M2: Wide Area Wireless Network

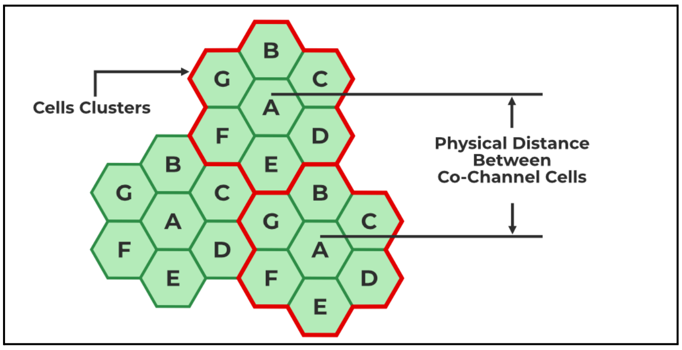
1. Define the following terms: Frequency reuse, Cochannel cells, cochannel interference, Frequency reuse distance, cluster, cluster size

Frequency Reuse:

- Definition: Frequency reuse is a concept in cellular communication where the available radio frequency spectrum is divided into smaller cells, and the same set of frequencies is reused in different cells within a geographic area. This allows for efficient utilization of the limited spectrum resources.

Cochannel Cells:

- Definition: Cochannel cells refer to cells in a cellular network that share the same set of frequencies. These cells are using the same carrier frequencies for communication. Cochannel cells are an essential aspect of frequency reuse.



Co Channel Interference:

- Definition: Cochannel interference occurs when signals from different cells that share the same frequencies interfere with each other. This interference can lead to a degradation of the communication quality in the affected cells.

Frequency Reuse Distance:

- Definition: The frequency reuse distance is the minimum distance between cells that are using the same set of frequencies. It is determined to ensure that cochannel interference is kept within acceptable limits, allowing for efficient frequency reuse.

Cluster:

- Definition: A cluster is a group of cells in a cellular network that collectively use a set of frequencies. The frequencies used by one cluster are reused by another cluster at a certain distance to minimize interference. The concept of clustering is part of the strategy to implement frequency reuse.

Cluster Size:

- Definition: Cluster size refers to the number of cells within a cluster in a cellular network. The size of a cluster is determined by factors such as the geographic area covered, user density, and the frequency reuse pattern

2. Classify the wireless networks based on coverage, mobility and infrastructure.

1. Based on Coverage:

- Wide Area Network (WAN):
    - Coverage: Large geographical area, often spanning cities, countries, or even continents.
    - Examples: Cellular networks (4G, 5G), satellite communication.
- Local Area Network (LAN):
    - Coverage: Limited to a small geographical area, typically within a building, campus, or specific location.
    - Examples: Wi-Fi networks, Ethernet networks within a building.
- Personal Area Network (PAN):
    - Coverage: Very short-range, typically within the range of an individual person or device.
    - Examples: Bluetooth, NFC (Near Field Communication).

2. Based on Mobility:

- Mobile Networks:
    - Mobility: Designed to support mobile devices that can move across cells or areas.
    - Examples: Cellular networks (2G, 3G, 4G, 5G), satellite communication.
- Fixed Networks:
    - Mobility: Infrastructure is set up for stationary devices with little or no mobility.
    - Examples: Wi-Fi networks in homes or offices, fixed-line broadband.

3. Based on Infrastructure:

- Infrastructure-Based Networks:
    - Infrastructure: Relies on a fixed infrastructure of base stations, access points, and network elements.
    - Examples: Cellular networks, Wi-Fi networks.
- Infrastructure-Less Networks (Ad-hoc Networks):
    - Infrastructure: No fixed infrastructure; devices communicate directly with each other.
    - Examples: Ad-hoc Wi-Fi networks, mesh networks.
- Hybrid Networks:
    - Infrastructure: Combination of fixed infrastructure and ad-hoc connectivity.

3. List the elements of the cellular system and explain the function of each in brief. Explain the main functions of HLR & VLR in GSM system.

Elements of a Cellular System:

Mobile Station (MS):

- Function: The mobile device used by the end-user for making and receiving calls. It includes the mobile handset and the Subscriber Identity Module (SIM) card.

Base Station (BS) or Cell Site:

- Function: The base station is responsible for establishing a radio link with the mobile station. It provides the radio coverage for a specific geographical area known as a cell.

Mobile Switching Center (MSC):

- Function: The MSC is a central component that connects calls within the cellular network and interfaces with other networks. It handles call setup, routing, and handovers between different cells.

Home Location Register (HLR):

- Function: The HLR is a database that stores subscriber information, including user profiles, subscription details, and current locations. It is used for call routing and subscriber management.

Visitor Location Register (VLR):

- Function: The VLR is a temporary database that stores information about subscribers currently within the coverage area of a particular MSC. It helps in call processing for roaming subscribers.

Authentication Center (AUC):

- Function: The AUC provides authentication and encryption functions to ensure the security of communication between the mobile station and the network. It prevents unauthorized access to the network.

Equipment Identity Register (EIR):

- Function: The EIR is a database that stores a list of valid and invalid mobile equipment identities (IMEIs). It helps in identifying stolen or unauthorized mobile devices.

Gateway Mobile Switching Center (GMSC):

- Function: The GMSC is responsible for routing calls between different networks, such as from the cellular network to the **public switched telephone network (PSTN)** or another mobile network.

Base Station Controller (BSC):

- Function: The BSC manages and controls multiple base stations within its coverage area. It handles the allocation of radio resources, handovers, and power level control.

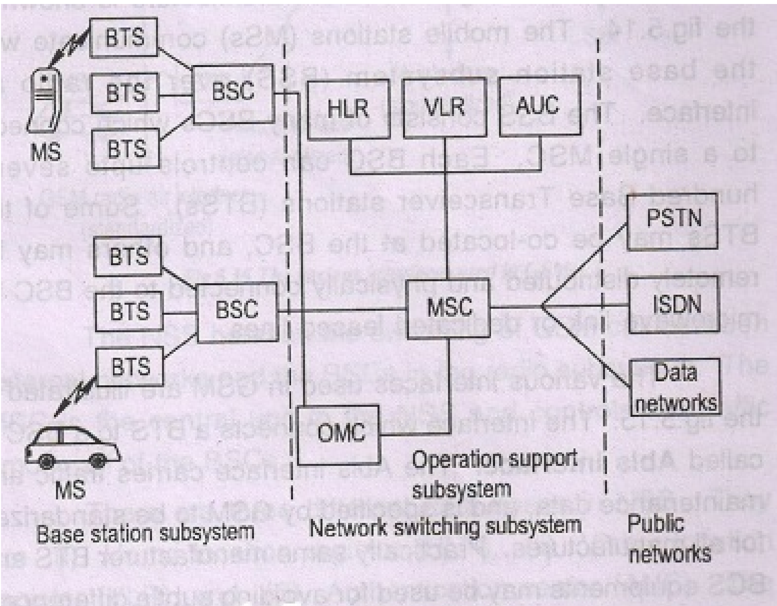
Functions of HLR and VLR in GSM System:

Home Location Register (HLR):

- **Subscriber Information Storage:** HLR stores subscriber profiles, subscription details, and authentication information.
- **Call Routing:** HLR is responsible for routing calls to the appropriate MSC based on the subscriber's home location.
- **Subscriber Management:** HLR manages subscriber-related services, such as call forwarding, call barring, and roaming.

Visitor Location Register (VLR):

- **Temporary Subscriber Information:** VLR stores temporary information about subscribers currently within the coverage area of a specific MSC.
- **Call Processing for Roaming Subscribers:** VLR facilitates call processing for subscribers who are roaming, providing necessary information to the MSC.
- **Update of Location Information:** VLR updates the HLR with the current location of a subscriber when they enter a new MSC coverage area.



GSM system architecture

4. Why is the cell shape considered Hexagonal?

The hexagonal cell shape is considered in cellular communication systems for several practical and technical reasons. The choice of a hexagonal cell shape is mainly driven by the desire to achieve efficient coverage and network performance. Here are some reasons why hexagonal cells are preferred in cellular systems:

Uniform Coverage:

- A hexagon is the shape that can be tessellated or repeated most efficiently **without any gaps or overlaps**. This allows for uniform coverage across a geographic area, minimizing variations in signal strength and quality.

Equal Signal Strength at Cell Boundaries:

- In a hexagonal cell, the **distance from the center of the cell to any of its vertices is the same**. This uniformity ensures that **signal strength remains relatively constant** at the cell boundaries, reducing issues related to handovers and interference.

Maximized Area Coverage:

- Hexagonal cells maximize the coverage area for a given amount of infrastructure. This efficient packing of cells helps in providing extensive **network coverage with fewer base stations.**

Simplicity in Network Planning:

- The hexagonal cell shape simplifies network planning and optimization. It allows for straightforward calculations of distances, signal propagation, and interference, making it easier to design and manage the cellular network.

Frequency Reuse:

- Hexagonal cells facilitate efficient frequency reuse patterns. When using the same set of frequencies across different cells, the hexagonal layout **minimizes interference between cochannel cells**, optimizing the utilization of available spectrum.

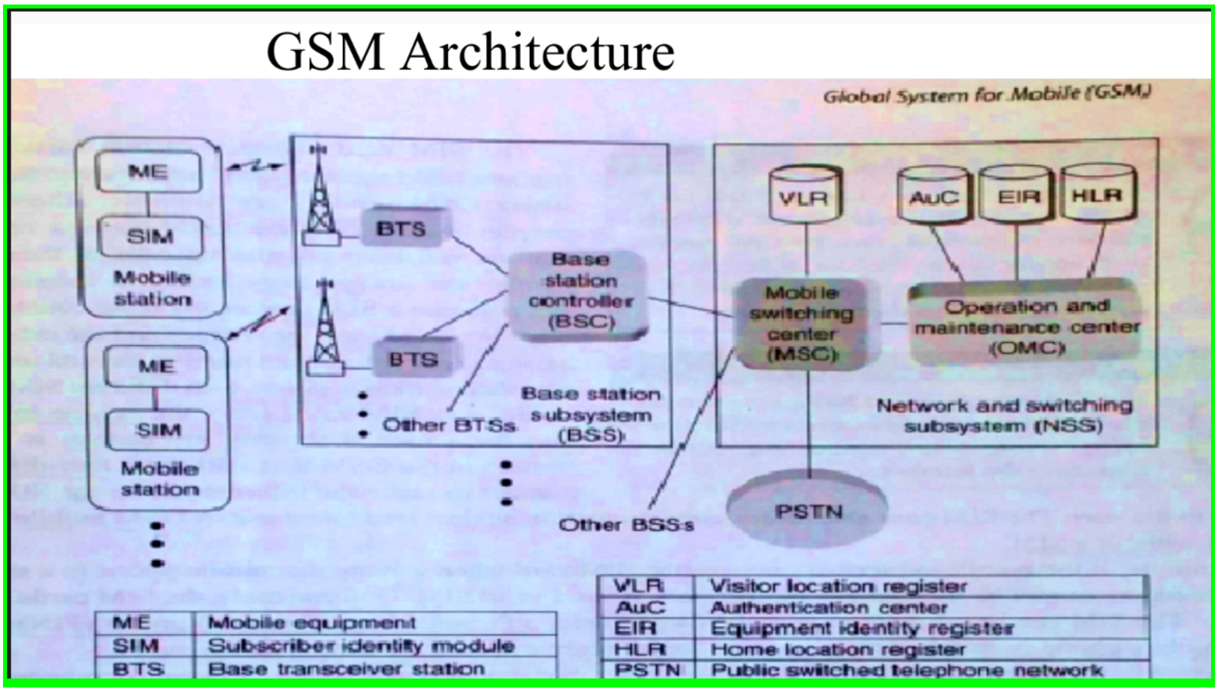
Reduced Interference:

- Hexagonal cells minimize interference between adjacent cells. The geometry of hexagons ensures that the angles between cells are 120 degrees, which helps in reducing cochannel interference.

Optimal Interference and **Load Balancing:**

- The hexagonal layout provides an optimal balance between interference and load balancing. It allows for effective control of the overlap between neighboring cells, leading to better overall network performance.

5. Draw the block diagram of GSM architecture and explain each block in detail.



ME-physical device, consists of Transceiver, Digital Signal Processors and the antenna.uniquely identified by the International Mobile Equipment Identity (IMEI).

SIM-smart card issued at the subscription time identifying the specification of a user such as a unique number and type of the service.

The SIM card contains the International Mobile Subscriber Identity (IMSI) used to identify the subscriber to the system, a secret key for authentication, service area and other information.

The SIM card may be protected against unauthorized use by a password or personal identity number (PIN)

Base Station Subsystem (BSS) :(BTS & BSC)

BSC:is the connection between the mobile station and the Mobile service Switching Center (MSC).It is a small switch inside BSS in change of frequency administration, maintains appropriate power levels of signal and handoff among the BTSs inside a BSS. This reduces burden of MSC

BSC Controller manages the radio resources for one upto several hundred BTSs.From 13kbps to 64kbps-at BSS

Base Transceiver Station (BTS):defines a single cell (radius 100m to 35km)

BTS components include a Tx, a Rx and signaling equipment to operate over the air interface.

Interface between BTS & BSC – Abis interface- carries traffics and maintain data

Interface between BSC & MSC – A interface- standardized within GSM.

User's speech is converted to 13kbps digitized voice with speech coder –at

MS

Wired network uses 64kbps PCM digitized voice in PSTN technology.

6. A mobile communication system is allocated a spectrum of 25 MHz and uses RF channel bandwidth of 25 Khz so that total no of 1000 voice channels are available.

a) If the service area is divided into 20 cells with a frequency reuse factor of 4, compute the system capacity.

Given values:

- Total allocated spectrum = 25 MHz
- RF channel bandwidth = 25 kHz
- Number of voice channels per cell = 1000
- Number of cells (N) = 20
- Frequency reuse factor (N/K) = 4

System Capacity Calculation:

1. **Total Number of Channels in the System:**
   $\text{Total Channels} = \text{RF Channel Bandwidth} \times \left(\frac{\text{Total Allocated Spectrum}}{\text{RF Channel Bandwidth}}\right)$
   $\text{Total Channels} = 25\,\text{kHz} \times \left(\frac{25\,\text{MHz}}{25\,\text{kHz}}\right) = 25,000$
2. **Number of Channels Per Cell:**
   $\text{Channels Per Cell} = \frac{\text{Total Channels}}{\text{Number of Cells (N)}} = \frac{25{,}000}{20} = 1250$
3. **Number of Channels Available for Traffic (Considering Frequency Reuse):**
   $\text{Channels Per Cell Available for Traffic} = \text{Channels Per Cell} \times$
   $\text{Frequency Reuse Factor (N/K)}$
   $\text{Channels Per Cell Available for Traffic} = 1250 \times 4 = 5000$
4. **System Capacity:**
   $\text{System Capacity} = \text{Channels Per Cell Available for Traffic} \times \text{Number of Cells (N)}$
   $\text{System Capacity} = 5000 \times 20 = 100,000$

Total no.of channels=total spectrum;i.e 25kHz

Channels per cell=25000/20=1250

Channels for traffic= Channel per cell x freq. reuse factor

=1250 x 4 = 5000

System capacity=5000 x 20(total no.of cells)=1,00,000

b) If the cell size is reduced to the extent that the service area is now covered with 100 cells with a frequency reuse factor of 4, compute the system capacity.

Given values:

- Number of cells (N) = 100

System Capacity Calculation:

1. **Number of Channels Per Cell Available for Traffic (Considering Frequency Reuse):**

$$\text{Channels Per Cell Available for Traffic} = \text{Channels Per Cell} \times \text{Frequency Reuse Factor (N/K)}$$

$$\text{Channels Per Cell Available for Traffic} = 1250 \times 4 = 5000$$

2. **System Capacity:**

$$\text{System Capacity} = \text{Channels Per Cell Available for Traffic} \times \text{Number of Cells (N)}$$

$$\text{System Capacity} = 5000 \times 100 = 500,000$$

System capacity=5000 x 100(total no.of cells)=5,00,000

7. Compare and contrast GPRS & EDGE Technology. List their air interface specifications.

GPRS (General Packet Radio Service):

Overview:

- GPRS is a **2.5G (second and a half generation) technology** that provides packet-switched data transmission in GSM networks.
- It enables more efficient use of the radio spectrum by allowing the transmission of data in packets rather than dedicated circuit-switched connections.

Data Rates:

- GPRS offers data rates ranging from **56 kbps to 114 kbps**, depending on channel conditions and network configurations.

Modulation:

- GPRS uses a variety of modulation schemes, including GMSK (Gaussian Minimum Shift Keying) for modulation.

Air Interface Specifications:

- Modulation: GMSK
- Channel Bandwidth: 200 kHz
- Time Slots: **Time Division Multiple Access (TDMA) with 8 time slots per carrier.**

Technology Enhancement:

- GPRS represents the **initial step toward providing mobile data services**, and it serves as the foundation for further enhancements.

EDGE (Enhanced Data rates for GSM Evolution):

Overview:

- EDGE is an enhancement of the GSM and GPRS networks, often considered a **2.75G (2.5G to 3G transitional) technology**.
- EDGE provides higher data rates compared to GPRS and serves as a stepping stone toward 3G technologies.

Data Rates:

- EDGE offers data rates ranging from 200 kbps to 384 kbps, providing a significant improvement over GPRS.

Modulation:

- EDGE introduces more advanced modulation schemes, such as **8PSK (8 Phase Shift Keying),** allowing for higher data transmission rates.

Air Interface Specifications:

- Modulation: GMSK for backward compatibility and 8PSK for higher data rates.
- Channel Bandwidth: 200 kHz
- Time Slots: **TDMA with 8 time slots per carrier.**

Technology Enhancement:

- EDGE builds upon the GPRS infrastructure, providing a **smoother transition to higher data rates** before the widespread deployment of 3G technologies like UMTS.

Comparison:

Data Rates:

- GPRS offers data rates up to **114 kbps,** while EDGE provides higher data rates ranging from **200 kbps to 384 kbps.**

Modulation:

- GPRS primarily uses **GMSK,** while EDGE introduces **8PSK** for more efficient use of the available spectrum and higher data rates.

Improvements:

- EDGE is an enhancement over GPRS, providing a significant boost in data rates and spectral efficiency.

Backward Compatibility:

- Both GPRS and EDGE maintain backward compatibility with existing GSM networks, allowing for a smooth transition and coexistence.

Applications:

- **GPRS and EDGE cater to various mobile data applications, including web browsing, email, and multimedia messaging, offering users improved data connectivity compared to traditional GSM.**

8. What are the two additional components added in GPRS and Edge? List their functions.

Two additional components were introduced to enhance the capabilities of the mobile communication system.

SGSN (Serving GPRS Support Node):

- Function:
    - The SGSN is a key network element in GPRS and later technologies.
    - It serves as the anchor point for packet-switched data within a GPRS network.
    - The primary function of the SGSN is to manage the mobility of mobile stations (MS) that are communicating via packet-switched data services.
    - It is responsible for tracking the location of mobile devices, authenticating users, managing security functions, and handling the mobility of devices across different cells and areas.
- Key Functions:
    - **Mobility Management:** SGSN manages the mobility of mobile stations within the GPRS network, keeping track of their location.
    - **Authentication and Authorization:** SGSN authenticates and authorizes users, ensuring secure access to GPRS services.
    - **Session Management:** It establishes and maintains sessions for packet-switched data between mobile devices and the GPRS network.
    - **Quality of Service (QoS):** SGSN plays a role in ensuring the desired quality of service for data transmission.

GGSN (Gateway GPRS Support Node):

- Function:
    - The GGSN serves as the interface between the GPRS network and external packet data networks, including the internet.
    - It acts as a gateway that connects the GPRS network to external networks, enabling communication between mobile devices and the wider internet or private networks.
    - GGSN is responsible for assigning IP addresses to mobile devices and facilitating the routing of data packets between the GPRS network and external networks.

- Key Functions:
  - **IP Address Assignment:** GGSN assigns IP addresses to mobile devices, allowing them to communicate in the packet-switched mode.
  - **Packet Routing**: GGSN routes data packets between the GPRS network and external networks, enabling connectivity to the internet or private networks.
  - **Charging and Billing:** GGSN may play a role in charging and billing for data services based on usage.

9. What are the new features added in EDGE Technology to get higher data rates?

Advanced Modulation:

- GMSK and 8PSK: EDGE introduced a more advanced modulation scheme known as 8PSK (8 Phase Shift Keying) in addition to the GMSK (Gaussian Minimum Shift Keying) used in GPRS. 8PSK allows for the transmission of three bits per symbol, compared to one bit per symbol in GMSK. **This results in a higher data transfer rate.**

Increased Symbol Rate:

- EDGE increased the symbol rate compared to GPRS. The increased symbol rate, combined with the use of 8PSK modulation, allows for a **higher number of bits to be transmitted per unit of time, contributing to higher data rates.**

Enhanced Coding and Error Correction:

- Higher Coding Schemes: EDGE introduced higher coding schemes (MCS-7 to MCS-9) compared to GPRS, allowing for more efficient use of the available spectrum. These coding schemes provide **better error correction and data reliability.**

Adaptive Modulation and Coding (AMC):

- Dynamic Adjustment: EDGE incorporates Adaptive Modulation and Coding (AMC), allowing the system to **dynamically adjust modulation and coding schemes based on channel conditions.** This adaptive approach optimizes data transmission based on the quality of the radio link, ensuring efficient use of resources.

Link Adaptation:

- Dynamic Link Adaptation: EDGE supports dynamic link adaptation, allowing the system to adapt the modulation and coding schemes based on the instantaneous channel conditions. This flexibility ensures that the system can **operate efficiently in various radio environments.**

Time Division Multiple Access (TDMA) Enhancements:

- Higher Order Modulation in TDMA Frames: EDGE utilizes **higher-order** modulation within TDMA frames, enabling more bits to be transmitted in each time slot. This contributes to the overall increase in data rates.

Reduced Inter-Symbol Interference (ISI):

- Improved Filtering Techniques: EDGE incorporates improved filtering techniques to reduce Inter-Symbol Interference (ISI), which can degrade signal quality. The reduction in ISI enhances the reliability of data transmission.

Improved Receiver Sensitivity:

- Enhanced Receiver Sensitivity: EDGE technology often includes improvements in receiver sensitivity, allowing for **better detection of signals, especially in challenging radio environments.**

10. Name the modulation scheme used in EDGE? What is the advantage of using it?

The modulation scheme used in Enhanced Data rates for GSM Evolution (EDGE) is **8PSK (8 Phase Shift Keying)**. In addition to GMSK (Gaussian Minimum Shift Keying), which was used in GPRS (General Packet Radio Service), **EDGE introduced 8PSK to achieve higher data rates and spectral efficiency.**

Advantages of 8PSK in EDGE:

Increased Data Transfer Rate:

- 8PSK allows the transmission of **three bits per symbol, a**s opposed to one bit per symbol in GMSK. This results in a higher data transfer rate within the same frequency bandwidth.

Improved Spectral Efficiency:

- The use of 8PSK improves spectral efficiency by **transmitting more bits in each symbol**. This efficient use of the available spectrum contributes to higher data rates without requiring additional frequency resources.

Enhanced Modulation Scheme:

- 8PSK is a more advanced modulation scheme compared to GMSK. It provides a **higher order of modulation,** allowing for the representation of a greater number of distinct symbols, which translates into a **higher data capacity.**

Optimal Use of Frequency Spectrum:

- By efficiently modulating three bits per symbol, 8PSK contributes to optimal utilization of the frequency spectrum. This is particularly important in cellular networks where the available spectrum is a valuable and limited resource.

Compatibility with Existing GSM Networks:

- **EDGE's use of 8PSK is designed to be compatible with existing GSM networks.** It allows for a smooth transition from GPRS to EDGE, enabling backward compatibility while introducing higher data rates.

11. Define one time slot and one super frame structure used in GSM.

In GSM (Global System for Mobile Communications), the time division multiple access (TDMA) technique is employed to allow multiple users to share the same frequency channel. The basic time unit in GSM is a time slot, and a group of time slots forms a superframe. Let's define each:

Time Slot:

- Definition: **A time slot is the basic time unit in GSM and represents the duration during which a specific user's transmission is sent. In GSM, a time slot lasts for 0.577 milliseconds (ms), and eight time slots together make up a TDMA frame.**
- **Duration:** Each time slot has a duration of **0.577 ms**, and there are a total of eight time slots in a TDMA frame.
- Usage: Time slots are used for the transmission of **user data, voice, and control information.** They enable multiple users to share the same frequency channel by dividing time into discrete intervals.

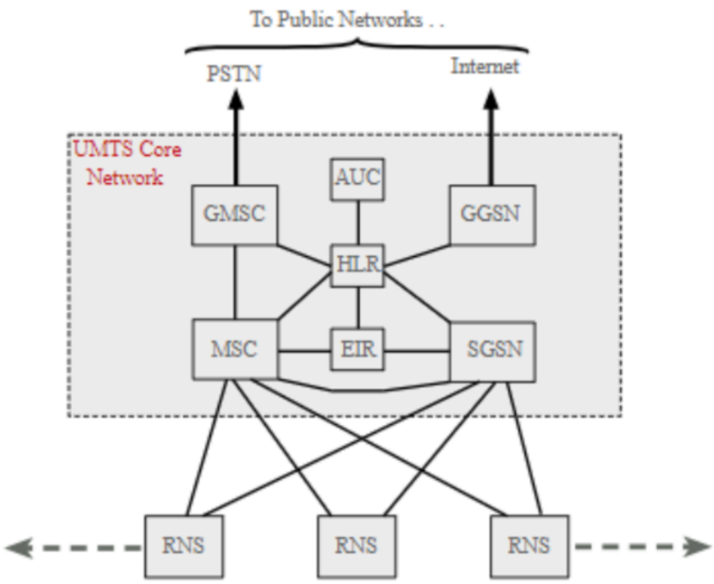
Superframe:

- Definition: A superframe is a larger time structure that consists of **multiple TDMA frames.** In GSM, a superframe is made up of 51 TDMA frames.
- Duration: A superframe in GSM has a total duration of **26.666 seconds.**
- Usage: The superframe structure is primarily **used for synchronization and control purposes.** It includes various control channels and synchronization bursts that facilitate the coordination of multiple base stations and mobile devices within the network.

12. What is incremental redundancy in EDGE?

Incremental Redundancy in EDGE is a technique where, **if errors occur during data transmission, only the specific parts of the data block that were not correctly received are retransmitted.** This selective retransmission approach improves efficiency by focusing on the essential information, enhancing the reliability of data communication in varying radio channel conditions.

13. With reference to UMTS, draw the network architecture and list the functions of RNC & nodeB.



UMTS Network Architecture Overview

UE (User Equipment):

- Function: UE refers to the User Equipment, which includes mobile devices such as smartphones and tablets. It serves as the endpoint for communication and interacts with the UMTS network.

NodeB (Node B):

- Function: NodeB is the UMTS base station responsible for radio communication with the mobile devices. It handles tasks such as radio transmission, channel coding, and modulation/demodulation.

RNC (Radio Network Controller):

- Function: RNC is a central element in the UMTS network responsible for radio resource management, mobility management, and connection control. It coordinates multiple NodeBs, manages handovers, and controls the overall radio access network.

Sgsn (Serving GPRS Support Node):

- Function: SGSN is part of the UMTS core network and serves as a gateway for packet-switched data. It handles tasks such as session management, mobility management, and routing data packets to and from mobile devices.

Ggsn (Gateway GPRS Support Node):

- Function: GGSN is another core network element responsible for connecting the UMTS network to external packet data networks, such as the internet. It assigns IP addresses to mobile devices and facilitates data routing.

MSC (Mobile Switching Center):

- Function: MSC is a core network element that traditionally handles circuit-switched voice calls. In UMTS, it may also play a role in call setup, routing, and handovers for voice services.

HLR (Home Location Register):

- Function: HLR stores subscriber information, including user profiles, subscription details, and security parameters. It is a vital database for authentication and authorization.

VLR (Visitor Location Register):

- Function: VLR is a temporary database that stores information about subscribers currently within the coverage area. It assists in call routing and management of mobile subscribers in a specific location.

AuC (Authentication Center):

- Function: AuC is responsible for subscriber authentication and generating security parameters to ensure secure communication between the mobile device and the network.

EIR (Equipment Identity Register):

- Function: EIR is responsible for tracking the status of mobile devices by maintaining a list of valid and invalid device identities. It helps prevent the use of stolen or unauthorized devices in the network.

Interfaces:

- Various interfaces connect different network elements, including interfaces like Iu (between RNC and NodeB), Iub (between NodeB and RNC), Iur (between RNCs), Iu-CS (for circuit-switched services), Iu-PS (for packet-switched services), and more.

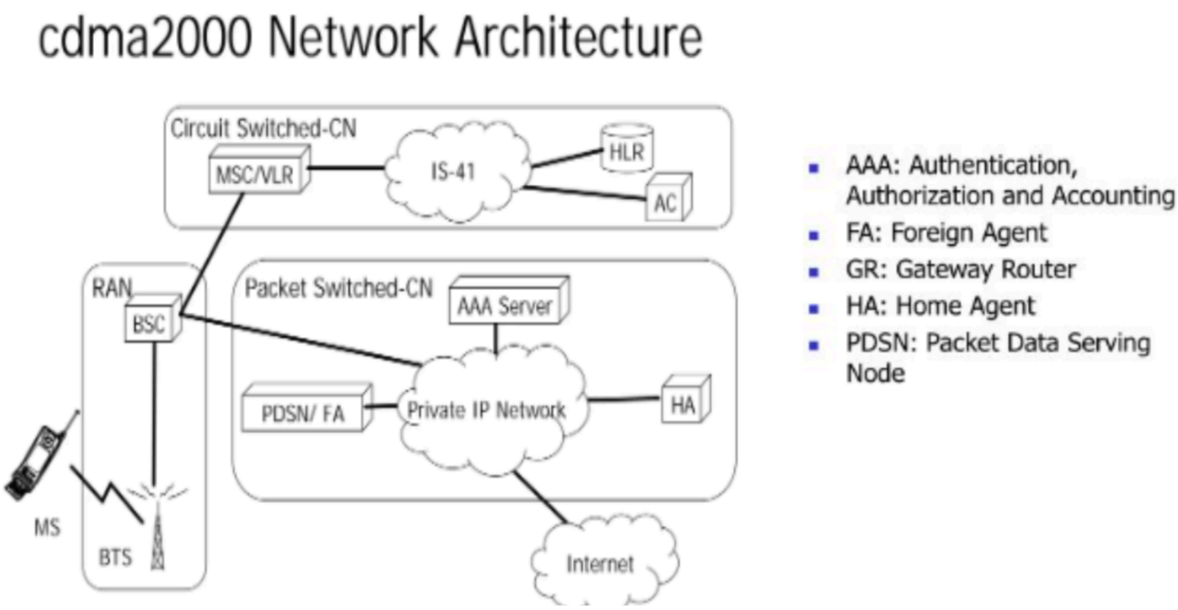
RNC (Radio Network Controller):

- Radio Resource Management: Manages power, handovers, and frequency allocation.
- Mobility Management: Tracks location, manages handovers, ensures seamless connectivity.
- Connection Control: Establishes, maintains, and releases connections for voice and data services.
- Security: Provides ciphering (encryption) and integrity protection for user data.
- QoS Management: Ensures Quality of Service for voice, video, and data services.
- Load Balancing: Distributes traffic to optimize network resources and avoid congestion.
- Handover Decision: Decides when and how handovers should occur for continuous connectivity.

NodeB (Node B):

- Radio Transmission: Handles modulation, demodulation, power control, and data transmission.
- Channel Coding/Decoding: Performs error correction for reliable data transmission.
- Signal Processing: Processes radio signals, converts digital data to analog for transmission.
- Mobility Functions: Reports radio measurements to assist in handover decisions.
- Broadcast System Info: Broadcasts network parameters and configuration details to mobile devices.
- Power Control: Controls transmission power levels for energy-efficient communication.
- Connection Handling: Manages connection establishment, maintenance, and release with mobile devices.

14. With reference to CDMA 2000, draw the network architecture and explain how it is different from UMTS.



CDMA2000 and UMTS (Universal Mobile Telecommunications System) are both 3G (third-generation) mobile communication technologies, but they use different air interface technologies and have some differences in their architecture and deployment. Here are key differences between CDMA2000 and UMTS:

Air Interface Technology:

- CDMA2000 (CDMA): CDMA2000 uses Code Division Multiple Access as its air interface technology. It relies on the **spread spectrum technique**, where each user is assigned a unique code to separate their signals.
- UMTS (WCDMA): UMTS uses **Wideband Code Division Multiple Access** as its air interface technology. It also employs a spread spectrum technique but with a wider bandwidth compared to CDMA2000.

Network Architecture:

- CDMA2000: CDMA2000 networks are based on a CDMA architecture. They consist of Base Transceiver Stations (BTS), Base Station Controllers (BSC), and Mobile Switching Centers (MSC).
- UMTS: UMTS networks are based on a WCDMA architecture. They include NodeB (similar to BTS in CDMA2000), RNC (Radio Network Controller, similar to BSC), and a Core Network that includes MSC or Mobile Switching Center and SGSN (Serving GPRS Support Node).

Data Transmission Rates:

- CDMA2000: CDMA2000 offers various data transmission rates, including 1xRTT (Radio Transmission Technology) with data rates up to 144 kbps and

EV-DO (Evolution-Data Optimized) with higher data rates, reaching Mbps range.

- UMTS: UMTS supports higher data rates compared to CDMA2000. It offers data rates ranging from 384 kbps (3GPP Release 99) up to several Mbps with HSPA (High-Speed Packet Access) and later releases.

Frequency Bands:

- CDMA2000: CDMA2000 operates in various frequency bands, including 850 MHz, 1900 MHz (in North America), and 2100 MHz (in some regions for EV-DO).
- UMTS: UMTS operates in frequency bands around 2100 MHz (commonly referred to as the UMTS band), with additional frequency bands in some regions for extended coverage.

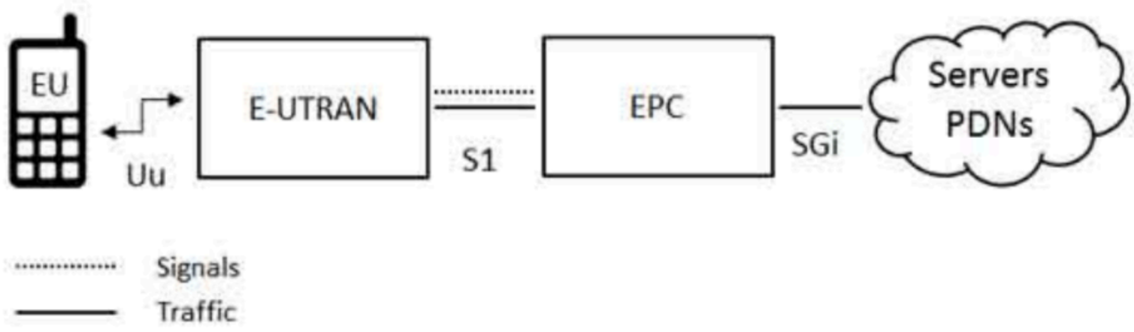
Global Deployment:

- CDMA2000: CDMA2000 is more widely deployed in North America and some parts of Asia, with limited presence in other regions.
- UMTS: UMTS has a more global presence and is widely deployed in Europe, Asia, and other parts of the world.

Evolution Path:

- CDMA2000: CDMA2000 has further evolved to include technologies like EV-DO Rev. A, Rev. B, and EV-DO Rev. C.
- UMTS: UMTS has evolved to include HSPA (High-Speed Packet Access), HSPA+, and later releases. Additionally, UMTS is a part of the evolution path towards LTE (Long-Term Evolution) in the 4G domain.

15. Draw the network architecture of LTE and explain the functions of each component is brief.



LTE (Long-Term Evolution) is a 4G wireless communication technology that provides high-speed data transmission for mobile devices. The network architecture of LTE is based on an all-IP (Internet Protocol) architecture, and it consists of several key components. Here's an overview of the LTE network architecture and the functions of each component:

UE (User Equipment):

- Function: UE refers to the User Equipment, which includes mobile devices such as smartphones, tablets, and other wireless devices. The UE communicates with the eNodeB to access LTE services.

eNodeB (Evolved NodeB):

- Function: The eNodeB is the base station in LTE. It is responsible for radio communication with the UE. The key functions include radio resource management, radio bearer control, and handovers. The eNodeB connects to the EPC (Evolved Packet Core) for core network functionalities.

EPC (Evolved Packet Core):

- Function: The EPC is the core network in LTE and is composed of several elements, each with specific functions:
    - a. MME (Mobility Management Entity): The MME manages the mobility of UEs, including tracking and paging, authentication, and connection setup.
    - b. SGW (Serving Gateway): The SGW is responsible for routing and forwarding user data packets, as well as managing mobility-related functions within the EPC.
    - c. PGW (Packet Data Network Gateway): The PGW connects the LTE network to external packet data networks, such as the internet. It performs functions like IP address allocation and manages user plane traffic.

- d. HSS (Home Subscriber Server): The HSS stores subscriber information, including user profiles, subscription details, and security parameters.
- e. PCRF (Policy and Charging Rules Function): The PCRF is responsible for policy enforcement and charging control, ensuring efficient network resource utilization.

Interfaces:

- a. S1 Interface: The S1 interface connects the eNodeB to the EPC. It is divided into two parts: S1-MME for communication between eNodeB and MME, and S1-U for communication between eNodeB and SGW.
- b. X2 Interface: The X2 interface connects different eNodeBs for direct communication. It supports functions such as handovers and load balancing.

IMS (IP Multimedia Subsystem):

- Function: IMS is a subsystem that enables multimedia services over LTE. It provides services like voice over LTE (VoLTE) and multimedia communication.

Policy Control and Charging:

- Function: The Policy Control and Charging functions, supported by PCRF, manage policy enforcement and charging within the LTE network. It ensures that the usage of network resources aligns with policies and controls charging mechanisms.

16. write short notes on LoRA and LoRAWAN.

LoRa (Long Range):

- **Technology:** LoRa is a wireless communication technology designed for long-range, low-power communication in the **Internet of Things (IoT)** and machine-to-machine (M2M) applications.
- **Modulation:** LoRa uses a patented spread spectrum modulation technique known as Chirp Spread Spectrum (CSS) to achieve long-range communication with minimal power consumption.
- **Range:** LoRa devices can achieve communication **ranges of several kilometers** in urban environments and even longer distances in rural settings, making it suitable for wide-area IoT deployments.
- **Power Consumption:** LoRa devices are designed for low power consumption, allowing for **long battery life in IoT devices.** This makes LoRa well-suited for applications where devices are deployed in **remote or inaccessible locations.**
- **Scalability:** LoRa supports a **large number of devices within a network**, making it scalable for massive IoT deployments. It operates in the license-free industrial, scientific, and medical (ISM) bands.

LoRaWAN (Long Range Wide Area Network):

- Network Protocol: LoRaWAN is a communication **protocol built on top of the LoRa** technology. It defines the communication protocol and system architecture for the network, providing **efficient communication between LoRa devices and a LoRaWAN network.**

- Architecture: LoRaWAN typically consists of end devices (sensors or actuators), gateways, and a network server. The gateways forward the communication between end devices and the network server, which manages the network and handles device registration, security, and data routing.

- Security: LoRaWAN incorporates robust security measures, including end-to-end encryption and authentication, ensuring the integrity and confidentiality of data transmitted over the network.

- Classes of Devices: LoRaWAN supports different classes of devices with varying levels of power consumption and communication capabilities. Classes include Class A (bi-directional with lowest power consumption), Class B (bi-directional with scheduled receive slots), and Class C (bi-directional with continuous receive).

- Adaptive Data Rate (ADR): LoRaWAN supports ADR, allowing the network to dynamically optimize the data rate and transmit power for each device based on its signal strength and environmental conditions. This contributes to efficient use of network resources.

- Public and Private Networks: LoRaWAN can be deployed in public networks managed by service providers or in private networks for specific applications or enterprises.