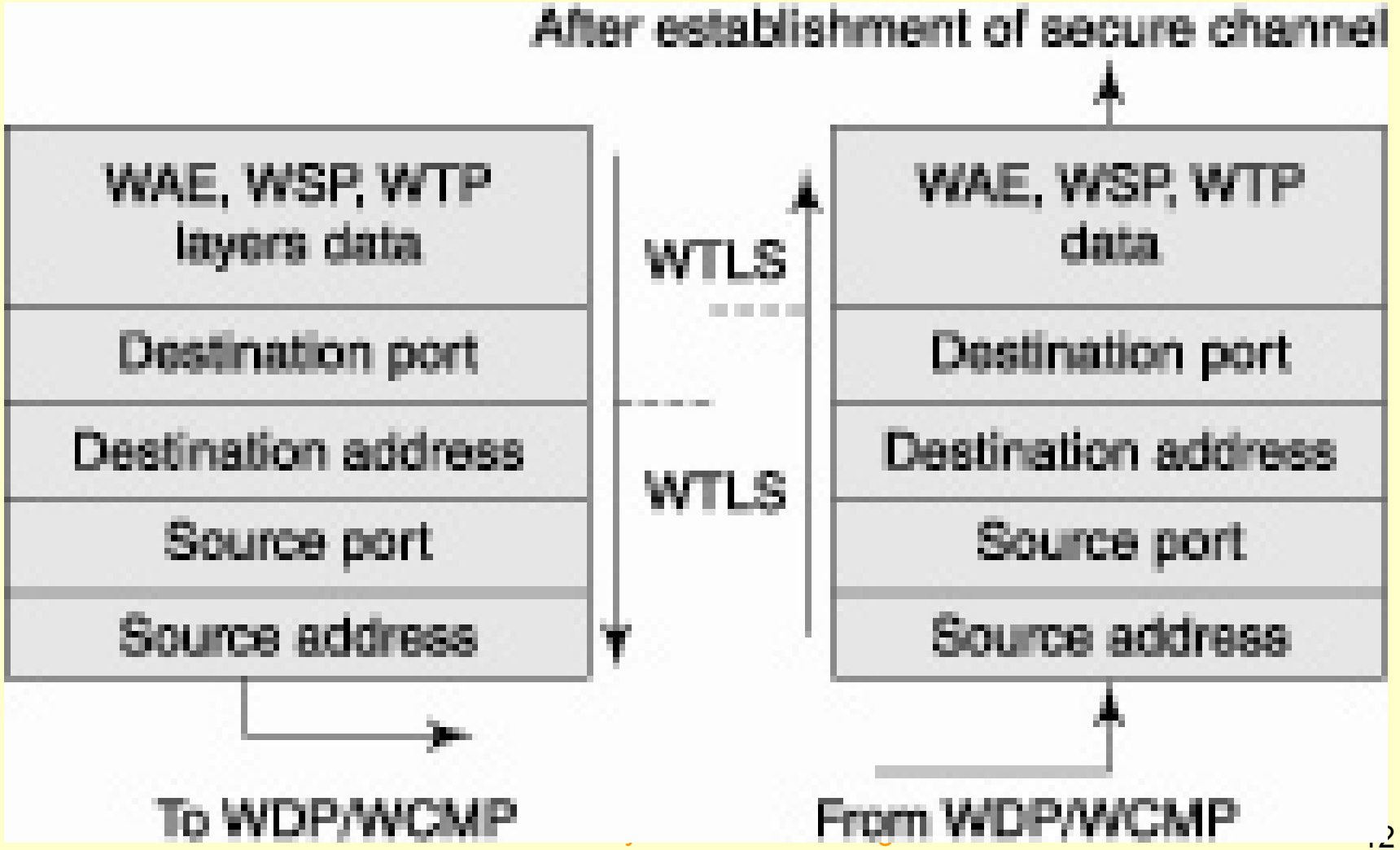
WTLS protocol header over the upper layer data in requests and WTLS protocol header in responses



WTLS specifications for establishment of the secure session

- Source device messages create process:

(i) source address and port

(ii) destination address and port

(iii) RSA or ECC (a proposed suite of algorithms for key exchange

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WTLS specifications for establishment of the secure session

(iv) IDEA or DES (a proposed suite of algorithms for ciphering the data)

(v) Compression method for data compression

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WTLS specifications for establishment of the secure session

- Other end messages for secure channel exchange for confirmation of *create* process as follows:

(i) sequence number mode

(ii) how many times key is refreshed and exchanged again

(iii) identification of session after establishment of the session

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WTLS specifications for establishment of the secure session

(iv) RSA or ECC (a chosen suite of algorithms for key exchange)

(v) IDEA or DES (a chosen suite of algorithms for ciphering the data)

(vi) chosen compression method for data compression

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WTLS specifications for establishment of the secure session

- On request from the other end, source device messages for secure channel public key authentication by a client certificate
- Source device messages to commit request
- Other end peer messages for commit confirmation request

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Wireless Transaction Protocol (WTP)

- Transmits data to WTLS in case of secure transactions and directly to WDP or WCMP
- Supports joining (fusion) of the messages and enables asynchronous transactions
- Supports abortion of the transactions and provides the information about the success or failure of a transaction to the sender

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WTP interface to ensure reliability of transactions– Class 0

- Three WTP service classes—0, 1, and 2
- Class 0— a source sends the messages with no response from the other end

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WTP interface to ensure reliability of transactions– class 1

- Source first invokes a transaction along with the request
- Device then obtains the confirmation of invocation
- Followed by the transaction for the resulting response
- The device sends the acknowledgement

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WTP interface to ensure reliability of transactions – Class 1

- The transaction removes duplicate data, provides retransmission as well as a transaction identifier
- Provides push services in which there is no acknowledgement of data by user, except that there is confirmation of invocation

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WTP interface to ensure reliability of transactions– class 2

- Source first invokes a transaction along with the request
- Device then obtains the acknowledgement of data (through gateway or proxy) from user
- Followed by a transaction for the resulting response
- The device sends the acknowledgement

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WTP interface to ensure reliability of transactions– Class 2

- The transaction removes duplicate data, provides retransmission as well as a transaction identifier
- Provides acknowledgement of two types— user acknowledgement and automatic acknowledgement

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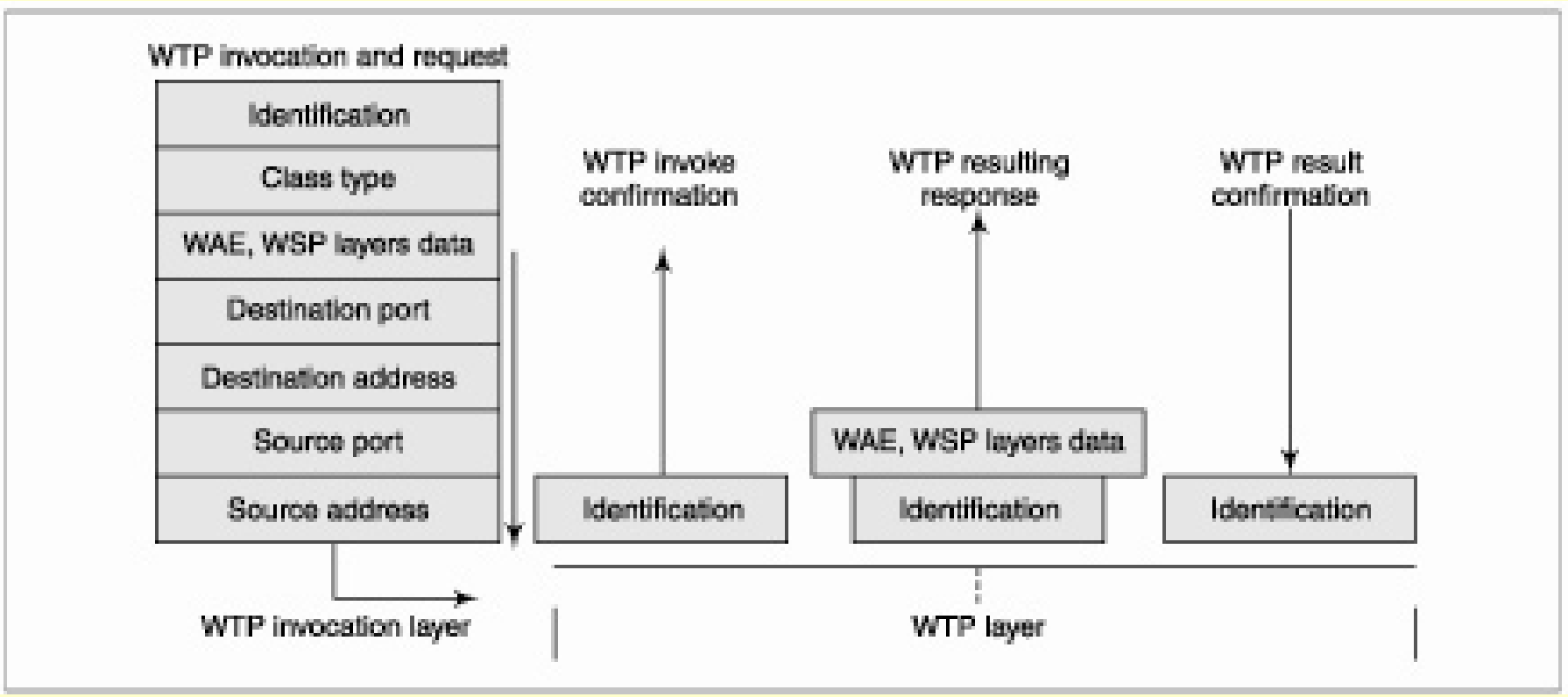
WTP headers when sending WTP invocation and request for results, confirmation of WTP invocation



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Wireless session protocol (WSP)

- Transmits data to WTP in case of thin client transactions or directly to WDP or WCMP
- WTLS serves as a layer above WDP when a secure transfer is required for a datagram

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Wireless session protocol (WSP)

- Like HTTP, supports stateless data transfers
- Enables a browser to get the packets from the server in any sequence

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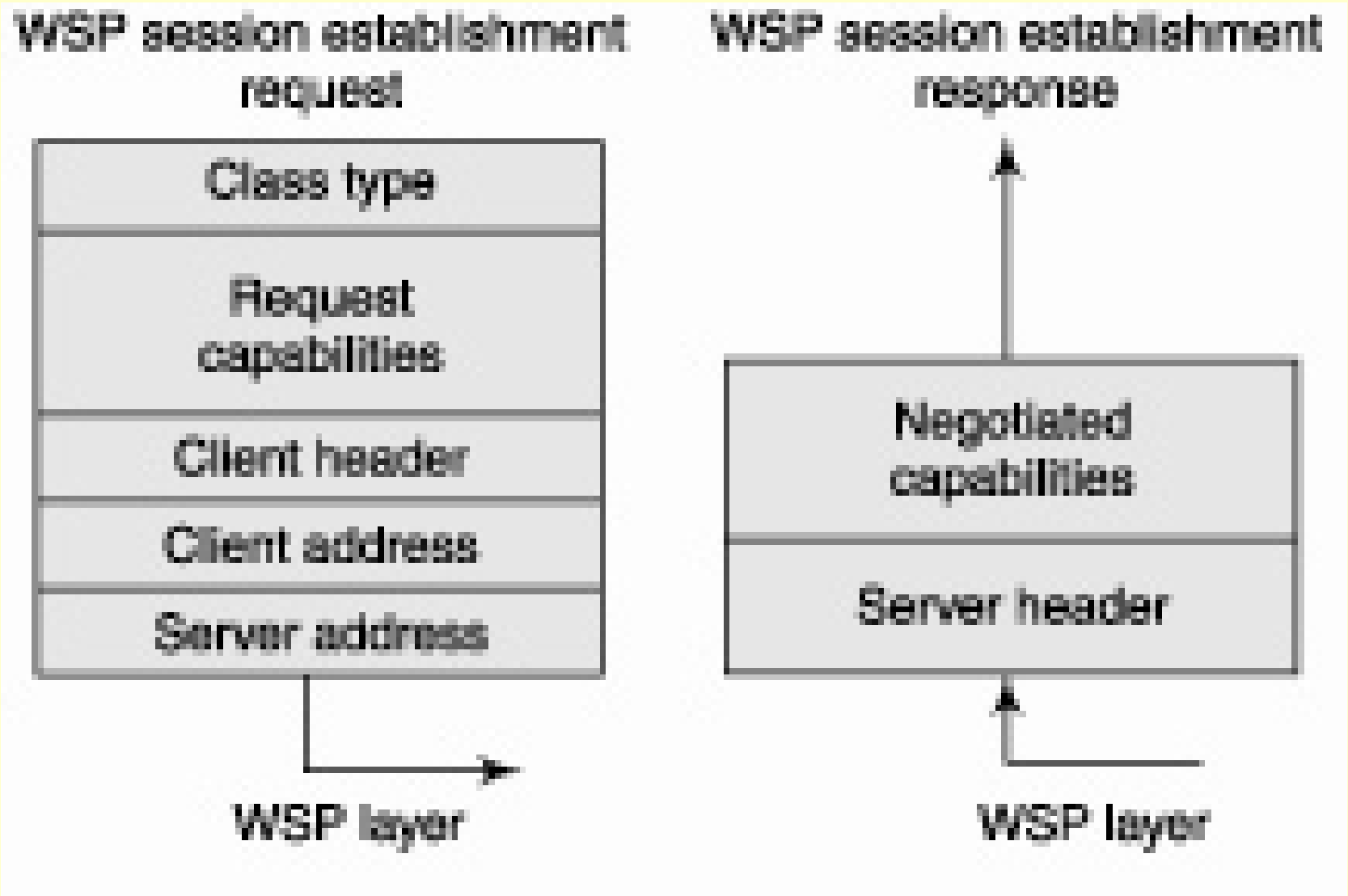
WSP protocol session connection establishment and resulting response headers



WSP

- Also supports asynchronous exchanges
- Multiple requests
- Push and pull mechanisms of data dissemination
- Capability negotiation
- Content encoding

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WSP

- Content type definitions
- WBXML (WAP binary XML)
- Possesses HTTP functionality

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WSP session

- Session is first established– use the functions of agreed common protocol
- An established session can be suspended and then resumed from the point at which it was suspended.
- A session can be terminated (released)

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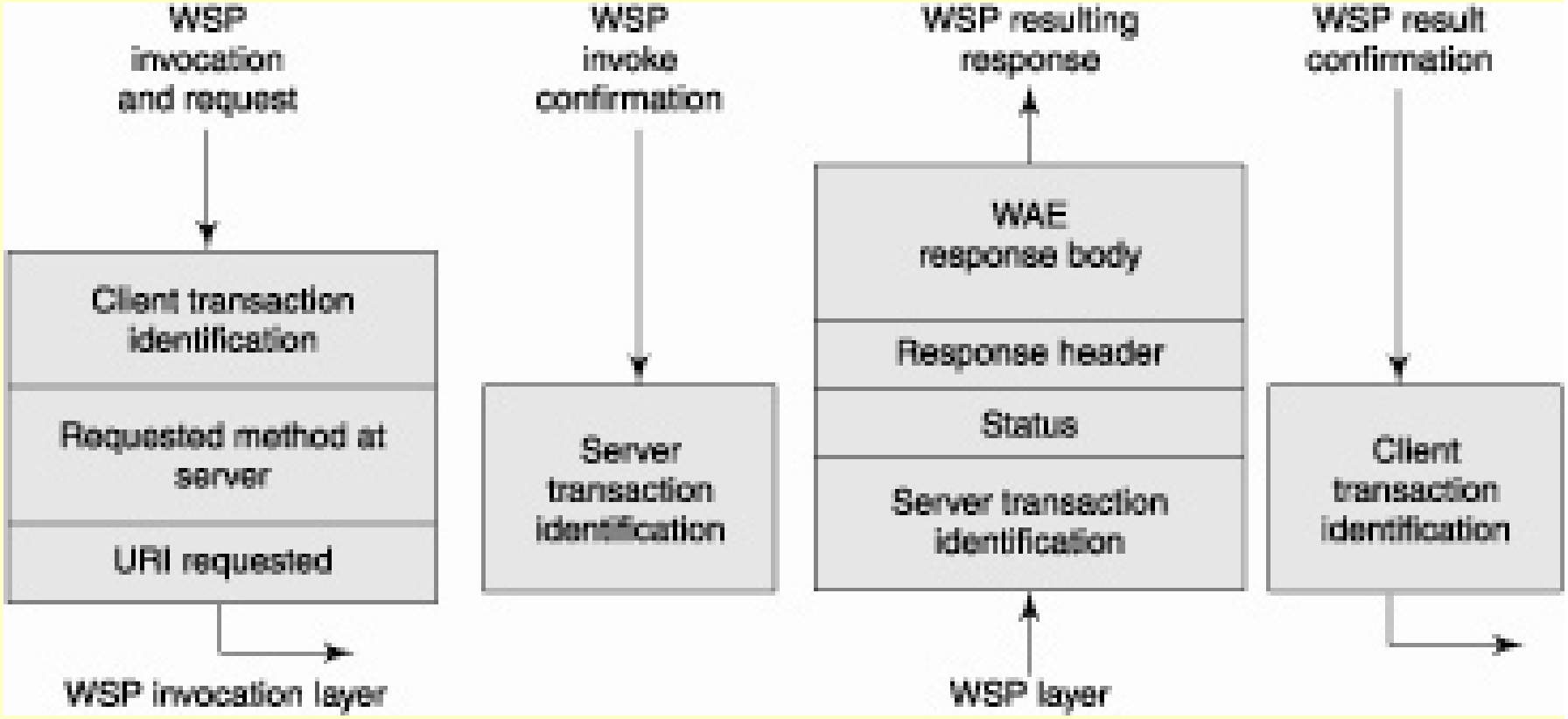
WSP headers when sending WSP invocation and request



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Three WSP service classes

- Class 0—This class is for a source sending the unconfirmed push
- Supports session suspension, resumption, and management
- The messages sent from the source do not get any response from the other end

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WSP service classes 1 and 2

- Class 1—for a source sending the confirmed push
- Class 2—for a source supporting session invocation, suspension, and resumption

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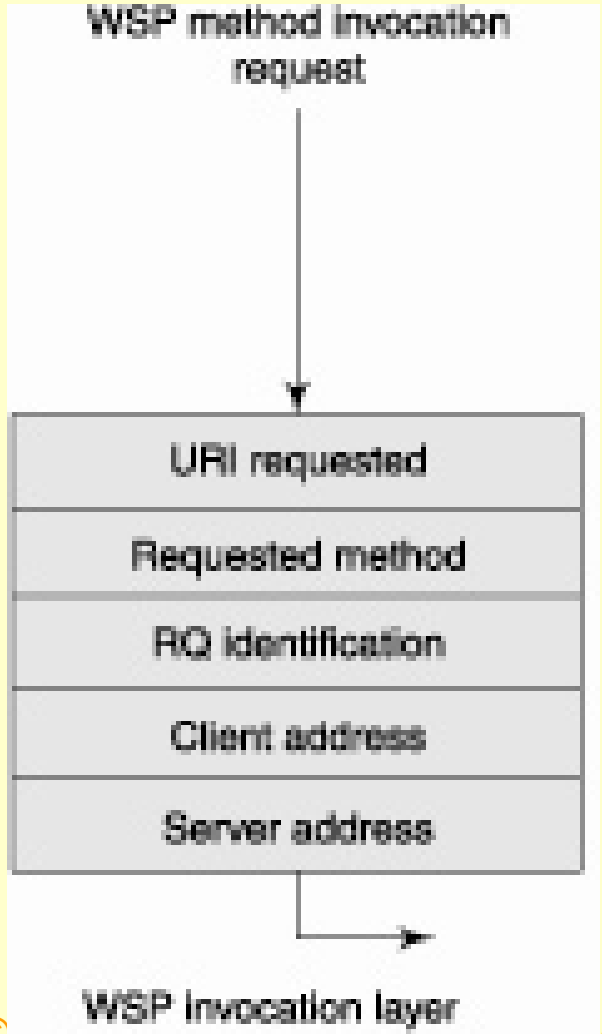
WSP header for the method invocation and request to server



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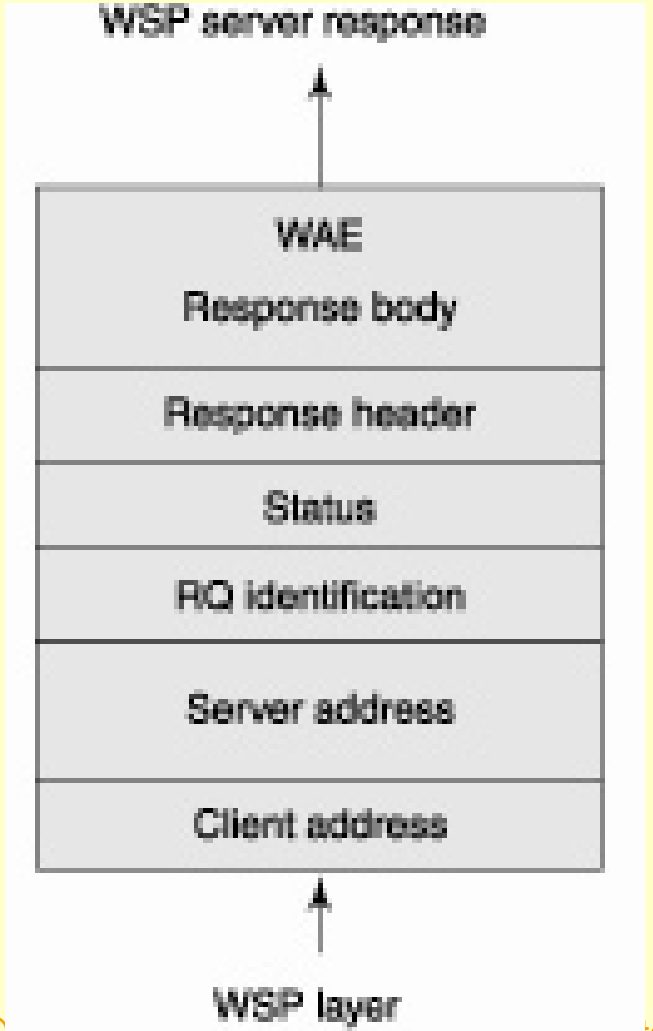
WSP header for server response



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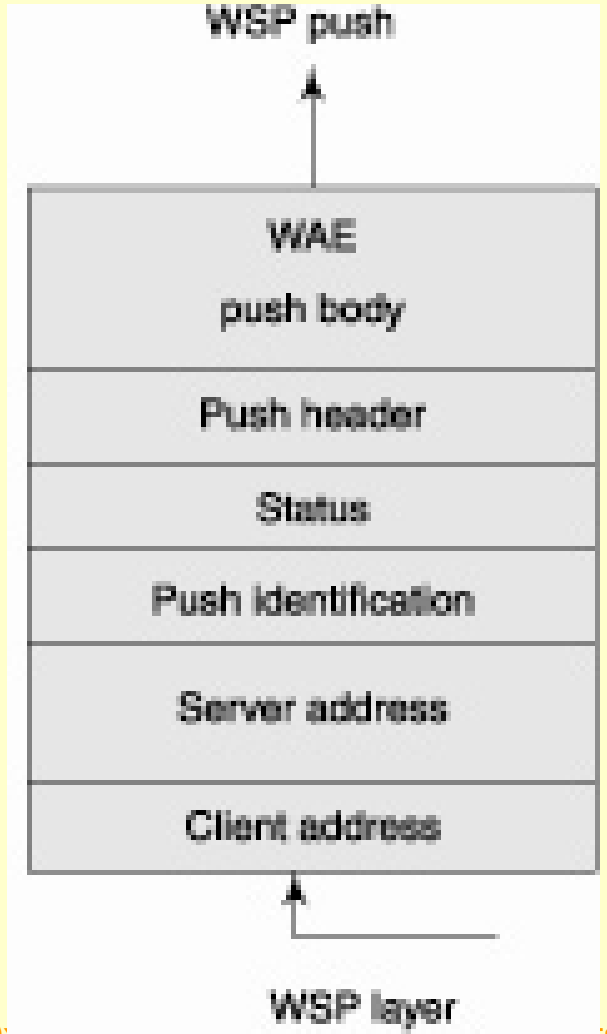
WSP header when WSP Push



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WAP Push

- The constraints of mobile devices are low computing capability and narrow bandwidth network connection with intermittent loss of connectivity
- WSP in WAE used for WAP user agent push service
- WTA events used to push the data to the device

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WAP Push OTA (over the air)

- A simple protocol sub-layer in WSP
- Provides authentication of the push initiator (server) and also helps in selection of the pushed contents
- The protocol handles push-session-request, connect, suspend, resume, and disconnect functions
- Handles push, server-confirmed push, abort, and unit-push functions

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Summary

- Physical layer– HSCSD, GPRS, CDPD and 3G Bearer service
- WDP datagram layer
- WTLS transport layer security protocol layer
- WTP transaction protocol layer
- WSP session layer
- WTA Push and WTA Push OTA

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Lesson 04

WAP Protocol Layers

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Wireless LAN, Mobile Internet Connectivity, and Personal Area Network

Lesson 05

Wireless Markup Language (WML) and WMLScript

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Markup by tags in between a text

- Done to give the characteristic information
- A specific meaning to the text
- Define the specific function or action of the text
- The definition of attribute along with a tag provides the data or additional characteristic information for the text within a pair of start and end tags

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Mobile Device Characteristics

- Narrow bandwidth network connection with intermittent loss of connectivity
- String parameterization and state management, for example, display sate management
- State management– an important feature in mobile devices [Refer Example of state management]

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Mobile Device Characteristics

- Constraints of limited user input and output facilities [T9 keypad input, text presentation in a layout with small display screen, or image or pictogram presentation on a screen with small resolution]
- Constraints of computational resources and limited memory

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WML

- Used to create the cards for mobile application (s)
- Two versions– WML 2.x and WML 1.x
- WML 2.x includes XHTML-MP which includes XHTML
- WML 1.x does not include XHTML

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Information in WML

- A collection of decks and cards
- A WML deck is saved in a file with extension wml
- Each file contains one deck
- For example, a welcome deck can be saved in a WML file welcome.wml

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WML deck

- Can have number of cards
- There is a navigational link from one card to another
- WML provides for management of the navigation between cards and decks

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WML card

- A scaled down set of procedural elements
- Used to control navigation between cards
- A card represents an interaction with the user and the deck contains the cards

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WML card

- Provides the content (for example, a program, command, data, string, or image)
- Supports variety of formatting commands as well as layout commands
- Commands are defined by tags and attributes

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WML card

- Provides user interface for mobile devices with constraints as mentioned in the preceding text
- Organizes similar to deck and cards

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WML parser

- Parses the tags, attributes, and underlying text within the tags present within the deck or card
- The parser is a part of a browser or server

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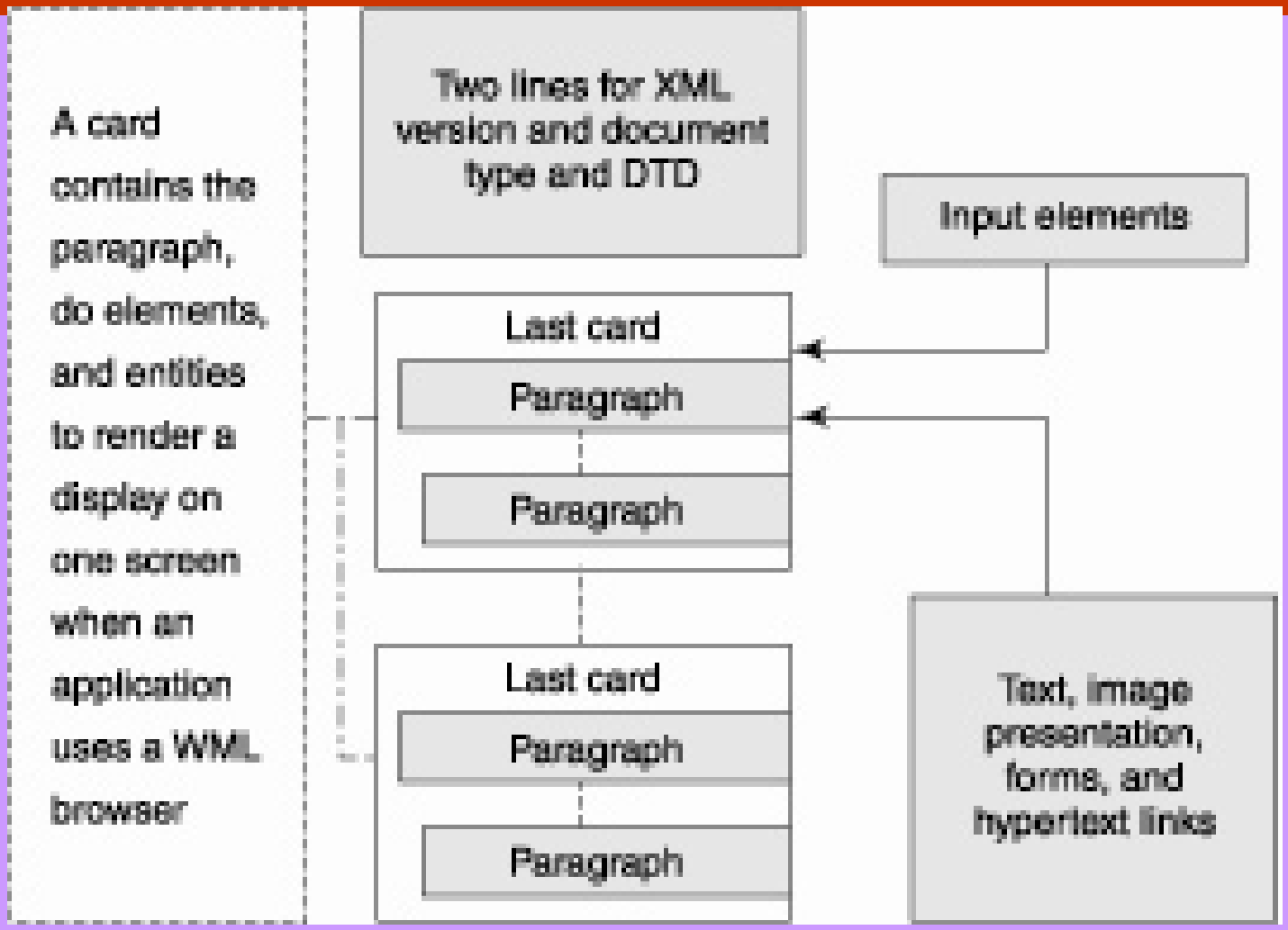
The format of a WML deck and card



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WML card

- First validated against its declared document type using WML 1.3 DTD (document type definition) before parsing
- Parsed data, information, and contents used to give input to a Java program for the application or server which runs *method*(s) at the browser or server
- Browser program runs at the client

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WinWAP

- WinWAP has an Emulator which is an alternative program used for emulating the actual run at the mobile client and runs on a PC
- WinWAP is for a computing system running on PocketPC, WindowsMobile 2003, or Windows operating system

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Application Running using WML Card

- A WML card containing a client-request is transmitted and response is received from server
- Element *do* is used to process the text within the do tags
- The element *label* is an attribute which defines a text, the purpose of which is simply to specify the incoming text or action

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Example

```
<do>
<p mode="wrap" label = "Show Welcome
    Message">
<go href = “#FirstCard”>
</p>
</do>
```

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Application Running using WML Card

- Label text is not the input to any program or processing element
- For example, label = “Show Welcome Message”
- This means that next action in the sequence of actions for navigation to the card is showing the welcome message
- The navigation is by <go href = “#FirstCard”>

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WML Tags

- <b>, <u>, <i>, <big>, <small>, , and for bold, underline, italic, big, small, strong, and emphasis rendering, respectively, for a text-display
- HTML anchor tag <a with attribute href = ….> is used for linking and navigation in WML also

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WML Tags

- <timer>— the actions on events are by the tags <ontimer>, <oneventbackward>, <oneventforward>, and <oneventpick>
- The renderings after the actions on the events occur as per the interior paragraph entities

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WMLScript

- A script language in which each line is loaded in computer and is executed at run time only
- There is no pre-compilation
- WMLScript in WAP is similar to JavaScript and is used for client-side scripting

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WMLScript

- It obviates the need to communicate with the server by sending a request and waiting for the response generated by an application running at the server

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WMLScript

- Can embed the markups in WML
- WAP browser displays the page having WML and WMLScript
- WMLScript used to open dialog box so that the user can input data or text
- Also used for generating error messages
- The execution of WMLScript is fast

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Example of the division *z* = *x* + *y* carried out using WMLScript

```
extern function divide (varCompute x, y)
{
var z = x/y;
WMLBrowser.setvar (varCompute, z)
WMLBrowser.refresh ( );
}
```

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Standard Library Function—WMLBrowser

- Has the functions to control the WML browser or to get information from the browser

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Standard Library Function- WMLDialogs

- Has the functions which display the input boxes to users, also provides for alert and confirmation messages

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Standard Library Function—WMLLang

- WMLLang library has the core WML functions, for example, for converting a data type integer to string character

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Standard Library Function– WMLString

- Has the functions that help in concatenation, truncation, picking of select portions, and manipulation or finding the length of the strings. An example is the find() function to know whether a sub-string is a part of a string

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Standard Library Function– WMLString

- If yes, then the function returns the index of the first character of the match in the string, otherwise it returns –1
- String.find (“09229122230”, “30”) returns 9 which is the index of first character of the match in the string

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Standard Library Function– WMLString

- String.find (“09229122230”, “39”) returns –1 since there is no match between sub-string characters and the string
- var strlen = String.length (“WELCOME TO ABC MOBILE) returns 21 because number of string characters are 21
- Space is also a character

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Standard Library Function– WMLURL

- Has functions for using relative URLs or absolute URLs for finding the port number or for testing whether a URL is valid or not. [For example, http://www.microsoft.com/msoffice/winword/ is a relative URL
- Full form http://www.microsoft.com/msoffice/winword/newfile.doc in which the file name newfile.doc is also mentioned in the end after the winword/ is called absolute URL

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Standard Library Function– WMLFloat

- Has the functions that help in performing floating-point arithmetic operations in case a specific WAP device supports floating-point operations, conversions, and calculations

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Summary

- WML deck
- WML cards
- A card method runs an application
- WML library functions

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End of Lesson 05

Wireless Markup Language (WML) and WMLScript

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Wireless LAN, Mobile Internet Connectivity, and Personal Area Network

Lesson 06

XHTML-MP

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HTML

- Not rigid in syntax
- For example, if the end tag corresponding to a start tag or an inverted comma is missing or some other syntax error is present, then also the HTML browser will interpret it somehow
- Makes the required assumptions

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HTML

- Has limited number of tags
- Does not support very small or multiple screen sizes or reduced pixel resolution required to fit an image or pictogram on the screen

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HTML

- Does not support multiple ways of user inputs
- Does not let the user give inputs by using different keys, keypads, stylus with touch screen, and voice while interacting with the device
- Moreover, HTML does not allow state transitions based on user inputs and displayed information

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XML

- Rigid in syntax and needs the document to be *well-formed* (syntactically correct)
- Does not make any assumptions
- Uses the corresponding DTD for validation of the document

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XML

- XML can thus be encoded into other formats and then retrieved back into original format
- For example, it can be encoded in WBXML for transmission and WBXML can be decoded back into XML on reception

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XML

- Is in document form
- Is textual and structured.
- Extremely valuable in developing GUIs, VUIs, or any other human interface with computer

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XML

- Due to the feature of extensibility, XML supports the use of very small or multiple screen sizes or reduced pixel resolution
- It also supports multiple ways of user inputs, that is, inputs from different keys, keypads, stylus with touch screen, and voice inputs when a user is interacting with the device

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XML

- Due to its extensibility feature, XML has unlimited number of tags and allows state transitions based on user inputs and displayed information
- XLINK feature of XML facilitates the state transitions and display of nested menus

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XML-based languages

- SyncML, Funambol, SMIL, and WML for enabling the development of the data synchronization applications, Java applications, multimedia interchange applications, and WAP device applications, respectively

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XHTML-MP (Extensible Hypertext Markup Language Mobile Profile)

- Deployed by WAP 2.0
- XHTML has two forms—XHTML basic and XHTML-MP
- XHTML basic– HTML with strict syntax
- XHTML-MP is for mobile devices and PDAs

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An XHTML document

- Can be parsed using a standard XML library and processed like any other standard XML document but using the same set of tags as in HTML
- XHTML 1.1– a W3C recommendation since middle of 2001

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XHTML

- Can be partitioned into modules and provides for navigation from one module to another
- This feature is characteristic of XLINK
- For example, WML deck is partitioned into cards and navigation from one card to another is permitted through hyperlinks

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XHTML

- XHTML basic does not support scripting but supports the basic forms with POST/GET features as in case of HTML
- It supports tables but not the client-side style sheets since small devices are assumed to possess small computation resources
- Frames are also not supported in basic XHTML

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XHTML 2.0

- New features added
- The elements can function as a hyperlink or with src attribute
- The src is attribute which specifies a source file, for example, a jpg image file
- This feature is similar to the cards in WML
- XHTML 2.0 user agent parser is compatible with XHTML 1.1

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XML-based user input specification

- HTML form will be replaced by XML-based user input specification and can be displayed as per user specfications and on the appropriate display devices
- XFORMs permitted

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XML-based user input specification

- XFrames– new features compared to HTML frames
- The document object model (DOM) events– now XMLEvents and will use XML DOM

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XHTML 2.0

- Has a number of modules
- Edit, presentation, meta information (abstract or title of information, which specify how and what the full information are) of a document, text, list, table, forms, structures, targets, bi-directional text, style-sheets, server-side image map, client-side image map, scripting, and link

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Summary

- HTML Not rigid in syntax
- XML rigid
- XHTML has two forms—XHTML basic and XHTML-MP
- XHTML basic— HTML with strict syntax
- XHTML-MP— for mobile devices and PDAs

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End of Lesson 06

XHTML-MP

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Wireless LAN, Mobile Internet Connectivity, and Personal Area Network

Lesson 07

Bluetooth Enabled Devices Network

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Bluetooth

- Derived from the name of a Danish king
- The king Harald Blatand which means Bluetooth in English reigned before 1000 A.D.

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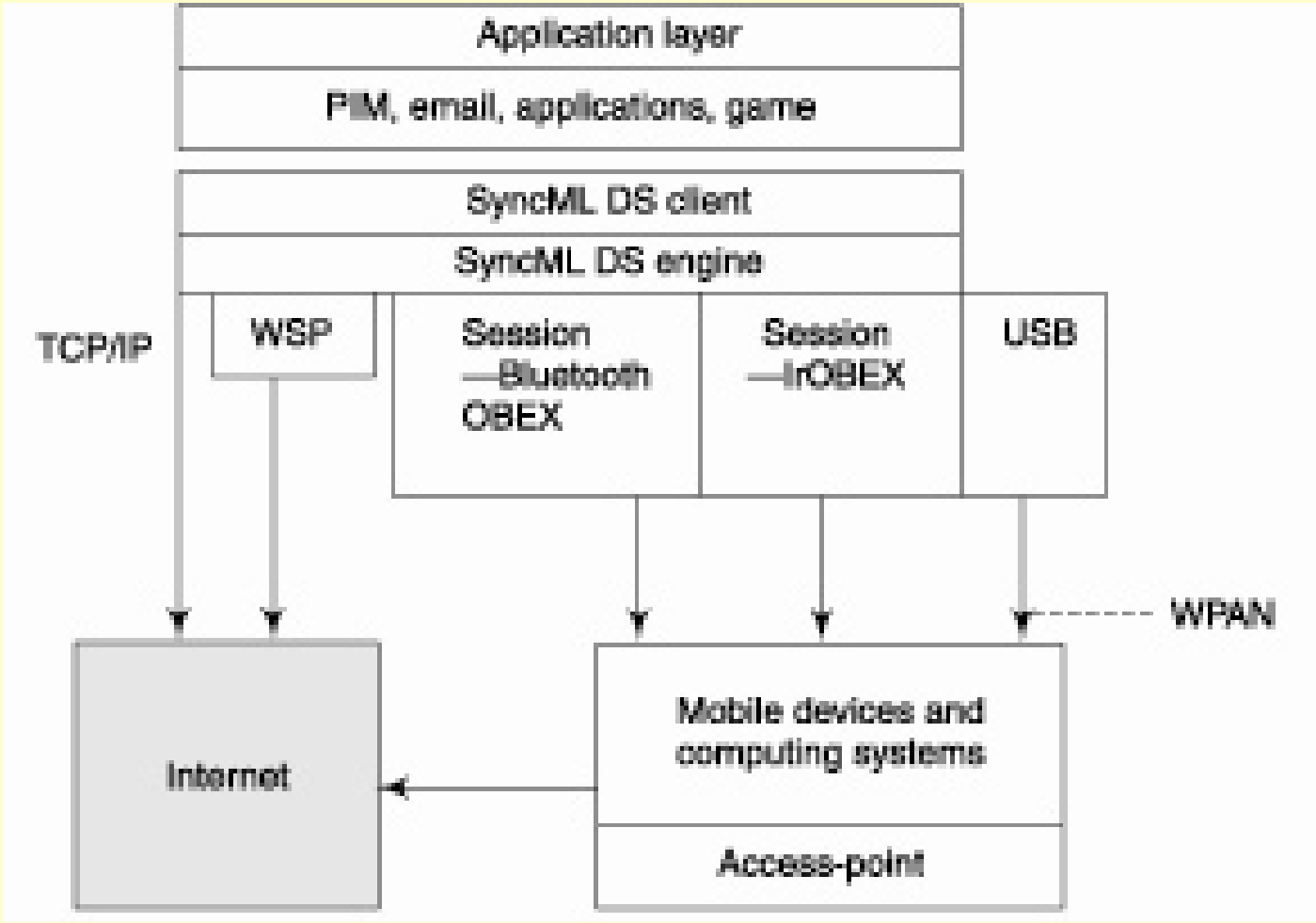
Data synchronisation between the mobile devices and computing systems in a WPAN



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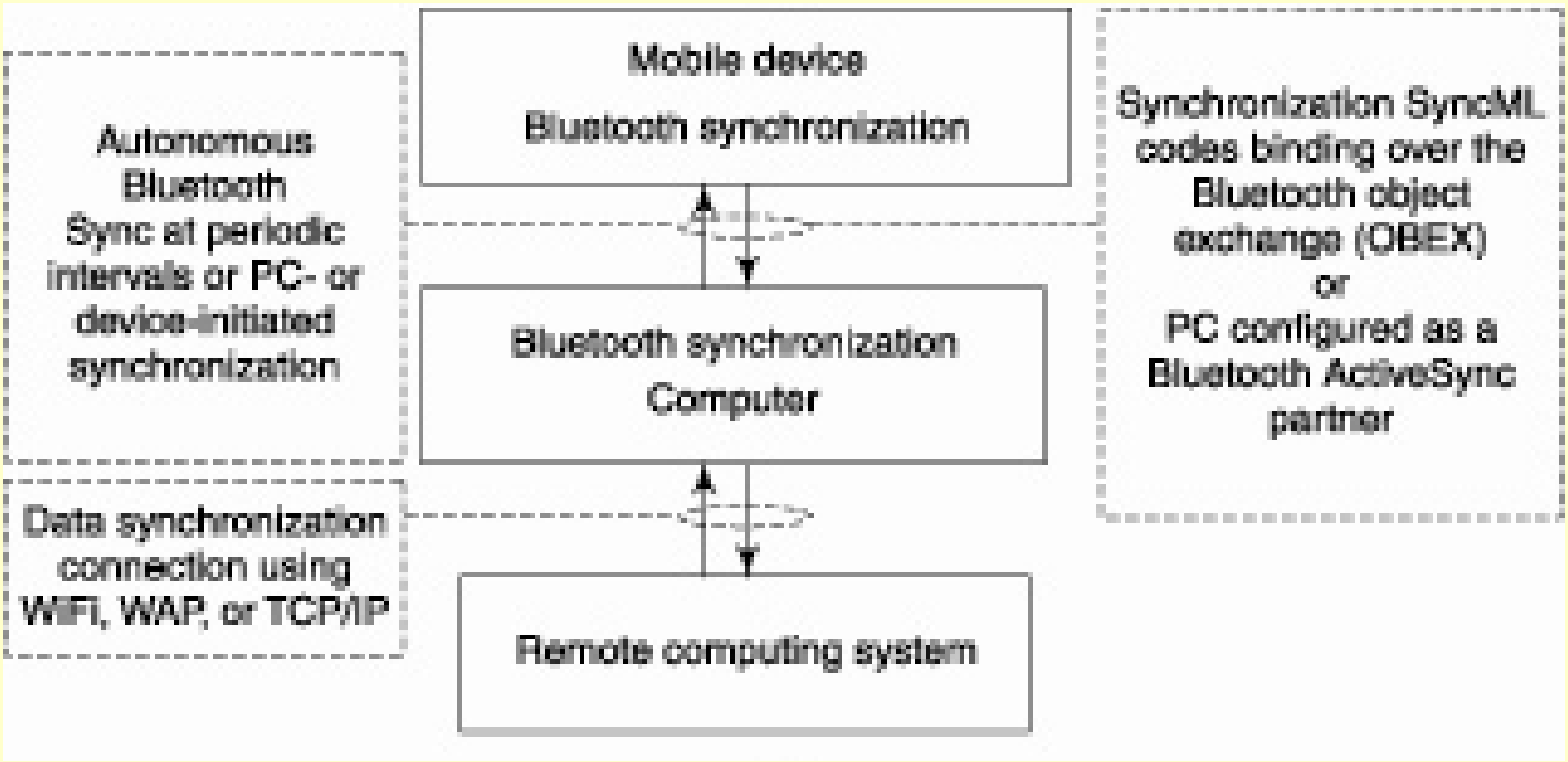
Synchronisation of remote system with the Bluetooth devices



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Bluetooth devices network

- Any device can function as master or slave
- The device which first establishes a piconet becomes master and others which discover the master become slaves in the piconet
- Slave means that the clock of the master functions as reference for synchronization

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Master

- Synchronizes all active devices and there are identical hopping sequences of their frequencies for each device's radio (transmitter)
- A hopping sequence defines one channel
- There can be a maximum of eight devices with a master in piconet and a maximum of 79 channels in Bluetooth networks

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Piconet and scatternet

- Piconet– Bluetooth devices network with the devices within a distance of about 10 m
- Scatternet– an ad-hoc network formed by various piconets within 100 m through a Bluetooth-enabled bridging device

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Example of Piconet of 3 active Bluetooth devices and a master

- Each device synchronised and using same hopping sequence of their frequencies forming a fixed infrastructure network architecture
- Two are in park/hold state and Three are in standby mode

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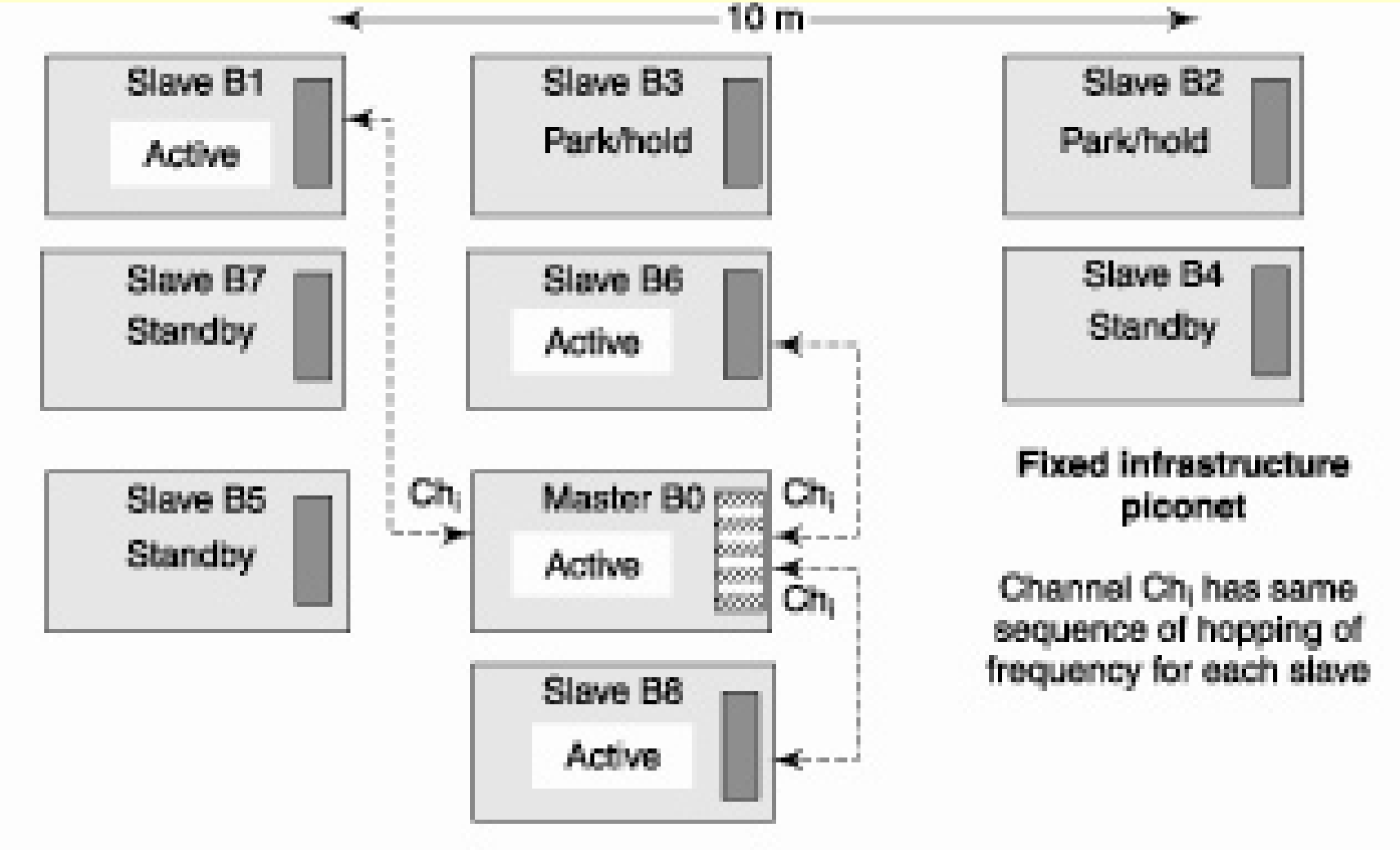
Piconet of 3 active Bluetooth devices and a master



State of devices in a piconet

- Standby
- Active
- Park
- Hold
- Sniff

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Standby

- Waiting to discover the master and thus the piconet
- No RF signal communication is taking place)
- Device is yet to be assigned an address in the piconet

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Active state– one of the three modes

(a) Inquiring– (carrying out discovery broadcasting in all neighbourhood and listening to the response for finding out a radio channel to connect

(b) Paging – sending a page specifying the relationship with master after discovering the channel

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Active state– one of the three modes

(c) Connected and performing data transactions–

- When a device is discovered and becomes an active device
- 3 bit address called AMA (active member address) assigned by the master device
- 000 reserved for use when a broadcast to all active devices takes place

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Active state device

- Listens the data in the piconet at short intervals
- The messages are transmitted sixteen hundred times in one second

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Park state

- Device already discovered the piconet
- But not communicating at present
- Is held in power-saving mode
- Assigned a 3 bit address called PMA (parked member address) after being released of the AMA
- Retained as a member of piconet
- To save power, it reduces duty cycle of the bit rate (clock frequency)

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Hold state

- Hold state retains the AMA but suspends asynchronous connectionless link (ACL)
- It maintains synchronous connection oriented (SCO) link
- Reduces power dissipation for communication in this piconet when there are no packet exchanges with the master

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Sniff state

- Retains the AMA
- Operates at high power level
- Sniffing means listening to the existing Bluetooth device in the vicinity
- Sniffs the data of communicating piconet at large programmable intervals as compared to active state short intervals

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Example

1. At t_0: A Bluetooth device B0 discovers a device B1 within 10 m
2. At t_1: Then the devices B2, B3, B6, and B8 also reach within 10 m and join the network

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Example

- At t_2: After some time, since B2 and B3 are not exchanging objects, they go to park state to save the power
- At t_3: After some time, the devices B7, B5, B4, B9, and B10 move in sequence within 10 m but they have to discover the network

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The states, devices, AMAs, PMAs in the piconet

- After t_0: B0 will function as master in the piconet as it first discovered the device B1 in its vicinity
- After t_1: Slaves B1, B6, and B8 will be in active (either inquire, page, or connected) states, master can assign AMAs 001, 100, and 111

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The states, devices, AMAs, PMAs in the piconet

- After t_2: Slaves B2 and B3 are in park state, PMAs can be 001 and 010
- After t_3: B7, B5, and B4 are in standby mode waiting to discover the service network, yet to be assigned member address by the master

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Other piconet outside the Piconet

- B9 and B10 cannot be a part of this piconet and will form another piconet operating at another channel with another sequence of frequency hops

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Master and slave devices moving out to another piconet

- Master becomes slave in a new piconet
- When it moves to another established piconet, the communication in the previous piconet freezes

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Master and slave devices moving out to another piconet

- The device which rediscovers another device then becomes master in the previous piconet
- When a slave moves to another area, it communicates its unavailability to its master
- It then synchronizes with a new piconet

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Scatternet

- An ad-hoc network formed by the bridging devices
- A bridging device connects two piconets
- Any Bluetooth device can function as a bridge in order to form the ad-hoc network
- In such a network, two devices in two piconets communicate as in a peer-to-peer communication

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Scatternet

- The two devices use two different channels (two different hopping sequences from among the 79 provided)
- Each piconet uses FH-CDMA so that there is a distinct hopping sequence with respect to other piconets in the scatternet
- Therefore, there are no collisions between signals in two piconets

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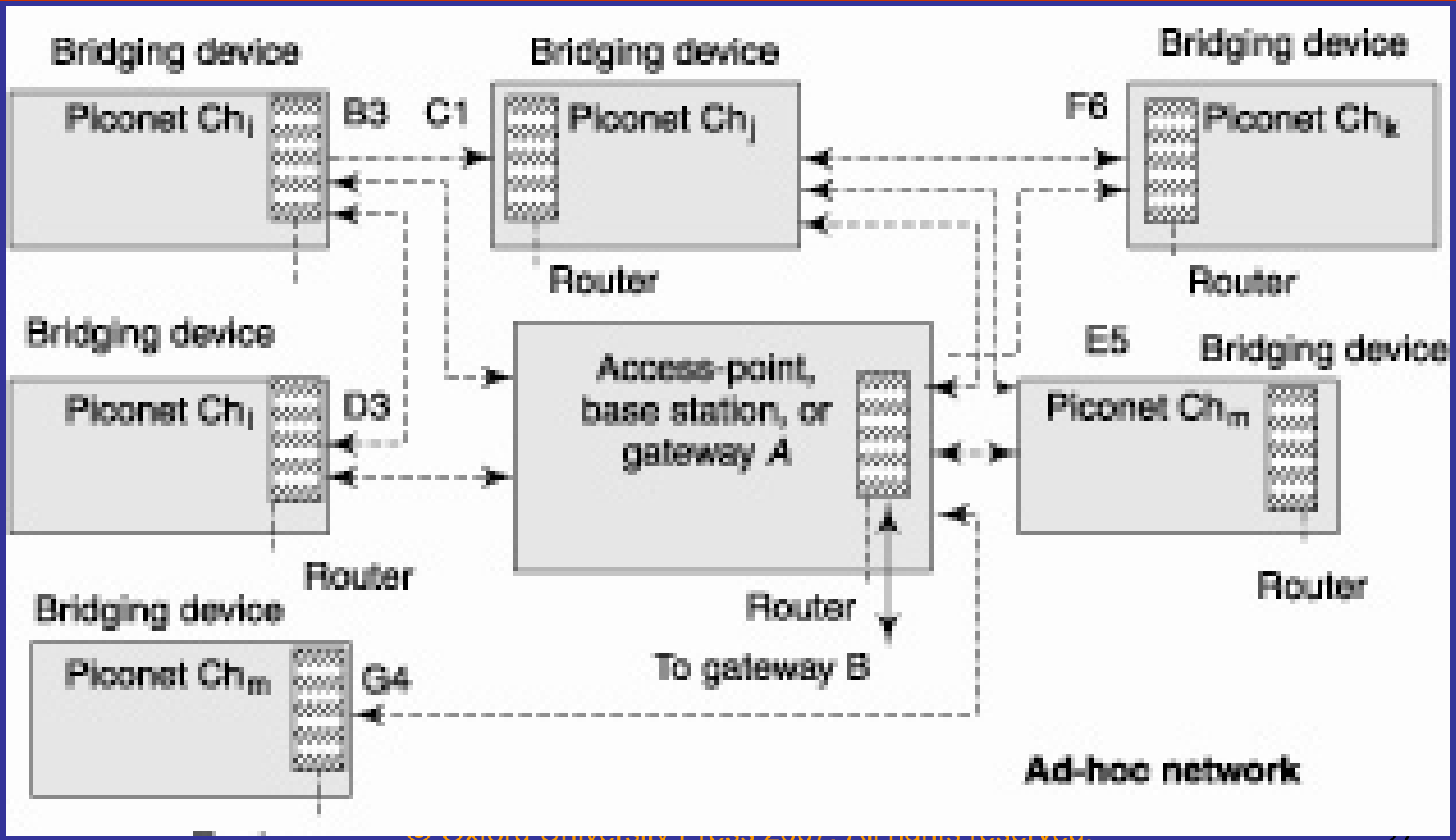
Bluetooth devices ad-hoc network (scatternet) through bridging devices



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Ad-hoc network architecture of Bluetooth-enabled devices

- Formed by the bridging devices
- Six piconets consisting of the devices B0, …, B7, C0, …, C7, D0, …, D7, E0, …, E7, F0, …, F7, and G0, …, G7
- Scatternet forms with B3, C1, D3, E5, F6, and G4 as bridging devices

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Summary

- Bluetooth devices network
- Piconet– within about 10 m
- Standby, Active, Park, Hold, Sniff states
- Scatternet– an ad-hoc network formed by various piconets within 100 m
- Bridging Devices between the piconets

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…Summary

- Any device can function as master or slave, first establishing device in a piconet becomes master
- Maximum of eight devices with a master in piconet
- Maximum of 79 channels in Bluetooth networks

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Bluetooth Enabled Devices Network

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Wireless LAN, Mobile Internet Connectivity, and Personal Area Network

Lesson 08

Bluetooth Protocol Layers

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Bluetooth protocol IEEE 802.15.1 specifications

- A Bluetooth device has number of protocols that can be used at the application, presentation, session, transport, network, data link, and physical layers (layers 7-1)

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Protocols at the application layer

- vCard
- vCal
- Telephonic network protocol
- Device management protocol
- SyncML, SyncML Client, SyncML Engine

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Functions of Protocol Layers

Application
- vCard, vCal-telephonic
- Network
- Device management, SyncML client, engine
- Modem commands to RFCOMM serial

TCSP
- Telephony control specification protocol

BNEP
- Bluetooth network encapsulation protocol

Baseband
- Fast FHSS algorithm
- Establishment of connection
- Packets formation
- Timing control for synchronization
- Basic QoS maintenance

L2CAP
(logical link control and adaptation protocol)
- Multiplexing data of higher layer protocols.
- Segmentation and reassembly of packets.
- Transmission management to a group of devices.
- Communication over the host ACL
- QoS management

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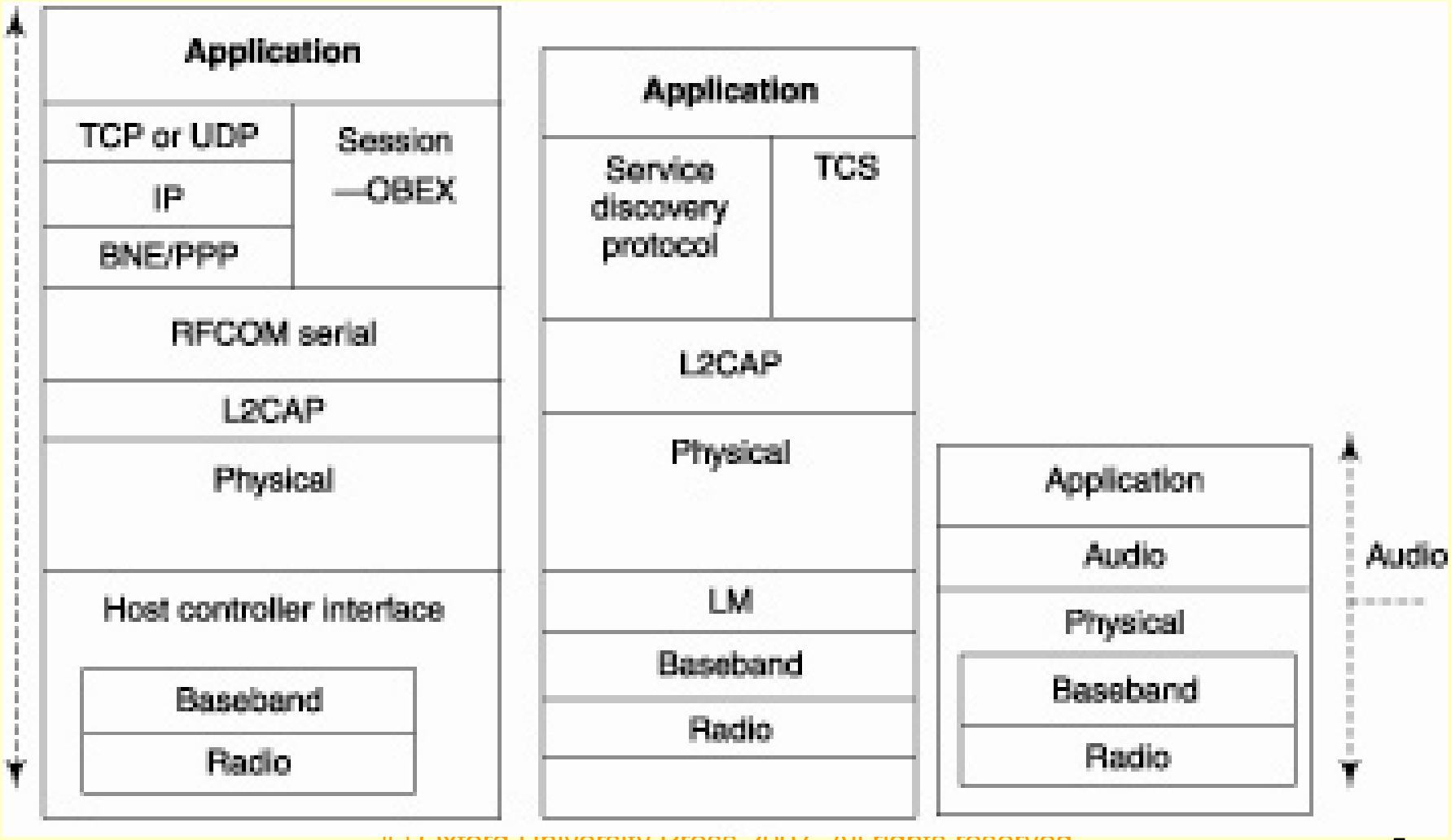
Host protocol layers and other protocol layers between the object client, device and server



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Physical layer

- Responsible for transmitting header fields encapsulating the payload and payload
- Payload– means data to be transmitted after passing through the layers 7 to 2 and retrieved at other end after passing through layers 2 to 7

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Bluetooth device physical layer has three sub-layers

- Link manager or host controller interface— sub-layer responsible for interfacing with the upper layers
- Baseband— another sub-layer generates the baseband signal used for transmission
- Radio — Another generates the radio signals as per the data bits from or for the MAC (layer 2)

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Radio

- Transmits packets received from baseband sub-layer
- At the other end of the link, it receives
- Operate at the least required power levels so that the transactions may not be detected by a distant receiver of signals, thus maintaining confidentiality

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Radio

- Frequency hopping CDMA ensures negligible interference and least risk of jamming by distant sources

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Radio Sub-layer characteristics

- Frequency band– 2.4 GHz
- Maximum power levels for devices — 1, 2, or 3 corresponding to 100 mW, 2.5 mW, or 1 mW

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Radio Sub-layer characteristics

- Bluetooth radio — FHSS with each carrier separated by 1 MHz, 1600 frequency hops per second among 79 carriers, and frequency changing after every 1/1600 s or 625 μs
- Transceiver modulation— GFSK

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Radio Sub-layer characteristics

- Data transfer rates — 1 Mbps or less
- Range — 10 m in a piconet and 100 m in a scatternet
- Baseband— uses a fast frequency hopping algorithm and after 625 μs, the frequency of a channel changes according to a code which defines the sequence in which the carrier frequency has to change

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Baseband Two types of links two between Bluetooth devices

- ACL (asynchronous connectionless link)
- SCO (synchronous connection oriented) link
- ACL link provides best effort traffic
- SCO links provide real-time voice traffic using reserved bandwidth

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Baseband Packet

- Of about 350 bytes and has a payload of 2744 bits or 343 bytes, b0-b2743
- It has 68 bits access code plus 4 bit trailer to access code (or alternatively 72-bit channel access code) at the beginning
- It is followed by a 54 bit packet header
- Packet deploys FEC for correcting the transmission errors [refer Section 12.5.1.2]

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Link Manager

- Baseband and radio provide a link between master and slave
- The functions of the link manager—

(i) supervision

(ii) monitoring of power, synchronization, state, and mode of transmission,

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Link Manager

(iii) exchange of QoS parameters (for example, packet flow latency, peak data rate, average data rate, and maximum burst size) for L2CAP and higher layers and capability information exchange

(iv) handling device pairing

(v) handling data encryption and device authentication

- Table 12.3 for details [Refer section 12.5.1.3]

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Bluetooth host-controller interface (HCI)

- Manages the link between the upper layer and baseband and radio sub-layers of the physical layer
- It is hardware abstraction layer in place of link manager

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Bluetooth host-controller interface (HCI)

- Host controller interface (HCI) interfaces RF communication serial [3 wire UART (universal asynchronous receiver and transmitter) which is an RS232 emulation in RF communication] line and mode through L2CAP software layer

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MAC layer

- Data link control carried out using L2CAP
- L2CAP– to provide logical link control and provide an adaptation mechanism using Bluetooth
- Passes the segmented or reassembled packets directly to the link manager or HCI in case of host-controller-based system

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A logical-link adaptaion-request

- Received from upper layers at client device
- Then multiplexed and segmented as per available maximum transferable units (MTUs) at the baseband
- After this, the logical link adaptaion confirmation sent to higher protocol layers

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A logical-link adaptaion-request

- Then a link program request is sent to lower layer HCI or LM
- The link program protocol confirmation is then received back at L2CAP layer

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L2CAP

- Facilitates segmentation of packets while transmitting and reassembling of packets on reception
- Multiplexes the data between different higher layer protocols and manages forward transmission from a Bluetooth device to other devices

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L2CAP

- Does QoS management for higher layer data
- [A program file needs error free transfer. A picture being transferred can contain errors but still look good. It means ensuring the expected level of service.]
- Provides connection-establishment-based communication after a host ACL is established

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L2CAP three logical channels

(i) signalling messages between L2CAP at transmiiter and receiver devices

(ii) bi-directional connection-oriented with support for QoS parameters from higher layers, and

(iii) unidirectional connectionless broadcast from master to slave

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Summary

- Bluetooth device number of protocols that can be used at the application, presentation, session, transport, network, data link, and physical layers (layers 7-1)
- Physical layer three sublayers: radio, baseband and Link manager or HCI
- MAC layer L2CAP
- Three logical channels

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End of Lesson 08

Bluetooth Protocol Layers

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Wireless LAN, Mobile Internet Connectivity, and Personal Area Network

Lesson 09

Security in Bluetooth Protocol

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Bluetooth devices

- Have the ability to detect the signals from the select transmitting device only
- Can operate in secured as well as unsecured modes and can enforce link-level as well as service-level security

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Bluetooth protocol

- Provisions for highly secure personal area wireless communication
- Using various keys
- Encryptions
- Pseudo-random number generation

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Ability to detect by select transmitting device only

- Bluetooth devices operate at the least required power levels so that their transactions may not be detected by the distant receiver of signals, thus maintaining confidentiality and frequency hopping
- CDMA ensures negligible interference and least risk of jamming by distant sources

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Security modes 1

- Link-level enforced security
- Authentication of the linked device and authorization by the linking device

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Service-level enforced security

- A servicing device can deny the service to a device which has discovered its services

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Non-secure

- For common devices, for example, printer, headphone, and ear-buds

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Link layer security

- Uses a private key of 8 to 128 bits for encryption and a 128 bit pseudo-random key for authentication
- Device generates 128 bit pseudo-random number and has a 48 bit public address
- Both together ensure the link-level enforced security

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Keys

- Initialization key before device installation, *unit key* for the device after installation, a unique *combination key* for two Bluetooth devices communicating with each other, and *master key* instead of current link layer key when a master communicates with multiple slaves

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Three encryption modes

- Master key encryption for all data exchanges
- Master key encryption for data exchanges except broadcasts (for example, for service discovery)
- No encryption

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Summary

- Bluetooth devices operate at the least required power levels so that their transactions may not be detected by the distant receiver of signals
- Have the ability to detect the signals from the select transmitting device only
- Can be operate in secured as well as unsecured modes and can enforce link-level as well as service-level security

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End of Lesson 09

Security in Bluetooth Protocol

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Wireless LAN, Mobile Internet Connectivity, and Personal Area Network

Lesson 10

Infrared Data Association (IrDA)

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Infrared (IR) rays

- Invisible radiations of wavelength higher than that of red
- An LED or a solid-state laser emits IR rays when given 10–20 mA current from a low power battery or power source
- When the 1s and 0s are transmitted, the IR source current is modulated as per the 1s and 0s

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Direct line-of-sight IR

- Wavelength- 900 nm
- From an LED detected at the receiver (photo-detector) to get the data
- The detector has 30? (?15?) window to detect the incoming radiation
- Used for remote control of TV

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IrDA (infrared data association)

- A protocol for personal communication area network deploying infrared rays

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IrDA Applications

- IR-based data transfer between a laptop (computer) and mobile hand-held PocketPC when the two come in vicinity and line-of-sight of the IR receivers and detectors in each of them

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IrDA Applications

- Synchronization of PIM data (calendar, email, business card, and text messages) between a PC and mobile device or a device at cradle and IR COM port

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Network characteristics

- Point to shoot communication from peer to peer

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IrDA device levels of communication

- Five levels of communication? minimum, access, index, sync, and SyncML (Levels 1-5)
- A level specifies a method of communication from simple to SyncML-based

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IrDA data transfer rates

- IrDA 1.0 protocol for data rates up to 115 kbps
- Data rates of 1.152 Mbps to 4 Mbps (16 Mbps draft recommended)

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IrDA Functions of Protocol Layers

Application
- Security
- Sync (PIM), Object Push (PIM),or Binary File Transfer

Session
- IrOBEX, IrLAN, IrBus, IrMC, TrTran, IrComm

IrLMIAS
- Service discovery from other device

IrTinyTP
- Segmentation and reassembly
- Connection to IrLMP

IrLMP
- Multiplexes multiple applications data as well as exclusive link access
- Ad-hoc connection between peers

Physical layer
- Half duplex access or alternating directions duplex access
- 1 m or 10 cm (for low power LED)
- Mode:
  (i) synchronous PPM [Section 12.1.2.(1) (c)],
  (ii) synchronous serial 1.152 Mbps, or
  (iii) asynchronous serial 115.2 kbps down to 9.6 kbps

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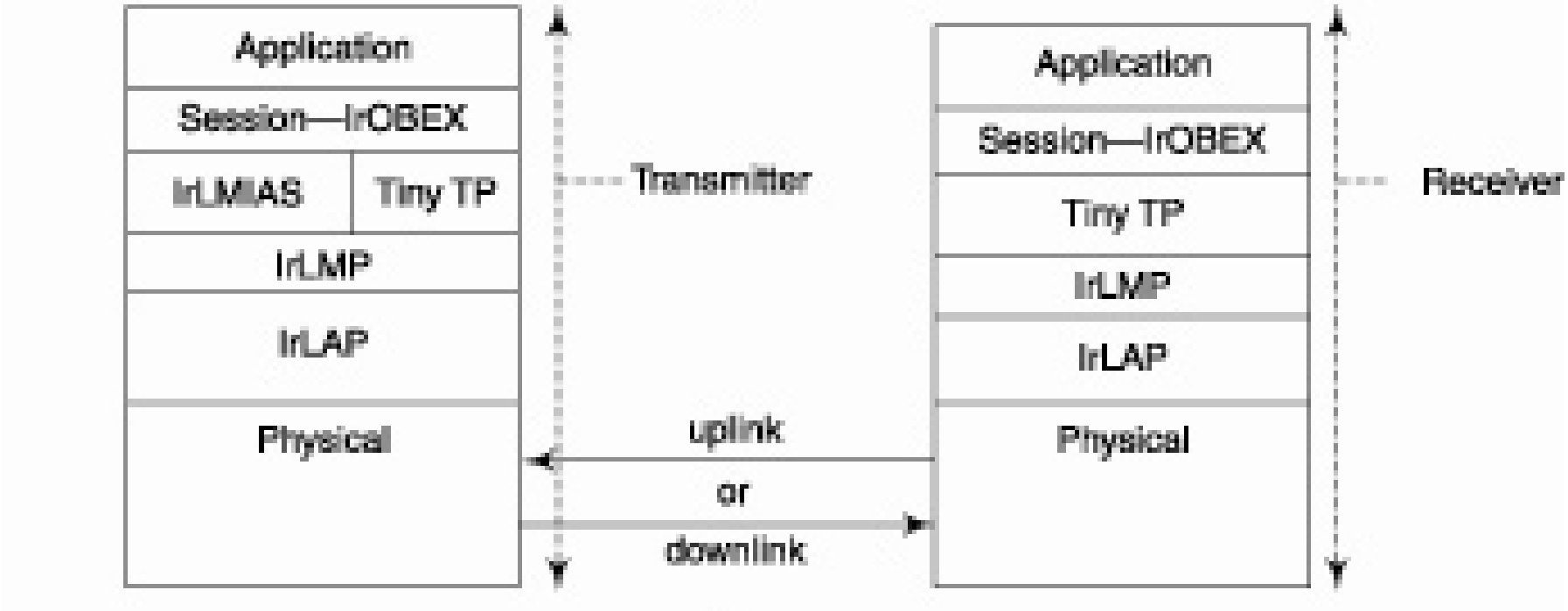
IrDA Protocol Layers



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IrDA protocol layers

(a) Layer 1—physical

(b) Data link layer? 2a—IrLAP (link access protocol), 2b—IrLMP (link management protocol)

(c) Layer 3-4—transport layer? tiny TP (transport protocol) or IrLMIAS (link management information access service protocol)

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IrDA protocol layers

(d) Layer 5—session? IrLAN, IrBus, IrMC, IrTran, IrComm, and IrOBEX (object exchange)

(e) Layers 6 and 7—security and application software layers as specified by the IrDA Alliance Sync (PIM), object push (PIM), or binary file transfer

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Session and transport IrDA protocols

- IrLAN (for Infrared LAN access)
- IrBus (for access to serial bus by joysticks, keyboard, mice, and game ports)

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Session and transport IrDA protocols

- IrMC (IrDA mobile communication and telephony protocol)
- IrTran (IrDA transport protocol for image or file transfers)
- IrComm [IrDA communication protocol by emulating serial (for example RS232C COM) or parallel port]

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Object exchange IrDA protocols

- IrOBEX (for object exchange)

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OBEX

- Supports security by encryption and decryption at transmitter and receiver, respectively
- Communicates and exchanges binary data by establishing a client–server network between two IR devices

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OBEX client

- Makes a request and server returns the response
- OBEX client and server either establish connection-oriented connection before data transmission
- Send requests and responses through connectionless connection

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Dissimilarity with Bluetooth

- Bluetooth for wireless short range exchanges in mobile environment within 10 m network
- IrDA is for exchanges within a range of one meter in the vicinity of line-of-sight
- IrDA has small form factor in radiation pattern and has 30? (?15?) window

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Comparison of Bluetooth and IrDA

- Network connection Latency—3 s for Bluetooth and a few ms for IrDA
- Bit rate—1 Mbps for Bluetooth and 1.152 Mbps to 4 Mbps for IrDA

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Comparison of Bluetooth and IrDA

- Protocol stack—250K bytes
- Code Size—50% down to 2% as compared to a Bluetooth device
- FHSS for Bluetooth and serial synchronous, asynchronous, or PPM for IrDA

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Similarity of Bluetooth and IrDA

- Efficiency
- Used for low power short range transmission

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Summary

- IrDA protocol for personal communication area network deploying line of sight 30? (?15?) window infrared rays
- Five levels of communication? minimum, access, index, sync, and SyncML (Levels 1-5)

...

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…Summary

- Serial synchronous, asynchronous, or PPM for IrDA
- IrOBEX for object exchange using IrDA
- Data rates of 1.152 Mbps to 4 Mbps (16 Mbps draft recommended)

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End of Lesson 10

Infrared Data Association (IrDA)

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Wireless LAN, Mobile Internet Connectivity, and Personal Area Network

Lesson 11

ZigBee

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ZigBee— a suite of high-level communication protocols

- ZigBee 1.0 specification released in December 2004
- ZigBee devices conform to the IEEE 802.15.4-2003 Wireless Personal Area Network (WPAN) standards

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ZigBee IEEE 802.15.4

- Lower stack size (28 KB) in the protocol than Bluetooth
- Lower network-joining latency when compared to Bluetooth (250 KB)

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ZigBee— a suite of high-level communication protocols

- ZigBee devices form a personal area (home) network of embedded sensors, industrial controllers, or medical data systems

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ZigBee IEEE 802.15.4

- For Low transmitting power systems
- Interoperable standard based on RF wireless communication

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ZigBee

- Expected to provide large-scale automation and the remote controls up to a range of 70 m
- Data rates of 250 kbps, 40 kbps, and 20 kbps at the spectra of 2.4 GHz, 902 MHz to 928 MHz, and 868 MHz to 870 MHz, respectively
- Uses DSSS

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ZigBee

- Designed for robotic control
- Industrial
- Home
- Monitoring applications

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ZigBee Applications

- ZigBee enabled electric meter communicates electricity consumption data to the mobile meter reader
- A ZigBee enabled home security system alerts the mobile user of any security breach at the home

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Three type of ZigBee devices in networks

- ZigBee Coordinator
- End-devices
- ZigBee router-devices

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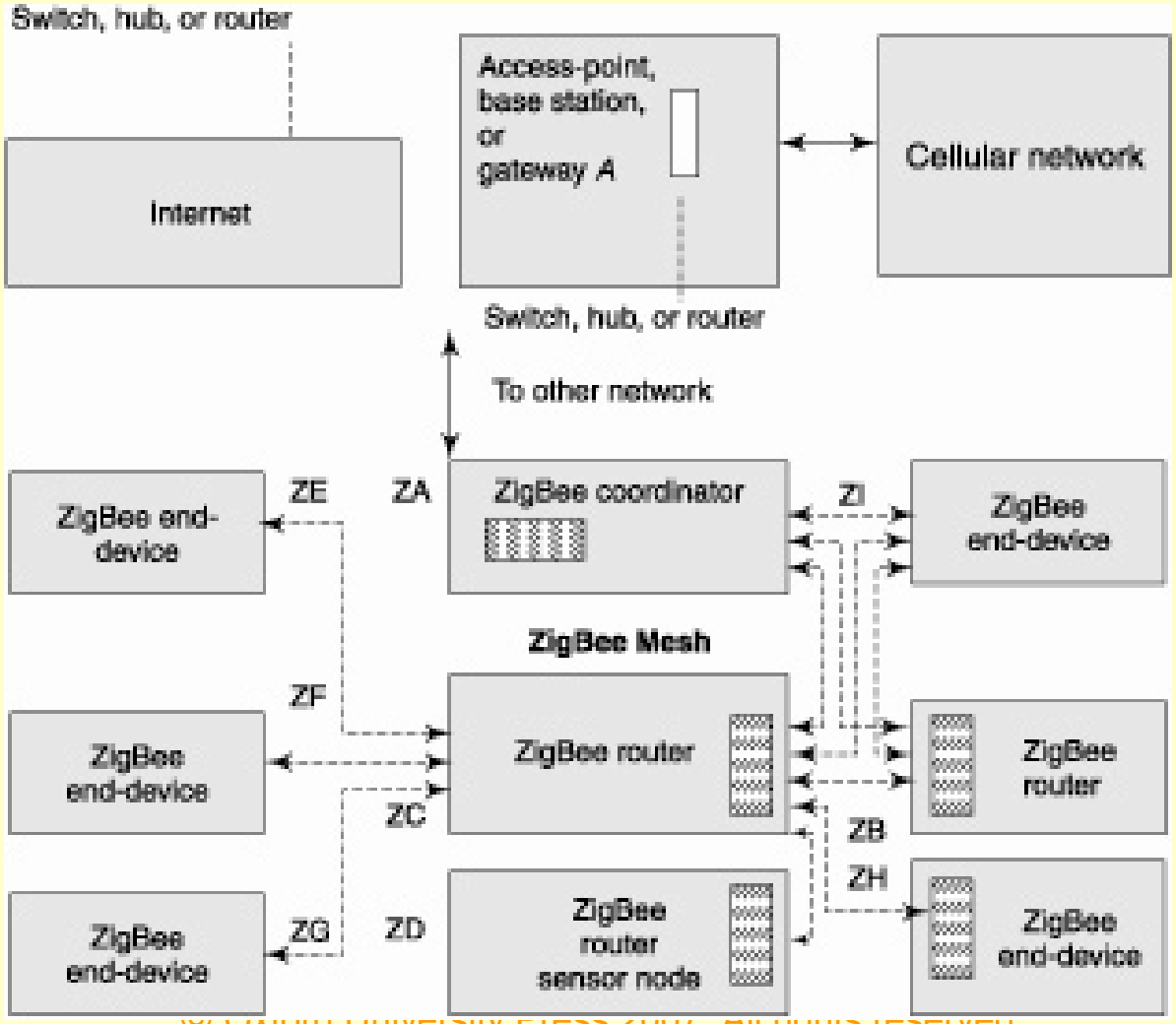
Three type of ZigBee devices in networks



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ZigBee coordinator

- Root node at each ZigBee network tree
- It can connect to other networks and has full network information along with a store of the security keys for the ZigBee network nodes [ZA]

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ZigBee router node

- Responsible for transfer of packets from the neighboring source to nearby node in the path to destination [ZB, ZC, and ZD]

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ZigBee end-device

- Receives packet from a nearby node in the path from a source

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ZigBee networks of two types

- Peer-to-peer—For example, ZC—ZD—ZH network in which each node has a single path to neighbouring node only
- Mesh—For example, ZA— ZB— ZC network in Fig. 12.17 in which each node has a path to every other node

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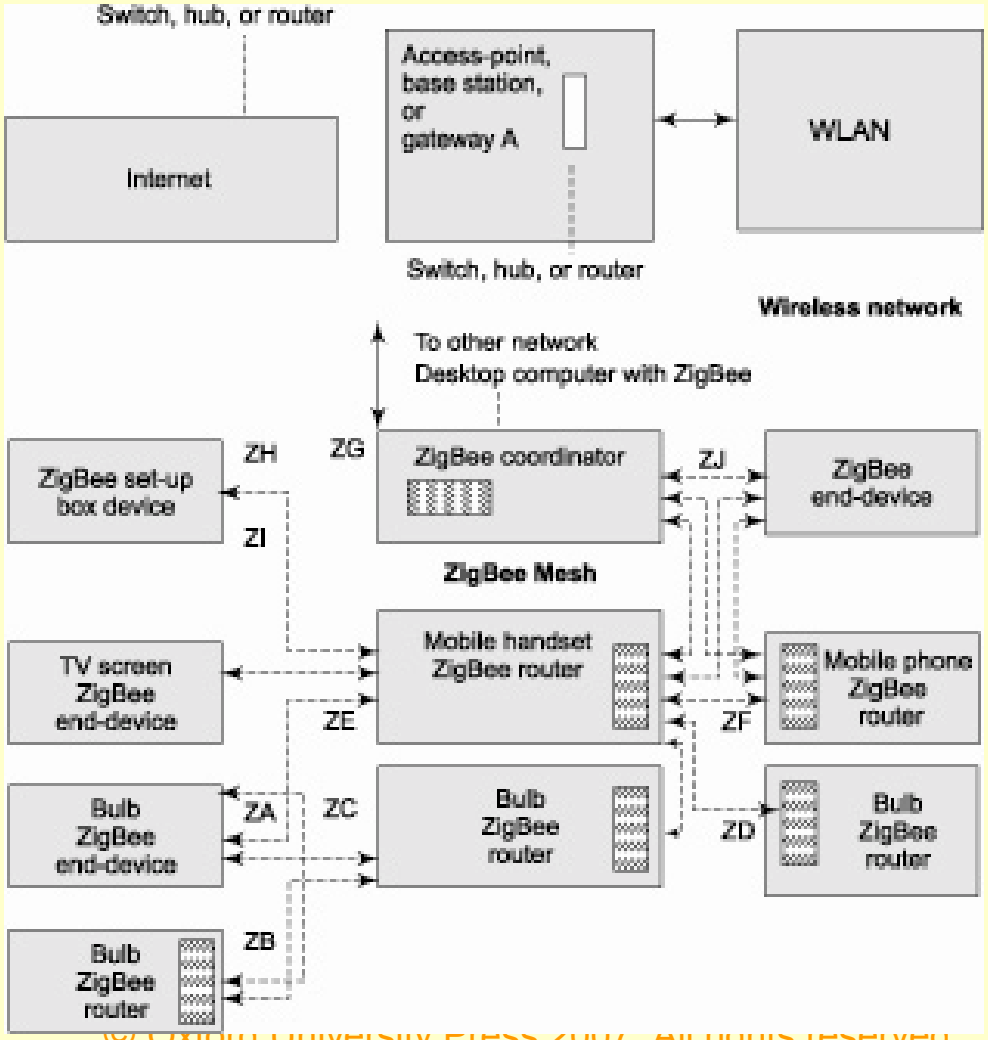
Wireless personal area network of each sensor, device, or node using ZigBee



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ZigBee devices

- ZA– ZigBee end-device
- ZB, ZC, and ZD – a set of electric bulbs associates with the ZigBee routers
- Each router in parallel
- The set forms a peer-to-peer connection network (ZE—ZD —ZC—ZB — ZA) with last one being ZigBee end-device (ZA)

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ZigBee coordinator (ZG)

- Connect this network with other ZigBee networks (for example, of mobile hand-held devices ZE and ZF)
- The coordinator ZG also connects the access-point for WLAN and provides Internet connectivity to router ZJ for security system, to cellular phone network and set-up box device ZH, and screen ZI

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ZigBee network router nodes

- ZE, ZF, and ZG use mesh network connections

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Basic Features of ZigBee

- Radio frequency bands and modulation methods— ISM bands— 2.4 GHz orthogonal QPSK , 915 MHz (USA) BPSK, and 868 MHz (USA) BPSK
- ZigBee device channels— For 2.4 GHz, there are 16 ZigBee channels
- Each channel has freuency band (2400 + 5× *n*) ± 1.5 MHz, where *n* = 1, 2, ..., 15, or 16

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Basic Features of ZigBee

- ZigBee data transfer rates– 2.4 GHz at 250 kbits/s per channel, 915 MHz bands at 40 kbit/s per channel, and 868 MHz bands at 40 kbit/s per channel
- Radio interface– DSSS

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Basic Features of ZigBee

- ZigBee protocol layers— Physical and a DLL (data link layer) part, called MAC (media access control)
- Device types— Coordinator, router, and end-device types
- Routing protocol— AODV

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Protocol layers

- Physical layer as provided in IEEE 802.15
- MAC layer as provided in IEEE 802.15
- Security and application software layers as specified by the ZigBee Alliance

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Network Characteristics

- Self organization
- Peer-to-peer
- Mesh networks

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Dissimilarity with Bluetooth

- Bluetooth for wireless short range exchanges in mobile environment
- ZigBee for big scale mesh-network-based automation and remote control

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Comparison of Bluetooth and ZigBee

- Network connection latency—3 s for Bluetooth and 20 ms for ZigBee
- Bit rate—1 Mbps for Bluetooth and 250 kbps for ZigBee
- Protocol stack—250KB for Bluetooth and 28 kB for ZigBee

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Comparison of Bluetooth and ZigBee

- Code Size—50% down to 2% as compared to a Bluetooth device
- FHSS used for Bluetooth and DSSS for ZigBee

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Similarity of Bluetooth and ZigBee

- Both conform to IEEE 802.15 set of standards
- Use of spread spectrum modulation results in spectrum efficiency in both
- Use of 2.4 GHz (in USA) in both

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Similarity of Bluetooth and ZigBee

- Used for low power short range transmission
- Both have small form factors radiation pattern

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Summary

- ZigBee for automation and the remote controls up to a range of 70 m
- For Data rates of 250 kbps, 40 kbps, and 20 kbps at the spectra of 2.4 GHz, 902 MHz to 928 MHz, and 868 MHz to 870 MHz, respectively
- DSSS

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…Summary

- Three types of devices: Coordinator, end-device and router
- Two type of networks- peer to peer and mesh
- Low stack size of protocol header

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End of Lesson 11

ZigBee

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Mobile Application Languages– XML, Java, J2ME and JavaCard

Lesson 01

XML

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A markup language

- For presentation of the marked (tagged) textual content
- An encapsulated text– processed, displayed, or printed as per the tag
- A browser– for the presentation

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XML or XML-based language

- Not only encapsulates the data and metadata but can represent a behaviour or set of actions
- XML document– a text with the tags
- The XML document has an extension .xml
- A tag in the document specifies the meaning of the text encapsulated within the start and corresponding end tag

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XML (extensible markup language)

- A derivative of SGML (standard generalized markup language)
- Extensible— special instances of the tag-based languages can be defined such that each instance observes the fundamental rules of representing and structuring the XML document

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An XML-based language

- Uses the extensible property of XML to define the standarized sets of instances of the tags, attributes and their represntation and behaviour and other characteristics
- Examples– SyncML, Funambol, and SMIL

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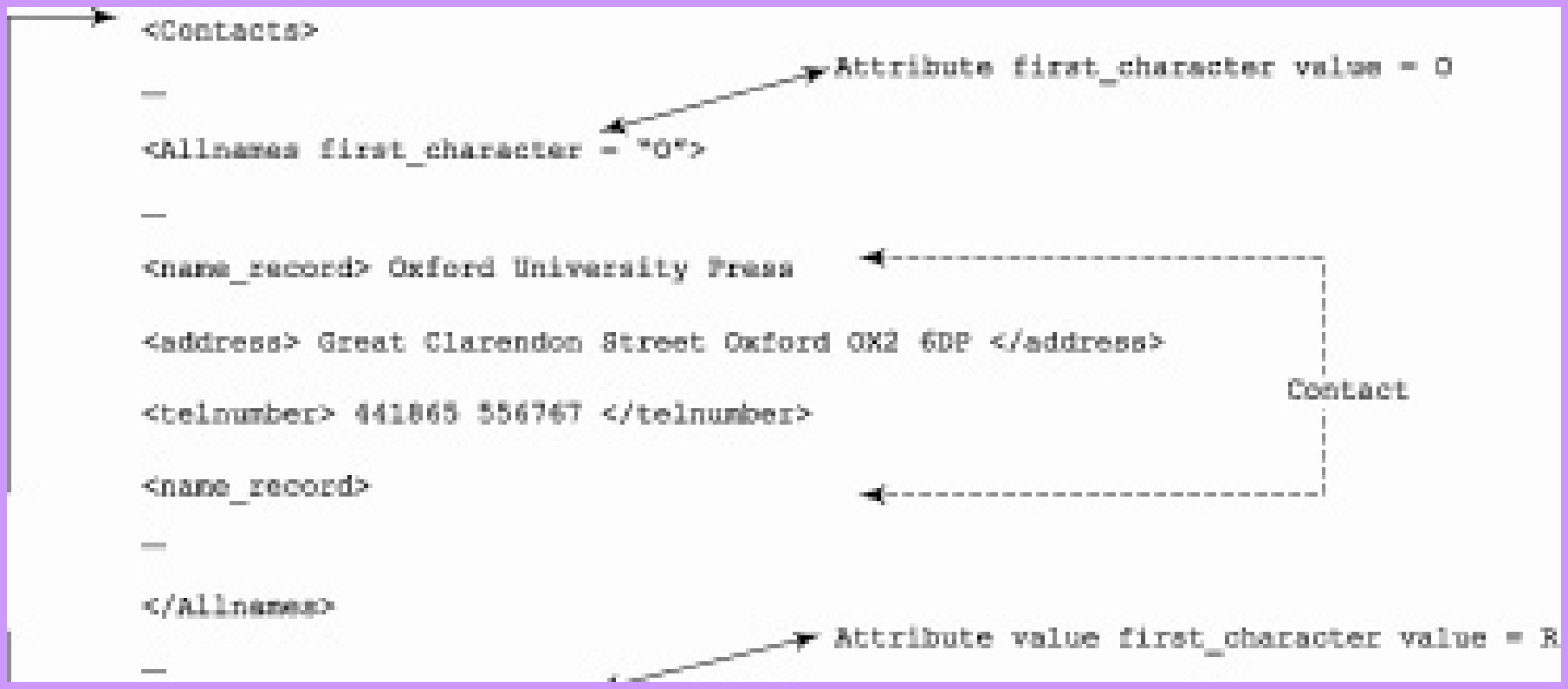
Example of XML document which can be used as contacts in a mobile smart phone



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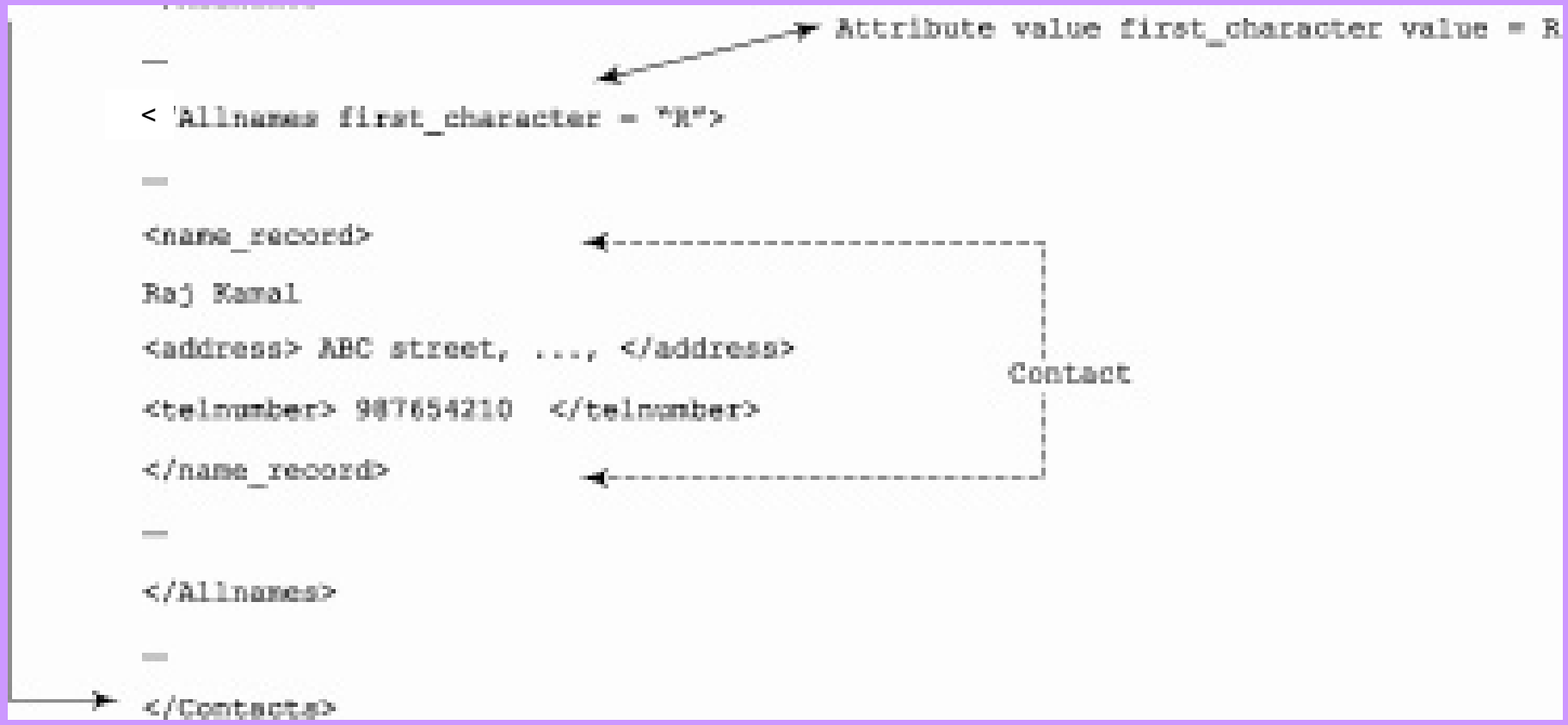
Example of XML document which can be used as contacts in a mobile smart phone



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XML document representation of a database

- Using tags and a pair of start and end tag in the document specifies the start and end of a record in the database
- A database— used to retrieve the specific record or set of records by querying the database or by business logic transaction

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Example of a hierarchical structure in a mobile application – contacts

- The elements name_record, address, and telnumber
- name_record has a textual content (Raj Kamal) and two elements address (ABC Street, ….) and telnumber (9876543210) within it
- A document formed by XML document creating a database named Contacts

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Example of XML for textual document to represent a database

- <name_record> Raj Kamal <address> ABC Street, …. </address> <telnumber> 9876543210 </telnumber> </name_record>

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XML document making non-textual use of text– command

- A tag can represent a command
- For processing the data using the command name within the pair of start and end tags in the document text
- A tag along with its attributes can specify the command, source file(s), and data to process the command

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Example— <Cmd>Alert</Cmd> <CmdRef>1</CmdRef> <MsgRef>1</MsgRef>

- When data is modified (for example, new email or newly downloaded music file) at the server (PC or remote mail server), the server alerts the client so that the client can synchronize its data with the modified data
- Command— Alert (means a server- or client-initiated notification)

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Example– <Cmd>Alert</Cmd> <CmdRef>1</CmdRef> <MsgRef>1</MsgRef>

- A number within CmdRef refers to a notification
- In place of transmitting full text of the server-notification for alerting the client, only a number is sent
- The client at the other end interprets the notification from the referred number

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Example– <Cmd>Alert</Cmd> <CmdRef>1</CmdRef> <MsgRef>1</MsgRef>

- Command refers to a command referred by 1 within <CmdRef> and </CmdRef>
- Server message which is used to alert is identified by 1 as there is reference to 1 within the start and end tags <MsgRef> and </MsgRef>

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SMIL Sample Code 9.5—<audio id = “my_id” src = “myaudio.wav” begin = “0s” dur = “10s”/>

- The tag and attributes together represent the system behaviour
- Command is audio
- Attribute id specifies the user id is my_id

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SMIL Sample Code 9.5—<audio id = “my_id” src = “myaudio.wav” begin = “0s” dur = “10s”/>

- Attribute src specifies the source file, myaudio.wav
- Attribute begin specifies 0s time for start of playing the audio file

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SMIL Sample Code 9.5—<audio id = “my_id” src = “myaudio.wav” begin = “0s” dur = “10s”/>

- Attribute dur specifies 10 s time for duration of playing the audio file,
- Command is to play a .wav file “myaudio.wav” and begins it from 0 second mark for a duration of 10 seconds

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Document Type Defintions (DTDs) file or within the document

- Gives the specification of the role of text elements in a model document
- Specifies the attributes associated with an element as well as their valid values
- An external DTD document has file extension .dtd

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Functions of DTD

- To enable validation of a document
- To specify which document structures can be used for authoring of the document
- To specify which structures a parser must handle

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Parser

- A parser first validates an XML document and then handles the specified document structures
- Needs the DTDs for validation of the document

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Validation

- Investigating–

(i) whether the document contains a root element with the same name as of DTD

(ii) whether it contains the header information for the version, encoding, and reference to other files

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Validation

(iii) whether it contains the DTD with declaration of the markups in the document or in a linked external DTD document

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Parsers

- kXML parser is a parser which parses XML document using J2ME and KVM (Kilo-byte virtual machine) in mobile devices
- .NET XML parsers in Microsoft Windows Mobile- and Windows CE-based devices
- WAP 1.x supports XML parser
- Enables processing of WML (wireless markup language)

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Two models of an XML document

- One model is called SAX (simple API for XML) model
- Other DOM (document object model)
- Two types of parsers

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Summary

- Extensible markup language
- XML document– a text with the tags
- Attributes in the tag
- XML tag in the document specifies the meaning of the text encapsulated within the start and corresponding end tag
- XML Not only encapsulates the data and metadata but can represent a behaviour or set of actions or database records …

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Summary

- Data type definition DTD internal or in separate file
- Parser for parsing XML document before running an application
- Two models of documents– SAX and DOM

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End of Lesson 01

XML

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Mobile Application Languages- XML, Java, J2ME and JavaCard

Lesson 02

SAX and DOM Models for XML Document, Parsing, and applications of parsed information and data

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SAX (simple API for XML)

- Each set of elements within the tags is independent and need not be considered as in a tree-like structure

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SAX model APIs

- SAX provides the API a serial access and event-driven mechanism for reading and parsing data from an XML document
- SAX model document such that its parser can generate the series of events which are created as processing proceeds from beginning to end

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Example of XML file contacts.xml having many contacts

- Application needs to dial a contact with name record Raj Kamal and dial the corresponding telnumber

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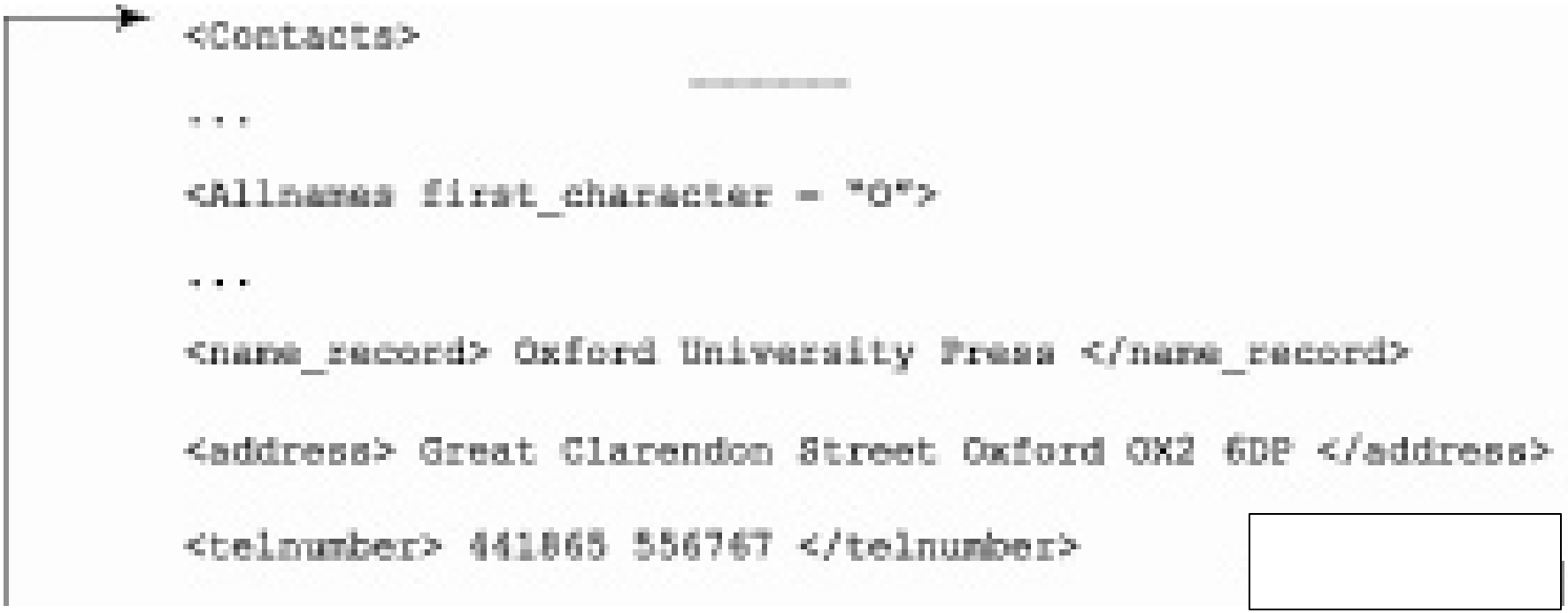
Example of SAX model of an XML document corresponding to Contacts



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Example of SAX model of an XML document corresponding to Contacts

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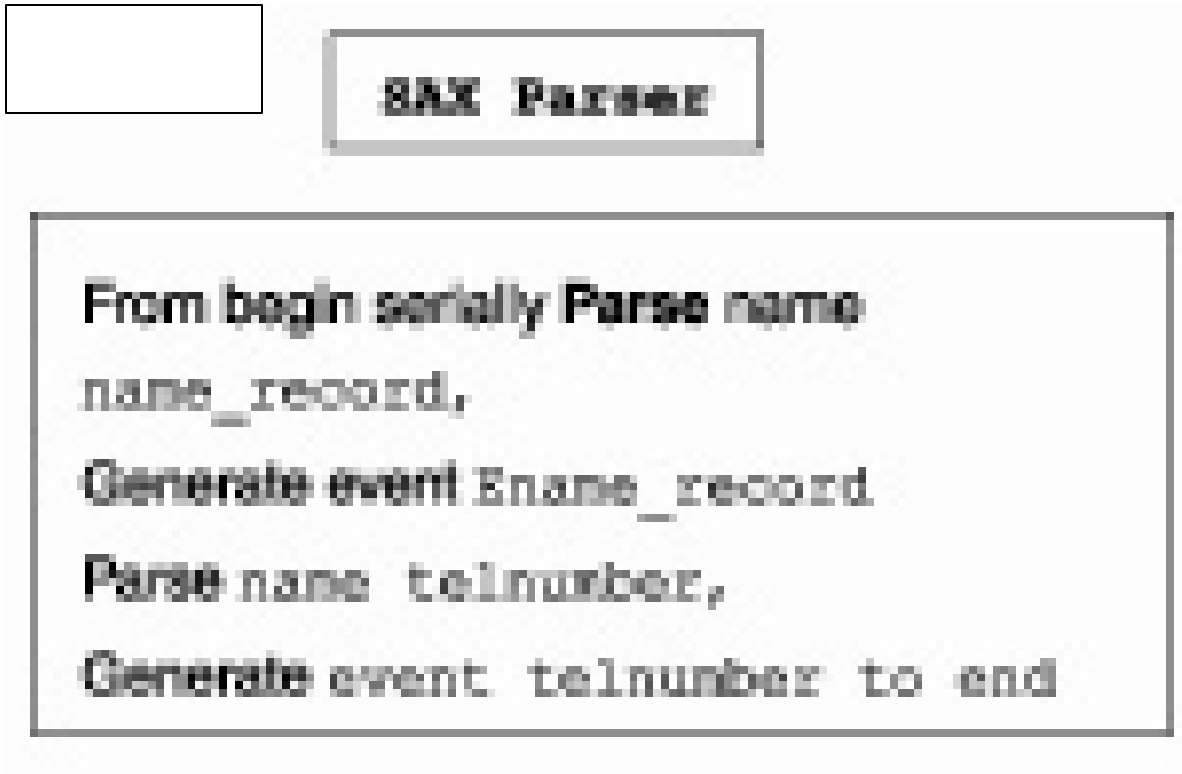
Example of Parser for SAX model Contacts



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Example

- Demonstrates a SAX parser of XML document and an alternative arrangement of elements for each contact in the Contacts which helps in fast processing by the parser

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SAX parser

- Generates an event on name_record as it parses through the record and on event accepts the value ‘Raj Kamal’
- Then it generates another event on telnumber as it parses through the document and on event accepts the value ‘9876543210’

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Advantages of XML SAX parser

- Entire document need not be first parsed thoroughly
- All the needed data need not be extracted

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Document object model (DOM)

- In which each set of elements is dependent and derives from a root element
- Whole document forms a tree-like structure

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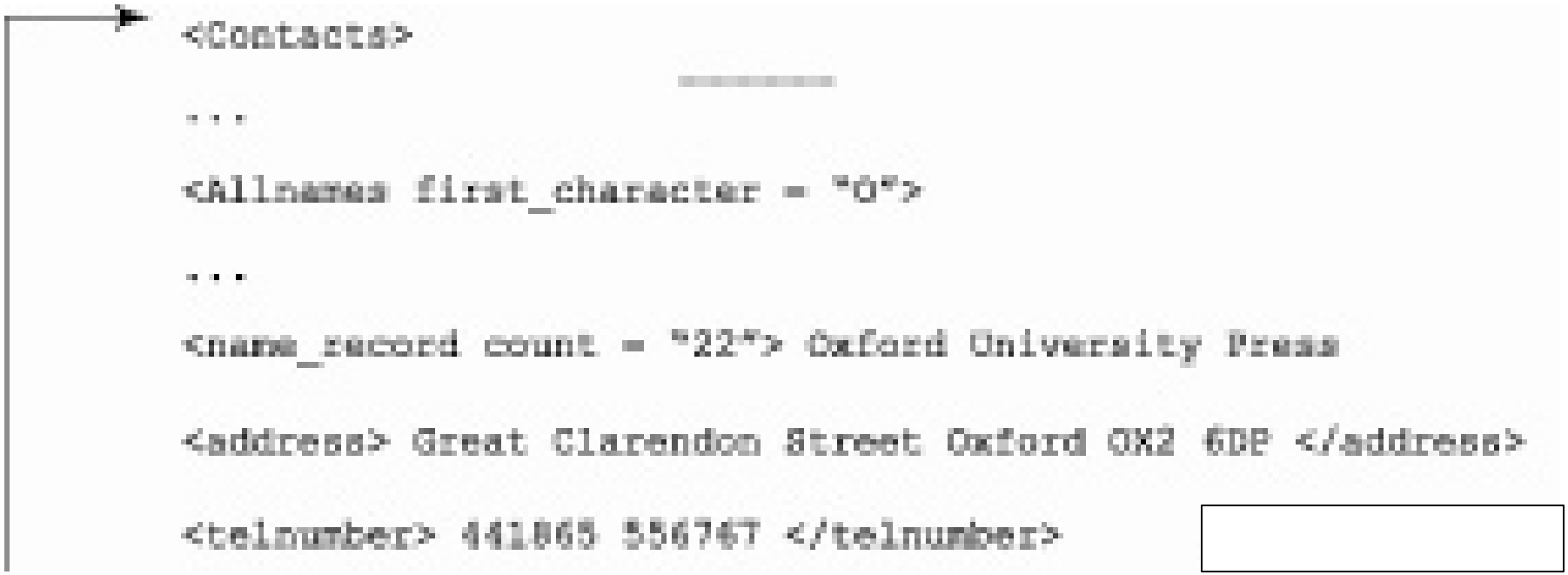
DOM model of an XML document corresponding to Contacts



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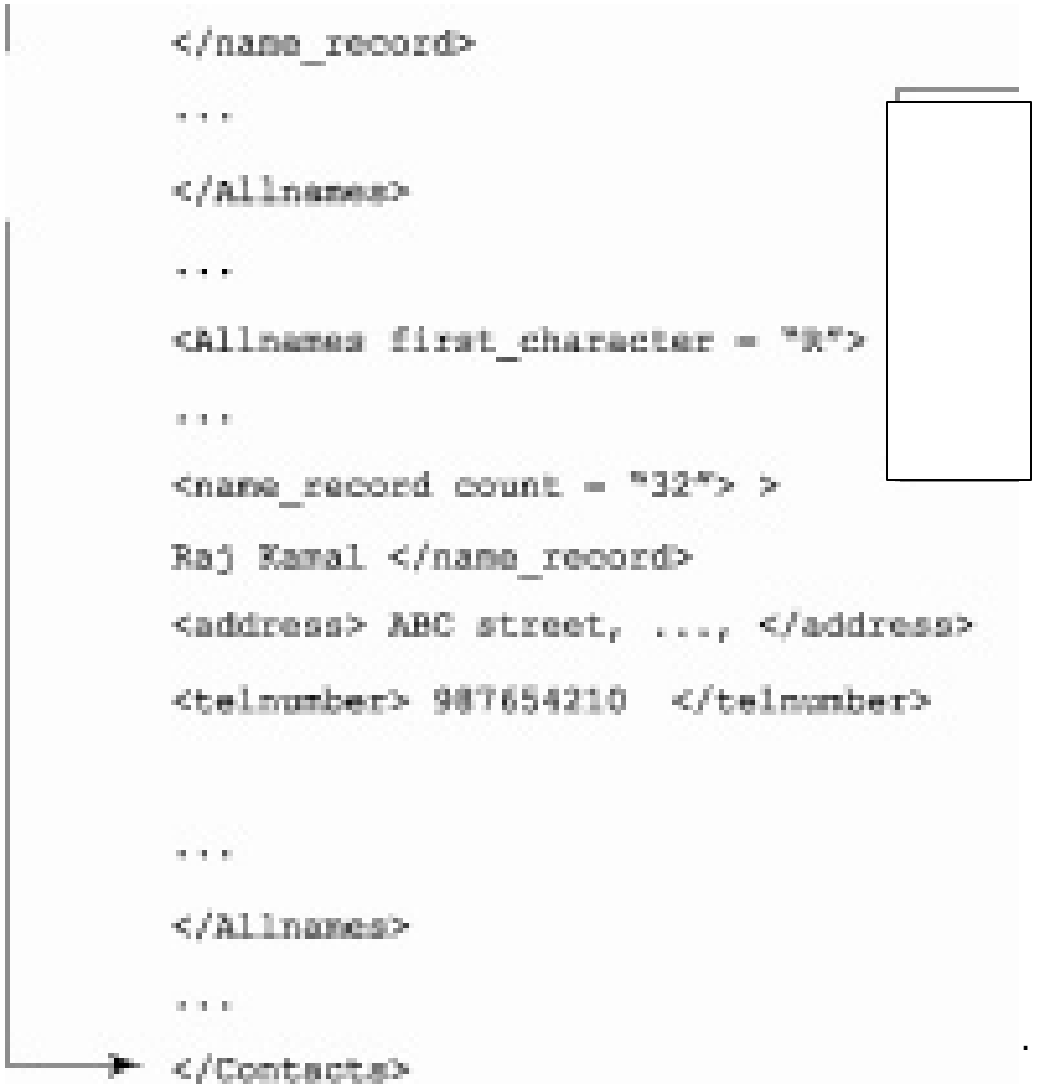
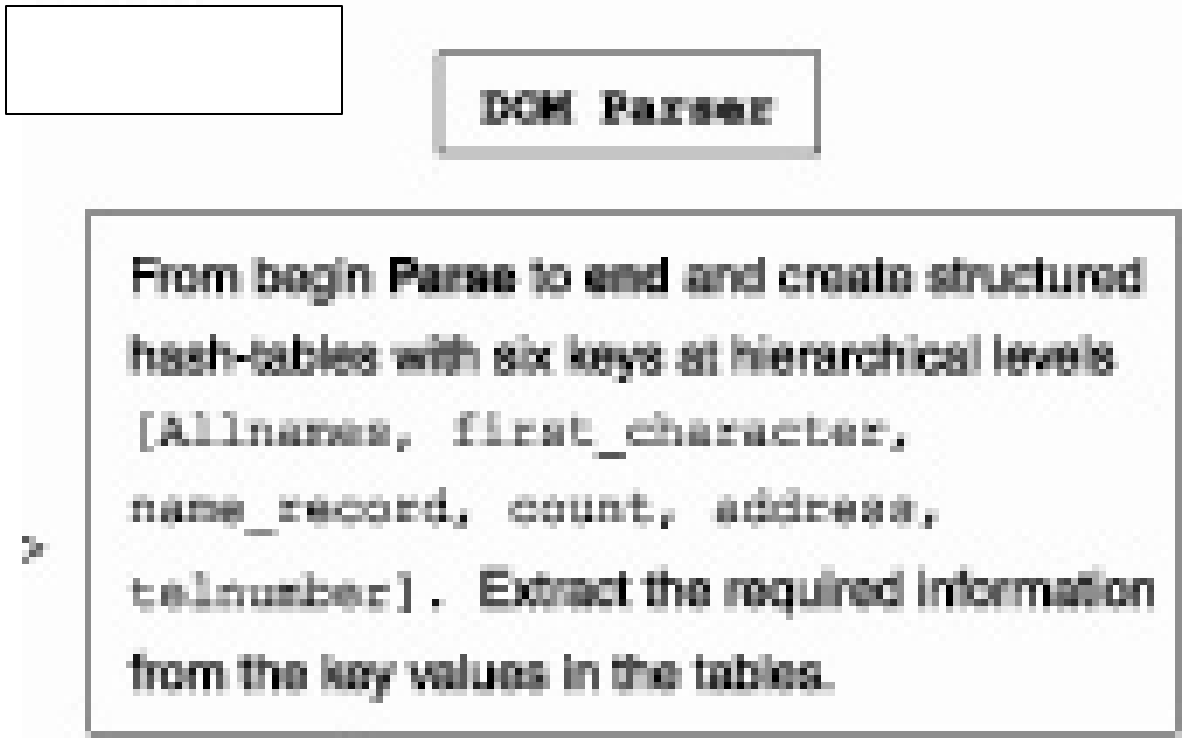
DOM model of an XML document corresponding to Contacts



Parsing of DOM model document Contacts



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DOM model document hierarchically arranged

- The whole document must be parsed initially to create a hash table of keys and corresponding values for each key

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Advantage of DOM

- The structure is well-defined and thus same parser can be used for parsing all XML documents
- Later the interpreter or processing program is able to extract the desired information by simply using the keys

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Disadvantage of DOM

- In an intermittently connected wireless environment or in case of a long document with many levels of hierarchy, it could take a long time before whole document is received at the parsing end

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Example of the applications

1. Create ascending or descending order tabular data as per selection by the user
2. Count the number of contacts
3. Display the desired contact using appropriate GUI by deploying up-down menu keys in the keypad

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Use of parsed inforamtion and data by an application

- Extracted output inforamtion and data from the parser further processing using a programming language
- The parsed data interprets at the application

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XML textual document for platform-independent application data

1. Database
2. Data objects for synchronization, device configuration, user interface
3. Forms for processing of data at the server
4. Web applications at the server
5. Web services

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XML textual document for platform-independent application data

6. Representing behaviour of or action by a tag and its attributes
7. An integrator of two diverse platforms for running an application
8. As a client application when sending a request to server for data or result of executing a method (routine) or search of database record at the associated backend server
9. Used by server to push the data to devices

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XML

10. Used by WAP protocol for presentation of data to client using an XML browser
11. For multimodal user interfaces.
12. Internally for specifying the information in an application or framework

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XML

13. Used by HTML browser after translating XML information into HTML information using a technology called XSLT (extensible style-sheet language transformation)
14. XHTML-MP format of XML used as HTML web pages with portability and extensibility in mobile devices

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Use of Metadata at the XML document

- To represent the relationships among the data in the document
- To describe the structure and workable methods to facilitate an organized use of information
- To describe the method for manage that information

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Use the metadata in XML document by an application

- To speed up and enrich searching for the resources
- Organising the information and managing the data

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Summary

- Each set of elements within the tags is independent and need not be considered as in a tree-like structure
- SAX provides the API a serial access for reading and parsing data
- SAX model document such that its parser can generate the series of events
- Entire document need not be first parsed thoroughly …

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… Summary

- DOM model
- Hierarchical structure
- Entire document parsed first and then parsing creates hash table of keys and corresponding values for each key
- XML document data after parsing used in number of applications and databases
- Metadata also used in the applications

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End of Lesson 02

SAX and DOM Models for XML Document, Parsing, and applications of parsed information and data

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Mobile Application Languages– XML, Java, J2ME and JavaCard

Lesson 03

XML based Standards and Formats for Applications

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XML

- An extensible language
- The tags and attributes and markup language format standardized for the applications

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A Form

- Have several UIs (user interfaces) like text area fields, buttons, check-boxes, and radios
- Has the fields (keys) which are initially specified
- Fields either have no intiial field values or default field values

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The Form

- Presented to a user using a browser or presentation software and user interactions take place
- The user supplies the values for these fields by entering text into the fields, checking the check-boxes, and selecting the radio

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The Form

- The user then submits the form which is transmitted from client to server for carrying out the needed form processing
- The server program can be at remote web server or at the device computing system

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XML for Forms– XForms

- An application may generate a form for answering the queries at server end, which needs to be filled and submitted by the client end
- XForms is a form in XML format which specifies a data processing model for XML data and UIs for the XML data

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XForms

- Provides a UI (user interface)
- Web forms which can also be used in a stand-alone manner or with presentation languages other than the ones for a set of common data manipulation tasks or user interface

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XForms controls

- <textarea>
- <input>
- <secret>
- A string data type attached with these fields

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XForms controls

- <selectOne> [for a radio]
- <choices> [for check-boxes]
- <item>
- <itemset>

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XForms attributes

- Input control are ref and xml:lang. xml:lang = “en” enables use of XML
- The other attributes– are accessKey, navIndex, and class

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XForms Elements

- <alert>
- <caption>
- <hint>
- <extension>

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Client-side as well as server-side validations

- Done before processing of the XForms—similar to XML document validation

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XML user interface (XUI)

- A framework in XML and Java for mobile and mobile handheld device applications

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WBXML (WAP binary markup language)

- A a format in which WAP presents XML document as binary numbers
- A binary number represents a string of characters for each element and attribute
- Use of the number reduces the size of the document and hence the transmission time from client to gateway or gateway to client

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VoiceXML (VXML) 2.0

- Version of an XML-based language in use from 2004 for interactive talking between a human being and a computer
- Also supported by IBM WebSphere
- Used with HTTP protocol on a network analogous to that for HTML

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VoiceXML (VXML) 2.0 Browser

- Analogous to an HTML display browser (e.g. NetScape or IE 5.0)
- Interfaces with mobile or landline telephone network
- Provides a voice user interface (VUI) to a voice browser

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Applications of VXML

- Bank account enquiry
- Report of loss of credit card
- Directory
- Flight enquiry

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The tags in VXML

- For playing a sound file from audio book
- Automatic speech recognition
- Dialog management
- Speech synthesis by voice browser

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VoiceXML (VXML) 2.0 tag Example

- <prompt> Hello Lucy </Prompt> gives the message Hello Lucy using speech synthesizer with the voice browser

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Conversion of text to speech (TTS)

- The displayed text message from a website for control of traffic and congestions at nearby places
- In a moving automobile, TTS required that the site data is downloaded and read and spoken to a driver

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SSML (speech synthesis markup language)

- Used in TTS (text to speech converter)
- For synthesizing the speech by interpretation of a text by a synthesizer
- Creates audio book

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SSML (speech synthesis markup language)

- Also Specifies *emphasis* of the voice
- For example, it specifies when the voice is normal and when it is loud
- SSML can be embedded in VXML scripts
- The scripts provide an interactive telephone

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Tags with attribute in SSML

- xml:lang– Specify attribute English, <s xml:lang="en">
- Specifies the synthesis source for voice as <voice name="Mary" gender="female" age="22">
- The text is then synthesized by spoken English in voice of Ms. Mary of age 22

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Speech recognition grammar specification (SRGS)

- Used in SSML
- Lets speech recognizer to define the pattern of sentences

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Call control extensible markup language (CCXML)

- A standard for an XML-based language, which can be used independently or with VXML for telephony support
- Commands the browser to handle the calls of the voice channel
- CCXML 2.0 handles the events and state transitions

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CCXML Example of commands and transition

- Commands for initial call set-up or call disconnect between a caller and voice browser
- Example transition from call set-up to call connected state or call connected to disconnected state)

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Summary

- XML based Standards and Formats required for the mobile and other Applications
- XForms for filling and submitting forms to the application
- VoiceXML
- TTS text to speech converter application
- SSML for speech synthesis

...

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…Summary

- SRGS for grammar support in specific recognition
- CCXML for telephony support

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End of Lesson 03

XML based Standards and Formats for Applications

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Mobile Application Languages– XML, Java, J2ME and JavaCard

Lesson 04

Java

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C and C++

- C and C++ with in-line-assembly, Visual Basic, and Visual C++— the programming languages used with Windows platform

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Java language

- Compiles into byte codes assuming a hypothetical CPU which possesses stack-organized architecture
- The codes run on a virtual machine
- Therefore, these can run on any operating system and hardware platform on which JVM is installed

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JVM

- Provides the execution engine
- Native interfaces
- Runs the codes on the given OS and hardware

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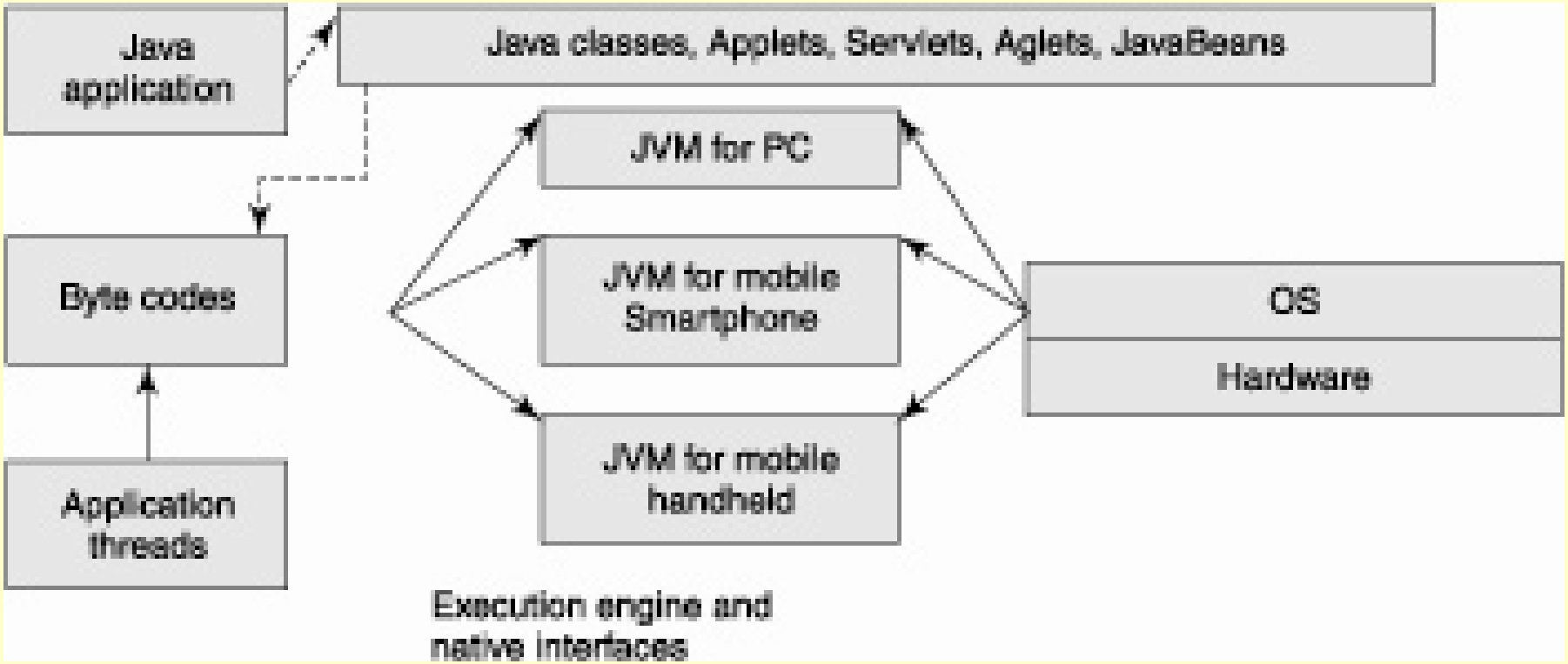
Java application, classes, and application threads compiled as platform-independent byte-codes



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An application

- A program which runs on the user system
- Application threads– the programs of the application, each one of which is assigned a priority and runs concurrently

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J2SE

- Used to program the *application*, threads, applets, servlets, and aglets

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Servlets

- The programs running on a web server

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Servlet Lifecycle

- Consists of the sequential steps—initiate, service, and destroy
- The init is analogous to main in a Java program
- Just as main ( ) executes first in Java program, init ( ) executes first in Servlets

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Applets

- The programs running on a client

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Applet Lifecycle

- Consists of the sequential steps—initiate, start, stop, and destroy
- The init– analogous to main in a Java program
- Just as main ( ) executes first in Java program, init ( ) is executed first in Applet

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Aglets

- The mobile agents which run on a host
- Can be retracted or cloned
- Can be used for messaging
- Supports weak mobility— can retain its state when it migrates from one host to another

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Aglets Life Cycle

- Consists of the sequential steps—creation, dispatch, activation, deactivation, and disposition

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An application

- Developed by programming a set of Components
- Database or server can be connected to the UI components using the APIs
-

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Java applications

- Developed using open software Java 2 SDK from Sun. JBuilder, Microsoft Visual Studio J++, and IBM Visual Age
- IBM Visual Age provides a visual programming method to a programmer
- The Visual Age tool provides source code and compiled byte codes

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Class

- A construct in Java or C++, which is used to define a common set of variables, fields, and methods and whose instances give the objects

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Java and Java-based languages possess some characteristic features

- Makes them the most used languages for mobile applications

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Object oriented language Feature

- Each class— a logical group with an identity, a state, and a behaviour specification
- A class is a named set of codes that has a number of members—fields, methods, etc., so that objects can be created as instances of the class
- The operations done on the objects by passing the messages to them

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Platform independence

- The program codes compiled in Java are independent of the CPU and OS used in a system because of the standard compilation into the byte codes
- Java codes complete mobility from one platform to another
- Java codes for mobile agents have weak mobility from one host to another

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Robustness

- Java does not let the user assign pointers and write code for pointer manipulations
- All references to memory, freeing of the memory (garbage collection), de-allocation (de-referencing), and validation of object types and array indices are done internally at the compile and run time

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Standard APIs (application programming interfaces)

- Help a Java program to connect an application to a program, database, distributed object, or server developed on other platforms

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Packages in Java

- Packages consisting of the classes and interfaces
- Packages help in fast development of the codes

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Packages in Java

- java.lang for fundamental classes of Java

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Packages in Java

- java.awt for Java foundation classes for creating GUIs

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Packages

- java.swing for Java swing classes for creating lightweight GUIs
- Lightweight means not depending on the platform [system (OS) resources (for example, buttons)] unlike foundation classes which depend on the system resources

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Packages in Java

- java.net is the package for network related classes for example, TCP/IP, UDP, HTTP, and FTP

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Packages in Java

- java.security for classes in Java security framework. The examples are classes for RSA, DSA, and certificates
- java.sound for audio processing

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Packages in Java

- java.io.Serializable– serializable interfaces

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Serialization of Object

- Object state, as defined by the heap in memory, is written in memory as a serial byte stream
- Therefore, when the object migrates, it is received as serial byte stream and after de-serializing, the original object is restored into memory

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JavaBean

- Has a *property* assigned to the fields in a class
- JavaBeans integrated into a *container*.
- Any change in property is listened to by a *listener* and the *action* method is executed

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JavaBean Example

- address property
- Any change in *address* has to be listened to by all related Beans in the container

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JavaBean

- JavaBean– valuable for developing reusable software components
- The application, applets, or servlets integrate the JavaBeans
- java.beans package contains the classes for developing the JavaBeans

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Summary

- Java Byte code compilation
- Virtual machine
- Objected oriented
- Platform independent
- Robust
- Class, object and packages
- JavaBean

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End of Lesson 04

Java

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Mobile Application Languages– XML, Java, J2ME and JavaCard

Lesson 05

J2EE

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Java 2 Enterprise Edition (J2EE)

- Used for web- and enterprise-server-based programming of the applications
- A J2EE *application* used for distribution across the multiple computing tiers

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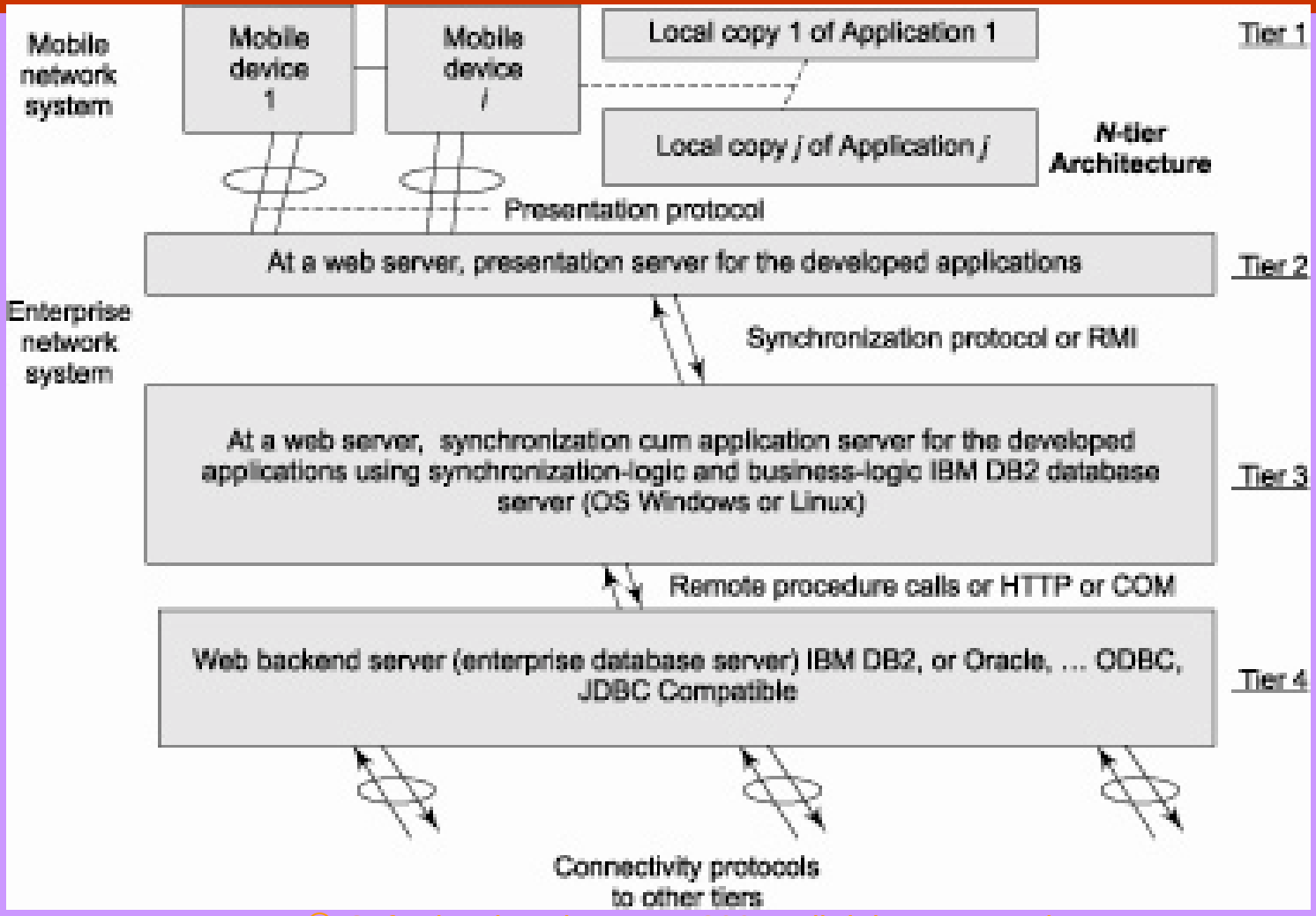
N-tier architecture in which a client-device connects to the enterprise databases



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Enterprise Java bean (EJB)

- A component at a server in an enterprise application
- It is managed such that it leads to a modular design
- Each EJB encapsulates a business logic of the application

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Enterprise Java bean (EJB)

- EJBs are configurable components. EJBs enable persistency of the application components
- An application *server* manages the security, scalability, transactions, and concurrent execution of the applications deploying the EJBs

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J2EE support to the APIs

- XML
- Web services
- Email
- RMI (remote method invocation) by using the package java.rmi

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J2EE support to the APIs

- JMS (Java messaging service) [A middleware API for interchanging messages between two or more clients]
- JDBC (Java database connectivity)
- JTA (Java transaction API)

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J2EE support to the APIs

- Servlets (to dynamically render the response to the client request), Java server pages (JSPs) (to create dynamic contents), and Java Portlet
- JNDI (Java Naming and Directory Interface) to provide lookup services to enterprise directory

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J2EE Container

- Has EJBs as Session Beans and Entity Beans
- Provides transactions, security, scalability, pooling of the resources, and concurrent execution of the applications
- Resources pooled by transactions between Entity Beans and backend servers for the resource at the enterprise tier

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Entity Beans

- Connect to enterprise tier which can have a database server or which connects to the distributed objects at higher tiers

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Transactions Persistency

- Maintained for data at enterprise server
- When data persists in a number of objects and files, maintaining persistency means that if a record is modified at a stored object, then the same modification is carried out in all the other objects using the same record

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Example

- If a user using a menu in an application changes email ID of a contact in a mobile device, then the changes are also made at each and every occurrence of that email ID for that contact
- The contact data is said to be maintain persistency

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Session Beans

- Establish a session between client request and server responses
- The transactions take place between the client and Session Beans

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Summary

- J2EE used in applications needing enterprise server connections
- N tier client server computing environment
- Distribution components across the multiple computing tiers

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J2EE

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Mobile Application Languages– XML, Java, J2ME and JavaCard

Lesson 06

J2ME

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Resource constraints

- Mobile smart phone
- Handheld computing system
- Set-top box
- Network and other constraints

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J2SE

- Needs 512 kB ROM and 512 kB RAM in a device.
- J2ME– a set of Java APIs which require small memory while developing Java applications
- Also a platform for development of mobile phone games

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Java 2 Micro Edition (J2ME)

- A micro edition of J2SE which provides for configuring the run time environment
- Examples of configuring– are deleting the exception-handling classes, user-defined class loaders, file classes, AWT classes, synchronized threads, thread groups, multi-dimensional arrays, and long and floating data types

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J2ME

- Only one object is created at a time when running multiple threads
- The objects– reused instead of using a larger number of objects

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J2ME

- J2ME or Java-based virtual machine not supported by Windows Mobile devices do not support
- J2ME platform binary implementations and virtual machine implementation are done by another source not from Windows

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J2ME, CLDC and CDC

- CLDC (connected limited device configuration), and CDC (connected device configuration)
- Provide the development platform for small memory devices and systems

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Profile

- Means a standardized agreed-upon subset and interpretation of a specification

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Profile

- Also mean a specification for a set of configuration seetings and other data which are used in the APIs for a device, user, or group of devices

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Profile

- Also mean a standarized specification for the APIs for a device, user, or group of devices
- J2ME-framework-based devices use Java APIs specified in a Profile

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Profiles

- Foundation Profile– APIs of J2SE without GUIs
- PersonalProfile– Profile for embedded devices, for example, PDAs and set-top boxes and contains the APIs of Foundation Profile, complete AWT as well as lightweight GUIs, and Applet Classes

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Mobile Information Device Profile (MIDP)

- Profile for mobile devices with small screen option for GUIs, wireless connectivity, and greater than 128 kB flash memory
- MIDP– a specification of APIs for mobile information, smart phone, and gaming devices

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MIDlet

- A J2ME application (similar to an Applet) for embedded devices which runs with MIDP
- MIDlet main class is a subclass of javax.microedition.midlet

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MIDlet

- MIDlets are programmed to run games and phone applications
- Also they are compiled once and are platform-independent. A MIDlet has to fulfill certain requirements in order to run on a mobile phone

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MIDP source packages and sets of Java class libraries

- java.lang– Standard java types and classes for String, Integer, Math, Thread, Security, and Exception
- java.io – Standard java types and classes for Input and Output streams

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MIDP source packages and sets of Java class libraries

- javax.microedition.lcdui— LCDUI for mobile devices with no Internet connectivity, provides a limited set of UIs in mobile devices
- TextBox, Form, List, and Canvas (low-level graphics as well as full screen games graphic mode)
- Graphics needed for games
- MIDP controls the GUIs

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MIDP source packages and sets of Java class libraries

- java.util— A set of classes such as TImers, Calendars, Dates, Hashtables, Vectors, and others
- javax.microedition.rms— A record management system (RMS) API to retrieve and save data and limited querying capability

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MIDP source packages and sets of Java class libraries

- javax.microedition.pim– Personal information management API (optional), access the device's address book.
- javax.microedition.pki– Secure connections authenticate APIs
- javax.microedition.messaging– Wireless messaging APIs used when sending SMS and MMS messages

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MIDP 3.0

- A Profile for special-featured phones and handheld devices
- Provides improved UIs, UI extensibility, and interoperability between the devices
- Moreover, it supports multiple network interfaces in a device

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MIDP 3.0

- IPv6 (Internet protocol version 6 for broadband Internet)
- Large display devices
- High performance games

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MIDP 3.0

- Provisioning for MIDlets using SyncML DM/DS (device management and device synchronization) protocol, Bluetooth, removable media (e.g., memory stick or card), and MMS

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MIDP 3.0

(i) auto-starting of MIDlets on device booting

(ii) running several MIDlets concurrently and sharing the class libraries for MIDlets

(iii) running background MIDlets (MIDlets without a UI)

(iv) specifications of the runtime behaviour

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MIDP 3.0

(v) proper firewalling and lifecycle managing functions for MIDlets

(vi) enabling MIDlets to draw to secondary display(s)

(vii) specifications of the behaviour of MIDlets in the CLDC and CDC

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MIDP 3.0

- Inter-MIDlet communication (similar to inter-process communication between the processes controlled by an OS) which in turn allows querying of device capabilities required to be done when a server sevice is to discover the device services

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Information module Profile (IMP)

- For embedded devices for example, security systems or vending machines which have no display UIs and game APIs

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IMlet

- An application created from IMP APIs
- IMlet is inherited from MIDlet

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Auto and TV Profiles

- Auto Profile (AutoP)– a Profile for automobile application develoment
- TV Profile (TVP)– a Profile for TV set-top box application develoment

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Configuration- CLDC

- A configuration for limited connected devices
- Defines a base set of APIs and VM for the resource-constrained mobile phones or handheld computers
- A subset of MIDP

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Configuration- CLDC

- Used for developing Java applications
- Usually CLDC can just connect to mobile application service provider and have less than 64 kbps data transfer rate
- CLDC has minimal needed subset of the Java class libraries running on virtual machine for a CLDC

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Configuration- CDC

- A configuration for connected devices
- A Java framework for developing an application that can be shared in networked devices, for example, set-top boxes

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Configuration- CDC

- CDC provides a J2ME framework for and applications which run on wirelessly connected devices and APIs for HTTP. The devices will need 2.5 MB flash or ROM and 2 MB RAM. Set-top box is an example of connected device.

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CLDC Profiles and source packages

- A configuration for the MIDP which does not provide for the applets, awt, beans, math, net, rmi, security, sql, and text packages in the java.lang.

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CDC Profiles and source packages

- A configuration for the Foundation and Personal Profiles, TV Profile, or Auto Profile which includes classes inherited from a limited number of classes at *net*, *security*, *io*, *reflect*, *security.cert*, *text*, *text.resources*, *util*, *jar*, and *zip* packages

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CLDC Virtual machine

- KVM—does not support weak reference which means full object reference to the object must be used for reaching to the object in the application program

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kVM

- A virtual machine which has no floating point mathematical operations support (supports only integers), limited exceptional handling, no automatic garbage collection (memory freeing), no native support using JNI (Java native interface) to use C/C++ application interface with the Java APIs, and no ThreadGroup

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CDC Virtual machine

- CVM (coherent virtual machine) for multi-protocol and multi-threading support

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Summary

- J2ME A micro edition of J2SE which provides for configuring the run time environment
- MIDP a mobile information device profile
- MIDlet or mobile applications
- CLDC
- CDC

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End of Lesson 06

J2ME

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Mobile Operating Systems

Lesson 01

Operating System

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Operating system (OS)

- The master control program
- Manages all software and hardware resources
- Controls, allocates, frees, and modifies the memory by increasing or decreasing it

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Operating system (OS)

- Also manages files, disks, and security, provides device drivers and GUIs for desktop or mobile computer, other functions, and applications
- Enables the assignment of priorities for requests to the system and controls IO devices and network

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Device driver

- As software component which enables the use of a device, port, or network by configuring (for *open*, *close*, *connect*, or specifying a buffer size, mode, or control word) and sends output or receives input
- Driver Functions– create, delete, open, close, read, write, io_control, connect, bind, listen and accept

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Operating system (OS)

- Has the utility programs, for example, file manager and configuration of OS (memory and resource allocation and enabling and disabling the use of specific resources and functions)
- Can be accompanied by a specific suite of applications, for example, Internet Explorer and MS Office

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Process

- A program unit which runs when scheduled to do so by OS and each state of which is controlled by OS
- Can call a function (method) but cannot call another process directly

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States of a process

- Can be in any of the states—

1. created
2. active
3. running
4. suspended
5. pending for a specified time interval

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Pending state of a process for a specific communication from other process

- Signal
- Semaphore
- Mailbox-message
- Queue-message
- Socket

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Task

- An application process which runs according to its schedule set by the OS
- Each state of which is controlled by OS
- Can be a real-time task which has time constraints or maximum defined latency within which it must run or finish

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Thread

- An application process or a process sub-unit (when a process or task has multiple threads)
- Runs as scheduled by the OS
- Each state controlled by OS
- Runs as a light-weight process

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Light-weight

- Does not depend on certain system resources, for example, memory management unit (MMU), GUI functions provided by the OS, or the functions which need running of other processes or threads for their implementation

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Interrupt service routine (ISR)

- A program unit (function, method, or subroutine) which runs when a hardware or software event occurs
- Running of which can be masked and can be prioritized by assigning a priority
- Higher priority than any other process or task or thread

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Hardware events for interrupts

- Time-out of a timer (clock tick)
- Division by zero
- Overflow
- Underflow detection by hardware during computation

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Hardware events for interrupts

- Finishing of DMA (direct memory access by a peripheral) transfer
- Data abort
- External FIQ (fast interrupt request through a pin input)
- External IRQ (interrupt request through a pin input)
- A memory buffer becoming full

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Hardware events for interrupts

- Port, transmitter, receiver, or device buffer— becoming half filled, buffer with at least one memory address filled, and buffer becoming empty
- Buffer— associated with the memory addresses for the LCD, printer, serial or USB port, keypad, or modem

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Software related events for interrupts

- Exception– software instruction for interrupt on detection of a certain condition during computations or error while logging in
- Illegal operation code provided to CPU

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Interrupt service thread (IST)

- A special type of ISR or ISR unit (function, method, or subroutine) which initiates and runs on an event or message from an high priority ISR
- ISTs can be prioritized by assigning a priority
- The type of IST depends on the specific OS

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Windows CE IST

- One which is placed in a priority queue so that the ISTs execute turn by turn—FIFO (first-in first-out)
- An IST is initiated and put in the FIFO according to ISR priority after the execution of an ISR starts on an event and the ISR puts a message or semaphore or signal for the IST

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ISR and IST

- The ISR, therefore, has an event-initiated short piece of code, which runs only the critical part of the code and rest of the code runs at the IST initiated by it
- The IST priority— lower than the ISR but higher than the processes or tasks or threads

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Page

- A unit of memory which can load from a program stored in a hard drive or from any other storage device to the program memory, RAM, before the execution of a program
- A contiguous memory address block of 4 kB (in x86 processors), 2 kB, or 1 kB

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Page table

- For address mapping
- Provides the mapping of fragmented physical memory pages with the pages of the virtual addresses which are the memory addresses
- Pages of memory are spread over the memory-address space leading to fragmentation of codes and data in physical memory space

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MMU

- Creates and maintains the page table and hence performs address mapping and translation
- Program during execution first translates the accessed address (virtual address) into a physical address using the page table at the MMU and then accesses the physical address and fetches the code or data

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Priority inversion

- Takes place when a process or thread which is to provide a waiting object to a higher priority process or thread gets preempted by a middle priority process or thread and thus the middle priority process or thread starts running on obtaining the object for which it was waiting and higher priority process or thread keeps waiting for wait object.

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Priority inheritence

- Process or thread which is to provide a waiting object to a higher priority process or thread, gets the priority of that process or thread
- Waiting object– signal, semaphore, queue, mailbox message, or bytes from a pipe

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Pipe

- A virtual device which sends the bytes from a thread to another thread

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Example of Linux OS – Mobile

- An open source OS
- Enables the user to customize their device to suit their specific needs
- Provides ease to suit different sorts of hardware and software applications

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Linux

- Embedded Linux Consortium (ELC) standards for Linux for designing user interfaces, managing power consumption in devices, and real-time operation
- Also considered to be more secure than most other operating systems
- Several international mobile phone manufacturers use Linux for their OS requirements

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Motorola Rokr E2 music phone

- A Linux-based mobile phone
- A 240 x 320 TFT display with 262,000 colours
- USB 2.0 PC networking for fast ‘drag-and-drop’ data transfer
- Built-in FM radio
- Support for Motorola’s iRadio service
- Support for Bluetooth

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Motorola Rokr E2 music phone

- 1.3-megapixel camera for video capture and playback
- MMS (multimedia messaging service) enabled
- Opera web browser
- *Airplane mode* for safely listening to music when aboard an aircraft
- PIM (personal information manager) with picture caller ID

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Summary

- OS– a master control program
- Manages all software and hardware resources
- Controls, allocates, frees, and modifies the memory by increasing or decreasing it
- Controls processes, tasks, threads, ISRs and ISTs

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… Summary

- Manages files, disks, and security, provides device drivers and GUIs for desktop or mobile computer, other functions, and applications
- MMU
- Priority inversion and inheritence
- Linux– An open source OS
- Enables the user to customize their device to suit their specific needs

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End of Lesson 01

Operating System

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Mobile Operating Systems

Lesson 02

Mobile Operating System

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Mobile computing systems

- Specialized hardware
- GUIs
- VUIs
- Provision for mobile communication
- Many constraints, for example, the constraints of connectivity, CPU speed, memory, battery life, display, and size of input devices

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Mobile OS

- An OS which enables running of application tasks taking into account such constraints of hardware and network
- Enables a programmer to develop application without considering the specifications, drivers, and functionalities of the hardware of the system

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Driver

- Software component which enables the use of a device, port, or network by configuring (for *open*, *close*, *connect*, or specifying a buffer size, mode, or control word) and sends output or receives input

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Mobile OS

- Enables an application to run by simply abstracting the mobile system hardware
- Enables the programmer to abstract the devices such that the application need not know full details of the font and font size of the mobile device display
- Application need not know how the message will be displayed by the LCD hardware

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Mobile OS Examples

- PalmOS
- Windows CE
- Symbian
- Android– released in 2008 by **Google** [open-source code which powers mobile operating system]

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Example of hardware abstraction by the OS

- Assume that keypad, LCD display, serial input, and serial output devices are abstracted by an application as the input and output devices with device numbers 1 2, 3, and 4, respectively

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Example of hardware abstraction by the OS

- write (1, 'Welcome to ABC Telecom') when a message Welcome to ABC Telecom is sent in the output for display
- The line can be *write* ('Welcome to ABC Telecom') when display device is taken as default output device

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Mobile OS

- Facilitates execution of software components on diversified mobile device hardware
- Application need not be aware of the details of the LCD driver and memory at which the CPU will send the message for display

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Mobile OS

- Provides interfaces for communication between processes, threads, and ISRs at the application and middleware layers
- Provides middleware for the system hardware
- Provides management functions (such as creation, activation, deletion, suspension, and delay) for tasks

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Mobile OS

- Provides memory management
- Enables running of processes
- Helps the processes in obtaining access to system resources

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Application

- Application tasks
- The OS provides the functions used for scheduling the multiple tasks in a system
- Synchronization of the tasks by using semaphores (tokens)
- A task may have multiple threads

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Mobile OS

- Provides for synchronization of the threads and their priority allocation
- Accomplishes real-time execution of the application tasks and threads

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Application

- Uses the system resources, for example, CPU, memory keypad, display unit, modem interface, USB or serial port, and battery
- Resources shared concurrently by the applications running on the system

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User application

- GUIs (graphic user interfaces)
- VUI (voice user interface) components
- Phone API
- Mobile OS provides configurable libraries for the GUI in the device
- It provides for multi-channel and multi-modal user interfaces

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Summary

- Mobile OS– An OS which enables running of application tasks taking into account mobile system constraints of hardware and network
- Enables a programmer to develop application without considering the specifications, drivers, and functionalities of the hardware of the system

...

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… Summary

- Device drivers
- GUIs
- VUIs
- Phone APIs

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End of Lesson 02

Mobile Operating System

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Mobile Operating Systems

Lesson 03

PalmOS– Part 1

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PalmOS

- An OS for handheld devices
- Designed for highly efficient running of small productivity programs for devices with a few application tasks
- Offers high performance due to a special feature that it supports only one process which controls all computations by the event handlers

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PalmOS Features

- Single process (no multi-processing and multi-threading)
- Compiled for a specific set of hardware, performance very finely tuned
- Memory space partitioned into program memory and multiple storage heaps for data and applications

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PalmOS Features

- A file in format of a database
- IP-based network connectivity and WiFi (in later version only)
- Integration to cellular GSM/CDMA phone

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PalmOS

- No multi-processing or multi-tasking
- Simplifies the kernel of the OS– there is an infinite waiting loop in the only process that kernel runs
- The loop polls for an event

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Polling for events at specific intervals

- Each polled event— sends interrupt signal
- Handled by an event handler
- Functioning as non-maskable non-prioritized ISR

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Example: Polling for the events

- For a request to run an application or sub-application
- For a search program request to process a query
- Notifications (like time-out alarm)
- GUI actions (such as touching or tapping the screen with stylus)

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PalmOS Hardware Support

- Compiles for a specific set of hardware, its performance is very finely tuned
- Optimized to support a very specific range of hardware, CPU, controller chips, and smaller screens of Palm OS-based devices

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Display Screen Support

- Generally wide screen
- 160 × 160 pixels
- Optimized layout of desktop programs displayed on screen
- 256 colour touch screen
- Higher resolution support in new versions

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PalmOS Memory Support

- 16 MB memory
- 256 MB internal flash (non-volatile ROM)
- 256 MB card consisting of flash memory which the user inserts into the device

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PalmOS Memory Space Partitions

- Program memory dynamic heap– for process stacks and global variables
- Multiple storage heaps– for data and applications

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PalmOS File Format

- Format of a database
- Multiple records
- Information fields about the file—name, attributes, and version of the database for the application

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PalmOS Connectivity

- IP-based network connectivity
- WiFi (in later version only)
- Wireless communication protocols
- Integration to cellular GSM/CDMA phone

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PalmOS APIs

- Simple APIs compared to Windows CE
- Simple APIs for developing the GUIs — buttons, menus, scroll bar, dialogs, forms, and tables
- Using HTML markup language

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PalmOS Desktop and Desktop Programs

- Desktop for Windows and Mac both and other essential software
- SMS, Address, Card-Info, HotSync, To-Do-List, SMS, Security, Date Book/Calendar, Calc, Welcome, and Clock

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PalmOS PIM

- Address book
- Data book for task-to-do and organization
- Memo pad
- SMTP (simple mail transfer protocol) email download

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PalmOS PIM

- Offline creation and sending of POP3 (post office protocol 3) email
- Internet browsing functions using Blazer (a browser for handhelds)
- Windows organizer
- PDA (personal digital assistant)

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PalmOS Query Development Platform

- Query development support platform—Palm query applications (PQA) written using HTML and ported at Palm device

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PalmOS Client side Applications

- GUI development support on C/C++ platform using Palm SDK
- For Java application using J2ME and advanced tools, for example, Metrowerk CodeWarrior
- Multimedia applications such as playing music (Palm Tungsten)

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PalmOS Ports

- Serial and infrared ports for communication with mobile phones and external modems
- Synchroniszing a PC personal area computer using HotSync after resolving the conflicts in different versions of files during data exchange

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Port Protocols

- IrDA or serial device
- System mounted on a cradle
- Connects to computerPCs through IR or serial port
- A cradle is an attachment on which the handheld device can rest near a PC and connects to the PC via a USB or infrared

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Device handling

- Assumed as a new flash drive of a PC
- HotSync facilitates drag and drop of files from device to PC and vice versa

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Cards

- MMC (multimedia card)
- SD (secure digital) memory card
- SDIO (secure digital input/output) memory card

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Third Party applications support

- Examples—games
- Travel and flight planner
- Calculator
- Graphic drawings
- Preparing slide shows

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Application layer in architectural layers of PalmOS

PIM, address book, data book for task-to-do and organizing, memo pad, SMTP (simple mail transfer protocol) e-mail download, offline creating and sending POP3 (post office protocol 3) e-mail, wireless Internet browsing functions, Windows organizer and PDA (personal digital assistant)

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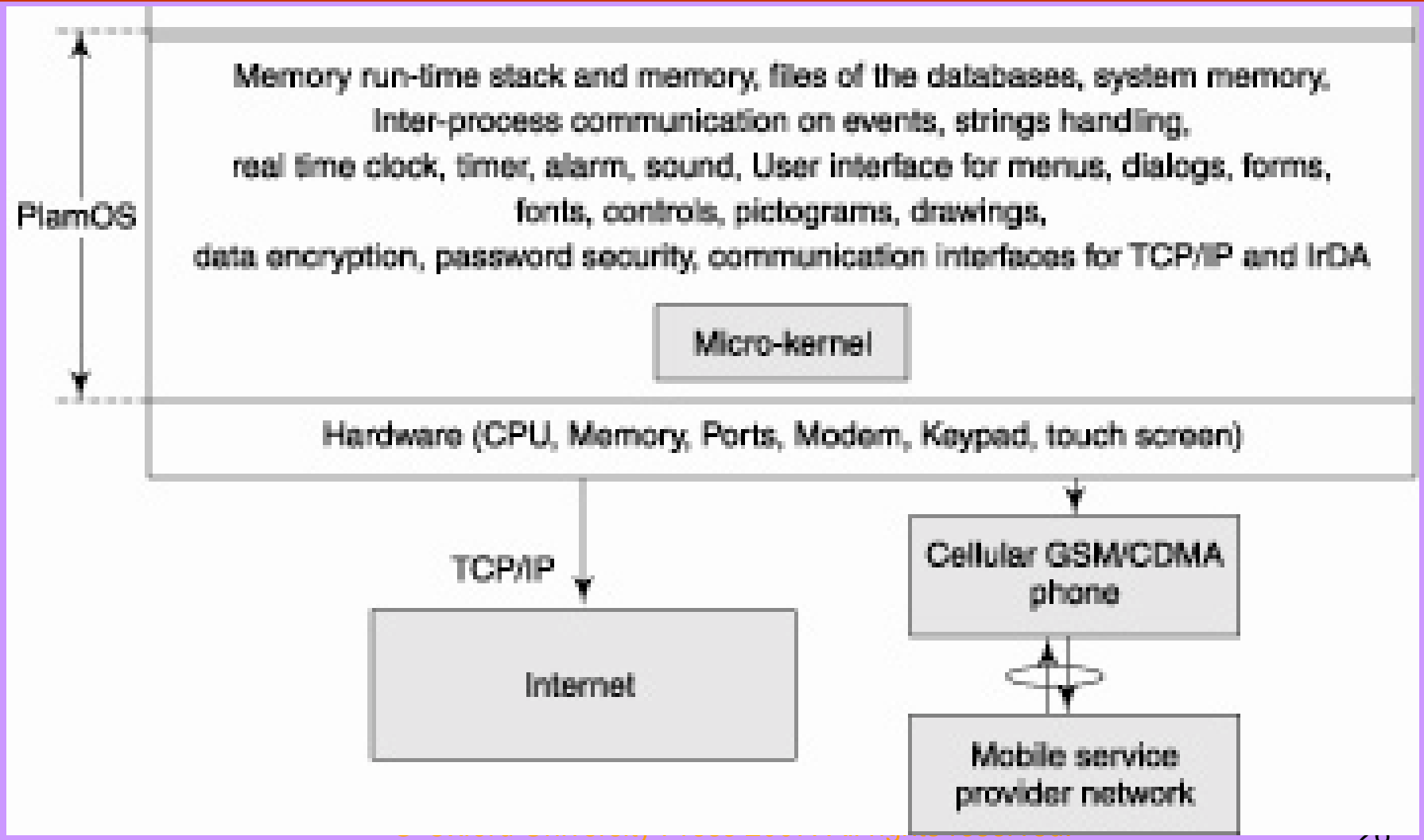
OS and hardware layer in architectural layers of PalmOS



Lowest level layer in OS

- Kernel
- Directly interfaces the assembler, firmware (software installed in the hardware devices in the system), and hardware
- PalmOS has a micro-kernel

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PalmOS 4.x

- Adds improved security
- Improved GUIs,VUIs, telephony libraries
- Standard interfaces for access to the external SD cards for the files

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PalmOS 5.x

- Supports—(i) a standardized API for high resolution screen
  (ii) dynamic input areas

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PalmOS 5.x

(iii) instead of persistent battery-backed RAM, a non-volatile file system using flash memory— saves the files and data in case the battery charge is draining out

(iv) ARM, the processor— providing efficient code and an energy-efficient architecture

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Advanced PalmOS Handheld

- Merged PDA and smart phones
- Feature to double as a hard drive using USB cable to PC
- Enables the drag and drop of files between the Palm and PC in a manner similar to the drag and drop functions in a PC between C: and D: drives

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Recent Developments

- Integration in Wndows CE
- A few Windows mobile handheld devices in use are Palm look-alikes
- But these do not deploy PalmOS platform but Windows CE

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PalmOS Deficiencies

1. Instead of multi-tasking, PalmOS provides for running a sub-application from within an application

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PalmOS Deficiencies

2. Not an ideal platform for running multimedia applications because due to PalmOS is not for designing real-time systems

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PalmOS Deficiencies

3. Does not offer much expandability
4. Inability to adapt to different sorts of hardware may also be considered a limitation for this operating system

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Summary

- PalmOS designed for highly efficient running of small productivity programs for devices with a few application tasks
- No multiprocessing support
- Simple
- File record as database
- HotSync
- Integrates with phone, Internet, and WiFi

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End of Lesson 03

PalmOS– Part 1

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Mobile Operating Systems

Lesson 04

PalmOS– Part 2

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PalmOS Memory Support

- Assumes that there is a 256 MB memory card(s)
- The card– RAM, ROM, and flash memories
- A memory card — logical hexadecimal addresses from 00000h to 3FFFFh

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PalmOS Memory Support

- RAM– for stacks of processes and for the global variables in the running processes of the application(s)
- ROM or flash– for permanent resident application programs and OS
- Flash– used for storage of non-volatile data

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PalmOS Memory manager functions

Allocation, increasing or decreasing or freeing or locking (e.g., for pointers)
the allocation of memory-chunks (chunk maximum space = 64 kB)
in a heap and write-protection from the processes,
managing a database based file-system

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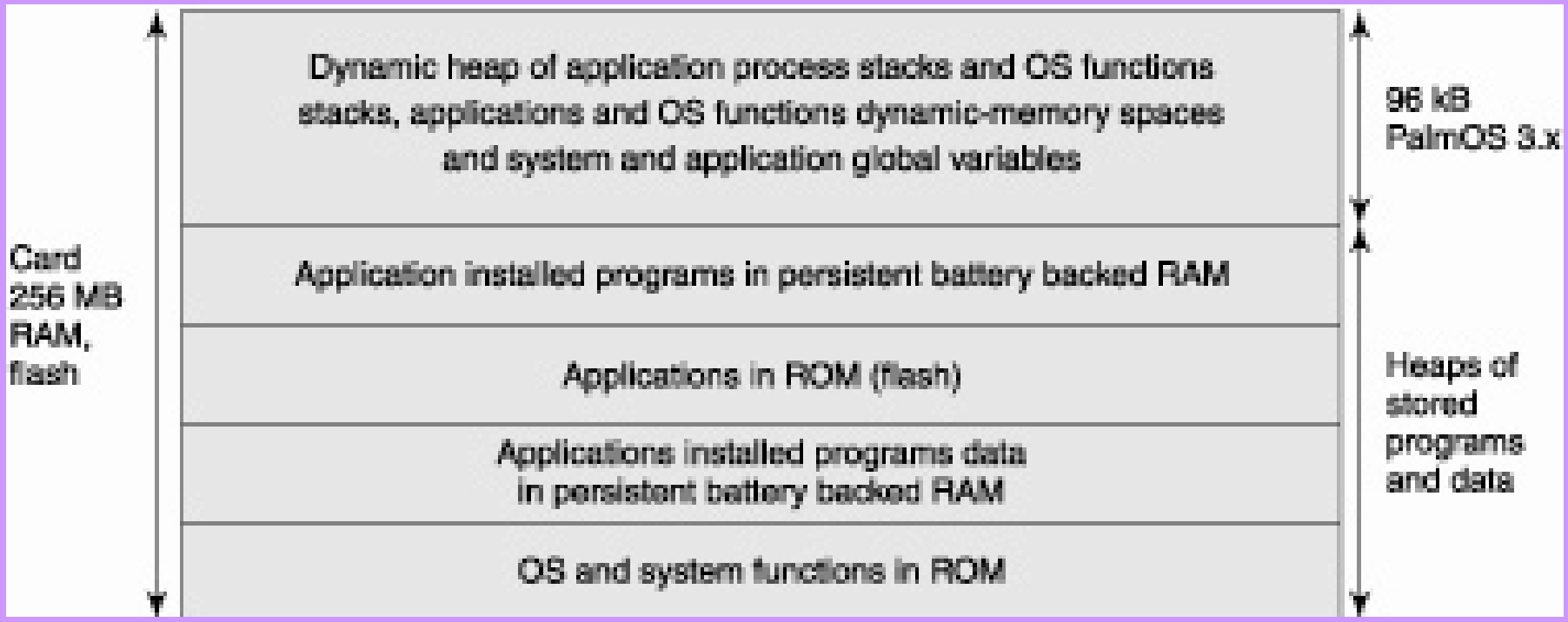
PalmOS memory partitioning



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Memory

- A dynamic heap (within 96 kB for PalmOS 3.x) of application process stacks (3kB)
- TCP/IP stack (32 kB)
- OS functions stack, applications and OS functions dynamic-memory spaces, system global variables (2.5 kB
- Application global variables

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Direct memory address spaces in card

- Used instead of allocated dynamic memory buffers for the I/O port devices (e.g., LCD display, keypad input, and modem I/Os)

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Execute-in-place system

- PalmOS 3.x and 4.x (not 5.x)
- Static allocation of the memory addresses for the application-installed programs and data storage

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File manager

- Manages each file as a database which has multiple records and information fields
- Each record attributes— protected record, deleted record (similar to deleted file), locked record (in use by application process or OS), and updated record
- Deleted record attribute helps in data recovery by a recovery program

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The info fields of each record

- Record ID and record attributes
- Info fields about the file have—(i) name, (ii) file attributes, (iii) version of application database, (iv) modification number (number of times modified) and access counter for number of times accessed), and (v) file local ID

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File Local ID

- In place of several characters– requiring several bytes
- The file local ID– a number used to identify the file locally when an application is running

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File ID

- A local file sorting table uses the file local ID to sort the file in the required order
- For example, the ordering may also be based on the time and date of the last modification made in the file

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Communication APIs

- For serial, IrDA, and TCP/IP communication
- Serial communication uses a cradle

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Serial manager (SM)

- Provides interface to the device on cradle with the RS232C COM port of the PC

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Protocols

- Connection management (CM) protocol
- modem manager (MM)
- Serial link protocol (SLP) interacts with SM to transmit the data to PC
- A device receives the data from the other end through serial manager and SLP, MM, or CM

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Communication Protocols

- MM for deploying a dial up-modem
- CM carries out exchanges for establishing connection, baud rate selection, and finding version number
- SLP for packet communication on serial line

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Communication Protocols

- A desktop link protocol (DLP) transmits data to PADP when serial device is sending data to PC and receives data from PADP when serial device is receiving data from the PC

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SLP

- Has on top of it, a packet assembly and disassembly protocol (PADP)

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IrDA

- Asynchronous serial (115 kbps)
- Synchronous serial communication (1.152 or 4 Mbps)
- Exchange manager as session layer and IrDA library functions (for IrDA protocol layers) at lower level

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Exchange manager

- Enables data interchange directly without HotSync
- Exchange manager and application use a set of launch codes to generate appropriate events

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Network library functions

- TCP/IP network library functions (for UDP and TCP) to send stack to a net protocol stack (NPS) and provides a socket API
- Berkeley Socket APIs also supported
- Uses HTTP/HTTPS net library for Internet connectivity

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Application Development Method

- Corresponding to each event, there is an event handler
- Application development means defining additional events and coding for the corresponding handlers

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Application Development Method

- An application can be assumed to be divisible into sub-applications a_m to a_{n-1} along with the existing event handlers a_0 to a_{m-1}
- Assume that a_i runs on the events e_i
- An event e_i polled at a sleep interval of t_{i-1} in an infinite while loop

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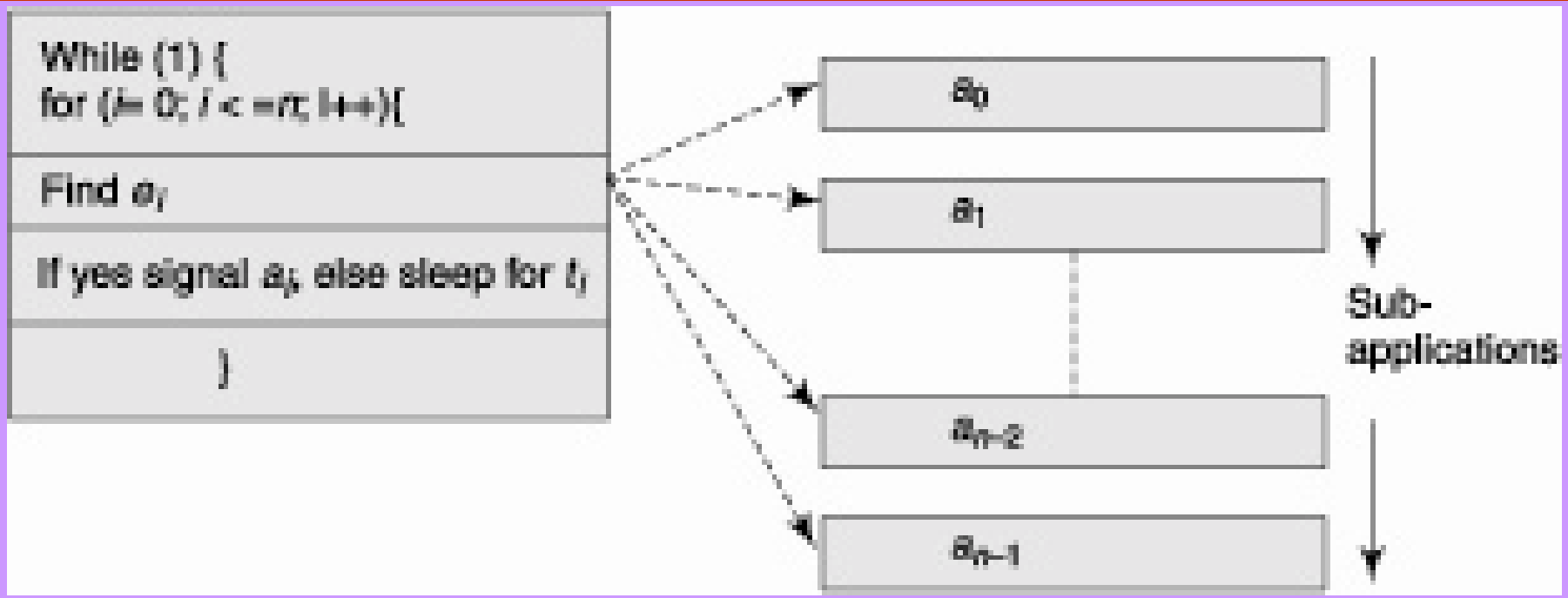
Application on PalmOS platform as event driven number of sub-applications



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Application

- SMS
- Address
- Card-Info
- HotSync
- To-Do-List
- Security
- Date Book/Calendar
- Calc, Welcome, and Clock

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Application Development Packages

- Supports development packages—Palm SDK (software development kit) and CDK (conduit development kit)
- A conduit is a path

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CDK conduit of Palm

- Provides a two-way path for data exchanges and synchronization between a desktop PC application (for Windows or Solaris) and the applications running on a device

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Summary

- PalmOS Memory management
- Partitioning
- Communication APIs
- Network Library Functions
- Application Development Method
- Application Development Packages

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End of Lesson 04

PalmOS– Part 2

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Mobile Operating Systems

Lesson 05

Windows CE– Part 1

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Windows CE

- A 32 bit OS from Microsoft
- Customized for each specific hardware and processor in order to fine-tune the performance
- Compatible with a variety of processor architectures
- Compiled for a specific set of hardware, its performance is very finely tuned

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Windows CE

- User— personal-computer-like feel and Windows-like GUIs
- Large number of Windows-based applications available at the device

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Windows CE 4.x

- Adds improved security, GUIs, VUIs, telephony libraries, and standard interfaces for access to the external SD cards for the files

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Windows CE 5.x

- Supports a non-volatile file system using flash memory
- Flash nowadays used instead of persistent battery-backed RAM

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Windows CE 5.x

- Windows CE supports a new file system that supports larger file sizes, removable media encryption, and larger storage media
- The flash file system saves the files and data in case the battery charge is draining out

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Windows Embedded CE 6.0

- Open, scalable, 32-bit operating system (OS) with small-footprint and advanced Windows technologies
- Provides hard real-time capabilities, with a redesigned kernel and embedded-specific development tools

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Windows Embedded CE 6.0 devices

- For home as well as work places
- Provisions for media and shared presentations
- Connectivity to cellular networks

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Windows Mobile 6 platform

- For mobile devices such as PocketPC
- for managing Visual C# and Visual Basic .NET codes
- Based on Windows CE and hardware such as personal digital assistants (PDAs) and smartphones

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Windows Mobile 6 platform

- Microsoft Visual Studio 2005
- Windows Mobile SDK for creating software for the platform
- The code developed in Visual C++

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Windows Mobile

- Windows CE 5.0 with a set of specific applications
- GUIs/VUIs and for a specific set of processors
- Windows Mobile 5.x—all user data in persistent (flash) memory and RAM to be used only for running applications
- External memory stick (strip) (e.g., 2 GB)

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Windows CE Memory

- Memory requirement large
- Minimum footprint of Windows CE is 350 kB
- Windows Mobile 5.x all user data in persistent (flash) memory and RAM to be used only for running applications
- Scales to the requirement of the device peripherals
- Memory space partitioned

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Processes in Windows CE

- Device based on CE 6.0 can run a larger number of complex applications and can run as many as 32,000 simultaneous processes
- Windows CE 6.0 provisions for each simultaneously running process—2 GB of virtual memory space
- Minimum footprint of Windows CE — 350 kB

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Thread

- Basic unit of computation
- A process– any number of threads
- Threads run concurrently

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Windows Mobile

- Deployed in (i) Smart phone, (ii) handheld PocketPC which features the *digitizer* in the human computer interface (HCI), and (iii) portable media player
- PDA with Microsoft Smartphone phone device, touch screen, touchpad, or directional pad

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PocketPC

- Has digitization software which converts

(i) analog signals to digital ones to enable scanning of photos and video recordings for storage or transmission

(ii) audio analog sources into digital form to enable speech processing, voice, or music for creatring records and files which are stored or transmitted

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Windows CE

- Kernel divided into two sublayers
- One sublayer consists of large part of the OS
- Then the OS is adjusted according to the device hardware by adding the remaining part of the OS
- Second sublayer called hardware abstraction layer

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Windows CE

- Shared source licensed with controlled access to full or limited parts of the source code for a product
- Windows CE 5.x developers have the freedom to modify down to the kernel level without the need to share their changes with Microsoft or competitors

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Windows CE

- A component-based, embedded, real-time operating system with deterministic interrupt latency
- Can be configured as a real-time operating system for handheld Smart phone, PocketPC, computers, and embedded systems

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Windows CE

- Modular/componentized to provide the foundation of several classes of devices and supports addition of features of other components for Windows, DCOM, and COM

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Windows CE

- Data format— database or object file
- File automatically compresses when stored and decompresses when loaded
- Visual C/C++ platform integrates use of web
- .NET XML parsing (trimmed version)

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GUIs development support

- Using markup language as well as C/C++ language
- Embedded complex APIs
- Gives the user a PC-like feel and Windows-like GUIs (window resizing not provided)

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VUIs development support

- Built-in microphone for voice recording
- VUIs (in PocketPC and automotive PC), buttons, shortcut icons, menus, scroll bar, dialogs, forms, and tables

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Display

- High resolution colour/ display
- Touch screen
- Stylus keypad with Windows layout of desktop programs displayed on coloured touch screen

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Software

- Desktop for Windows
- Other essential software
- PIM
- Contacts
- Task-to-do
- Smart phone
- Multimedia applications such as playing music

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Desktop Programs

- Owner
- Number of messages not read
- Tasks
- Present hour subject

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Desktop Programs

- Button and tool bar for task start menu
- Today calendar, contacts, Internet explorer, messages, phone, pocket MSN, album, MSN messenger, camera, programs, settings, and help], phone mode indicator (on/off), signal strength status, speaker status (on/off), and time

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Soft buttons

- Two context-sensitive *soft* buttons at the bottom of the screen
- Can be mapped to hardware buttons on any specific device

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Ports

- USB and infrared port support for communication of a device with mobile phones and for synchronizing a PC using ActiveSync after resolving the conflicts due to different versions of object files during data exchange.
- Bluetooth
- TCP/IP
- WiFi or Ethernet LAN interface

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ActiveSync

- Synchronization of mobile device data with PC using a USB, Bluetooth, and PC infrared port

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Connectivity to other devices

- A cradle connects to PC
- USB 2.0 in Windows CE 5.0 PocketPC conform as the USB mass storage class, the storage on device can be accessed, and drag and drop menu can be used from any USB port of PC, which considers the handheld device just another flash drive

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Third party support

- Very large support (about 20000) for games, applications, mobile e-commerce, and stock-trading

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Window CE device three states

(i) ON with clock frequency lowered in idle state

(ii) suspend with power to unused system units and port peripherals disconnected, memory data persistent, CPU idle till next interrupt, and clock running

(iii) dead with power disconnected

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Windows CE deficiencies

- Cooperative running of multi-threading does not support simultaneous multi-modal user interfaces (data by multiple modes, for example, text as well as speech)

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Poor Adaptability

- Adapts to different sorts of hardware limits mainly because of two reasons—(i) compiled for a specific set of hardware for very fine-tuned Windows CE performance, (ii) large parts of OS offered in the form of source code first and then adjusted to the hardware by the manufacturer

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Summary

- A 32 bit real time OS from Microsoft
- Customized for each specific hardware and processor in order to fine-tune the performance
- Compatible with a variety of processor architectures
- User– personal-computer-like feel and Windows-like GUIs …

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… Summary

- Large number of Windows-based applications available at the device
- Kernel consisting of source code and hardware abstraction sublayer
- Shared source and source code access
- Memory requirement large but scales to the requirement of the device peripherals

…

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… Summary

- Memory space partitioned
- Data formats database and object file
- File automatically compresses when stored and decompresses when loaded
- Visual C/C++ platform integrates use of web
- .NET XML parsing (trimmed version)

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End of Lesson 05

Windows CE– Part 1

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Mobile Operating Systems

Lesson 06

Windows CE– Part 2

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Application layer above the OS, hardware abstraction and hardware

Bluetooth, WiFi, Word mobile with embedded graphics, Excel mobile with charts, tables, ordered lists, Power Point Mobile, set of hardware application (e.g., camera) buttons, e-mail download, offline creating and sending POP3 (post office protocol 3) e-mail, Internet explorer functions on handheld mobile system, data call API, Telephony API and Wireless Smartphone support, Digital camera card, Direct3D (for 3-dimesional graphics and Games, Microsoft Windows Media and other players

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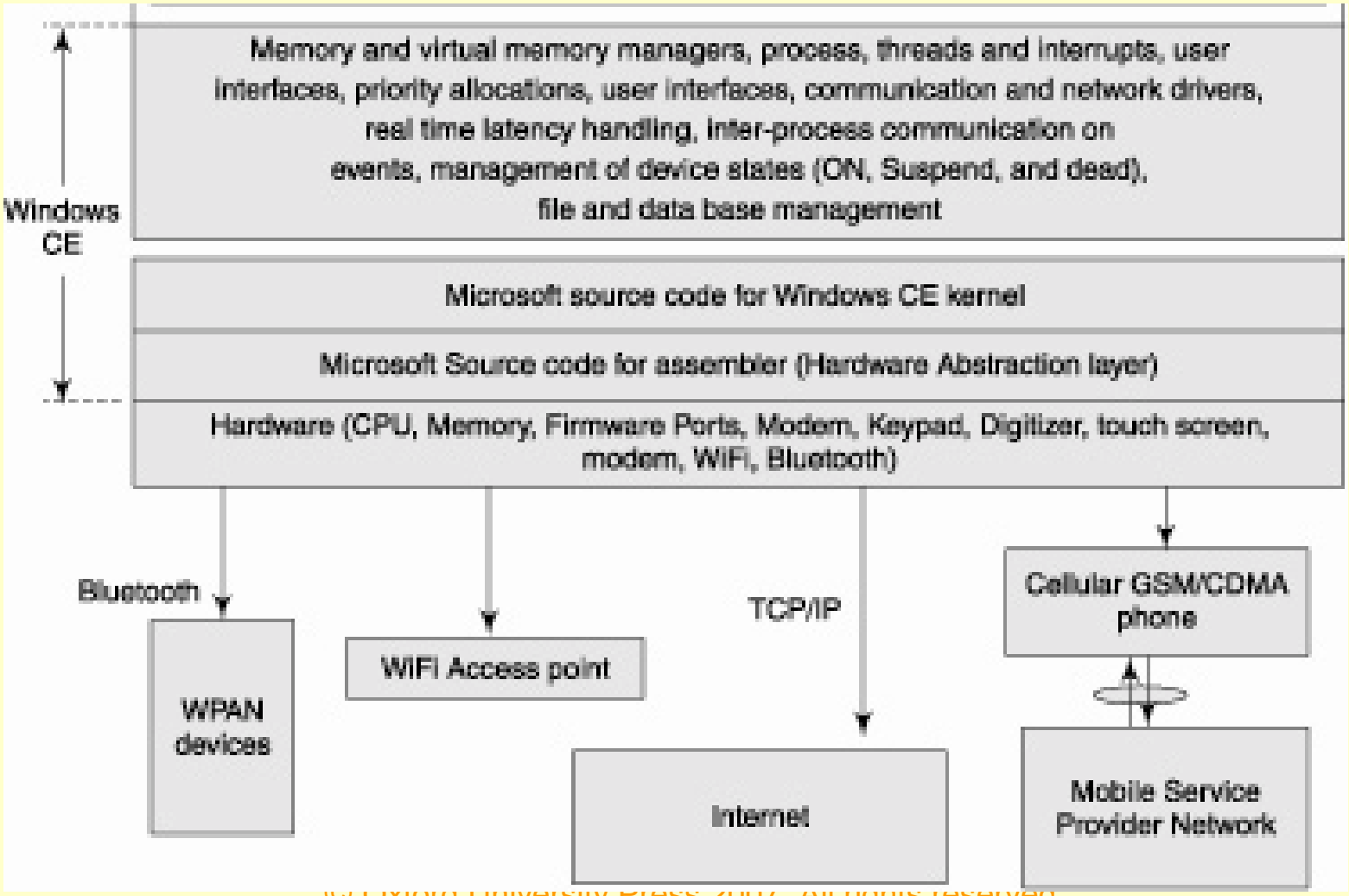
OS layer above the hardware abstraction and hardware



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Windows CE Memory Management

- Assumes 4 GB virtual memory
- RAM, ROM, and flash memories
- A memory has logical hexadecimal addresses from 000000000h to FFFFFFFFh

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Windows CE Memory Management

- A ROM image– the footprint of OS, data, and the applications at the permanently installed ROM (or flash memory)
- An OS configured and customized for an embedded application(s)– footprint is the ROM image
- The customization reduces the OS footprint

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Windows CE Memory Management

- Windows CE needs a minimum footprint of 350 kB
- Device applications optimized so that the devices need minimal storage below 1 MB with no disk storage
- Windows CE footprint burned in ROM and configured as it does not allow end-user extension

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Windows CE Memory manager functions

Allocation, increasing/decreasing/freeing/locking, MMU, all memory devices identically handled, program memory allocation and management as virtual memory, four memory access-mechanisms

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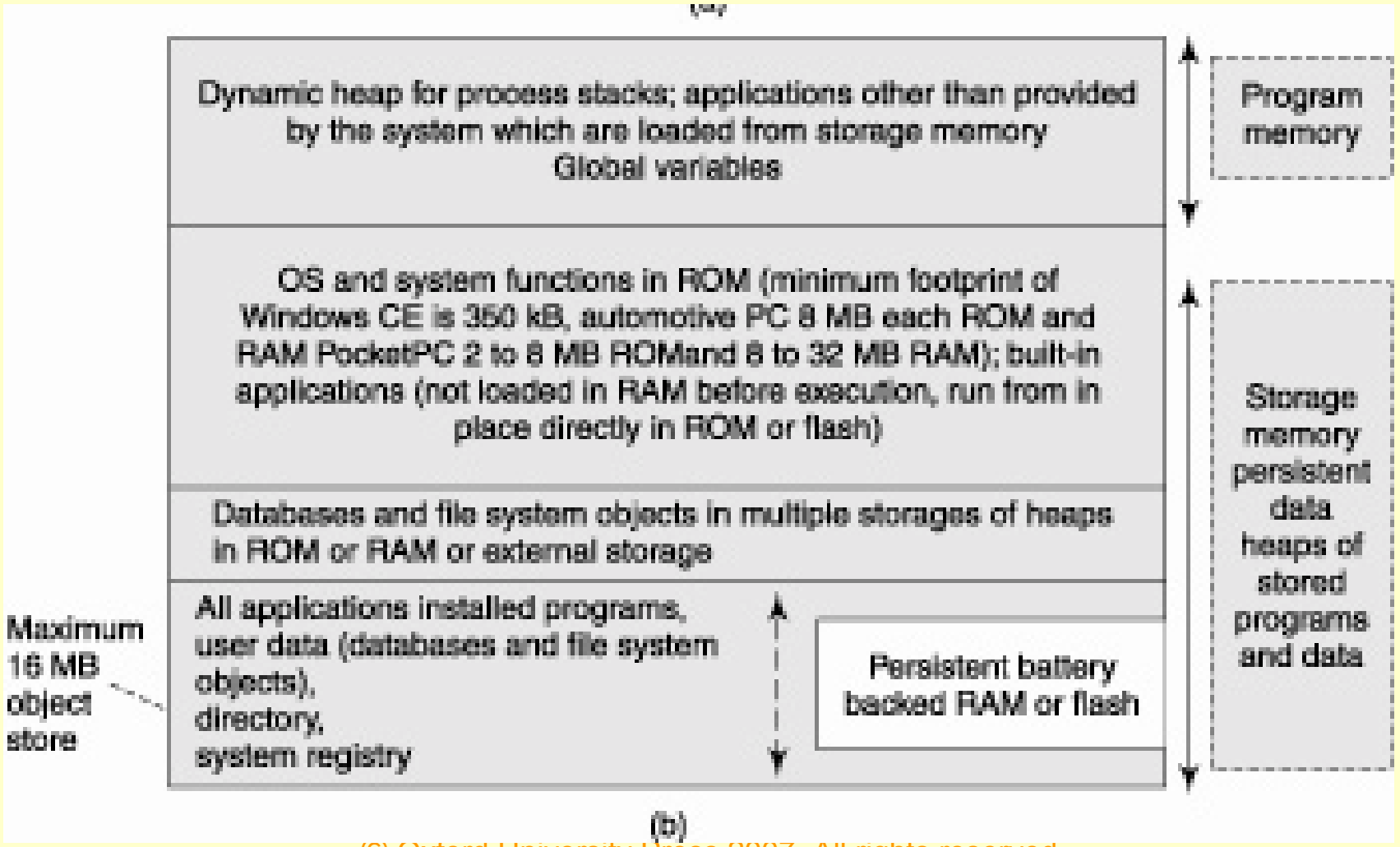
Windows CE memory partitioning



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Memory manager

- Assigns contagious pages in virtual address space to one of the 32 memory slots
- Each slot of 32 MB
- Allocates a distinct slot to a distinct process among the maximum 32 concurrently running processes

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Memory manager

- Allocation of memory slots reduces fragmentation of pages to a significant extent as pages of processes are at the contagious addresses in the slot
- Fragmentation occurs only when the memory needed by the process code and data is more than 32 MB

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Dynamic heap in the program memory

- Of application process stacks, TCP/IP stack, OS functions stack, applications and OS functions dynamic-memory spaces, system and application global variables, Bluetooth stack, and WiFi stack

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Windows CE memory manager— four different types of access mechanisms

- Simple– There is no use of paging or cache.
- Cache– Cache is used but paging is not used. Processor cache is used along with the RAM/ROM/flash memory.
- Page– Paging is used but not cache.
- Sophisticated– both cache and paging are employed

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Execution in place (XIP) storage memory addresses

- Windows CE 3.x and 4.x (not 5.x) provides XIP
- Static allocation of memory addresses for the application-installed programs and data storage

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XIP storage memory addresses

- Built-in applications in storage memory and not loaded in RAM before execution
- Process runs these from XIP directly from process codes and data in ROM or flash)

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ROM and RAM

- OS and system functions in ROM
- An automotive PC with Windows CE 8 MB ROM and RAM each
- The PocketPC 2–8 MB ROM and 8–32 MB RAM in *storage memory*

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File manager

- Manages data as a database or object file
- A file system– a root directory with which the file folders associate in a tree-like structure
- Division of all file folders into volumes
- A volume – unit which can be loaded from the device to the computer or can be stored on the device from the computer

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File Volume

- Each volume has a root directory which has directories and file folders
- Each directory can have further divisions into subdirectories and file folders
- Each subdirectory can have further divisions into files and subdirectories till the leaf node which has a single file folder

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Communication, Network, Device, and Peripheral Drivers

- Communication and network APIs for serial, IrDA, TCP/IP, Bluetooth stack, and WiFi stack
- IP-based connectivity to the network and WiFi-based connectivity in later versions
- Window CE integrates Microsoft Smart phone software
- Enables the application of Windows CE device as cellular GSM/CDMA phone

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Serial communication

- Uses a cradle
- A serial manager (SM) provides interface to the device on cradle with the RS232C COM port of the PC
- Connection management (CM) by using the serial link interface protocol (SLIP) and point-to-point (PPP) protocol
- IrDA asynchronous serial (115 kbps) or synchronous serial communication (1.152 or 4 Mbps) uses ActiveSync

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Network connectivity

- By radio transceiver and LAN adapter
- A NDIS (network driver interface specification) used for the drivers other than the driver loaded at the hardware

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Windows CE TCP/IP network library functions (for UDP and TCP)

- To transmit or receive the stacks and application [HTTP, HTTPS, FTP, or RAS (remote access service)] requests and response on or from the network

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Windows CE device drivers

- Device driver and peripheral driver functions for low-level drivers at the kernel

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Windows CE

- USB connectivity provided for the peripherals

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Windows CE CSP (cryptographic service providers) server

- For actual implementation of the encryption and security
- Deploys CAPI (cryptographic application programming interface)

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Windows CE thread

- A fundamental unit of execution and providing access of CPU
- Applications developed by coding for the threads
- Supports 256 priority levels for assignment to the threads
- Provides protection from priority inversion as it provides for prioirty inheritence mechanism

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Event

- Sends interrupt signal which is checked for source, that is, whether the source is a hardware event, software exception, user-action-based event, or kernel event (e.g., a kernel command, WM_HIBERNATE)

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Event handler

- Separate for For each event
- Asynchronous events
- Event handler calls interrupt service thread (IST) in Windows CE device

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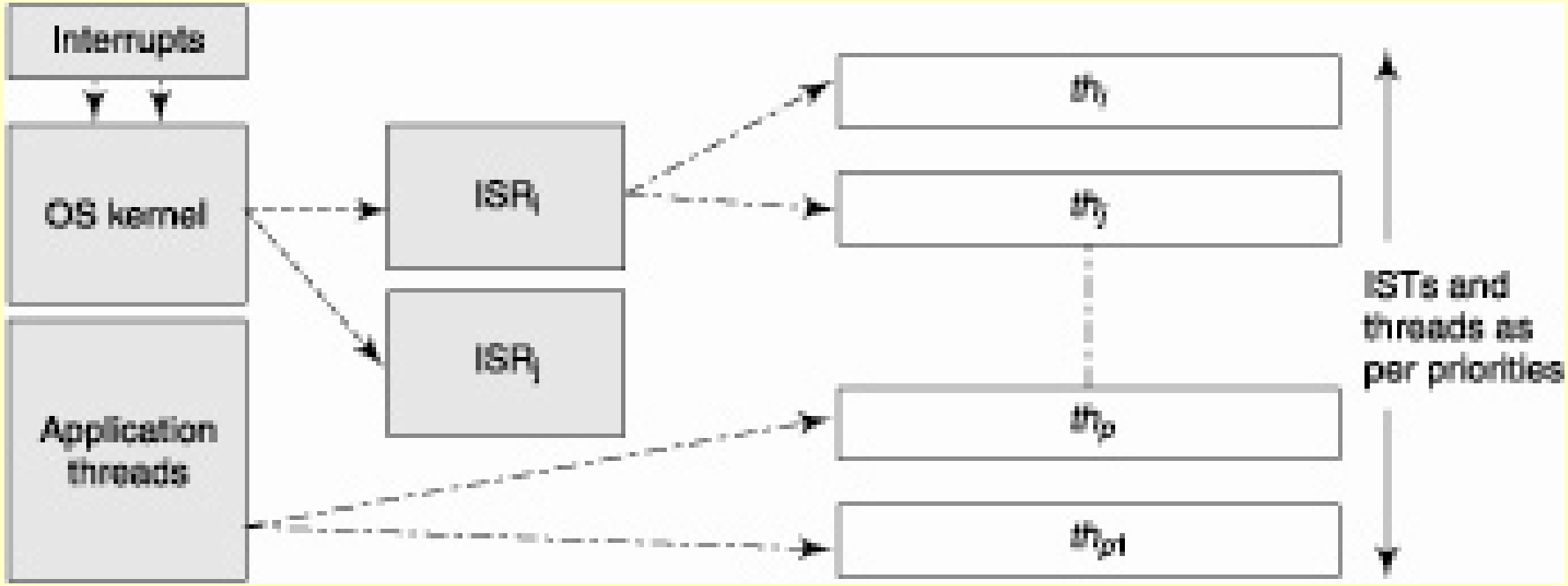
Application as event-driven number of ISTs (i, j, …) and application threads (p, q, …)



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External interrupt

- Notified to the OS and for each request, there is an ISR assigned by the OS on notice
- ISR is a short kernel code which identifies the IST for service and thus activates the IST corresponding to the request (event)

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External interrupt

- Using the concept of ISR, thread priority, and ISTs, Windows CE provides the OS for a hard real-time system with multiple processes

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IST

- Can have one of the eight priority levels
- Highest priority level means *time critical* priority (to run in hard real-time mode when latency is least and thread execution critical)
- Lowest priority level means *idle* priority (to run when system is idle)

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IST

- If priorities are same, each thread is allotted a time slot
- Initiated ISTs form a priority-ordered queue of routines and are executed as per priorities

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Application Development tools

- Visual basic and Visual C++
- PlatformBuilder– for developing a Windows CE application by carrying out OS image creation and integration
- PlatformBuilder provides an integrated environment for customized operating system designs based on Windows CE

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Summary

- Windows CE
- Memory manager and memory partitioning
- File manager
- Event handlers
- ISTs
- Communication and network APIs for serial, IrDA, TCP/IP, Bluetooth stack, and WiFi stack

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… Summary

- IP-based connectivity to the network and WiFi-based connectivity
- Integrate phone software
- Visual basic and Visual C++
- PlatformBuilder

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End of Lesson 06

Windows CE– Part 2

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Mobile Operating Systems

Lesson 07

Symbian OS

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Symbian OS– multi-modal communication support

- OS for handheld SmartPhones and mobile handhelds with phone and multi-modal communication features
- Multi-modal means usage of different modes—text, image, video, or audio
- Multi-modal communication integrates and synchronizes multimedia (Video with text, audio with text, …)

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Symbian OS– C/C++ as well as Java Support

- Supports application development in C/C++ as well as Java and many communication protocols
- JavaPhone

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Fine-tuning with ARM processors

- Symbian OS performance fine-tunes to ARM processors which are used in about more than 70% of mobile devices, for example, Nokia mobile devices

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Symbian application architecture

- GUIs and VUIs— APIs for the buttons, menus, advanced voice features such as a hands-free speakerphone, and conference calling capability
- Application view
- Application engine
- Powerful development platforms and GUIs

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Application development tools

- Personal Java and Symbian Everywhere
- Symbian C++ Software development kit (SDK)
- Symbian emulator for application development using Windows Metrowerk, CodeWarrior

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Synchronization

- SyncML synchronization
- Can also deploy C/C++-based synchronization software

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Symbian OS

- Low boot time
- OS supports multi-processing or multi-tasking
- Multithreading
- Internet connectivity for Web browsing, IP-based network connectivity, and WiFi (in later version only).
- Integration to cellular GSM/CDMA phone

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Memory Support

- Large storage memory
- Includes 80 MB of built-in memory in a MultiMediaCard (MMC)
- MMC (multimedia card), SD (secure digital) memory card, and SDIO (secure digital input/output) memory card.

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Security, MD5, RSA, and many other additional features

- . Symbian supports—(i) a standardized API for high resolution screen, (iii) non-volatile file system using flash memory to save the files and data instead of saving them in persistent battery-backed RAM, and (iv) ARM, the processor which provides efficient code and an energy-efficient processor architecture.

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Software

- Desktop both for Lotus and Windows programs
- Push-to-talk
- Graphics support including support for 3D rendering
- Simple APIs as compared to Windows CE, PIM, JavaPhone
- Telephony standard interfaces

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Software

- MIDP (mobile information device profile)
- contacts
- SyncML
- Office
- address book
- Spreadsheet

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Software

- Calendar
- Agenda
- Word processor
- Text-to-speech converter
- Browsing

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Software

- Messaging (SMS, MMS, email, and IMAP4)
- WAP push Microsoft Office formats (MS Office 97 onwards)

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Software

- Slide shows
- email download, offline creation and sending of POP3 (post office protocol 3) email
- Internet browsing
- GUI development support on C/C++ and Java platform

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Software

- Java application using J2ME
- multimedia applications such as playing music (Palm Tungsten)
- Wireless communications Support for WLAN

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Software

- Adobe Reader for accessing PDF files
- Symantec Client Security 3.0
- Fujitsu mProcess Business Process Mobilizer
- IBM WebSphere Everyplace Access

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Software

- BlackBerry Connect
- Oracle Collaboration Suite
- Secure mobile connections via VPN Client

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Ports

- Serial
- USB
- Infrared
- Telephony
- Bluetooth for communication with mobile phones and external modems

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Third Party Support

- Extensive
- Games
- Travel and flight planner
- Enterprise solutions
- Calculator
- Graphic drawings
- Preparing slide shows

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Application layer above the Symbian with OS layer

JavaPhone, JVM, MIDP (mobile information device profile), contacts, SyncML, office, address book, spreadsheet, Calendar, Agenda, word processor, text to speech converter, Browsing, Messaging (SMS, MMS, e-mail, IMAP4), WAP push

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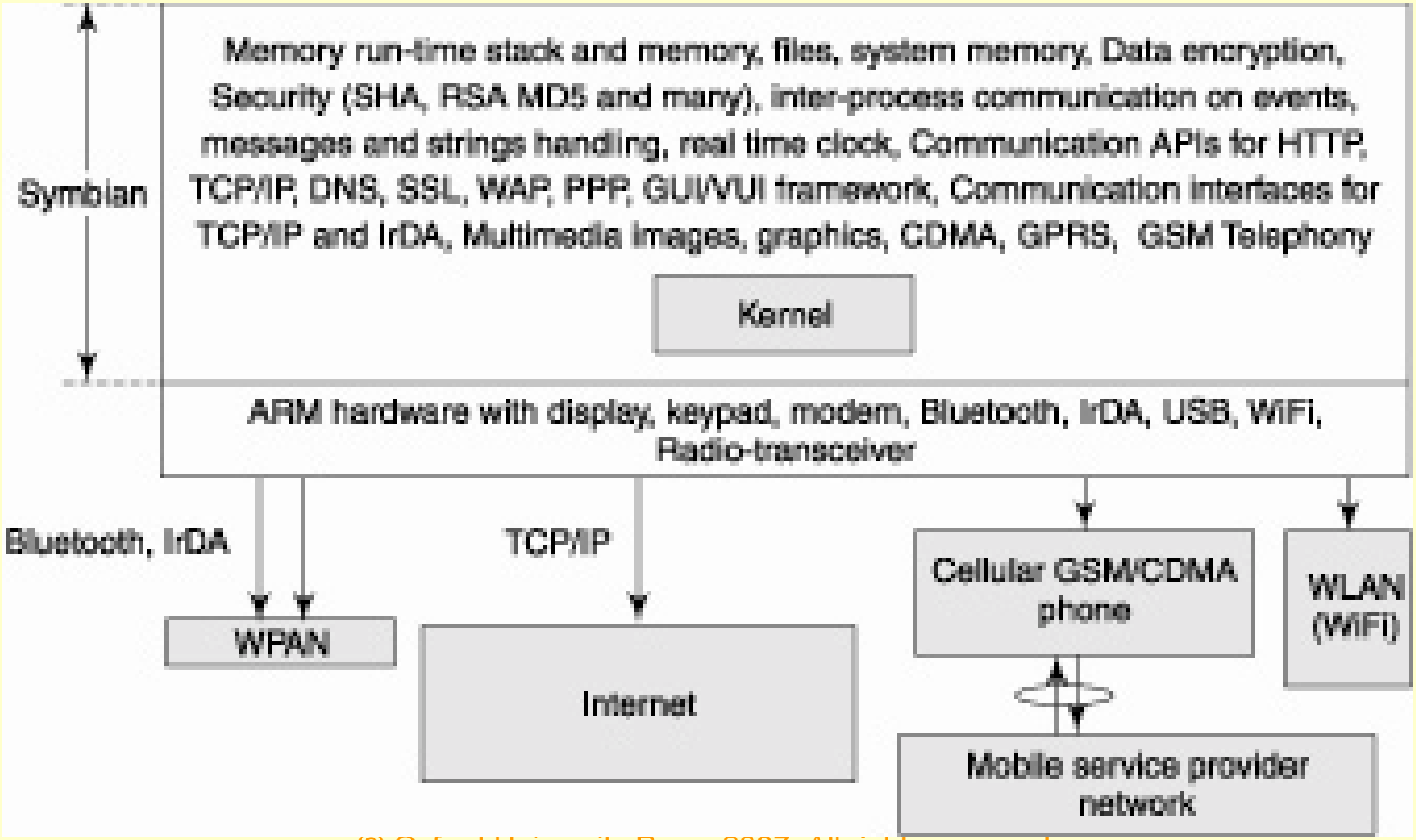
Os and Hardware layers of Symbian



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Communication APIs

- WAP
- WiFi
- CDMA
- GPRS
- GSM Telephony

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Network APIs

- Serial
- Bluetooth
- IrDA
- TCP/IP, communication APIs for HTTP, TCP/IP, DNS, SSL, WAP, PPP

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Summary

- Symbian OS
- Multithreading
- Multi-modal communication integrating and synchronizing multimedia
- C, C++, Java support
- Fine tuned with ARM processors
- Telephony
- Networking

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End of Lesson 07

Symbian OS

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