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DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

20CS501 – MOBILE COMPUTING

HANDOUTS
V SEMESTER

UNIT I INTRODUCTION

- *Mobile Computing = Mobility + Computing*
- Mobility
 - Capability to change location while communicating to invoke computing services at some remote computers
 - Kinds of Mobility
 - User mobility
 - Refers to a user who has access to the same or similar telecommunication services at different places
- Computing
 - Capability to automatically carry out certain processing related to service locations on a remote computer
 - Mobile Computing is a technology that allows transmission of data, voice and video via a computer or any other wireless enabled device without having to be connected to a fixed physical link. The main concept involves
 - Mobile communication
 - Mobile hardware
 - Mobile software
- Mobile Communication
- [Mobile Communication](#) specifies a framework that is responsible for the working of mobile computing technology.
- In this case, mobile communication refers to an infrastructure that ensures seamless and reliable communication among wireless devices.
- This framework ensures the consistency and reliability of communication between wireless devices.
- The mobile communication framework consists of communication devices such as protocols, services, bandwidth, and portals necessary to facilitate and support the stated services.
- These devices are responsible for delivering a smooth communication process.
- Mobile communication can be divided in the following four types:
 - Fixed and Wired
 - Fixed and Wireless
 - Mobile and Wired
 - Mobile and Wireless
- **Fixed and Wired:** In Fixed and Wired configuration, the devices are fixed at a position, and they are connected through a physical link to communicate with other devices.
- **For Example,** Desktop Computer.
- **Fixed and Wireless:** In Fixed and Wireless configuration, the devices are fixed at a position, and they are connected through a wireless link to make communication with other devices.
- **For Example,** Communication Towers, [WiFi](#) router
- **Mobile and Wired:** In Mobile and Wired configuration, some devices are wired, and some are mobile. They altogether make communication with other devices.
- **For Example,** Laptops.

- **Mobile and Wireless:** In Mobile and Wireless configuration, the devices can communicate with each other irrespective of their position. They can also connect to any network without the use of any wired device.
- **For Example,** WiFi Dongle.

History and Evolution of Mobile Computing

- The main idea of Mobile computing was evolving since the 1990s. It has evolved from two-way radios to modern day communication devices.
- Devices used in Mobile Computing
- Following is the list of most common forms of devices used in mobile computing:
- . Portable Computers
- A portable computer is a computer that is designed in a way that you can move it from one place to another.
- It includes a display and a keyboard. Generally, portable computers are microcomputers.
- 2. Personal Digital Assistant/Enterprise Digital Assistant (PDA or EDA)
- A Personal Digital Assistant (PDA) is also known as a palmtop computer. Sometimes, it is also called Enterprise Digital Assistant (EDA).
- A personal Digital Assistant (PDA) is a mobile device used to function as a personal information manager or a personal data assistant.
- . Ultra-Mobile PC
- An ultra-mobile PC was a small form factor version of a pen computer.
- It was a class of laptops whose specifications were launched by Microsoft and Intel in 2006.
- 4. Laptop
- A laptop is a small, portable personal computer (PC) built in a foldable device. The folding structure of a laptop is called a clamshell form factor.
- The flip or clamshell is a form factor of a mobile phone or other devices that include two or more folded sections via a hinge. A laptop typically has a thin LCD or [LED](#)

MOBILE COMPUTING Vs WIRELESS NETWORKING

- Mobile is a word that is commonly used to describe portable devices. A mobile device is one that is made to be taken anywhere.
- Therefore, it needs an internal battery for power, and must be connected to a modern mobile network that can help it to send and receive data without attaching to a hardware infrastructure.
- Wireless, on the other hand, does not mean mobile. Traditional computers or other non-mobile devices can access wireless networks.

- One very common example is the use of a localized browser product in a local area network (LAN), where the router takes what used to be a cabled interaction and makes it wireless.
- Other kinds of wireless networks called wide area networks (WAN) can even use components of 3G or 4G wireless systems made specifically for mobile devices, but that doesn't mean that the devices on these networks are mobile.
- They may still be plugged in or require proximity to a router or network node.

Application:

VEHICLES

- Transmission of news, road condition, weather, music, etc.,
- Personal communication using GSM/UMTS
- Position via GPS
- Local ad-hoc network with vehicles close-by to prevent accidents, guidance system, redundancy
- Vehicle data (e.g., from busses, high-speed trains) can be transmitted in advance for maintenance

EMERGENCIES

- Assume that an ambulance with a high-quality wireless connection is connected to a hospital
 - Information about injured persons is sent to the hospital from the scene of the accident to
 - Prepare necessary steps for this particular type of accident
 - Consult the specialists for an early diagnosis
- Wireless networks are the only means of communication during natural disasters such as hurricanes or earthquakes than wired networks
 - Only decentralized, wireless ad-hoc networks survive

BUSINESS

- Businessman needs instant access to the company's database to
 - Ensure that files on laptop reflect the current situation
 - Enable the company to keep track of all activities of their travelling employees,
 - Keep database consistent etc.
- With wireless access, efficient and powerful synchronization mechanisms are needed to ensure data consistency when laptop is turned into a true mobile office

Location dependent services

- Location dependent services are those services that allow the user to connect and use services that are available in their surrounding area.

- Location aware services
 - what services, e.g., printer, phone, server etc. exist in the local environment
- Follow-on services
 - Automatic call-forwarding
 - Forwarding calls to the current user location by assigning a temporary phone number to the user's actual phone
 - Allows the user to redirect incoming calls to the user location

CHARACTERISTICS OF MOBILE COMPUTING:

A communication device can exhibit any one of the following characteristics:

- ➤ **Fixed and wired:**
 - This configuration describes the typical desktop computer in an office. Neither weight nor power consumption of the devices allow for mobile usage. The devices use fixed networks for performance reasons.
- ➤ **Mobile and wired:**
 - Many of today's laptops fall into this category; users carry the laptop from one hotel to the next, reconnecting to the company's network via the telephone network and a modem.
- ➤ **Fixed and wireless:**

This mode is used for installing networks, e.g., in historical buildings to avoid damage by installing wires, or at trade shows to ensure fast network setup

- **Mobile and wireless:**
 - This is the most interesting case. No cable restricts the user, who can roam between different wireless networks. Most technologies discussed in this book deal with this type of device and the networks supporting them. Today's most successful example for this category is GSM with more than 800 million users.
- **Ubiquity** - Ability of a user to perform computations from anywhere and at any time.
- **Location Awareness**- Can provide information about the current location of a user to a tracking station.
- **Adaptation**- GPS Implies the ability of a system to adjust bandwidth fluctuation without inconveniencing the user.
- **Broadcast**- Efficient delivery of data can be made simultaneously to hand reads of mobile users.
- **Personalization**- Services in a mobile environment can be easily personalized according to a user's profile

Structure of Mobile Computing Application:

A mobile computing application is usually structured in terms of the functionalities implemented.

The network-centric mobile computing architecture uses three-tier architecture

1. Presentation Tiers
2. Application Tiers
3. Data Tier

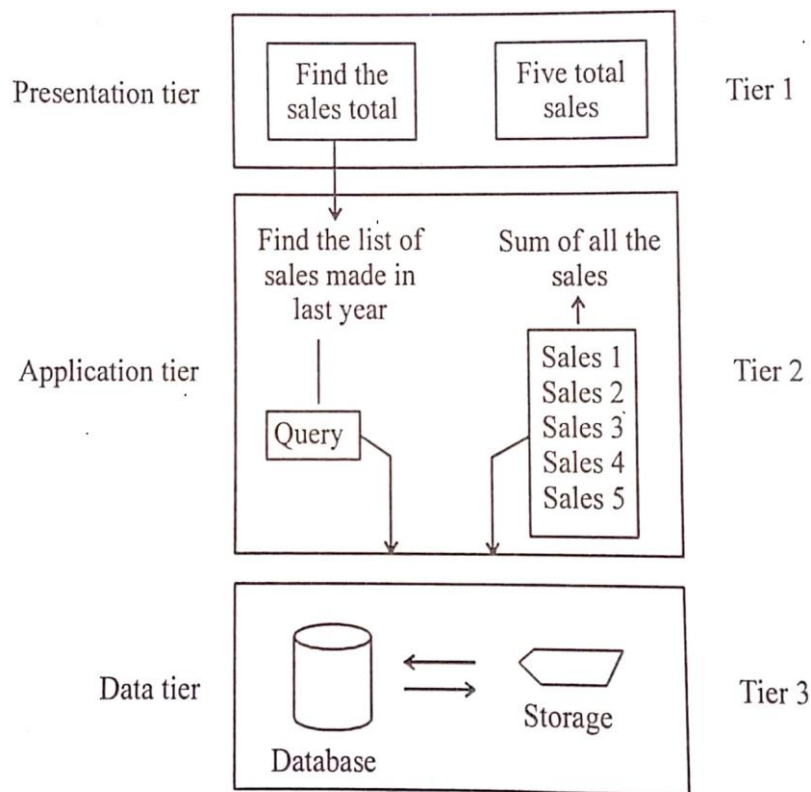


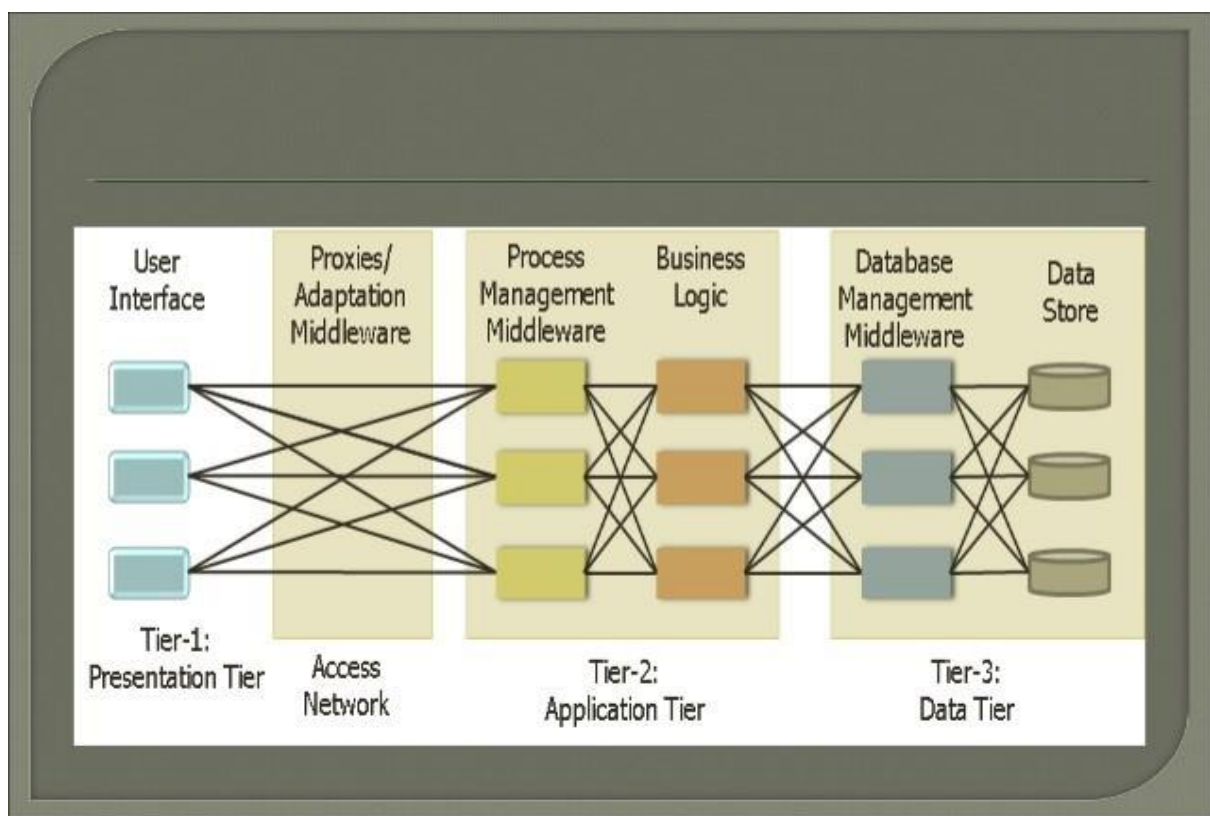
Figure 1.4 Functionalities provided by each tier structure of a mobile computing application

Presentation Tier:

- User Interface
- User face device handling and rendering.
- This tier includes a user system interface where user service reside.
- To issue request and to present the results that is run on the client's computer.

Application Tier:

- Process Management
- This layer is capable of accommodating hundreds of users.
- The middle process management tier controls transaction and asynchronous queuing to ensure reliable completion of transaction.
- To make logical decisions and perform calculations in this layer.
- To move and access the data between the Presentation and Data tier.



Data Tier:

- Database Management
- The three-tier architecture is better suited for an effective networked client/server design.
- It provides increased performance, flexibility, maintainability, reusability and scalability while hiding the complexity of distributed processing from user.
- To provide the facilities of data storage, access and manipulate the data.

wireless MAC issues in detail.

Design issues of MAC Protocol

- **Bandwidth Efficiency** –
The shortage of data transfer capacity assets in these networks requires its proficient use. To evaluate this, we could state that bandwidth capacity is the proportion of the bandwidth used for data transmission to the complete accessible bandwidth capacity.

Quality of Service Support –

Quality of service support is difficult due to the mobility of the nodes. Once a node moves out of reach, the reservation in it is lost. In these networks, QoS is extremely important because if it is being used in military environments, the service support needed time to time

Synchronization –

Some instruments must be found so as to give synchronization among the nodes.

Synchronization is significant for directing the bandwidth reservation.

Hidden Terminal Problem –

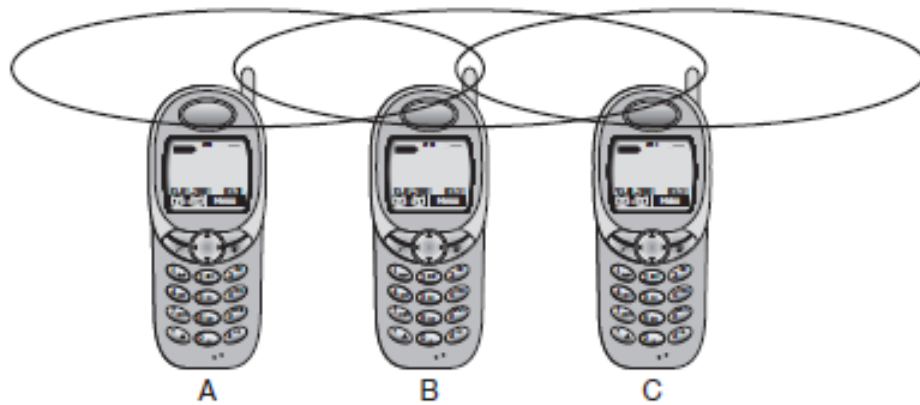
When there are two nodes, both are outside of each other's range and try to communicate with same node within their range at the same time, then there must be packet collision.

Exposed Terminal Problem –

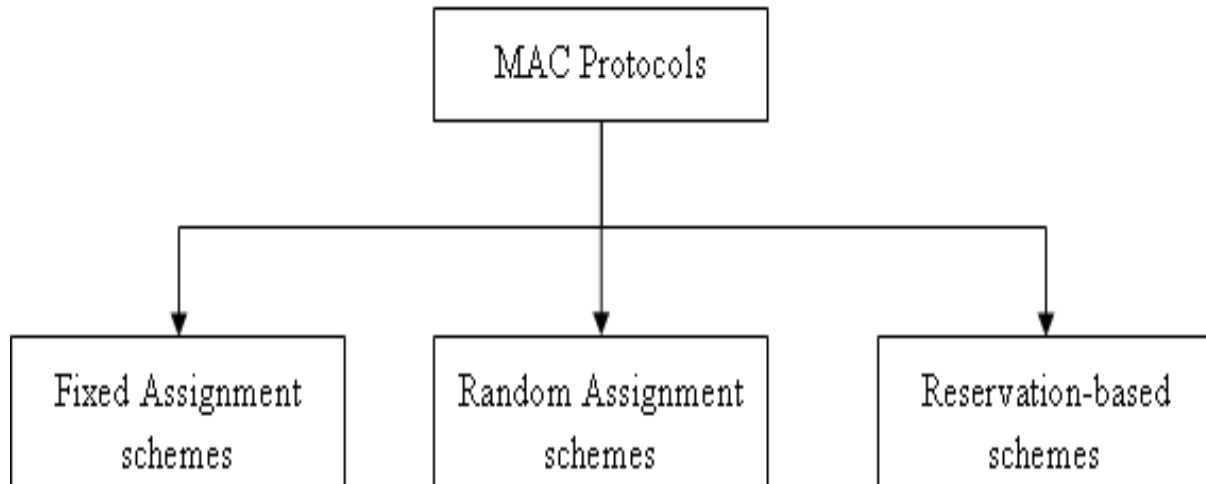
Uncovered nodes might be denied channel access pointlessly, which implies under usage of the bandwidth resources.

1. Hidden terminal problem
 - A hidden node is one that is within the range of the intended destination but out of range of sender it causes collisions
2. Exposed terminal problem

- An exposed node is one that is within the range of the sender but out of range of destination it causes unnecessary delay



Classification of MAC Protocols:



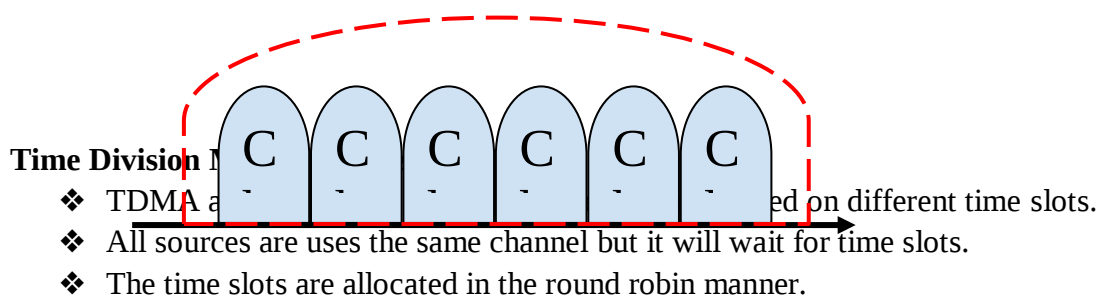
Fixed assignment MAC protocols with neat diagram

Fixed assignment MAC protocols

- ❖ It is also called as circuit switched scheme.
- ❖ The Resource or Channel is shared by nodes based on Time, Frequency or Code.
- ❖ There are three types of schemes available
 - Frequency Division Multiple Access (FDMA).
 - Time Division Multiple Access (TDMA).
 - Code Division Multiple Access (CDMA).

Frequency Division Multiple Access (FDMA)

- ❖ In FDMA the available bandwidth is divided into many narrow frequency band called channels.
- ❖ Each user need a two link
 - Forward link (Mobile to Base Station).
 - Reverse Link (Base Station to Mobile).
- ❖ Two channels are allocated to one user.
- ❖ These 2 channels are unable to allocate to other users while on use.

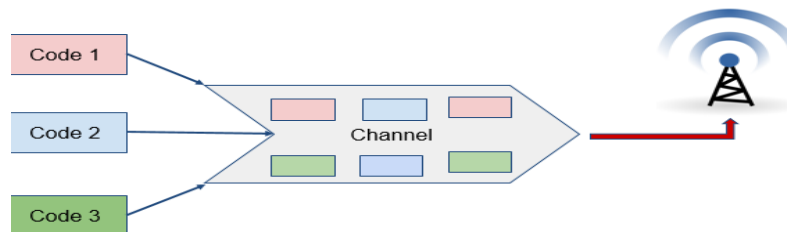


- ❖ Unused time slot makes the channel idle so this leads to poor utilization of channel.

Ch 1	Ch 2		Ch N	Ch 1	Ch2	...	Ch N	Ch 1	Ch 2	...	Ch N
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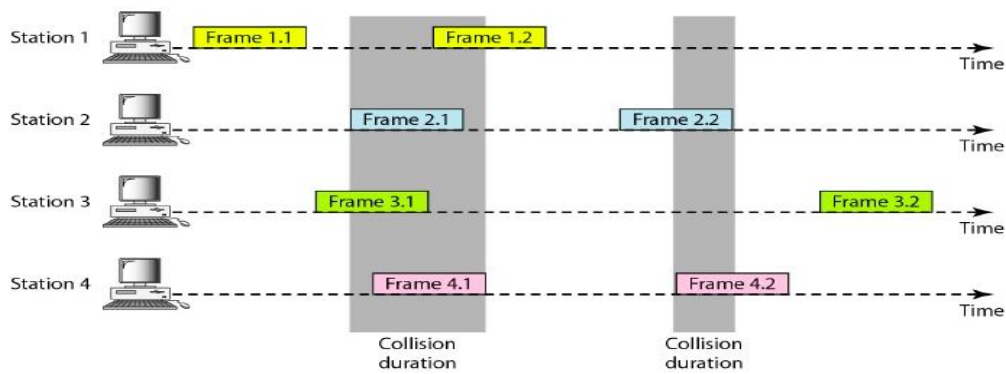
Code Division Multiple Access (TDMA):

- ❖ In CDMA Technology multiple users can use the same channel same time.
- ❖ No scheduling is needed.
- ❖ Message or data is encoded in the one end and decoded in the other end.
- ❖ Quite expensive procedure when compared to FDMA and TDMA.



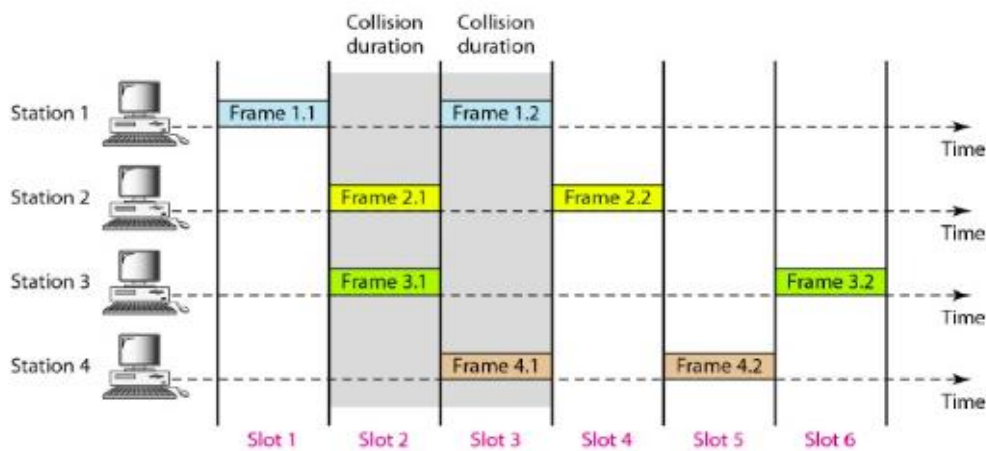
Random assignment schemes that are used in CDMA protocol.

- In this protocol, all the station has the equal priority to send the data over a channel. In random access protocol, one or more stations cannot depend on another station nor any station control another station.
- Depending on the channel's state (idle or busy), each station transmits the data frame. However, if more than one station sends the data over a channel, there may be a collision or data conflict.
- Due to the collision, the data frame packets may be lost or changed. And hence, it does not receive by the receiver end.
- **Types of Schemes**
- ALOHA.
- Slotted ALOHA.
- CSMA.
 - CSMA/CD.
 - CSMA/CA.
- ❖ Whenever data is available for sending over a channel at stations, we use Pure Aloha. In pure Aloha, when each station transmits data to a channel without checking whether the channel is idle or not, the chances of collision may occur, and the data frame can be lost.
- ❖ When any station transmits the data frame to a channel, the pure Aloha waits for the receiver's acknowledgment.
- ❖ If it does not acknowledge the receiver end within the specified time, the station waits for a random amount of time, called the backoff time (T_b).
- ❖ And the station may assume the frame has been lost or destroyed. Therefore, it retransmits the frame until all the data are successfully transmitted to the receiver.



Slotted ALOHA Scheme

- The slotted Aloha is designed to overcome the pure Aloha's efficiency because pure Aloha has a very high possibility of frame hitting. In slotted Aloha, the shared channel is divided into a fixed time interval called slots.
- So that, if a station wants to send a frame to a shared channel, the frame can only be sent at the beginning of the slot, and only one frame is allowed to be sent to each slot.



CSMA Scheme:

- ❖ CSMA = Carrier Sense Multiple Access.
- ❖ Before the transmission begins the node check with a medium for traffic and it defers the transmission rate.
- ❖ Two Techniques
 - CSMA/CD
 - CSMA/CA

CSMA (Carrier Sense Multiple Access)

- ❖ It is a carrier sense multiple access based on media access protocol to sense the traffic on a channel (idle or busy) before transmitting the data. It means that if the channel is idle, the station can send data to the channel. Otherwise, it must wait until the channel becomes idle. Hence, it reduces the chances of a collision on a transmission medium.

MAC protocol for Ad-hoc Networks.

Medium Access Control (MAC) address is a hardware address use to uniquely identify each node of a network. It provides addressing and channel access control mechanisms to enable the several terminals or network nodes to communicate in a specified network.

- MAC stands for **M**edia **A**ccess **C**ontrol. A MAC layer protocol is the protocol that controls access to the physical transmission medium on a LAN

- (MAC) data communication Networks protocol sub-layer, also known as the Medium Access Control, is a sub-layer of the data link layer specified in the seven-layer OSI model
- It acts as an interface between the Logical Link Control
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Time Division Multiple Access (TDMA)

Examples for fixed and dynamic schemes in TDMA as used for wireless transmission. These schemes can be combined with FDMA to achieve even greater Flexibility and transmission capacity

- Fixed TDM
- Classical aloha
- Slotted ALOHA
- CSMA
- DAMA
- PRMA
- Reservation TDMA
- MACA

UNIT II INTERNET PROTOCOL AND TRANSPORT LAYER

Mobile Internet Protocol (or Mobile IP)

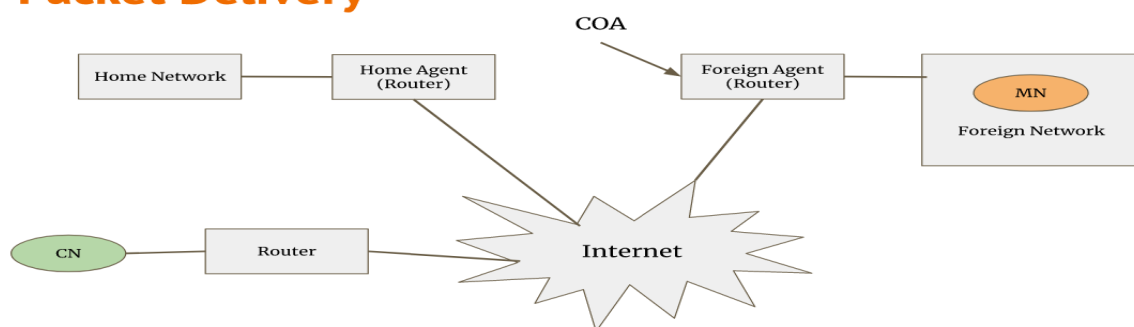
- Mobile IP is a communication protocol (created by extending Internet Protocol, IP) that allows the users to move from one network to another with the same IP address.
- It ensures that the communication will continue without user's sessions or connections being dropped.
- This is an IETF (Internet Engineering Task Force) standard communications protocol designed to allow mobile devices' (such as laptop, PDA, mobile phone, etc.) users to move from one network to another while maintaining their permanent IP (Internet Protocol) address.
- Defined in RFC (Request for Comments) 2002, mobile IP is an enhancement of the internet protocol (IP) that adds mechanisms for forwarding internet traffic to mobile devices (known as mobile nodes) when they are connecting through other than their home network.

Components of Mobile IP:

- **The mobile IP has following three components as follows:**
- **1. Mobile Node (MN)**
- The mobile node is an end system or device such as a cell phone, PDA (Personal Digital assistant), or laptop whose software enables network roaming capabilities.
- **Home Agent (HA)**
- The home agent provides several services for the mobile node and is located in the home network. The tunnel for packets towards the mobile node starts at home agent. The home agent maintains a location registry, i.e. it is informed of the mobile node's location by the current COA (care of address). Following alternatives for the implementation of an HA exist.
- Home agent can be implemented on a router that is responsible for the home network. This is obviously the best position, because without optimization to mobile IP, all packets for the MN have to go through the router anyway.
- If changing the router's software is not possible, the home agent could also be implemented on an arbitrary node in the subset.
- One biggest disadvantage of this solution is the double crossing of the router by the packet if the MN is in a foreign network.
- A packet for the mobile node comes in via the router; the HA sends it through the tunnel which again crosses the router.
- **Foreign Agent (FA)**
- The foreign agent can provide several services to the mobile node during its visit to the foreign network.
- The FA can have the COA (care of address) acting as a tunnel endpoint and forwarding packets to the MN. The foreign agent can be the default router for the MN.
- Foreign agent can also provide security services because they belong to the foreign network as opposed to the MN which is only visiting.
- **Care of Address (COA)**

- The Care- of- address defines the current location of the mobile node from an IP point of view. All IP packets sent to the MN are delivered to the COA, not directly to the IP address of the MN.
- Packet delivery toward the mobile node is done using a tunnel. To be more precise, the COA marks the endpoint of the tunnel, i.e. the address where packets exit the tunnel.
- Foreign Agent COA: The COA could be located at the foreign agent, i.e. the COA is an IP address of the foreign agent.
- The foreign agent is the tunnel endpoint and forwards packets to the MN. Many MN using the FA can share this COA as common COA.
- Co-located COA: The COA is co-located if the MN temporarily acquired an additional IP address which acts as a COA.
- This address is now topologically correct, and the tunnel endpoint is at the mobile node. Co-located address can be acquired using services such as DHCP. One problem associated with this approach is need for additional addresses if MNs request a COA. This is not always a good idea considering the scarcity of IPv4 addresses.
- **Correspondent Node (CN)**
 - At least one partner is needed for communication. The correspondent node represents this partner for the MN. The correspondent node can be a fixed or mobile node.
- **Home Network**
 - The home network is the subset the MN belongs to with respect to its IP address. No mobile IP support is needed within this network.
- **Foreign network**
 - The foreign network is the current subset the MN visits and which is not the home network
- **Packet Delivery**

Packet Delivery



- The correspondent node sends the data to the mobile node. Data packets contain the correspondent node's address (Source) and home address (Destination). Packets reach the home agent.
- But now mobile node is not in the home network, it has moved into the foreign network.
- The foreign agent sends the care-of-address to the home agent to which all the packets should be sent.
- Now, a tunnel will be established between the home agent and the foreign agent by the process of tunneling.
- [Tunneling](#) establishes a virtual pipe for the packets available between a tunnel entry and an endpoint.
- It is the process of sending a packet via a tunnel and it is achieved by a mechanism called encapsulation.
- Foreign agent, on another side of the tunnel, receives the data packets, decapsulates them, and sends them to the mobile node.
- The mobile node in response to the data packets received sends a reply in response to the foreign agent.
- The foreign agent directly sends the reply to the correspondent node.

Requirements of Mobile IP

- Compatibility
- Transparency
- Scalability and efficiency
- Security

Transparency

- ❖ Mobile IP mechanism must be invisible to higher level protocol and applications.
- ❖ The applications must be able to serve effectively even in general issues of the mobile networking like *lower bandwidth and interruption in services*.

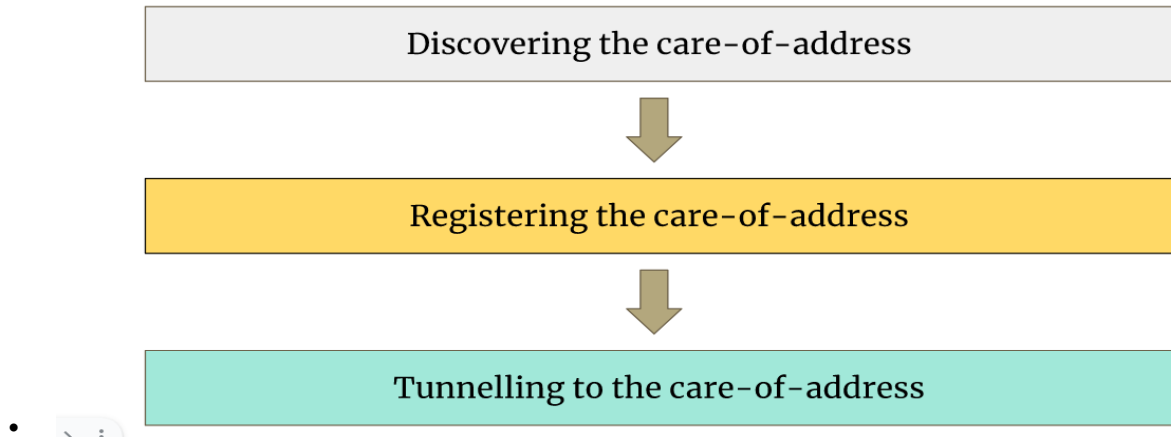
Compatibility

- ❖ Must not introduce any new tech in networking layers.
- ❖ Must support web browser as it is right now.
- ❖ Need of special applications to access all things is *unacceptable*.
- ❖ Most of the applications are meant to serve over traditional internet setup, so we can't afford so much changes like protocol change or something.
- ❖ Enhanced mobile system must still be able to communicate with stable end-point that has no mobile ip feature.

Key Mechanisms of IP:

- Agent Discovery
- Agent Registration
- Tunneling

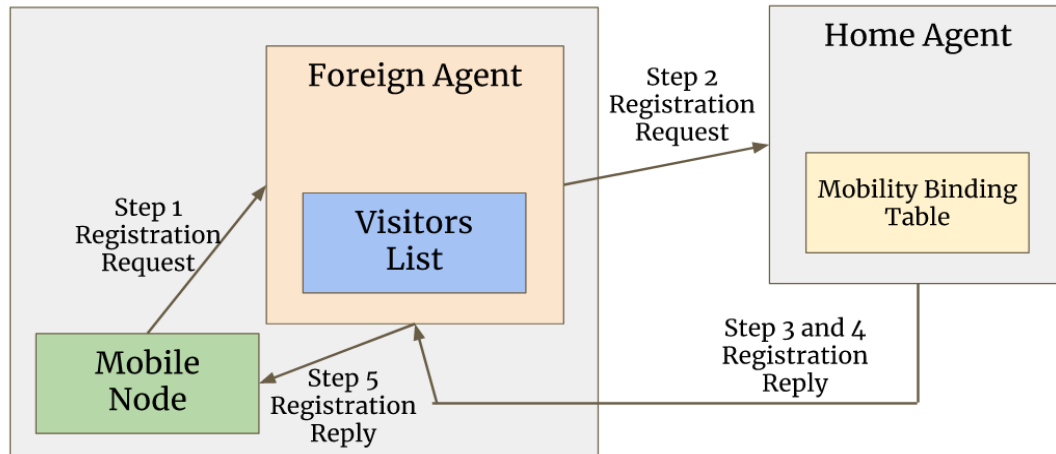
Mechanisms of Mobile IP



Discovering the care-of-address

- ❖ First Step of mobile node must obtain mobile IP from the DHCP server.
- ❖ Router or Agent is responsible for allocating IP address for mobile Node.
- ❖ Mobile Node get the ip address from the Agent discovery process.
- ❖ Agent discovery includes 2 methods,
 - Agent Advertisement
 - Agent Solicitation.
- ❖ This is done with ICMP Packets.
- ❖ As soon as mobile node enters into foreign network either it must wait for foreign agent to advertise list of care-of-address or it must inform that agent to it's presence by solicitation.

Registering the care-of-address



Registering the care-of-address

- ❖ After receiving COA from Foreign agent it must register the new COA in Home Agent.
- ❖ Mobile node contacts with home agent with COA for registration using registration request.
- ❖ Home agent obtains the COA from received request and record with IP table this process is known as **mobility binding**.
- ❖ Current address of the mobile node is bond with new address(COA) of mobile node is known as mobility binding.
- ❖ The foreign agent in turn updates its visitors list by inserting the entry for the mobile node and relays the reply to the mobile node.

Tunnelling to the care-of-address

- ❖ When a home agent receives a packet addressed to a mobile host, it forwards the packet to the care-of-address using IP-within-IP (encapsulation).
- ❖ Using IP-within-IP, the home agent inserts a new IP header in front of the IP header of any datagram.
- ❖ Destination address is set to the care-of-address.
- ❖ Source address is set to the home agent's address.
- ❖ After stripping out the first header, IP processes the packet again.

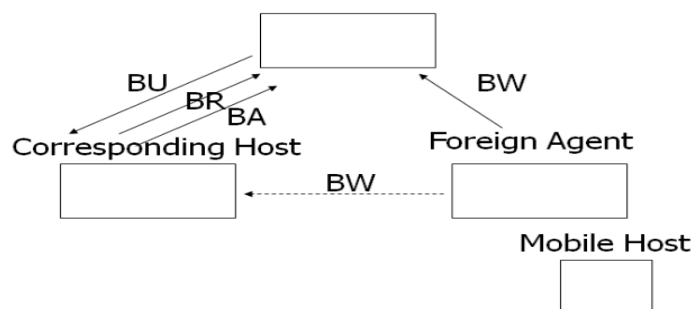
Route Optimization in Mobile IP

— Deliver a packet as fast as possible —

Need of Route Optimization

- ❖ Route Optimization is very essential in IP system for efficient use of network.
- ❖ Mobile IP is an extension of IP and also it needs a deliberate route optimization technique to solve network traffic problems.
- ❖ Every packet that received from CN is tunneled by HA to FA and FA will forward the packet to MN.
- ❖ 6 Step Process is leads to traffic overhead.
- ❖ So we need to solve this problem.

Binding Warning



Optimization of packet forwarding

Problem:

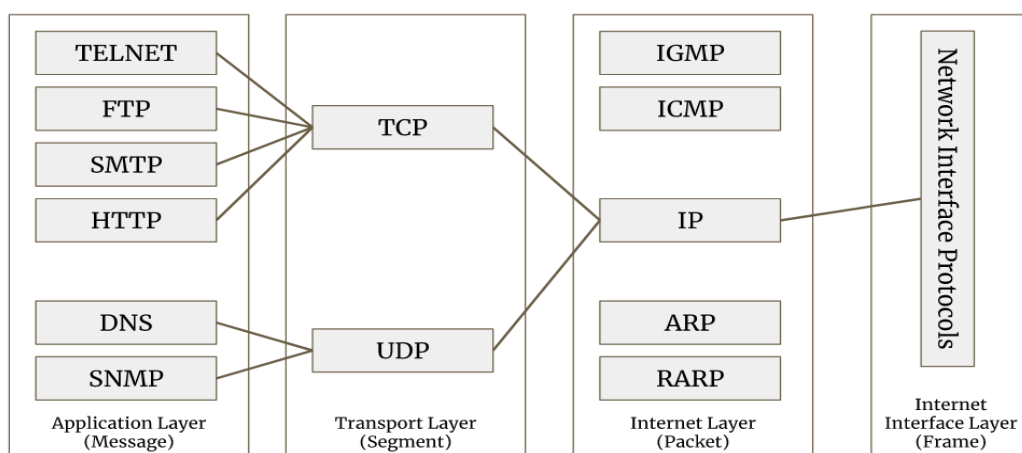
- ❖ Triangular Routing
- ❖ Sender sends all packets via HA to MN
- ❖ Higher latency and network load

Overview of TCP/IP:

Overview of TCP/IP

- ❖ The TCP/IP Protocol suite was developed by DARPA (*Defense Advanced Research Projects Agency*) in 1960.
- ❖ It is created to provide seamless communication services across an internetworking consists of a large number of protocols.
- ❖ It is named after two famous protocols TCP (*Transmission Control Protocol*) and IP (*Internet Protocol*).
- ❖ Suite has 4 Layers
 - Application Layer
 - Transport Layer
 - Internet Layer
 - Network Interface Layer

TCP/IP Protocol stack

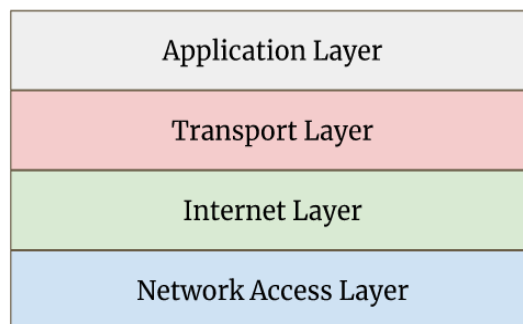


Overview of TCP/IP

- ❖ Application programmers mainly concern about application layer protocols.
- ❖ Application layer protocol give the access to lower layer protocols.
- ❖ Application layer convert the data into messages and sent to Transport layers.
- ❖ Transport layer converts the message into small part called as segments.
- ❖ Then TCP layer passess the segments to Internet Layer Protocols and it converted into Packets.
- ❖ Finally network interface layer converts packets into frame and adddes the additional information like checksums.

Architecture of TCP/IP:

Architecture of TCP/IP



TCP/IP Protocol Layers

Application Layer

- ❖ The protocols at the layer are used by the applications used to establish communication with other applications running on other hosts.
- ❖ Eg.
 - HTTP, FTP, TELNET...

Transport Layer

- ❖ It provides reliable end-to-end data transfer services.
- ❖ It is also referred as host-to-host protocols.
- ❖ First computer must be identified and then application must be identified to serve for an exact purpose.
- ❖ Computer identified using IP and applications identified by the *portnumber*.
- ❖ Once message reaches the host now it is demultiplexed with port numbers and delivered to appropriate applications.

Internet Layer

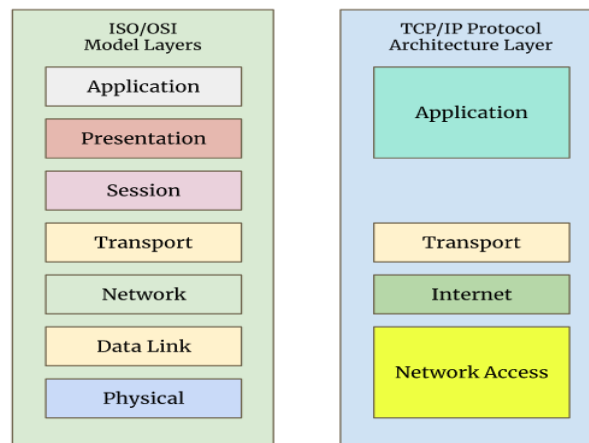
- ❖ It packs the data into packets known as IP datagrams.
- ❖ Each IP datagram contains source and destination address.
- ❖ This is the layer that manages the addressing of packets and delivery of the packets between networks using IP address.
- ❖ This protocol includes at the Internet layers are IP, ICMP, ARP, RARP and IGMP.

Network Access Layer

- ❖ This layer functions for encoding the data and transmitting at the signal points of the physical layer.
- ❖ It provides the error detection and framing functionalities.
- ❖ It has two layers,
 - Data Link Layer.
 - Physical Layer.
- ❖ Data Link Protocols are Ethernet, Token, Ring, FDDI, and X.25.
- ❖ Physical layer controls the network medium, such as coaxial cable, optical fibre, or twisted pair of copper wires.

Adaptation of TCP Window:

TCP/IP vs ISO/OSI Model



Flow Control

- ❖ It is technique to control the congestion in the network.
- ❖ Traffic congestion occurs when the rate of transmission by the sender is over the receiver's buffer size.
- ❖ TCP's flow control technique is used to adapt the transmission rate according to the receiver host.
- ❖ It prevents the congestion build up in the network and buffer overrun at the slow receivers.

Improving TCP Performance:

- TCP enhancements for wireless protocols –
- Traditional TCP:
- Congestion control,
- fast retransmit/fast recovery,
- Implications of mobility
- Classical TCP improvements:
- Indirect TCP, Snooping TCP,
- Mobile TCP,
- Time out freezing,
- Selective retransmission

Congestion control:

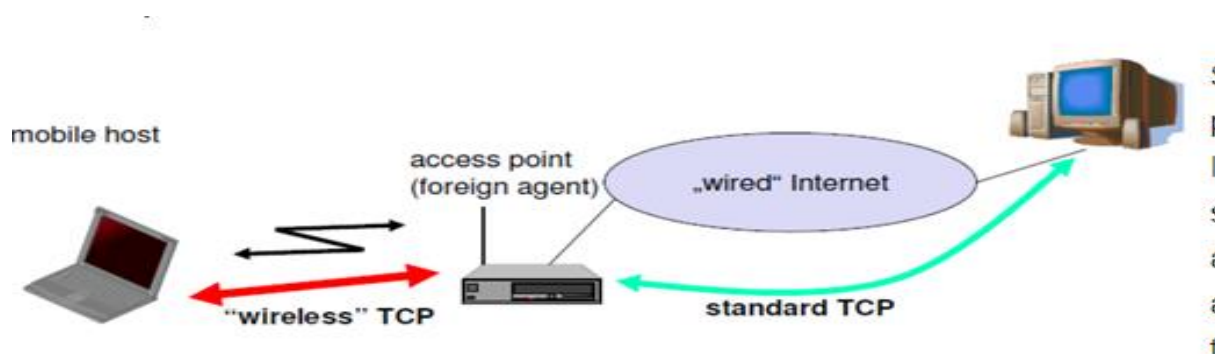
- During data transmission from sender to receiver, sometimes the data packet may be lost.
- It is not because of hardware or software problem. Whenever the packet loss is confirmed, the probable reason might be the temporary overload at some point in the transmission path.
- This temporary overload is otherwise called as Congestion.
- Congestion is caused often even when the network is designed perfectly.
- The transmission speed of receiver may not be equal to the transmission speed of the sender. if the capacity of the sender is more than the capacity of output link, then the packet buffer of a router is filled and the router cannot forward the packets fast enough.
- The only thing the router can do in this situation is to drop some packets.

Slow start:

- The behavior TCP shows after the detection of congestion is called as slow start.
- The sender always calculates a congestion window for a receiver. At first the sender sends a packet and waits for the acknowledgement.
- Once the acknowledgement is back it doubles the packet size and sends two packets.
- After receiving two acknowledgements, one for each packet, the sender again doubles the packet size and this process continues. This is called Exponential growth.

Fast re-transmission:

- In TCP, two things lead to a reduction of the congestion threshold. One of those is sender receiving continuous acknowledgements for the single packet.
- By this it can convey either of two things.
- One such thing is that the receiver received all the packets up to the acknowledged one and the other thing is the gap is due to packet loss.
- Now the sender immediately re-transmit the missing packet before the given time expires. This is called as Fast re-transmission.



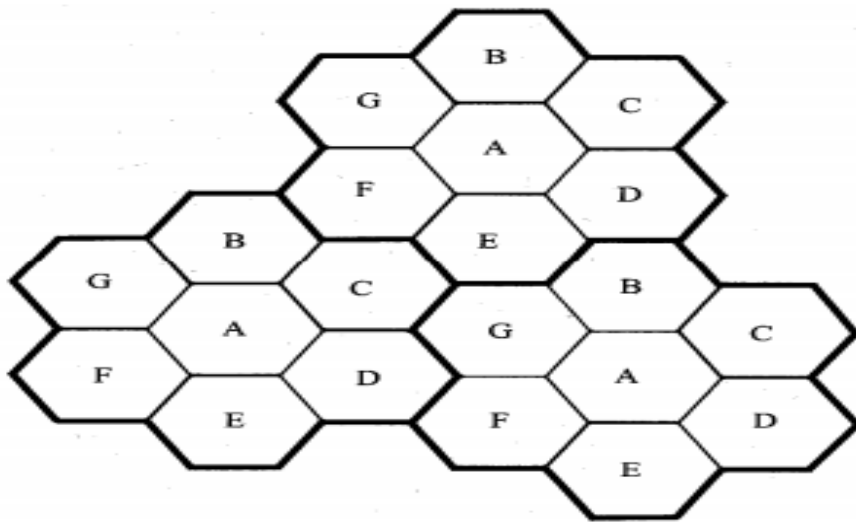
UNIT III TELECOMMUNICATION SYSTEM

Introduction to Cellular Systems:

- **Cellular** network is an underlying technology for mobile phones, personal communication systems, wireless networking etc
- The technology is developed for mobile radio telephone to replace high power transmitter/receiver systems.
- Cellular networks use lower power, long range and more transmitters for data transmission.

Features of Cellular Systems:

- The features of cellular systems are as follows –
- Offer very high capacity in a limited spectrum.
- Reuse of radio channel in different cells.
- Enable a fixed number of channels to serve an arbitrarily large number of users by reusing the channel throughout the coverage region.
- Communication is always between mobile and base station (not directly between mobiles).
- Each cellular base station is allocated a group of radio channels within a small geographic area called a cell.
- Neighboring cells are assigned different channel groups.
- By limiting the coverage area to within the boundary of the cell, the channel groups may be reused to cover different cells.
- Keep interference levels within tolerable limits.
- Frequency reuse or frequency planning.
- Organization of Wireless Cellular Network.
- Cellular network is organized into multiple low power transmitters each 100w or less.
- Shape of Cells:
 - The coverage area of cellular networks are divided into **cells**, each cell having its own antenna for transmitting the signals.
 - Each cell has its own frequencies. Data communication in cellular networks is served by its **base station transmitter**, receiver and its control unit
 - The shape of cells can be hexagon



- **Frequency Reuse**

- Frequency reusing is the concept of using the same radio frequencies within a given area, that are separated by considerable distance, with minimal interference, to establish communication.
- Frequency reuse offers the following benefits –
- Allows communications within cell on a given frequency
- Limits escaping power to adjacent cells
- Allows re-use of frequencies in nearby cells
- Uses same frequency for multiple conversations
- 10 to 50 frequencies per cell
- For example, when **N** cells are using the same number of frequencies and **K** be the total number of frequencies used in systems. Then each **cell frequency** is calculated by using the formulae K/N .
- In Advanced Mobile Phone Services (AMPS) when $K = 395$ and $N = 7$, then frequencies per cell on an average will be $395/7 = 56$. Here, **cell frequency** is 56.

GSM:

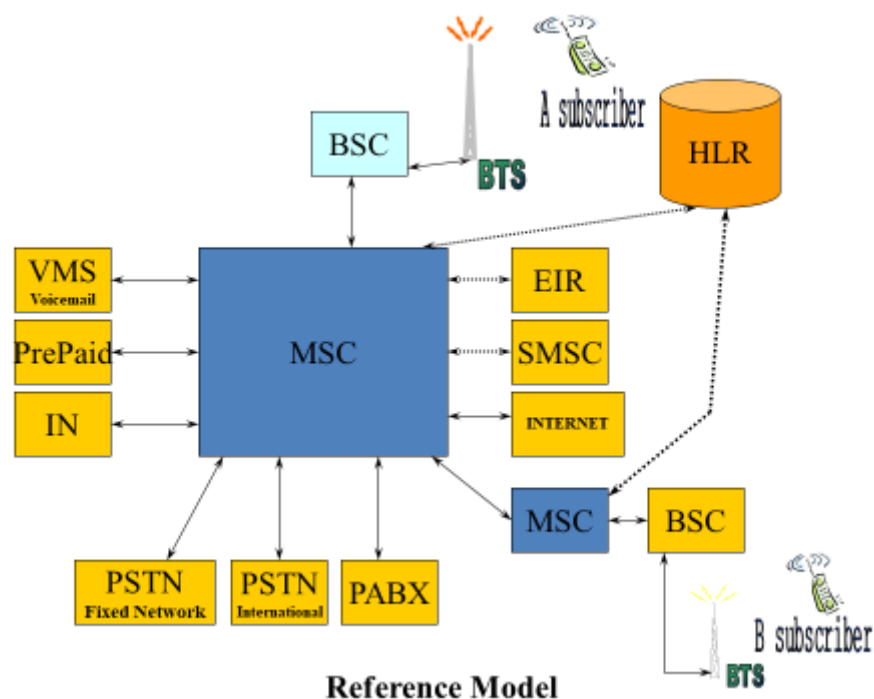
- GSM is a mobile communication modem
- it stands for global system for mobile communication (GSM). The idea of GSM was developed at Bell Laboratories in 1970.
- Presently GSM supports more than one billion mobile subscribers in more than 210 countries throughout the world.

It is a digital cellular technology used for transmitting mobile voice and data services

Why GSM?

- Listed below are the features of GSM that account for its popularity and wide acceptance.

- Improved spectrum efficiency
- International roaming
- Low-cost mobile sets and base stations (BSs)
- High-quality speech
- Compatibility with Integrated Services Digital Network (ISDN) and other telephone company services
- Support for new services
- MS Mobile Station = phone + SIM card
- BTS Base Transceiver Station
- BSC Base Station Controller
- HLR Home Location Register
- MSC Mobile services Switching Centre
- VLR Visitor Location Register
- AUC Authentication Centre
- EIR Equipment Identity Register
- SMSC Short Message Service "Support" Centre
- VMS Voice Messaging System
- IN Intelligent Network services
- PSTN Public Switched Telephone Network
- PABX Private Automatic Branch Exchange



GSM Services

- Bearer Services
- Teleservices
- Supplementary services

GSM SYSTEM ARCHITECTURE:

GSM architecture is mainly divided into three

Subsystems

1. Base Station Subsystem (BSS)
2. Network & Switching Subsystem (NSS)
3. Operations Subsystem (OSS)
4. GSM - The Base Station Subsystem (BSS)
5. The BSS is composed of two parts –
6. The Base Transceiver Station (BTS)
7. The Base Station Controller (BSC)
8. The Base Transceiver Station (BTS)

The BTS houses the radio transceivers that define a cell and handles the radio link protocols with the MS. In a large urban area, a large number of BTSs may be deployed

- The BTS corresponds to the transceivers and antennas used in each cell of the network.
- A BTS is usually placed in the center of a cell. Its transmitting power defines the size of a cell.
- Each BTS has between 1 and 16 transceivers, depending on the density of users in the cell.
- Each BTS serves as a single cell. It also includes the following functions –
- Encoding, encrypting, multiplexing, modulating, and feeding the RF signals to the antenna
- Transcoding and rate adaptation
- Time and frequency synchronizing
- Voice through full- or half-rate services
- Decoding, decrypting, and equalizing received signals
- Random access detection
- Timing advances
- Uplink channel measurements

- The BSC manages the radio resources for one or more BTSs. It handles radio channel setup, frequency hopping, and handovers. The BSC is the connection between the mobile and the MSC.

The BSC also translates the 13 Kbps voice channel used over the radio link to the standard 64 Kbps channel used by the Public Switched Telephone Network (PSDN) or ISDN

- It assigns and releases frequencies and time slots for the MS. The BSC also handles intercell handover. It controls the power transmission of the BSS and MS in its area.
- The function of the BSC is to allocate the necessary time slots between the BTS and the MSC. It is a switching device that handles the radio resources.
- The additional functions include—
- Control of frequency hopping
- Performing traffic concentration to reduce the number of lines from the MSC

GSM - The Network Switching Subsystem (NSS)

Network switching system (NSS), the main part of which is the Mobile Switching Center (MSC), performs the switching of calls between the mobile and other fixed or mobile network users, as well as the management of mobile services such as authentication

- **Home Location Register (HLR)**
- The HLR is a database used for storage and management of subscriptions.
- The HLR is considered the most important database, as it stores permanent data about subscribers, including a subscriber's service profile, location information, and activity status.
- When an individual buys a subscription in the form of SIM, then all the information about this subscription is registered in the HLR of that operator.
- Mobile Services Switching Center (MSC)
- The central component of the Network Subsystem is the MSC.
- The MSC performs the switching of calls between the mobile and other fixed or mobile network users, as well as the management of mobile services such as registration, authentication, location updating, handovers, and call routing to a roaming subscriber.
- It also performs such functions as toll ticketing, network interfacing, common channel signaling, and others.
- Every MSC is identified by a unique ID.

Equipment Identity Register (EIR)

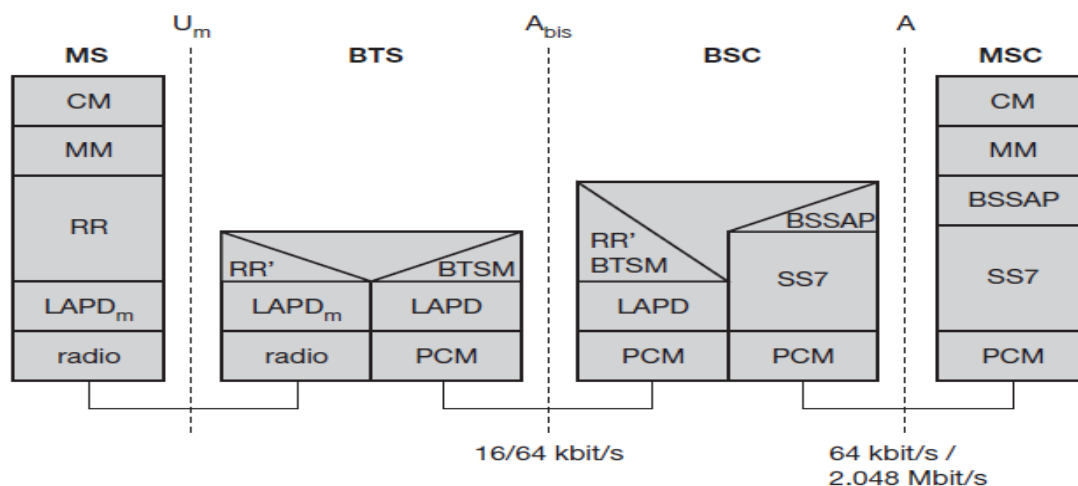
- The Equipment Identity Register (EIR) is a database that contains a list of all valid mobile equipment on the network, where its International Mobile Equipment Identity (IMEI) identifies each MS.
- An IMEI is marked as invalid if it has been reported stolen or is not type approved.

GSM - The Operation Support Subsystem (OSS)

- The operations and maintenance center (OMC) is connected to all equipment in the switching system and to the BSC. The implementation of OMC is called the operation and support system (OSS).
- Here are some of the OMC functions–
- Administration and commercial operation (subscription, end terminals, charging, and statistics).
- Security Management.
- Network configuration, Operation, and Performance Management.
- Maintenance Tasks.

Protocols of GSM

- GSM Architecture is a layered model that is designed to allow communication between two different systems.
- Lower layers and upper layers
- Each layer suitable notifications to ensure the transmitted data has been formatted, transmitted and received accurately



GSM protocol layers:

Mobility management (MM)

- The MM layer is in-charge of maintain the location data, in addition to the authentication and ciphering procedures

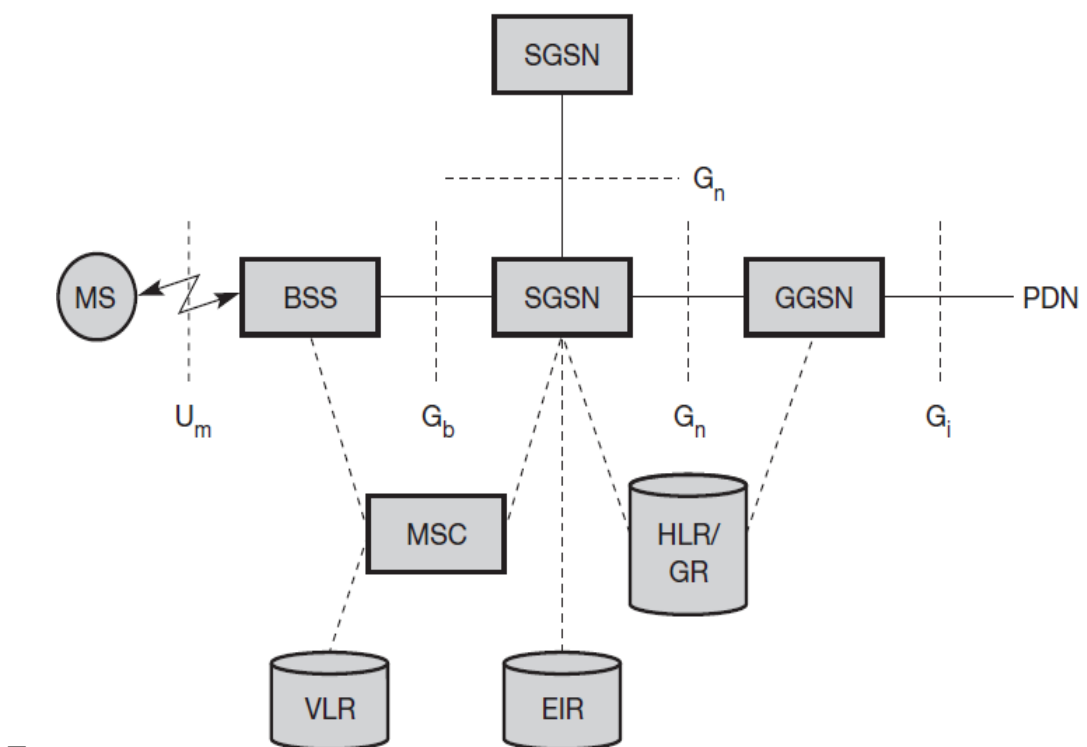
Communication Management (CM)

- The CM layer consists of setting up call at the user request
- Its functions are call control, which manages the supplementary services configuration, short message services which provides point-to-point short message services
- **Radio Resource (RR)**

- The RR management layer is in-charge of establishing and maintaining a stable uninterrupted communication path between the MSC and MS over which signaling and user data can be covered
- Handovers are part of the RR layer responsibility
- Most of the functions are controlled by the BSC, BTS and MS though some are performed by the MSC

GPRS(General Packet Radio Services) – Architecture:

- GPRS architecture works on the same procedure like GSM network, but, has additional entities that allow packet data transmission.
- This data network overlaps a second-generation GSM network providing packet data transport at the rates from 9.6 to 171 kbps.
- Along with the packet data transport the GSM network accommodates multiple users to share the same air interface resources concurrently.
- The GPRS architecture introduces two new network elements
 - gateway GPRS support node (GGSN)
 - serving GPRS support node (SGSN)



- **GPRS Mobile Stations**
- New Mobile Stations (MS) are required to use GPRS services because existing GSM phones do not handle the enhanced air interface or packet data.
- A variety of MS can exist, including a high-speed version of current phones to support high-speed data access, a new PDA device with an embedded GSM phone, and PC cards for laptop computers.

These mobile stations are backward compatible for making voice calls using GSM

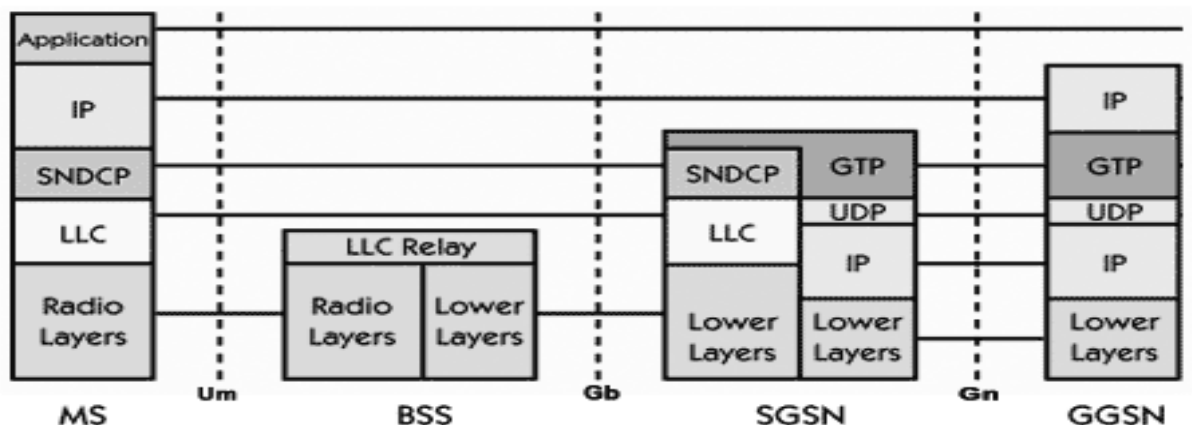
GPRS Base Station Subsystem:

- Each BSC requires the installation of one or more Packet Control Units (PCUs) and a software upgrade. The PCU provides a physical and logical data interface to the Base Station Subsystem (BSS) for packet data traffic.
- The BTS can also require a software upgrade but typically does not require hardware enhancements.
- When either voice or data traffic is originated at the subscriber mobile, it is transported over the air interface to the BTS, and from the BTS to the BSC in the same way as a standard GSM call.
- However, at the output of the BSC, the traffic is separated; voice is sent to the Mobile Switching Center (MSC) per standard GSM, and data is sent to a new device called the SGSN via the PCU over a Frame Relay interface.
- Gateway GPRS Support Node (GGSN)
- The Gateway GPRS Support Node acts as an interface and a router to external networks.
- It contains routing information for GPRS mobiles, which is used to tunnel packets through the IP based internal backbone to the correct Serving GPRS Support Node.

The GGSN also collects charging information connected to the use of the external data networks and can act as a packet filter for incoming traffic

GPRS APPLICATION

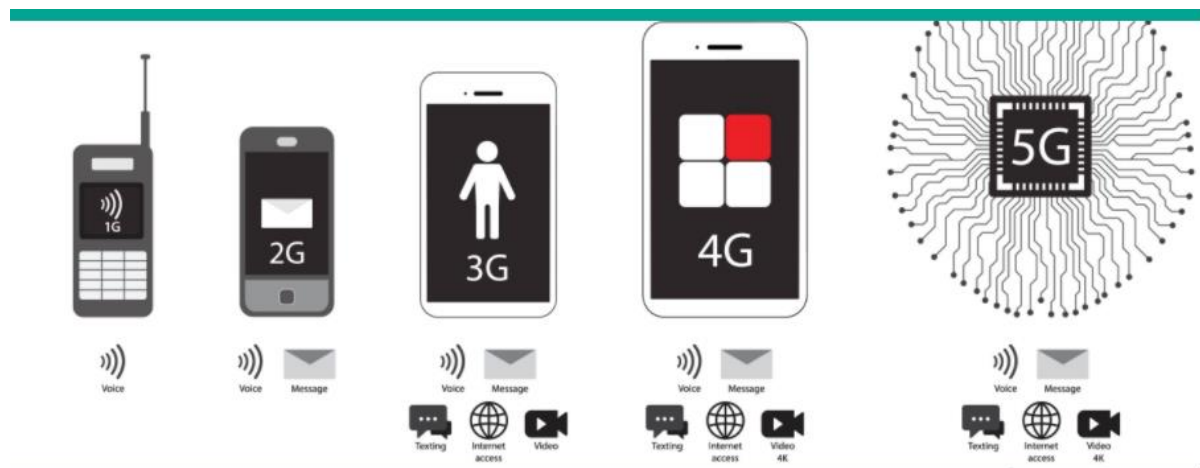
- Communications
- E-commerce
- Value-added services
- Location-based applications
- GPRS - Protocol Stack The flow of GPRS protocol stack and end-to-end message from MS to the GGSN is displayed in the below diagram. GTP is the protocol used between the SGSN and GGSN using the Gn interface. This is a Layer 3 tunneling protocol.



- The process that takes place in the application looks like a normal IP sub-network for the users both inside and outside the network.
- The vital thing that needs attention is, the application communicates via standard IP, that is carried through the GPRS network and out through the gateway GPRS.

GENERATIONS OF MOBILE COMMUNICATION TECHNOLOGIES:

- **First Generation**
- **Second Generation**
- **Third Generation**
- **Fourth Generation**
- **Fifth Generation**



First Generation:

- It uses analog technology that were introduced in the 1980s and continued until being replaced by 2G digital telecommunications

It introduces the following mobile technologies

- Mobile Telephone System (MTS)
- Advanced Mobile Telephone System (AMTS)
- Improved Mobile Telephone Service (IMTS)
- Push to Talk (PTT)

Features

- Maximum speed of 1G is 2.4 Kbps
- Allows voice calls in 1 country
- Use analog signal
- Channel bandwidth 30khz

Disadvantage

- Poor Voice Quality

- Poor Battery Life
- Large Phone Size
- No Security
- Limited Capacity

Second Generation:

- Second Generation based on GSM.
- It was launched in Finland in the year 1991.
- It uses digital signals for voice transmission.

It make use of either CDMA or TDMA

Features

- Lower power emissions
- Data speed was upto 64kbps
- Use digital signals
- Enables services such as text messages, picture messages and MMS(Multimedia message) Provides better quality and capacity

Limitations

- Requires powerful digital signals to work the mobile phones
- Unable to handle complex data such as videos

Third Generation:

- It make use of TDMA and CDMA.
- It provides value added services like mobile television, GPS (global positioning system), live streaming and video conferencing.
- It is designed for multimedia communication

Features

- Fast data transfer rates
- Speed 2 Mbps
- Send/receive large email messages
- Provide seamless global roaming

Limitations

- Requires higher bandwidth
- Cost is high

Fourth Generation:

- It is an all IP-based integrated system will be capable to provide 100 Mbps for high mobility and 1 Gbps.
- The user services include IP telephony, ultra-broadband Internet access, gaming services and High Definition Television (HDTV) streamed multimedia.

Feature

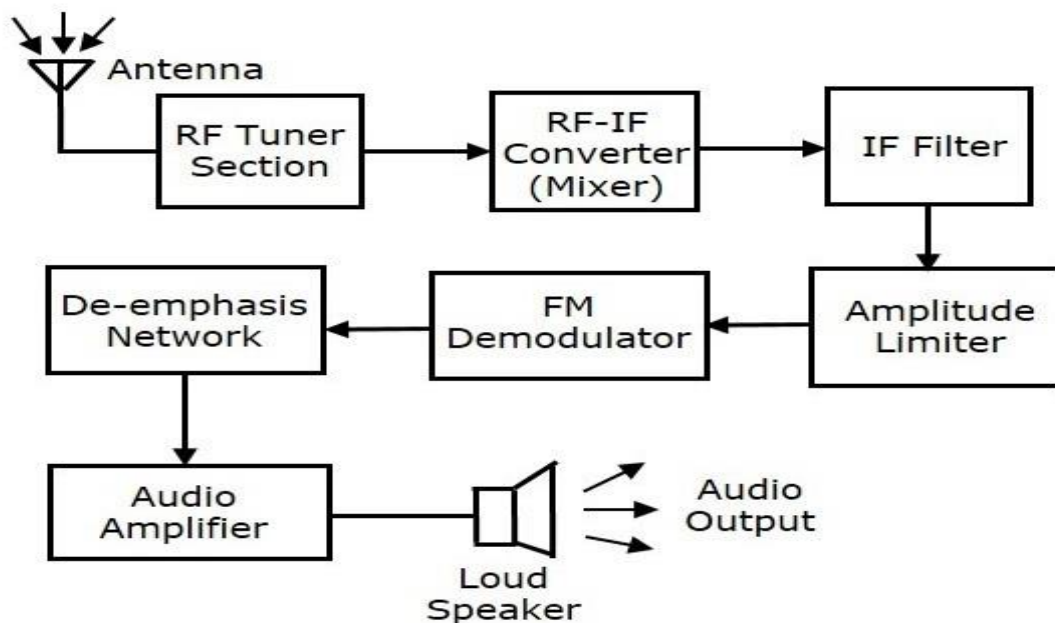
- Capable of provide 10Mbps-1Gbps speed
- High quality streaming video
- Combination of Wi-Fi and Wi-Max
- High security
- Low cost per-bit

Limitations

- Battery uses is more
- Hard to implement
- Need complicated hardware
- Expensive equipment required to implement next generation network
- Fifth Generation
- Its not yet have been deployed and are still at a research and development phase
- Increased data transmission capability 1 Gbps
- Connectivity to a large number of devices due to the IoT.
- Period of establishment 2016 to 2020.

Software Defined Radio Receiver:

- The basic concept of the SDR software radio is that the radio can be totally configured or defined by the software.
- In an ideal world the incoming signal is immediately converted to a digital format, and the signal is then processed totally digitally.
- Conversely for transmit, the signal is generated digitally, and converted to the final analogue signal at the antenna.
- This approach has the advantages that the radio can be totally reconfigured for a new application, simply by changing the software. Updates can be made to keep up with new modulation formats, new applications, etc, simply by updating the software



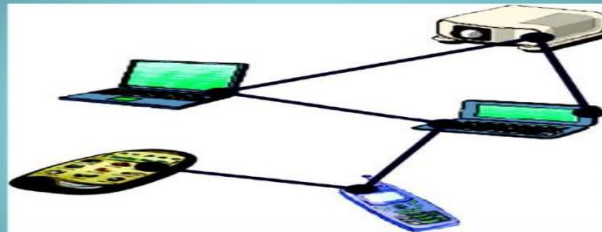
-
- **Software defined radio applications:**
- The SDR software radio concept is applicable to many areas of use:
- **Mobile communications:** Software defined radios are very useful in areas such as mobile communications. By upgrading the software it is possible to apply changes to any standards and even add new waveforms purely by upgrading the software and without the need for changes to the hardware. This can even be done remotely, thereby providing considerable savings in cost.
- **Research & development:** The software defined radio, SDR is very useful in many research projects. The radios can be configured to provide the exact receiver and transmitter requirements for any application without the need for a total hardware design from scratch.
- **Military:** The military have made much use of software defined radio technology enabling them to re-use hardware and update signal waveforms as needed.
- **Amateur radio:** Radio hams have very successfully employed software defined radio technology, using it to provide improved performance and flexibility.
- **Other:** There are very many other applications that can make use of SDR technology, enabling the radio to be exactly tailored to the requirements using software adjustments
- **Advantages of SDR technology**
- It is possible to achieve very high levels of performance.
- Performance can be changed by updating the software (it will not be possible to update hardware dependent attributes though).
- It is possible to reconfigure radios by updating software
- The same hardware platform can be used for several different radios

What is an ad-hoc network

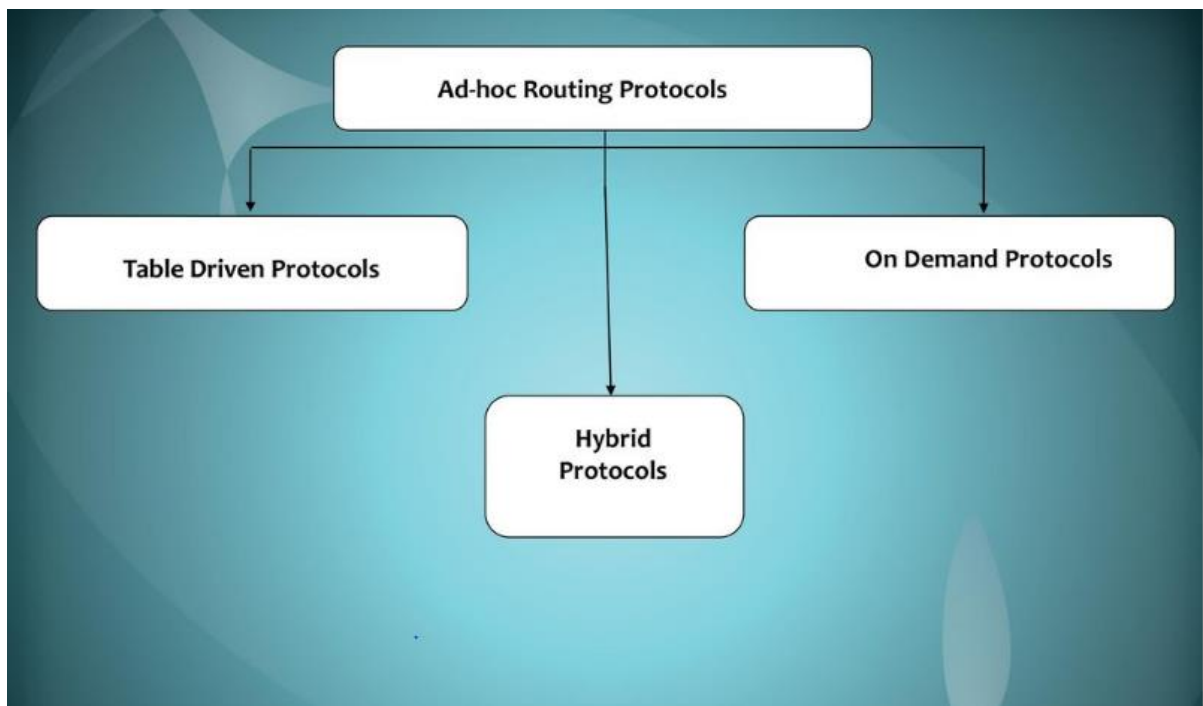
- An ad-hoc network is a local area network (LAN) that is built spontaneously as devices connect. Instead of relying on a base station to coordinate the flow of messages to each node in the network, the individual network nodes forward packets to and from each other
- In Latin, ad hoc literally means “for this purpose”.
- Ad hoc networks therefore refer to networks created for a particular purpose. They are often created for one-time or temporary use.
- Ad hoc networks are comprised of a group of workstations or other wireless devices which communicate directly with each other to exchange information

Mobile ad hoc networks (MANETs)	• This is a self-configuring, self-organising, wireless network of mobile devices.
Vehicular ad hoc networks (VANETs)	• This is network formed by communication between moving vehicles and other roadside devices.
Wireless mesh networks	• The devices connected to these networks forms a wireless mesh, depending upon the mobility patterns, nature of devices and inter-device distances.
Smart phone Ad Hoc Networks (SPANs)	• These are peer - to - peer networks created by smartphones within range of each other without requiring any cellular carrier networks, wireless access points etc.
Wireless Sensor Networks (WSN)	• Sensors are portable devices that capture specific information from environment like temperature, humidity, traffic volume etc. WSNs form ad hoc networks to capture information on the fly.

A Simple example for Ad Hoc Network



- Nodes or devices can join together to make up a simple ad-hoc network. Every device owes an equal status or designation in the network.



characteristics of adhoc network:

- **Lack of fixed Infrastructure**
 - Nodes can communicate
 - Directly within the transmission range
 - Through multi-hop communication
- **Dynamic topology**
 - Network topology changes unpredictably
 - Rate of topology change
 - Movement speed of the mobile devices
- **Bandwidth constrained, variable capacity links**
 - Have low bandwidth capacity
 - Factors that affects Bandwidth
 - Fading
 - Noise
 - Interference
- **Energy Constrained operation**
 - Small battery
 - Store very limited amounts of energy
 - Transmissions and Processing during routing consumes energy
- **Increased Vulnerability**

- Prone to new types of security threads
- Security Threads
 - Eavesdropping
 - Spoofing
 - Denial-of-service (DoS)
- Difficult to identify the attacker
 - Device keep moving
 - Do not have a global identifier
- Nodes are vulnerable to capture and compromise

Applications

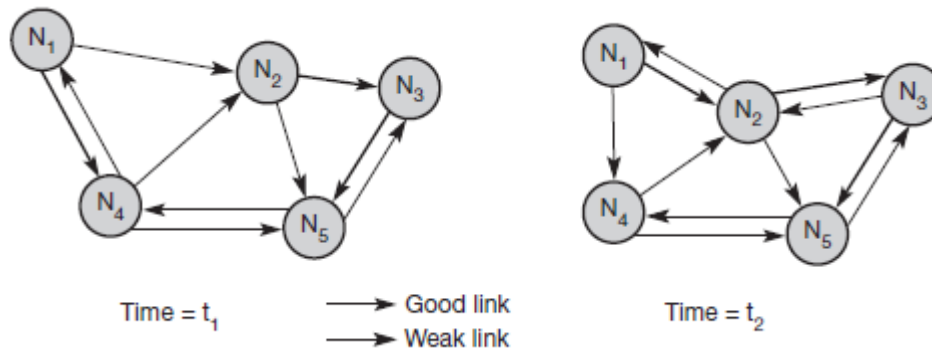
- Communication among portable computers
 - Portability should be within the range of wireless hub
 - Reduce device flexibility and mobility
 - Example
 - Cell phone
 - Laptop
 - Ear phone
 - Wrist watch
 - Group of people in a conference can share data
- **Environmental Monitoring**
 - Collection of various types of data about the environment in which it is deployed
 - **Applications**
 - Environmental Management
 - Security Monitoring
 - Road Traffic Monitoring
 - Road Traffic Management
 - Continuous data collection from remote locations
 - Miniature Sensors
 - Effective means of gathering environmental information
 - Rainfall
 - Humidity

Presence of animal, etc.,

- Environmental Monitoring Application
 - Deploys large number of sensors nodes in environment
 - Deploys adhoc sensor networks to collect data from remote locations
 - Sensor nodes respond with commands issued by data collection centre
 - MANETs efficiently handle
- **Military**
 - Set up an adhoc network in a frontline battle field with various military equipment
 - Take advantage of an information network among
 - Soldiers
 - Vehicles
 - Military Information Headquarters
- **Emergency Applications**
 - Adhoc networks can be easily and rapidly deployed
 - Search and rescue operation after a natural disaster
 - Policing and Fire fighting
 - crowd control
- Design Issues:
- Network size and node density
- Network Size
- Refers to the geographic coverage area of the network
- Node Density
- Refers to the number of nodes per unit geographical area
- Clustering required for large networks to avoid network overhead
- Depends on node density
- Connectivity
- Refers to number of neighboring nodes within transmission range
- Link between two nodes
- Link capacity refers bandwidth of the link
- In MANET
- Number of neighboring nodes

- Capacities of Links
- Vary significantly
- Network topology
- Refers connectivity among various nodes of the network
- Factors that affect the topology
- Mobility of nodes
- Hardware failures
- Discharged batteries
- Issues
- Rate at which the topology changes
- User traffic
- Design based on
- Node density
- Average rate of node movements
- Expected traffic
- Common traffic types
- Bursty traffic
- Large packets send periodically
- Combination of above two
- Operational environment
- Environment is either
- Urban
- Rural
- Maritime
- Supports Line of Sight (LoS) communication
- Requires different design of mobile networks due to difference in
- Node density
- Mobility Values
- **ROUTING IN MANET:**
- Purpose
- To find a path between source and destination and to forward the packets appropriately

- Example
- Each node must be able to forward data for other nodes
- Consider the following ad-hoc network

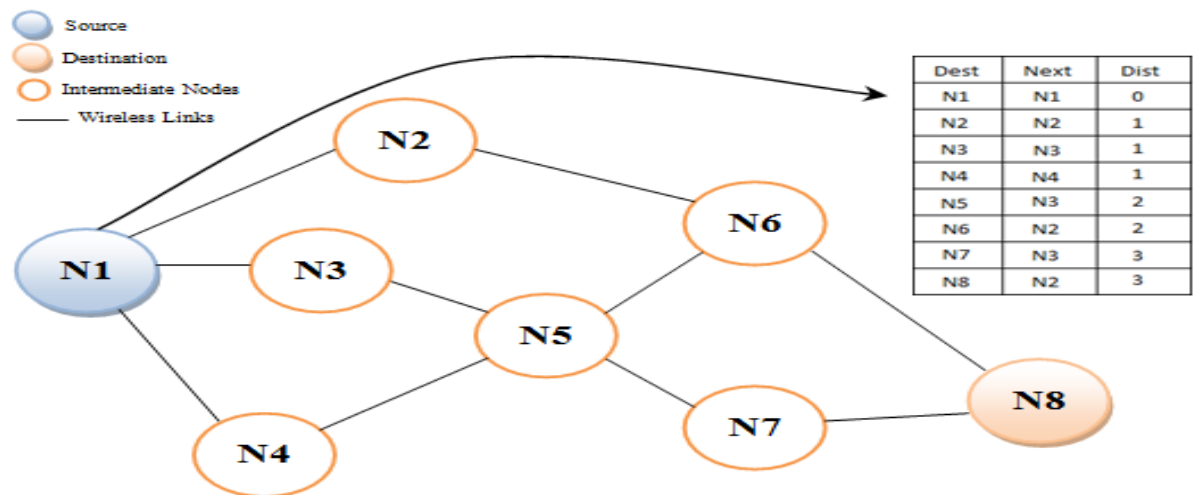


- **Functions of each node in MANET**
- Forward the packet to the next hop
- Before forwarding, Sender has to ensure that:
 - the packet moves towards its destination
 - the number of hops(path length) to destination is minimum
 - Delay is minimized
 - Packet loss is minimum through the path
 - Path does not have a loop
- **Routing Challenges in MANET:**
 - Host is no longer an end system - can also be an acting intermediate system
 - Changing the network topology over time
 - Potentially frequent network partitions
 - Every node can be mobile
 - Limited power capacity
 - Limited wireless bandwidth
 - No centralized entity –distributed
 - Presence of varying channel quality
- **ESSENTIALS OF TRADITIONAL ROUTING PROTOCOLS:**
 - Types
 - **Link state routing**
 - **Distance vector routing**
 - Popular in packet-switched networks

- Finds the shortest path to the destination based on number of hops in the route
- **LINK STATE PROTOCOLS (LSP):**
- Link state denotes connection establishment of one router with another router
- a neighboring node of a router will directly communicate without any intermediate routers
- Also known as shortest path first algorithms
- Each routers learns about its own directly connected networks
- Each node maintains a network topology based on cost for each link
- Each router determines its local connectivity information and floods to other nodes in the network through link state advertisement
- Each router in the network stores the information present in the link state advertisement in link state packet database (LSPDB)
- All routers in network maintains
- LSPDB and
- Routing table
- Each routers in the network have identical LSPDB
- **Routing Process:**
- Router floods the Link state advertisement to all of its neighbors
- A router receives this Link state advertisement examines the sequence number and keeps the most recent one by consulting its LSPDB
- The router forwards a copy to its neighbor
- Using Link state advertisement stored in LSPDB a router constructs a tree using Dijkstra's algorithm
- Using this algorithm a shortest path tree is constructed edge by edge
- **Link State tree Construction:**
- Each router maintains two data structure
- A shortest path tree containing nodes
- List of candidates
- Initially this algorithm starts with both the data structures as empty
- It first adds itself as a route of the tree and add other neighboring routers as nodes
- All routers are connected by emptying the candidate list
- The above step is repeated until candidate list is empty
- Once a network topology is formed a router uses its routing table to find the shortest path to the destination

- Rooting loops are formed when two nodes sends packet to each other endlessly
- Link state protocols are:
- Open Shortest Path First (OSPF)
- Intermediate System to Intermediate System (IS-IS)
- **DISTANCE VECTOR (DV) ROUTING PROTOCOL:**
- Each node knows the distance (=cost) to its directly connected neighbors
- Routing decisions are based on number of hops the packet have to traverse to reach the destination
- Here vector denotes distance and direction, that is number of hops to the destination and the next hop to the router
- Also known as Distributed Bellman-Ford or RIP (Routing Information Protocol)
- each router broadcast the routing information to all of its neighbors
- A node sends periodically a list of routing updates to its neighbors
- All the neighboring nodes updates its own routing table based on the routers broadcasted information
- Routers does not know entire path to the destination. Instead they have:
- Direction in which packets have to be forwarded
- its own distance from destination
- popular routing protocols based on distance vector are
- Routing Information Protocol(RIP)
- Interior Gateway Routing Protocol (IGRP)
- **DESTINATION SEQUENCED DISTANCE-VECTOR (DSDV):**
- It is a table-driven (Pro-active) routing protocol
- Based on classical distributed Bellman-Ford routing mechanism
- Routing loop is avoided by using number sequencing
- Each mobile node maintains a routing table in terms of number of hops to each destination.
- Routing table updates are periodically transmitted
- Each entry in the table is marked by a sequence number which helps to distinguish stale routes from new ones, and thereby avoiding loops.
- Updated routing tables are exchanged periodically to maintain table consistency
- **Important steps in operation of DSDV**
- Each router collects information from all its neighbor

- The node determines the shortest path to the destination
- A new routing table is generated
- The router broadcasts the generated table to its neighbors



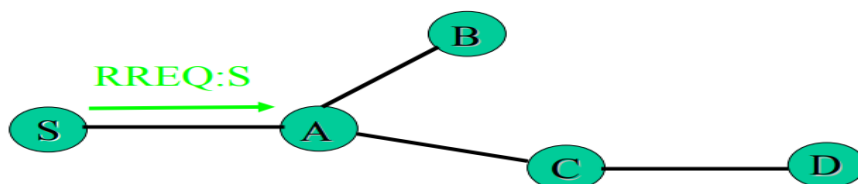
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- **REACTIVE (ON-DEMAND) PROTOCOLS:**
 - Also called as On-demand routing protocol
 - Nodes do not maintain up-to-date routing information
 - New routes are discovered only when required
 - Uses flooding technique to determine the route
 - Flooding technique is used when the node does not have routing knowledge
 - Advantages
 - Reduce large overheads
 - Eliminate periodic updates
 - Adaptive to network dynamics
 - Disadvantages
 - High flood-search overhead
 - Mobility, distributed traffic
 - High route acquisition latency
 - Example
 - Dynamic Source Routing (DSR)
 - Adhoc on-demand distance vector routing (AODV)
- **DYNAMIC SOURCE ROUTING (DSR):**
 - Developed for MANETs with small diameter and less mobility
 - It is a source initiated On-demand (reactive) routing protocol

- Uses source routing, the sender determines the complete sequence of the node to travel
- Exchanges routing table periodically
- Each node maintains a route cache which contains list of all nodes
- When a node finds a new route it adds in its cache
- Also maintains sequence counter to identify last request generated
- The protocol consists of two major phases: Route Discovery, Route Maintenance

Route Discovery:

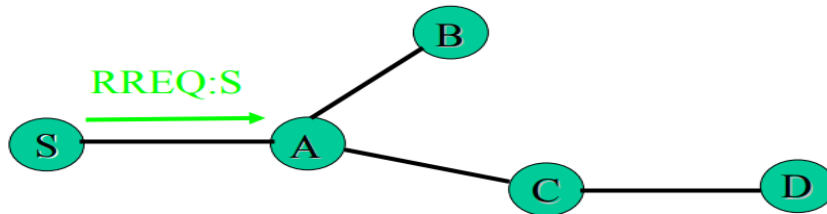
- When a mobile node has a packet to send to some destination, it first consults its route cache to check whether it has a route to that destination.
- If it is an un-expired route, it will use this route.
- If the node does not have a route, it initiates route discovery by broadcasting a Route Request packet.
- This Route Request contains the address of the destination, along with the source address.
- Each node receiving the packet checks to see whether it has a route to the destination. If it does not, it adds its own address to the route record of the packet and forwards it.
- *Route Reply* message containing path information is sent back to the source either by
 - the destination, or
 - intermediate nodes that have a route to the destination
 - Reverse the order of the route record, and include it in Route Reply.
 - Unicast, source routing
- If the node generating the route reply is the destination, it places the route record contained in the route request into the route reply.
- Each node maintains a *Route Cache* which records routes it has learned and overheard over time

DSR - Route Discovery



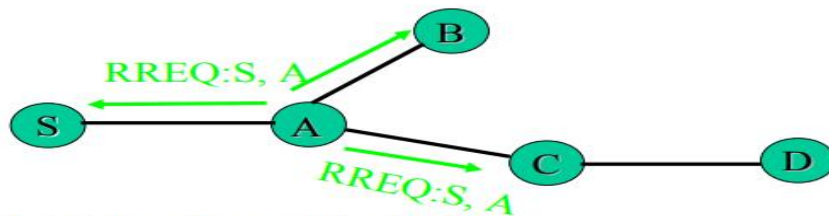
1. Node S needs a route to D
2. Broadcasts RREQ packet

DSR - Route Discovery



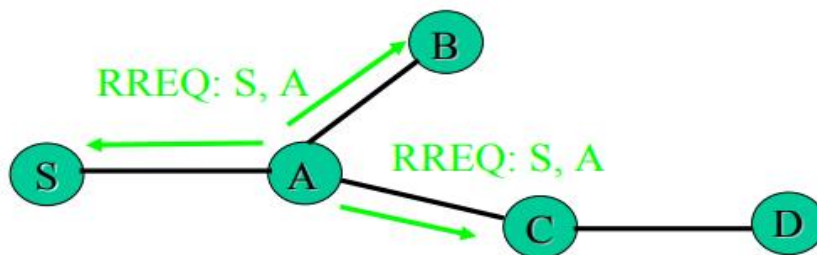
1. Node S needs a route to D
2. Broadcasts RREQ packet
3. Node A receives packet, has no route to D
 - Rebroadcasts packet after adding its address to source route

DSR - Route Discovery



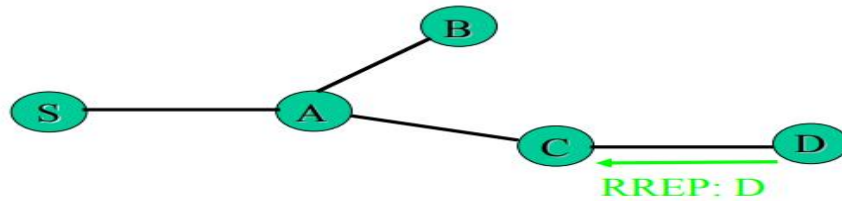
1. Node S needs a route to D
2. Broadcasts RREQ packet
3. Node A receives packet, has no route to D
 - Rebroadcasts packet after adding its address to source route

DSR - Route Discovery



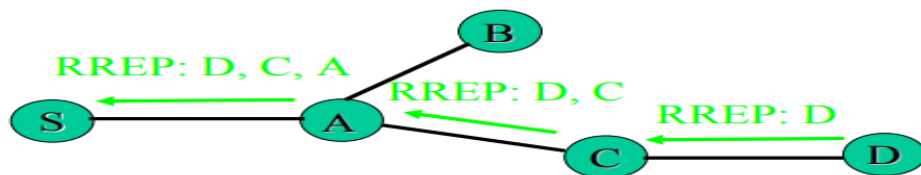
4. Node C receives RREQ, has no route to D
 - Rebroadcasts packet after adding its address to source route

DSR - Route Reply



4. Node C receives RREQ, has no route to D
 - Rebroadcasts packet after adding its address to source route
5. Node D receives RREQ, unicasts RREP to C
 - Puts D in RREP source route

DSR - Route Reply

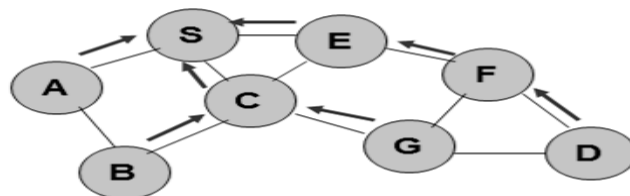


7. Node A receives RREP
 - Adds its address to source route
 - Unicasts to S

AD HOC ON-DEMAND DISTANCE VECTOR (AODV):

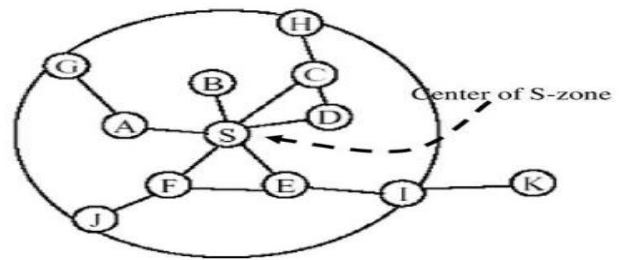
- AODV = Ad Hoc On-demand Distance Vector
- Routing protocol designed for wireless and mobile ad hoc networks
- AODV is an improvement over DSDV, which minimizes the number of required broadcasts by creating routes on demand.
- Route discovery and route maintenance are same as DSR
- Uses hop-by-hop routing, Sequence numbers and beacons
- A source node initiates a path discovery process broadcasts a Route Request (RREQ) packet to its neighbors.
- Source floods route request in the network.

Route reply forwarded via the reverse path:



The Zone Routing Protocol

- Peripheral nodes
G, H, J, and I
- Neighbor nodes
B, C,



We depict zones as circles, but they are not.

```

graph LR
    S((S)) --- A((A))
    S --- B((B))
    S --- C((C))
    S --- D((D))
    S --- E((E))
    S --- F((F))
    S --- J((J))
    A --- G((G))
    J --- I((I))
    I --- K((K))
    subgraph Circle
        G
        A
        S
        B
        C
        D
        E
        F
        J
        I
    end
    K
  
```

Node I bordercasts the request to its peripheral nodes (gray ones). Due to query control mechanisms, the request is not passed back to nodes D, F, and S. I will discuss query control later.

Application Types:

- Safety applications
 - Used to send safety messages
- Nonsafety applications
 - Provide an efficient and comfortable driving experience
 - Categories
 - Traffic management
 - Used to improve traffic flow and resolve congestion on the road
 - Infotainment
 - Used for information and entertainment purposes
 - Providing Internet access to passengers
 - » Data storage
 - » Video streaming

Video calling

Challenges :

- Intermittent connectivity
 - Control and management of network connection among vehicles and infrastructure is a key challenge
 - Intermittent connections due to the high mobility of vehicles or high packet loss in vehicular networks must be avoided
- High mobility and location awareness
 - Future VANETs require high mobility and location awareness of the vehicles participating in communication
 - Each vehicle should have the correct position of other vehicles in the network to cope with an emergency situation
- Heterogeneous vehicle management
 - Large number of heterogeneous smart vehicles
 - Management of heterogeneous vehicles and their sporadic connections is another challenge of future VANETs
- Security
 - Always a risk to the privacy of user's data content and location
 - Vehicles communicating within the infrastructure should allow users to decide what information should be exchanged and what information should be kept private

- Privacy can be assured by examining sensitive data locally, instead of sending it to the cloud for analysis
- Support of network intelligence
 - In future VANETs, there will be a large number of sensors installed in vehicles, and the edge cloud collects and preprocesses the collected data before sharing them with other parts of the network

SECURITY ISSUES:

- **Lack of Physical boundary**
 - Mobile node act as a router and forwards packets
 - Network boundaries become blurred
 - Distinction between internal and external nodes
 - Difficult to
 - Deploy firewalls
 - Monitor the incoming traffic
- **Low Power RF transmissions**
 - Malicious node transmit and monopolise the medium continuously
 - Cause neighboring nodes to wait endlessly for message transmission
 - Signal Jamming leads to Denial-of-Service(DoS) attack
- **Limited computational capabilities**
 - Reason
 - Difficult to deploy compute-intensive security solutions
 - Setting up a public key cryptosystem
 - Inability to encrypt messages
 - Invites a host of security attacks
- **Limited power supply**
 - Attacker attempt to exhaust batteries by causing
 - Unnecessary Transmissions
 - Excessive computations

UNIT V PLATFORMS AND APPLICATIONS

What Is an Application?

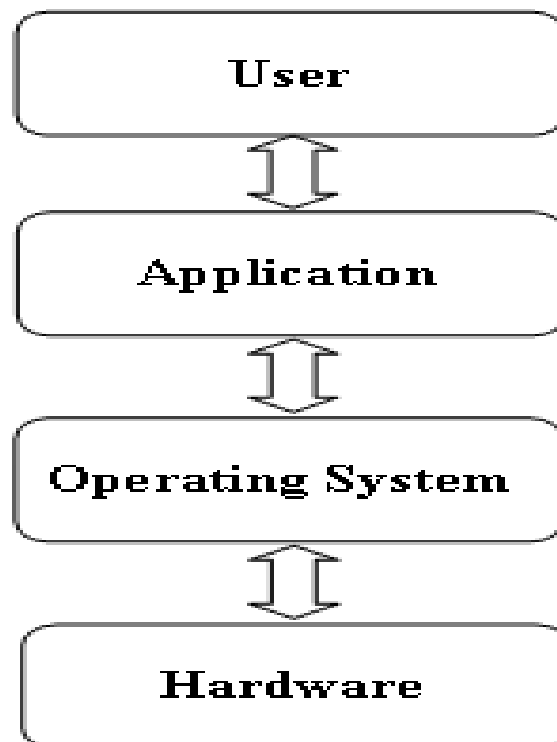
- **An application**, or software application, is a computer program that aims to **complete a specific task** separate from that of the operating system. Some applications have a single, narrow focus. Others contain several programs within them.
- Applications run locally on a server or computer system. They use application programming interfaces (APIs) to talk to other applications.
- Applications cover many functions. At one end, they are complex database systems or deployment tools. On the other, they are simple programs like word processors or image editors

What Is a Platform?

- A **platform** runs on both hardware (e.g., a server) and software (an operating system). It is the **foundation on which applications run**. A platform is there to be built upon and connect with external systems.
- This means that any smartphone is a platform because it includes hardware (form factor), an operating system, and connects with other systems.

Operating System

- Interface between hardware and user
- Manages hardware and software resources of the system
- Provides set of services to application programs



BASIC CONCEPT:

- OS is structured into
 - Kernel Layer
 - Shell Layer
- Kernel
 - Executes in the supervisor mode
 - Run privileged instructions that run in user mode
 - Memory resident part of an operating system
 - Responsible
 - Interrupt Servicing
 - Management of processes, memory and files
 - During booting
 - Kernel gets loaded first
 - Remain in the device's main memory
 - Paging does not apply to kernel code and data
- Shell
 - Provides facilities for user interaction with the kernel
 - Not memory resident
- **TYPES OF OPERATING SYSTEM**
- Monolithic Kernel
- Micro kernel
- **Monolithic Kernel OS design**
- Kernel contains the entire OS operations except shell code
- Motivation
 - OS services can run more securely and efficiently in supervisor mode
- Example
 - Windows
 - Unix
- Advantage
 - Provides good performance
 - Always runs in supervisor mode
 - More efficient and secure

SPECIAL CONSTRAINS AND REQUIREMENTS:

- **CONSTRAINTS**

- **Limited Memory**

- Less permanent and volatile storage
 - OS should be as small as possible
 - Provide rich set of functionalities to meet user demands

- **Limited Screen Size**

- To make mobile portable
 - Size should be small
 - Limits the display screen size

- **Miniature Keyboard**

- Design the mobile device with small Keypad or Small-sized display screen
- Drawback
 - Difficult in
 - Document typing
 - Entering string commands

- **Limited Processing Power**

- ARM-based processors
 - Popular processor used in modern mobile devices
 - Advantage
 - Energy efficient
 - Powerful
 - Cheaper
 - Disadvantage
 - Significantly slower
 - Limited
 - Processing power
 - Storage
 - Battery Power
- Mobile Application development activities
 - Memory intensive utility programs

- **Limited Battery Power**
 - Small battery
 - Due to its size and weight
 - Recharging cannot be done as and when required
 - Technique to reduce power consumption
 - Putting processor and display screen in sleep mode during inactivity
 - Varying the intensity of transmitted antennae power as per requirement
- **Limited and Fluctuating Bandwidth**
 - Bandwidth fluctuation
 - Show up short term fades
 - Reason
 - Atmospheric noise
 - Causes high bit error rates
 - Movement of some objects
 - Movements of mobile handset

REQUIREMENTS:

- **Support for specific communication protocols**
 - Requires enhanced communication support during
 - Connection between Mobile devices to
 - Base Station
 - Peripheral Devices
 - Computers
 - Other Mobile devices
 - Types of Interfacing Protocols
 - Depends upon on the generation of the communication technology
 - Make mobile to be used across the existing technology spectrum
 - TCP/IP and Wireless LAN Protocols
 - Communication with Other devices and Computers
 - Infrared / Bluetooth Connections
 - Web Browsing
 - Communication with other personal devices

» Pen Drives

» Headphones

- **Support for a variety of input mechanisms**

- Strongly influence the
 - Intended primary use of a device
 - Specific customer segment for which it is positioned
 - Challenges the user interaction part and internal design of OS
- Types of user input mechanism
 - Miniature Keyboard
 - QUERTY Keyboard
 - Touchscreen
 - Stylus-based input mechanism with handwriting recognition

- **Compliance with open standards**

- OS adhere to open standards to facilitate
 - Development of third-party innovative software development
 - Reduce the cost of
 - Development
 - time-to-market by the manufacturers
 - Designing the user interface and networking capabilities of Mobile OS

- **Extensive library support**

- Required by the cost-effective third party application development
- Includes
 - Availability of programmer callable primitives for
 - Email
 - SMS
 - MMS
 - Bluetooth
 - Multimedia
 - User interface primitives
 - GSM/GPRS functionalities

COMMERCIAL MOBILE OPERATING SYSTEMS:

- Mobile OS
 - Facilitate third party development of application software
 - Allow manufacturers of different brands of mobile devices to build their choice set of functionalities for the users
- **Example**
 - Windows Mobile
 - Palm OS
 - Symbian OS
 - iOS
 - Android
 - Blackberry
- **WINDOWS MOBILE OS**
- Mobile operating systems developed by Microsoft Corporation for smartphones and Pocket PCs
- **Evolution of Microsoft's Windows Mobile OS**
- Windows CE
 - Feature
 - Support for deterministic scheduling of time-constrained tasks
- Pocket PC 2000
 - Based on Windows CE
 - Originally codenamed “Rapier” on 2000
 - Targeted for PDAs and not mobile phones
- Pocket PC 2002
 - Based on Windows CE
 - Originally codenamed “Merlin” on 2001
- Windows Mobile
 - Versions
 - Three main versions of Windows Mobile for various hardware devices:
 - Windows Mobile Professional
 - Runs on smartphones with touchscreens
 - Windows Mobile Standard
 - Runs on mobile phones without touchscreens

- Windows Mobile Classic
 - Runs on personal digital assistant or Pocket PCs
- Windows Mobile 2003
 - Originally codenamed “Ozone” on 2003
 - Support touch screen-based user interface
 - Do not support any phone capability
 - Not targeted for cell phones, but for PDAs
- **Features**
- Graphics / Window / Event Manager (GWE) component handles all input and output
- Provides
 - Virtual Memory Management
- Does not provide true Multitasking
 - Background application goes into hibernate state
 - Foreground application only goes into active state
- Support Security
- Similar application development in Win32 environment
- Supports virtual private networking over PPTP protocol

Palm OS:

- Also known as **Garnet OS**
- Mobile operating system initially developed by Palm Inc., for personal digital assistants (PDAs) in 1996
- Developed for PDA called Palm Pilot
- Designed with the provision of touchscreen-based graphical user interface
- Upgraded to install the following devices
 - Smartphones of different makes
 - Wrist Watches
 - Hand-held gaming consoles
 - Bar Code readers
 - GPS devices
- **Key features**
- Essentially a simple single-tasking operating system
 - Only one application can run at a time

- Example
 - If the voice communication is on,
 - The calculator cannot be used
 - An SMS cannot be read
- Has an elementary memory management system
 - To keep the operating system small and fast,
 - Plam OS does not isolate the memory areas of application from each other
 - Misbehaving application can crash the system.
- Plam supplies Plam emulator,
 - Emulates the Plam hardware on a PC
 - Allows Plam programs to be developed and debugged on a PC before being run on the Plam hardware
- Different interfaces supported include
 - Serial port/USB
 - Infrared
 - Bluetooth
 - Wi-Fi connections
- Uses a proprietary format to store calendar, address, task and note entries and accessible by third- party applications.

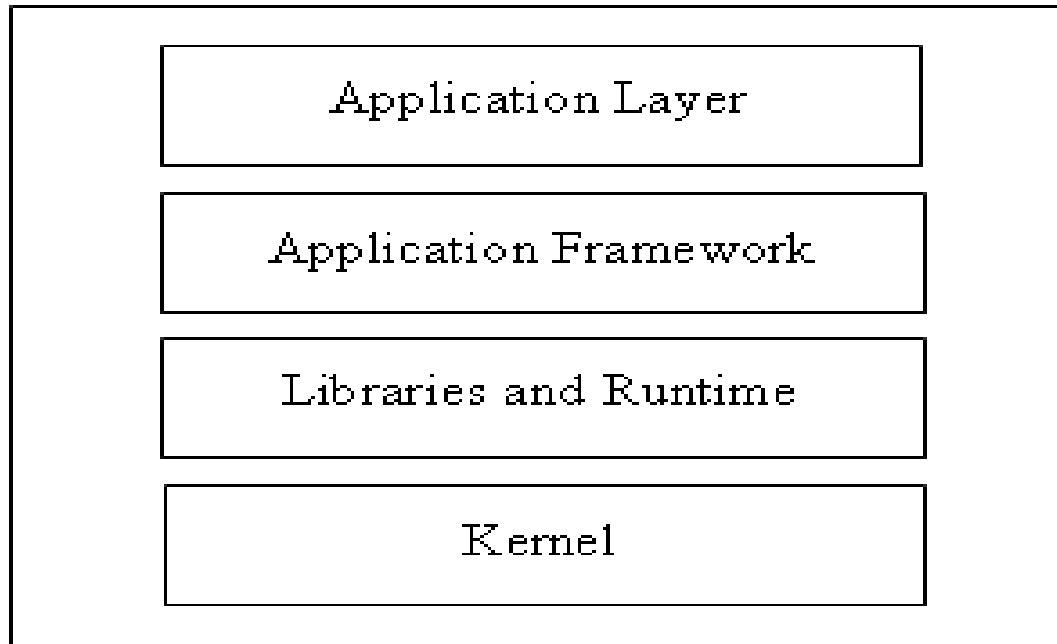
SYMBIAN OS:

- Developed through the collaboration among the prominent mobile device manufacturers
 - Nokia
 - Ericsson
 - Panasonic
 - Samsung
- Symbian source code was published under Eclipse Public License(EPL) in February 2010
- Symbian OS
 - Real time, multitasking, pre-emptive,32-bit operating System
 - Runs on ARM-based processor designs
 - Inherent Design : Microkernel-based

iOS:

- iOS stands for iPhone OS
- Developed and distributed by Apple Inc released in 2007
- Derivative of Mac OS
- Extended to support other Apple devices
 - iPod Touch
 - iPad
 - iPad Mini
 - Apple TV
- Closed and proprietary OS fully owned and controlled by Apple
- Does not installed on third party hardware
- Innovative Features that grabbed the market attention
 - User interaction through gestures
 - Swipe
 - Tap
 - Pinch
 - Reverse Pinch
- **ANDROID**
- Mobile operating system (OS) currently developed by Google, based on the Linux kernel
- Designed primarily for touchscreen mobile devices such as
 - Smartphones
 - Tablets
- Features
 - Provides the ability to use either phone-based keyboard or touchscreen
 - Provides a built-in full web browser capable of rendering full web pages
 - Android SDK works in Eclipse environment
 - Provides an RDBMS SQLite for data storage and data sharing
 - Has innovatice pre-installed applications
 - Gmail
 - Maps
 - Voice search, etc.,

- **Android Software Stack**
- **Android architecture** or **Android software stack** is structured into five parts
- Application Layer
- Application Framework
- Android Runtime
- Native libraries (Middleware)
- Linux kernel

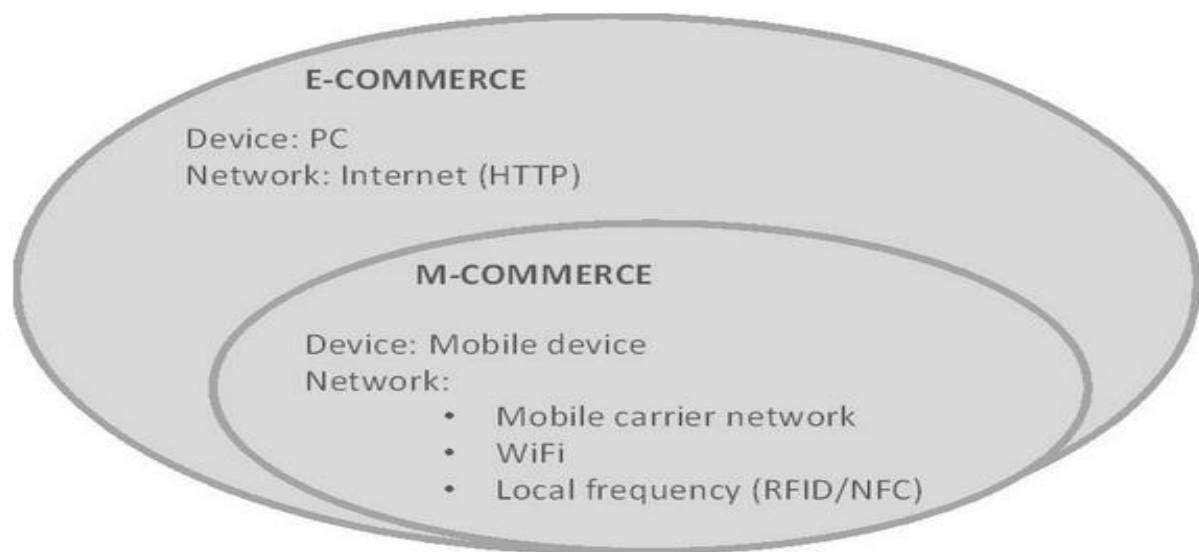


Application Layer

- Located on the top of android framework
- Applications
 - Web Browser
 - Email Client
 - SMS Program
 - Maps
 - Calender
 - Contacts repository management programs
- Applications are written using J2ME
- All applications are using android framework that uses android runtime and libraries
- Android runtime and native libraries are using linux kernal.

MCOMMERCE:

- M-Commerce stands for Mobile Commerce
- Buying and selling of goods and services through mobile handheld devices
- E-Commerce with mobile devices (PDAs, Cell Phones, Pagers, etc.)
- Use of mobile devices to
 - Transact
 - Communicate
 - Entertain
- M-Commerce = E-Commerce + Wireless web



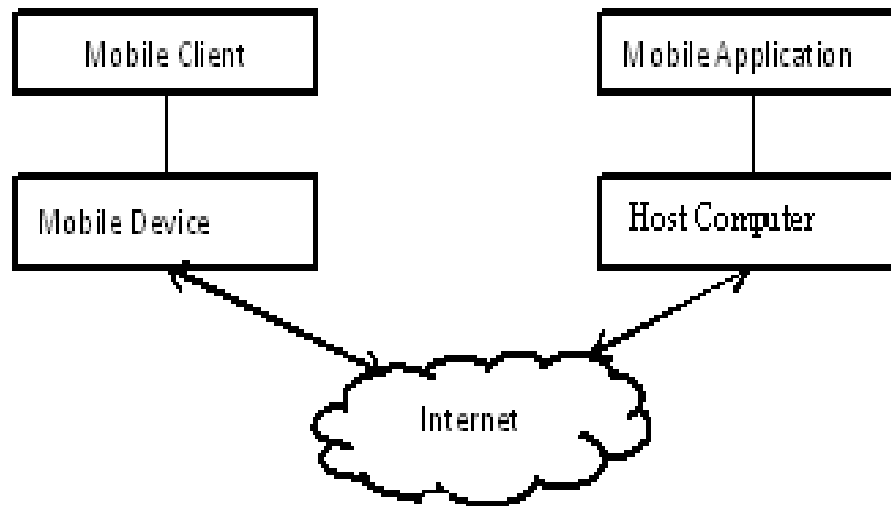
Applications:

- B2C
 - B2C stands for Business- to-Consumer
 - Form of commerce in which products or services are sold by a business firm to a consumer
 - Examples
 - Advertising
 - Done using the demographic information collected and user current location
 - Wireless service provider
 - » Collect the demographic information
 - » Keep track of the history of the purchases made by the customer
 - Customers solicit specific advertisements

- Comparison Shopping
 - Get a comparative pricing analysis of a product at different stores
 - Get the prices of the related products by scanning the bar code on a product
 - Access the web-based comparison shopping applications
 - Access the product reviews from consumer organizations or customers
- Information about a product
 - Access additional information about products
 - Example
 - » Read the dosage instructions in English by scanning the bar code on pack
- Mobile Ticketing
 - Used to purchase movie tickets (m-tickets) using credit cards
- Loyalty and payment services
 - Bar code is sent to the customer's mobile phone after signed up in supermarket loyalty scheme
 - Accumulates points based on the total amount spent by showing the bar code at the cash counter
- Interactive advertisements
 - Scan a bar code in an advertisement for a product appearing on a TV screen
- Catalogue shopping
 - Used to place orders for products listed in a catalogue
 - Used to buy products directly from the catalogue shopping company by scanning the bar codes
- B2B
 - B2B stands for Business- to- Business
 - Form of commerce in which products or services are sold from a company to its dealers
 - Examples
 - Ordering and delivery confirmation
- **Features**
- Provision for cash deposit and withdrawals

- Ability for third parties to make deposits into a user account
- Ability to make retail purchase
- Transfer cash between user accounts
- Provision for bill payments

STRUCTURE OF M-COMMERCE:



- M-Commerce implementation is provided by two sets of programs
 - Server side
- Performs database access and computations
- Reside on the host computer (servers)
 - Client side
 - Run on the micro browsers installed on the user's mobile phones

LAYERS OF M-COMMERCE FRAMEWORK:

- M-Commerce framework have four layers
 - Mobile devices
 - Mobile Middleware
 - Network
 - Host computers
- **Mobile devices**
- Provides user interface to the mobile users
- Users specify requests
 - Specified through the interface programs

- Transmitted to the mobile commerce application
- Obtained Results are displayed in suitable formats
- Features required for mobile devices
 - Good internet connectivity
 - Ability to display images
 - Good quality camera
 - Display bar codes properly on screen
 - Ability to read RFID tags

Mobile Middleware:

- Purpose
 - Map the internet content to mobile phones with variety
 - Operating systems
 - Markup languages
 - Micro-browsers
 - protocols
- **Network**
- Connected through wireless network
- Messages are delivered
 - Through the access points in wireless LAN or
 - Through base stations in cellular network
- Host computers are connected to internet through wired network
- **Host computers**
- Also called as servers
- Process and stores all the informations needed for needed for m-commerce applications
- Application program used for M-commerce are hosted
 - Require three major components:
 - Web servers
 - Interact with mobile client
 - Database servers