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Mobile Computing

- Mobile Computing enables transmission of data from one device to another wirelessly, without any physical link or cables
- It allows transmission of data, voice, and video via wireless-enabled devices such as mobiles, laptops, etc.
- With Mobile Computing, users can access and transmit data from remote locations without physically being present there
- Mobile Computing provides vast coverage diameter for communication and is one of the fastest and most reliable sectors of the computing technology field
- The concept of Mobile Computing can be divided into three parts:
    i. Mobile Communication,
    ii. Mobile Hardware
    iii. Mobile Software
- **Mobile Communication** refers to the ability to transmit data wirelessly using various technologies such as Bluetooth, Wi-Fi, cellular networks, satellite communication, and infrared

- **Mobile Hardware** refers to physical devices that enable mobile computing such as mobile phones, laptops, tablets, and smartwatches

- **Mobile Software** refers to applications and operating systems that run on mobile hardware, specifically designed for mobile devices taking into consideration the limited processing power, memory, and display size.

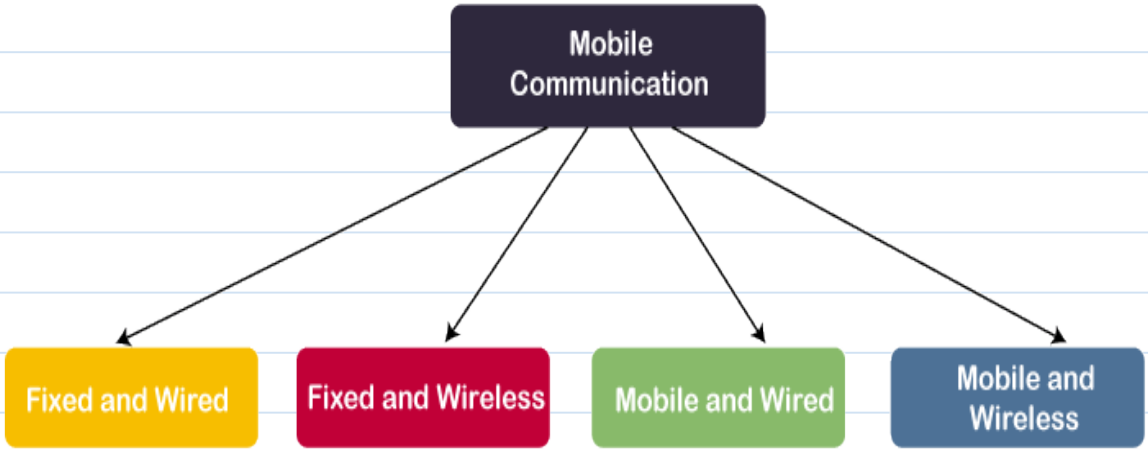
Mobile Communication

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:

1. Fixed and Wired
2. Fixed and Wireless
3. Mobile and Wired
4. Mobile and Wireless



1. **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.

2. **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

3. **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.

4. **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.

Mobile Hardware

- Mobile hardware includes devices or components that enable mobility such as smartphones, laptops, tablets, PDAs, etc.
- Mobile devices are built with a receptor medium that can send and receive signals wirelessly.
- These devices can operate in full-duplex, allowing them to send and receive signals simultaneously.
- They do not have to wait for one device to finish communicating before the other device can initiate communication.
- Mobile devices are designed to be portable and lightweight, making them convenient for use on the go.
- They often have limited processing power, memory, and battery life compared to desktop computers.
- Mobile hardware is constantly evolving, with new devices and technologies being developed to improve mobility and connectivity.

Mobile software

- Mobile software refers to a program that runs on mobile hardware, designed to meet the requirements of mobile applications.
- It is the operating system for mobile devices, serving as the heart of the mobile system.
- Mobile software is an essential component that operates the mobile device, allowing it to perform various functions.
- It enables mobile devices to be portable and provides wireless communication.

- Mobile software includes various applications such as email, social media, gaming, productivity tools, etc.
- Mobile software is specifically designed to work on mobile devices, taking into account the limited processing power, memory, and display size of these devices.
- Mobile software is constantly evolving, with new updates and versions being released to improve functionality and security.
- Different mobile devices run on different operating systems, such as iOS, Android, Windows, etc.

Applications of Mobile Computing

Following is a list of some significant fields in which mobile computing is generally applied:

- Web or Internet access.
- Global Position System (GPS).
- Emergency services.
- Entertainment services.
- Educational services.

Issues in the mobile computing

There are several issues associated with mobile computing, including:

1. **Security:** With the rise in the use of mobile devices for sensitive tasks such as online banking, mobile security has become a major concern. Mobile devices are vulnerable to malware, hacking, and other security threats that can compromise the user's personal information.

2. **Privacy:** Mobile devices collect a lot of personal data, including location, browsing history, and app usage. This data can be used by advertisers, hackers, and other entities to invade user privacy.

3. **Battery life:** Mobile devices have limited battery life, which can be a problem for users who are constantly on the go and rely heavily on their devices. The need for frequent charging can be inconvenient and disruptive.

4. **Network connectivity:** Mobile devices rely on wireless networks for connectivity, which can be unreliable in some areas. Users may experience dropped calls, slow internet speeds, and other connectivity issues that can hamper their productivity.

5. **Compatibility:** Different mobile devices run on different operating systems, which can lead to compatibility issues when sharing files and applications between devices.

6. **User interface:** Mobile devices have smaller screens and limited input options, which can make it challenging to navigate certain applications and websites.

7. **Data usage**: Mobile devices can quickly consume data, leading to high data charges for users who exceed their data limits. This can be a problem for users who rely on their devices for streaming, gaming, and other data-intensive tasks.

Fundamentals of cellular system

Cellular systems are a fundamental part of modern mobile communication networks. They are designed to provide wireless communication services to mobile users over a large geographic area, using a network of base stations and mobile devices. The following are the key fundamentals of cellular systems:

1. **Frequency Reuse:** To accommodate a large number of users, cellular systems use the concept of frequency reuse. In this approach, the same frequency band is reused in different cells, but with a certain distance between them to avoid interference.

2. **Cell Sites:** A cellular network consists of a series of cell sites or base stations, which are strategically placed to provide coverage over a large geographic area. Each cell site covers a specific area, and as the user moves from one cell site to

another, the connection is automatically handed over from one site to the other.

3. **Channel Allocation:** To transmit and receive signals between the base station and the mobile device, a communication channel is required. The channel allocation process is used to allocate channels to different users based on their requirements, such as voice or data transmission.

4. **Handoff**: When a mobile user moves from one cell to another, the system must transfer the call or data session from one cell site to another. This is known as a handoff or handover process, and it is a critical component of cellular systems.

5. **Roaming:** Cellular systems allow users to roam outside their home network and still maintain connectivity with their mobile devices. This is achieved through roaming agreements between different network operators.

6. **Cell Capacity:** Each cell has a limited capacity, determined by the number of channels available for use. As the number of users increases, the cell capacity can be increased by adding more channels or reducing the cell size.

7. **Signal Strength**: The signal strength of a mobile device can vary depending on the distance from the cell site and the presence of obstructions. This can affect the quality of the communication and the data transfer rate.

cellular system infrastructure:

Early wireless systems:

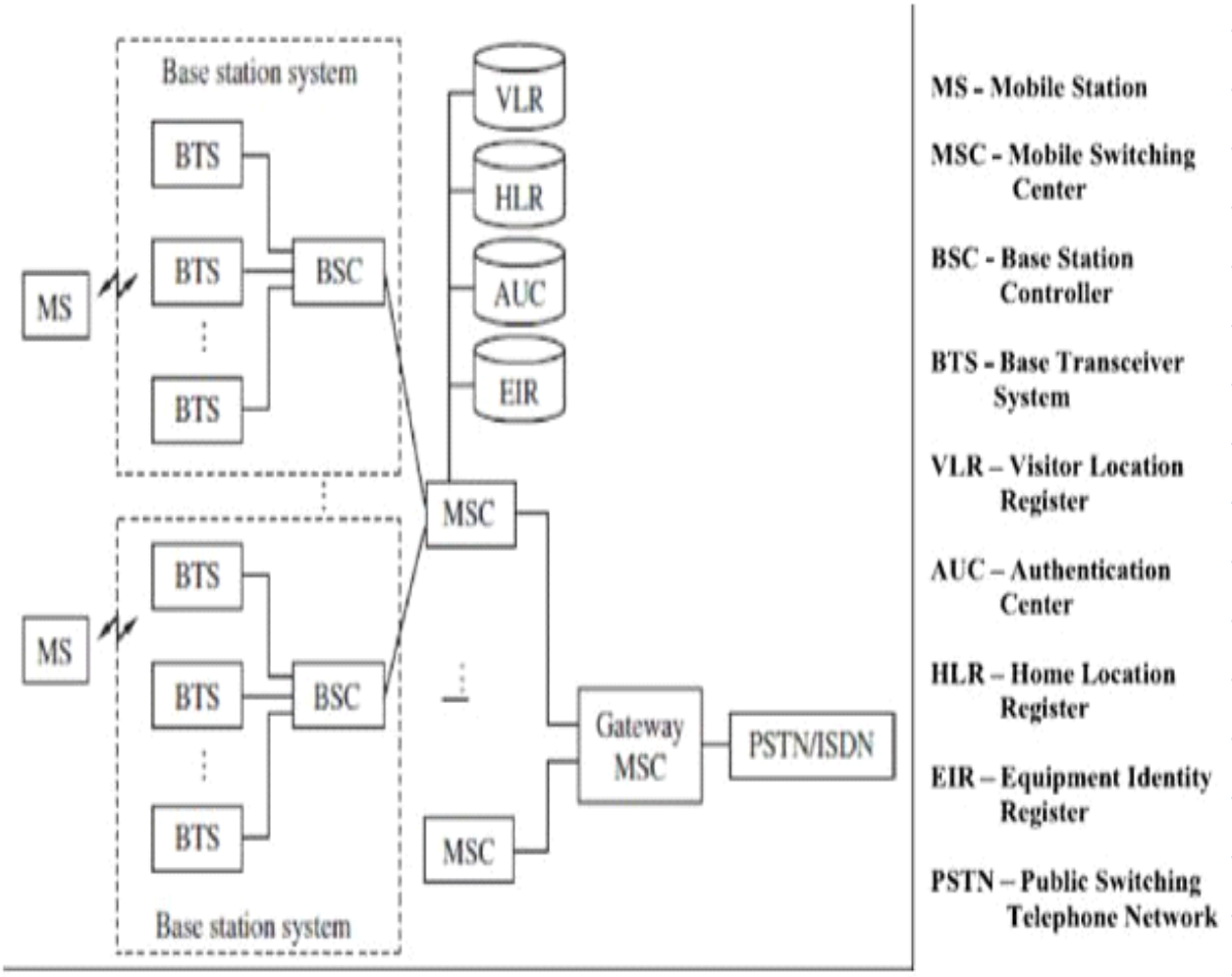
- Had a high-power transmitter that covered the entire service area.
- Required a huge amount of power and was not practical for many reasons.

Cellular system:

- Replaced the large zone with smaller hexagonal cells, with a

single base station (BS) covering a fraction of the area.

- Allows for mobility of the mobile station (MS) by communicating with the BS of the cell where the MS is located, which acts as a gateway to the rest of the world.
- Requires a complex infrastructure consisting of base transceiver system (BTS), BS controller (BSC), home location register (HLR), visitor location register (VLR), authentication center (AUC), and equipment identity register (EIR).
- Bidirectional HLR-VLR pointers allow for calls to be routed or rerouted to the MS, wherever it is located.
- Supports different types of wireless devices such as wireless telephones, laptops, personal digital assistants (PDAs), or web-enabled phones.



- **A BS** consists of a base transceiver system (BTS) and a BSC. Both tower and antenna are a part of the BTS, while all associated electronics are contained in the BSC.

BSC (Base Station Controller):

- BSC is a component of the cellular network infrastructure that controls a group of base stations (BSs).
- It is responsible for managing the radio resources and handover between BSs.
- The BSC communicates with the MSC to provide call setup and mobility management services.
- It is connected to the BTSs through a wired interface, which carries control signals and user traffic.
- The BSC can be implemented as a separate physical entity or as a functional unit within the MSC.

BTS

- BTS is a key component of the cellular network infrastructure that provides wireless communication between mobile devices and the network.
- It is a physical entity that includes a radio transmitter and receiver, antenna, and associated electronics.
- The BTS communicates with the BSC to manage the radio resources, handover, and other network functions.
- The BTS is typically installed on a tower or rooftop, and covers a specific area called a cell. A network can have many cells, each served by one or more BTSs.
- The BTS transmits and receives wireless signals using specific radio frequency bands allocated for mobile communication. Different frequency bands are used for different technologies such as 2G, 3G, and 4G.
- The BTS communicates with mobile devices using a wireless interface, which supports voice and data communication.
- The BTS can also provide additional services such as location-based services and network-based positioning.
- In some cases, the BTS can be combined with other network components, such as the BSC, to form a single physical entity called a base station.

MSC (Mobile Switching Center):

- MSC is a central component of the cellular network infrastructure that provides switching and signaling functions for mobile communication.
- It is responsible for routing calls between different MSs, including calls to and from the PSTN (Public Switched Telephone Network).
- The MSC is also responsible for mobility management, including location updates and handover between different BSCs.
- The MSC communicates with other network elements, such as the HLR and VLR, to obtain information about the MS and support the services it offers.
- The MSC can also provide additional services such as voice mail, call forwarding, and call waiting.
- The MSC can be connected to multiple BSCs and other MSCs through a wired interface, which carries control signals and user traffic.

- **The HLR** (home location register) and VLR (visitor location register) are two sets of pointers that support mobility and enable the use of the same telephone numbers worldwide.

- **The AUC** (authentication center) unit provides authentication and encryption parameters that verify the user's identity and ensure the confidentiality of each cell.

- **The EIR** (equipment identity register) is a database that information about identity of mobile equipment. Both AUC and EIR can be implemented as individual stand-alone units or as a combined AUC/EIR unit.

- **The HLR** is located at the MSC where MS is initially registered and is the initial home location for billing and access information.

Bluetooth

- Bluetooth is a wireless technology designed for communication and file transmission between portable devices such as phones and computers.
- It is based on mobile computing technology and uses low power radio communications to link devices without wires.
- Bluetooth operates on a band of 2.4 to 2.485 GHz and can connect devices up to a distance of 30 feet or 10 meters.
- It was developed by a group of 5 companies known as Special Interest Group in 1998, which included Ericsson, Intel, Nokia, IBM, and Toshiba.
- The range of Bluetooth technology for data exchange has improved in the latest version, Bluetooth 5.0, which can exchange data in the range of about 40-400 meters.
- The data rate speed of Bluetooth technology has also improved over time, with the latest version, Bluetooth 5.0, providing a faster data rate speed than the earlier versions. The speed of data transmission was around 1 Mbps in the very first version, while the latest version provides higher speeds.

The Architecture of Bluetooth Technology

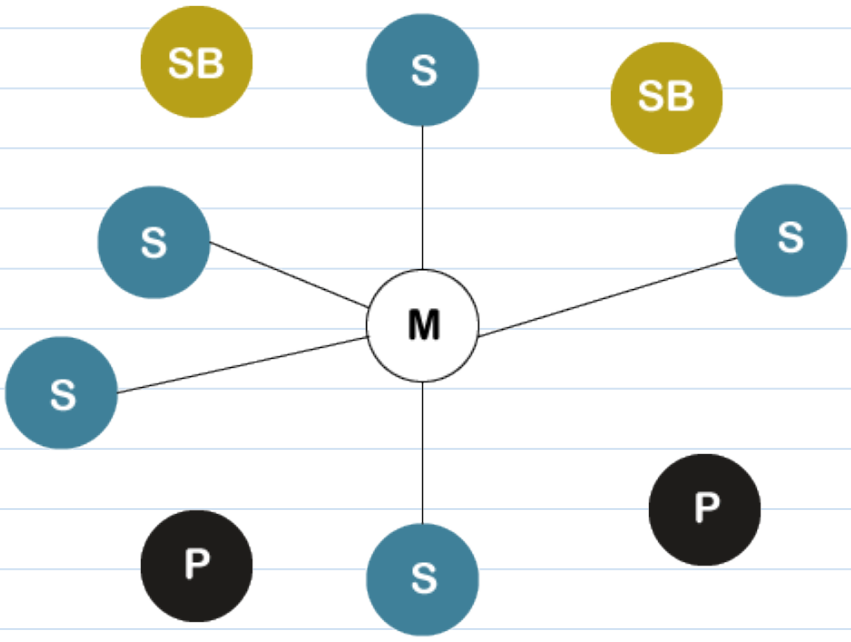
- In Bluetooth technology, the network of Bluetooth consists of a Personal Area Network or a
- Bluetooth's architecture is also called a "Piconet" because it is made of multiple networks.
- It contains a minimum of 2 to a maximum of 8 Bluetooth peer devices.

- It usually contains a single master and up to 7 slaves.
- Piconet provides the technology which facilitates data transmission based on its nodes, i.e., Master node and Slave Nodes.
- The master node is responsible for sending the data while the slave nodes are used to receive the data.
- In Bluetooth technology, data transmission occurs through Ultra-High frequency and short-wavelength radio waves.
- The Piconet uses the concept of multiplexing and spread spectrum. It is a combination of code division multiple access (CDMA) and frequency hopping spread spectrum (FHSS) technique.

Conditions for Successful Data transmission

Following is a list of some conditions that must be satisfied for a successful data transmission in Bluetooth technology:

- Maximum number of Master Node - 1
- Maximum number of Slave Nodes - 7
- Maximum number of Nodes in a Piconet - 8
- Maximum number of devices that can be paired - $2^8 - 1 = 255$
- Number of devices that can be parked → Infinite (∞)



Explanation

- The parked node is a type of node that is ready to be connected and stand by node is a type of node that can either become a slave or parked node or remains idle or disconnected.

- In Bluetooth technology, the data transmission can only occur between master and slave nodes. It cannot be done between slave and slave nodes. However, two master nodes can be connected.

- If the connection from the master node gets disconnected, the whole Piconet gets disconnected.

- If there is a connection between two master nodes, then that network is called as **Scatter-net**.

- It means scatter-nets are created when a device becomes an active member of more than one Piconet and the adjoining device shares its time slots among the different piconets.

- If the number of slaves or devices is increased in a Piconet, then the data transmission speed will be decreased, and if the

number of slaves or devices is decreased in number, then the data transmission speed will be increased.

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Advantages of Bluetooth Technology

- Bluetooth Technology is based on Wireless technology. That's why it is cheap because it doesn't need any transmission wire that reduces the cost.
- It is very simple to form a Piconet in Bluetooth technology.
- It removes the problem of radio interference by using the Speed Frequency Hopping technique.
- The energy or power consumption is very low, about 0.3mW. It makes it possible for the least utilization of battery life.
- It is robust because it guarantees security at a bit level. The authentication is controlled using a 128bit key.
- You can use it for transferring the data, and verbal communication as Bluetooth can support data channels of up to 3 similar voice channels.
- It doesn't require line of sight and one to one communication as used in other modes of wireless communications such as infrared
- .

Disadvantages of Bluetooth Technology

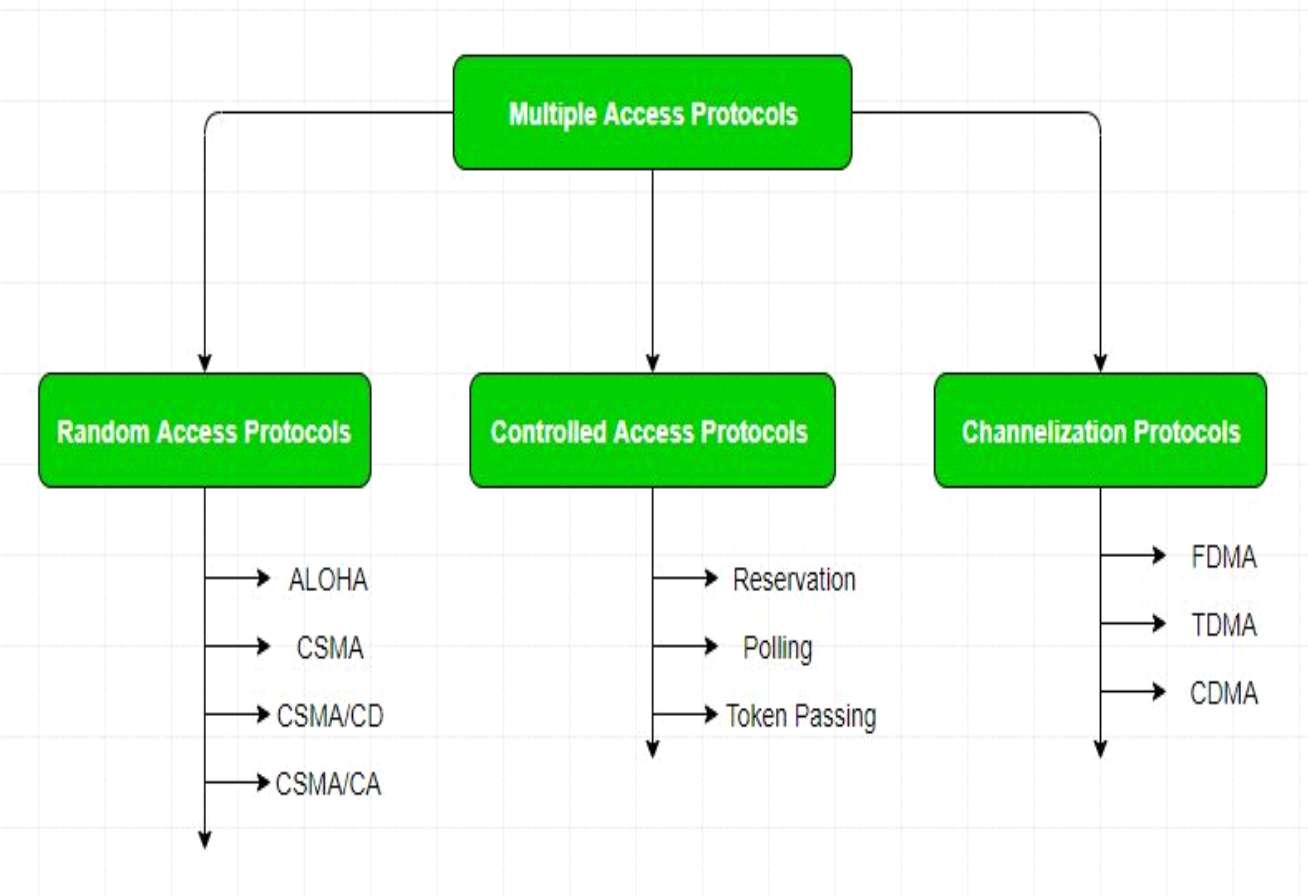
- In Bluetooth technology, the bandwidth is low.
- The data transmission range may also be an issue because it is also less.

Multiple Access Protocols in Computer Networks

- Multiple access protocols are a set of protocols operating in the Medium Access Control sublayer (MAC sublayer) of the Open Systems Interconnection (OSI) model.
- These protocols allow a number of nodes or users to access a shared network channel.

- Several data streams originating from several nodes are transferred through the multi-point transmission channel.

  Thus, protocols are required for sharing data on non dedicated channels. Multiple access protocols can be subdivided further as –



1. Random Access Protocol: In this, all stations have same superiority that is no station has more priority than another station. Any station can send data depending on medium's state(idle or busy). It has two features:

   a. There is no fixed time for sending data
   b. There is no fixed sequence of stations sending data

2. In controlled access, the stations seek information from one another to find which station has the right to send. It allows only one node to send at a time, to avoid the collision of messages on a

shared medium. The three controlled-access methods are:

- Reservation
- Polling
- Token Passing

3. Channelization:

In this, the available bandwidth of the link is shared in time, frequency and code to multiple stations to access channel simultaneously.

1. **Time Division Multiple Access (TDMA):** This MAC protocol divides the available time into slots and assigns each device a specific time slot during which it can transmit data. TDMA is commonly used in cellular networks, where each cell is assigned a set of time slots.

2. **Code Division Multiple Access (CDMA):** This MAC protocol assigns each user a unique code to transmit and receive data. CDMA is commonly used in 3G and 4G cellular networks.

3. **Frequency Division Multiple Access (FDMA):** This MAC protocol assigns each user a unique frequency band to transmit and receive data. FDMA is commonly used in older cellular networks.

Channel Allocation

Channel Allocation means to allocate the available channels to the cells in a cellular system. When a user wants to make a call request then by using channel allocation strategies their requests are fulfilled. Channel Allocation Strategies are designed in such a way that there is efficient use of frequencies, time slots and bandwidth.

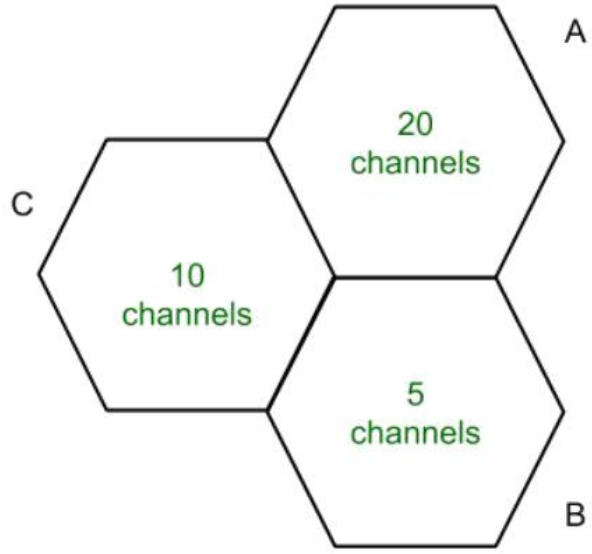
Types of Channel Allocation Strategies:

These are Fixed, Dynamic, Hybrid Channel Allocation and Borrowing Channel Allocation as explained as following

below.

1. **Fixed Channel Allocation (FCA):**

   Fixed Channel Allocation is a strategy in which fixed number of channels or voice channels are allocated to the cells. Once the channels are allocated to the specific cells then they cannot be changed. In FCA channels are allocated in a manner that maximize Frequency reuse.



   In cell A 20 Channels or Voice channels are allocated. If all channels are occupied and user make a call then the call is blocked. *Borrowing Channels* handles this type of problem. This cell borrow channels from other cells.

- **Advantages :**
- Simple to implement and manage
- Does not require complex equipment or algorithms

- **Disadvantages :**
- Limited channel utilization as unused channels remain unused.
- Susceptible to interference and congestion.

2. **Dynamic Channel Allocation (DCA):**

   Dynamic Channel allocation is a strategy in which channels are not permanently allocated to the cells. When a User

makes a call request then Base Station (BS) send that request to the Mobile Station Center (MSC) for the allocation of channels or voice channels. This way the likelihood of blocking calls is reduced. As traffic increases more channels are assigned and vice-versa.

- **Advantages :**
- Efficient use of available bandwidth.
- Reduces call blocking and improves call quality.
- Allows for dynamic allocation of resources.

- **Disadvantages :**
- Requires more complex equipment and algorithms.
- May result in call drops or poor quality if resources are not available

3. **Hybrid Channel Allocation (HCA):**

Hybrid Channel Allocation is a combination of both Fixed Channel Allocation (FCA) and Dynamic Channel Allocation (DCA). The total number of channels or voice channels are divided into fixed and dynamic set. When a user make a call then first fixed set of channels are utilized but if all the fixed sets are busy then dynamic sets are used. The main purpose of HCA is to work efficiently under heavy traffic and to maintain a minimum S/I.

- **Advantages :**
- Provides the benefits of both FCA and DCA.
- Allows for dynamic allocation of resources while maintaining predictable call quality and reliability.

- **Disadvantages :**
- Requires more complex equipment and algorithms than FCA.
- May not provide the same level of efficiency as pure DCA.

4. **Borrowing Channel Allocation (BCA):**

when a cell experiences high traffic demand and all of its channels are occupied, it can borrow channels from

neighboring cells that are not being used at that time. The borrowed channels are assigned to the busy cell and are used to support the additional traffic demand. Once the demand subsides, the borrowed channels are released and returned to their home cell. BCA can be implemented manually or automatically using algorithms or policies but the main disadvantage is that if the borrowed channel is reclaimed by the original cell the call drop may occur.

- **Advantages :**
- Efficient use of available bandwidth.
- Reduces call blocking and improves call quality.

- **Disadvantages :**
- Increases interference between cells.
- Can cause call drops if borrowed channels are reclaimed by the home cell.

Data Management Issues in Mobile Database

- A mobile database is a database that can be accessed by a mobile network and connected to a mobile computing device (or wireless network).

- there is a wireless connection between the client and the server. In the modern world, mobile computing is expanding quickly and has enormous promise for the database industry.

- It will work with a variety of various devices, including mobile databases powered by iOS and Android, among others. Couchbase Lite, Object Box, and other popular databases are examples of databases.

The following are some of the characteristics of the mobile database.

- To prevent frequent and transactions from being lost due to connection loss, a cache is kept.

- As more people utilize laptops, smart phones, and PDAs to live on the go.
- Mobile databases and the main database server are physically independent.
- Mobile gadgets housed mobile databases.
- Mobile databases can communicate with other mobile clients or a central database server from distant locations.
- Due to unreliable or nonexistent connections, mobile users must be able to function without a wireless connection with the aid of a mobile database (disconnected).
- Data on mobile devices is analyzed and managed using a mobile database.

Three parties are normally involved in Mobile Database

1. **Fixed Hosts:** It uses database servers to carry out the transactions and data management tasks.
2. **Mobile Units:** These are portable computers that can move within a space, including the cellular network they utilize to connect to base stations.
3. **Base Stations:** These are two-way radios installed in fixed places that transmit and receive communication from and to the mobile units.

Limitations

- Its wireless bandwidth is restricted.
- Speed of wireless communication in the mobile database.
- Access requires an unlimited supply of battery power.
- Less security exists.
- Theft-proofing is challenging to do.

issues related to data management in mobile databases

1. **Mobile database architecture**: The architecture of a mobile database is a critical issue in data management. The distributed nature of mobile systems creates challenges in terms of how data is managed and accessed. There are two distribution possibilities for mobile databases: the whole database is spread among the connected components, with full or partial replication possible, or the database is dispersed throughout the wired and wireless parts, with the task of managing the data divided between the mobile devices and base stations.

2. **Security:** Mobile data is less secure than data left in a fixed location, creating a need for techniques that can make up for data loss as data become more volatile. Security is a crucial concern for mobile databases, and techniques must be in place to ensure adequate protection of crucial data.

3. **Data replication and distribution:** Data replication and distribution among mobile devices and base stations can occur unevenly. This creates challenges in terms of data availability and the cost of distant access. Managing caches is also more difficult due to consistency restrictions, although caches can provide mobile devices with access to the most recent and frequently used data, along with their own transactions.

4. **Issues with replication:** As the number of replicas increases, so does the cost of updates and signaling. Additionally, mobile hosts can move anywhere and at any time, creating challenges for replication.

5. **Division of labor**: The division of labor in query processing may need to be modified due to various aspects of the mobile environment. In some cases, the client may need to operate independently of the server.

6. **Transaction models**: The ACID properties - atomicity, consistency, isolation, and durability - must all be met by transactions in a mobile context. However, this can be challenging when mobile computers are unconnected, and a mobile transaction may last a long time due to disconnects in mobile units.

7. **Recovery and fault tolerance:** Fault tolerance is critical in a mobile database environment, which must handle failures in communication, media, transactions, and sites. There are two categories of faults: transient and permanent, which can be caused by low battery power, failed transactions, and handoff issues.

8. **Limiting the availability of resources:** Mobile databases are characterized by limiting the availability of resources, recurring disconnects, extreme mobility, limited bandwidth, and location-based services.

9. **Location-based services:** The most difficult task for location-based services is determining the whereabouts of mobile users, which may require eviction techniques to manage cache information. Issues related to location and services include different mobile mapping standards, user privacy, market potential, and interoperability.

10. **Processing queries:** Query optimization is challenging due to the mobility and quick resource changes of mobile units. Query processing is impacted when mobility is taken into account, and input/output costs are significant in centralized systems. Communication costs are the most significant factor in dispersed contexts, and dynamic optimization techniques are necessary.

Mobile Computing is defined as a computing environment which is mobile and moves along with the user. There are various number of challenges that affected mobile computing and it has to overcome

them. Some of the major technical challenges faced by mobile computing are:

1. Mobility
2. Wireless Medium
3. Portability

1. Mobility: It is the most important aspect of mobile computing, but it has to face the certain challenges which are :

- Auto configuration of the system, as the environment of the system is developing continuously. Hence for every change, it has to configure itself to the new situation.
- Location management is also a big objection in mobility. To manage the location, following tasks are to be performed regularly over a fixed period of time.
- Track user's call.
- Update user's position and data.
- To maintain the heterogeneity is also a big task as the system is keep moving in a large variation of situations
- Range of spectrum.
- Verification of security.

2. Wireless Medium: The transmission medium in mobile computing is wireless, therefore the following points are considered:

- Various interferences occurs in the mobile computing by the different elements in the environment.
- Accuracy and quantity of bandwidth should be sufficient.
- Network cost is feasible.

3. Portability: This means that the communication device moves, for eg. mobile phones. The following mobile constraints are to be considered as the devices are also mobile:

- Minimum number of resources are used.
- Security is very less, as security risks include the processing of fake transactions, unauthorized access of data and program files,

and the physical theft or damage of the device.
- Restrictions of the battery.

Data Replication in Mobile Computing

Data Replication

Data Replication in mobile computing means the sharing of information to ensure data consistency between software and hardware resources connected via the internet, to improve reliability, availability, fault-tolerance, and accessibility of data. In simpler terms, data replication is the process of storing different copies of the database at two or more sites in order to improve data availability in less time and at a cheaper cost. Data replication in mobile computing is a popular fault tolerance technique for distributed databases.

Advantages of Data Replication

- In modern mobile computing, scenario data replication has been adopted as an efficient way to ensure data availability, integrity, and an effective means to achieve fault tolerance.
- Data replication not only ensures the availability of the data but also minimize the communication cost, increase data sharing, and enhance the security of sensitive data.
- Data replication in mobile computing also determines when and which location to store the replica of data, controlling different data replicas over a network for efficient utilization of the network resources.

Data Replication Benefits

Important benefits of data replication are as below-

- **Reliability** – Data replication provides the reliability of data. In case of failure of any site, the database system continues to work since a copy is available at another site(s).

- **Reduction in Network Load** – Since local copies of data are available through data replication. Therefore, query processing can be done with reduced network usage, particularly during prime hours.

- **Data updating can be done at non-prime hours** – Due to data replication data can be updated easily.

- **Quicker Response** – Availability of local copies of data ensures quick query processing and consequently quick response time.

- **Simpler Transactions** – Transactions require less number of joins of tables located at different sites and minimal coordination across the network. Thus, they become simpler in nature.

Disadvantages of Data Replication

- **Increased Storage Requirements** – Maintaining multiple copies of data is associated with increased storage costs.
  The storage space required is in multiples of the storage required for a centralized system.
- **Increased Cost and Complexity of Data Updating** – Each time a data item is updated, the update needs to be reflected in all the copies of the data at the different sites.
  This requires complex synchronization techniques and protocols.
- **Undesirable Application – Database coupling** – If complex update mechanisms are not used, removing data inconsistency requires complex co-ordination at the application level.

Data Replication in Mobile Computing

Data replication is the process of making copies of data stored on various sites in order to improve reliability, efficiency, robustness, simpler transaction, fault tolerance, and reduce network load.

Data replication is performed with the purpose of

- Increasing the availability of data.
- Speeding up the query evaluation.

Types of data replication

There are two types of data replication

1. Synchronous Replication

In synchronous replication, the replica of the database is modified immediately after changes are made in the relation table.
So there is no difference between the original data and the replicated data table.

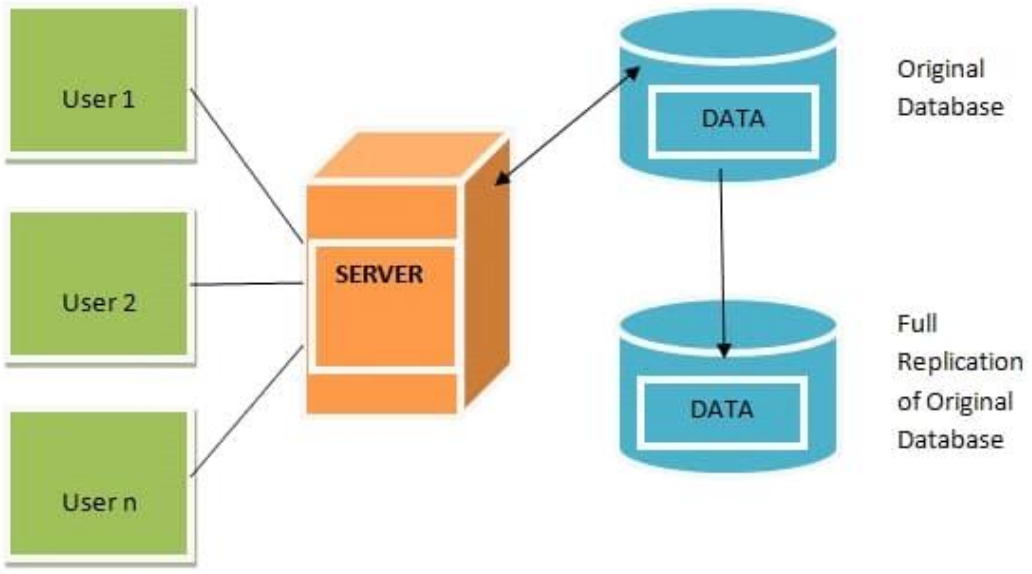
2. Asynchronous replication

In asynchronous replication, the replica will be modified after commit action is fired on to the database.

Replication Schemes

The three replication schemes are as follows:

1. **Full Replication scheme**
   In full replication scheme, the database is available at all the locations to ease the user in the communication network



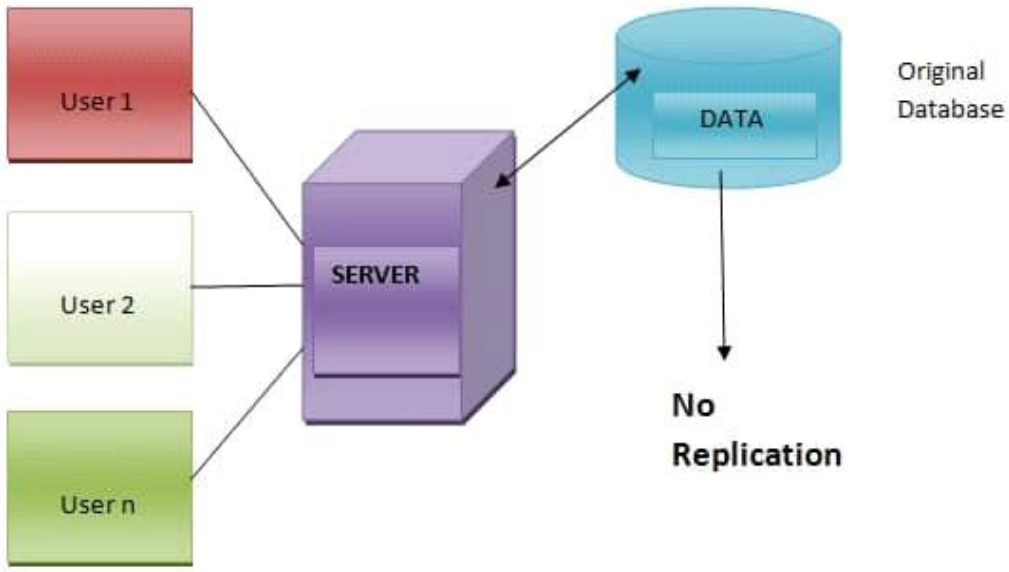
Advantages of full replication

- It gives high availability of data. In this scheme, the database is available at each location.
- It supports faster execution of queries.

Disadvantages of full replication

- In a full replication scheme, concurrency control is difficult to achieve in full replication.
- During updating each and every side need to be updated therefore update operation is slower.

1. **No Replication**
   No replication means each fragment is stored exactly at one location only.



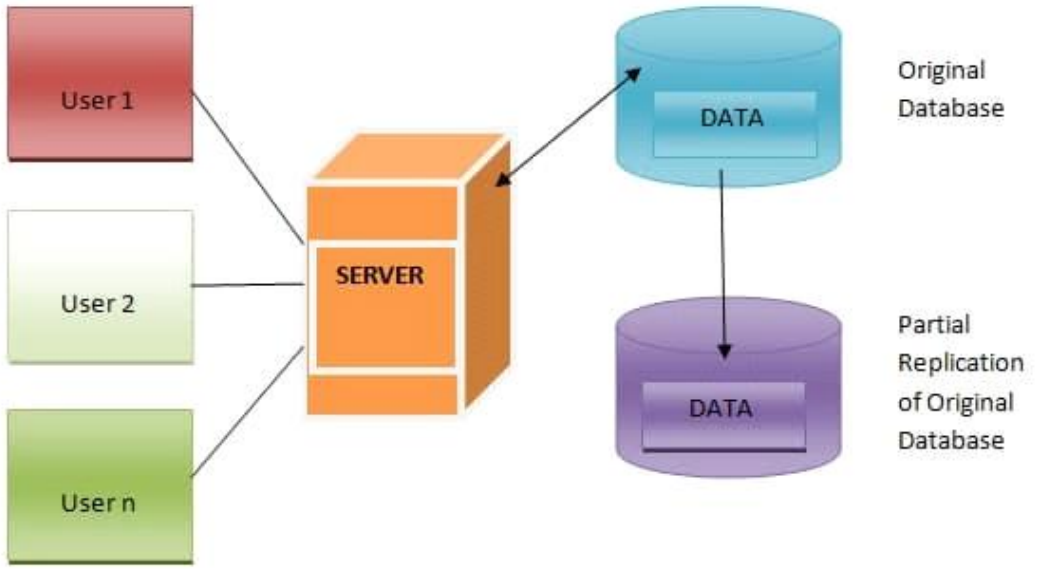
Advantages of no replication

- Concurrency can be easily minimized.
- Easy recovery of data becomes easy.

Disadvantages of no replication

- Poor availability of data.
- Slows down the query execution process, because multiple clients are accessing the same data at the same server.

2. **Partial replication**
   A partial replication scheme means only part of the or data fragments are replicated.



Multihopping

Multihopping is a communication technique used in wireless networks that enables data transmission between nodes that are not within each other's direct range. In a wireless network, nodes are typically connected to each other directly or through a base station or access point. However, in some cases, nodes may not be within direct range of each other or the base station, and multihopping is used to transmit data over multiple nodes to reach the destination node.

Here are some of the basic concepts of multihopping:

a. **Routing**: Routing is the process of finding the best path for data transmission between the source and destination nodes. In a multihop network, data is transmitted from one node to another until it reaches the destination node. Routing protocols are used to determine the best path for data transmission.
b. **Hop count**: A hop is the movement of data from one node to another in a multihop network. Hop count is the number of times data has to travel from one node to another to reach the destination node. The lower the hop count, the faster the data transmission.

c. **Relay nodes:** In a multihop network, relay nodes are nodes that receive data from one node and then transmit it to another node. Relay nodes are important in increasing the coverage area of the network and improving the network's performance.
d. **Network topology**: Network topology refers to the way nodes are connected to each other in a network. In a multihop network, the network topology can be complex due to the multiple paths data can take to reach the destination node.
e. **Delay:** Delay is the time it takes for data to travel from the source node to the destination node. In a multihop network, delay can be affected by factors such as the number of hops, the network topology, and the routing protocol used.
Multihopping is commonly used in wireless sensor networks, ad-hoc networks, and mesh networks to improve network coverage and performance.

Multicluster Architecture in mobile computing:

1. **Introduction**
- The need for a scalable and flexible architecture for mobile computing
- Multicluster architecture as a solution for managing large-scale mobile systems

2. **Basic concepts of multicluster architecture**
- Division of the mobile system into multiple clusters
- Each cluster consists of a set of mobile nodes and a clusterhead
- Clusterheads communicate with each other to exchange information and coordinate the system
- Clusterheads can be either fixed or mobile

3. **Advantages of multicluster architecture**

- Scalability: The system can easily accommodate a large number of nodes by adding more clusters
- Flexibility: The system can be adapted to changing requirements by adding or removing clusters
- Robustness: The system can continue to function even if some clusters or nodes fail
- Energy efficiency: The use of clusterheads can reduce energy consumption by minimizing communication overhead

4. **Multicluster routing protocols**

   A. **Hierarchical routing protocols:** The system is divided into multiple levels, with clusterheads at each level responsible for routing messages between clusters
   B. **Flat routing protocols:** Each node in the system is responsible for routing messages to their destination
   C. **Hybrid routing protocols:** A combination of hierarchical and flat routing protocols, where clusterheads at different levels cooperate to route messages

5. **Multicluster communication models**

- **Direct communication:** Nodes in different clusters communicate directly with each other

- **Indirect communication:** Nodes in different clusters communicate through their respective clusterheads

- **Multicast communication:** Messages are sent to multiple clusters simultaneously

6. **Applications of multicluster architecture**

- Sensor networks: Multicluster architecture can be used to manage large-scale sensor networks
- Mobile ad hoc networks: Multicluster architecture can be used to manage large-scale mobile ad hoc networks

- Internet of Things: Multicluster architecture can be used to manage large-scale IoT systems

7. Conclusion

- Multicluster architecture provides a scalable, flexible, robust, and energy-efficient solution for managing large-scale mobile systems
- Multicluster routing protocols and communication models can be adapted to different types of mobile systems and applications.