UNIT-1

Mobile Computing:

Mobile computing means using computers, smartphones, tablets, or other portable devices to access and process data without being fixed to one location. It allows communication and computing anytime, anywhere, using wireless networks like Wi-Fi, cellular networks, or Bluetooth.

Functions of Mobile Computing:

1. **Data Communication** –
   It enables sending and receiving data through wireless technologies such as 4G, 5G, Wi-Fi, etc.
2. **Remote Access** –
   Users can connect to applications, files, and services from anywhere without being in the office.
3. **Real-Time Information Access** –
   Provides updated information instantly, like GPS navigation, live news, and stock updates.
4. **Mobility Support** –
   Devices can move from one place to another while staying connected to the network.
5. **Application Support** –
   Allows running different apps like social media, online banking, e-commerce, and productivity tools on mobile devices.

Applications of Mobile Computing

Mobile computing allows users to access data, communicate, and perform tasks **anytime and anywhere** using wireless devices. It has applications in various fields:

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1. Mobile Banking and Payments

- Users can check balances, transfer money, and pay bills through smartphones.
- Example: **UPI, Google Pay, Paytm**.
- Provides 24×7 access without visiting a bank.

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2. Mobile Commerce (m-Commerce)

- Buying and selling products/services through mobile devices.
- Examples: **Amazon, Flipkart apps**.
- Saves time and provides location-based offers.

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3. Mobile Health (m-Health)

- Doctors can monitor patient health remotely using mobile apps and wearable devices.

- Example: ECG monitoring, telemedicine consultations.

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4. Field Work and Real-Time Data Access

- Sales representatives, delivery agents, and technicians can update data on-site.
- Example: Courier tracking, utility meter reading.

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5. Education and e-Learning

- Students can attend online classes, access study materials, and give tests via mobile.
- Example: BYJU'S, Coursera apps.

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6. Transportation and Navigation

- Mobile apps help track vehicles, find routes, and book rides.
- Example: Google Maps, Uber, Ola.

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7. Entertainment and Social Networking

- Streaming movies, music, and connecting with friends through mobile apps.
- Example: YouTube, Instagram, Netflix.

Pure ALOHA:

Pure ALOHA is a simple communication protocol used in wireless and satellite networks for data transmission.
It was developed at the University of Hawaii for radio-based communication.
In Pure ALOHA, a station can send data whenever it has data to send, without checking if the channel is free.

Working:

- The sender transmits the data immediately.
- If two or more stations send data at the same time, a **collision** occurs.
- In case of collision, the sender waits for a random time and then retransmits the data.

Features:

1. **No synchronization** is required between stations.
2. **Simple** to implement.
3. **Vulnerable to collisions**, leading to low efficiency.

Efficiency:

- Maximum efficiency is **18.4%** (only 18.4% of the time channel is used successfully).

i) Slotted ALOHA

- **Definition:**
  An improved version of ALOHA where time is divided into **equal slots** and each packet is sent **only at the start of a slot**.
- **Operation:**
  1. Station waits for the **next time slot** before sending data.
  2. If no other station sends in that slot → success.
  3. If collision occurs, retransmit after a **random number of slots**.
- **Efficiency:**
  Maximum efficiency is **36.8%**, almost double that of Classical ALOHA.

1. CSMA/CD (Carrier Sense Multiple Access with Collision Detection):

- Used mainly in **wired networks** like Ethernet.
- **Working:**
  1. A station first listens to the channel (Carrier Sense).
  2. If the channel is free, it sends data.
  3. If a collision occurs during transmission, it is detected (Collision Detection).
  4. The station stops sending, waits for a random time, and tries again.
- **Purpose:** To reduce collisions and improve channel efficiency.

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2. CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance):

- Used mainly in **wireless networks** like Wi-Fi.
- **Working:**
  1. A station first listens to the channel.
  2. If the channel is free, it waits for a short period (Interframe Space).
  3. Then it sends a signal to reserve the channel (Request to Send – RTS).
  4. Receiver responds with Clear to Send (CTS), and then data is sent.
- **Purpose:** To **avoid collisions** before they happen, as collision detection is hard in wireless networks.

Conclusion:

- **CSMA/CD**: Detects collisions after they occur (wired networks).
- **CSMA/CA**: Avoids collisions before sending data (wireless networks).

CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance):
CSMA/CA is a network protocol used in **wireless networks** to avoid data collisions.
Since detecting collisions in wireless communication is difficult, CSMA/CA tries to **prevent collisions before they occur**.
Working:

1. **Carrier Sense** – The device listens to the channel to check if it is free.

2. **Wait Time** – If the channel is free, it waits for a short random time (backoff time).
3. **RTS/CTS Exchange** – The sender sends a *Request to Send* (RTS) to the receiver. The receiver responds with *Clear to Send* (CTS).
4. **Data Transmission** – The sender sends data, and the receiver sends an acknowledgment (ACK) after successful reception.
5. If the channel is busy, the sender waits and retries later.

Reason for Implementing CSMA/CA in Wireless Networks:

- In wireless communication, a device **cannot listen and send at the same time** (half-duplex nature).
- Due to the **hidden node problem**, collisions are hard to detect.
- CSMA/CD (used in wired networks) is not effective in wireless because collision detection needs simultaneous listening, which is not possible in wireless signals.
- Therefore, CSMA/CA **avoids collisions in advance** to improve efficiency.

Channel Access Methods Based on Time:

In time-based channel access, the available communication time is divided into slots or periods so that multiple users can share the same channel without interference.

Main Methods:

1. **Time Division Multiple Access (TDMA):**
    - The total channel time is divided into fixed time slots.
    - Each user is assigned a specific slot for transmission.
    - No two users send data in the same slot, so collisions are avoided.
    - Example: GSM mobile communication.
2. **Time Division Duplexing (TDD):**
    - The channel time is split into two periods — one for **downlink** (base station to user) and one for **uplink** (user to base station).
    - Both directions use the same frequency but at different times.
    - Example: Some 4G and 5G systems.
3. **Polling:**
    - A central controller gives permission to devices one by one to transmit.
    - Each device sends data only when it receives a polling signal.
    - Avoids collisions but needs extra control time.
4. **Reservation Systems:**
    - Time slots are reserved in advance before data transmission.
    - Useful for applications needing guaranteed bandwidth, like video streaming.

Frequency Division Multiple Access (FDMA):
FDMA is a channel access method where the **available frequency band** is divided into multiple smaller frequency channels.
Each user is assigned a **separate frequency channel** for communication, and these channels are used simultaneously by different users.

Working:

- The total bandwidth is split into equal frequency ranges.
- Each range is allocated to a specific user for the entire duration of the communication.
- Guard bands are kept between channels to avoid interference.

Features:

1. Simple to implement.
2. No collisions since each user has a separate frequency.
3. Bandwidth utilization may be less efficient due to guard bands.

Advantages:

- No interference between users on different frequencies.
- Continuous transmission without waiting for a time slot.

Disadvantages:

- Limited number of channels due to fixed frequency allocation.
- Not flexible if demand changes.

Comparison of TDMA and FDMA:

Feature	TDMA (Time Division Multiple Access)	FDMA (Frequency Division Multiple Access)
Principle	Divides time into slots, each user gets a slot.	Divides frequency into bands, each user gets a band.
Bandwidth Use	All users share the same frequency but at different times.	Each user has a fixed frequency for the whole communication.
Equipment Cost	Requires precise synchronization, slightly higher cost.	Simple equipment, lower cost.
Efficiency	More efficient, as no guard bands are needed between users.	Less efficient due to guard bands between frequencies.
Flexibility	Flexible allocation of time slots.	Fixed frequency allocation, less flexible.
Interference	Less prone to interference if synchronized properly.	Less interference due to dedicated frequency bands.

Feature	TDMA (Time Division Multiple Access)	FDMA (Frequency Division Multiple Access)
Synchronization	Requires strict time synchronization.	No time synchronization required.
Example Use	GSM mobile communication.	Analog mobile systems, radio broadcasting.

Merits & Demerits in Short:

TDMA Merits:

- Better bandwidth utilization.
- Flexible for different data rates.

TDMA Demerits:

- Needs strict synchronization.
- Delay possible if waiting for a slot.

FDMA Merits:

- Simple design.
- Continuous communication without delay.

FDMA Demerits:

- Guard bands waste bandwidth.
- Limited number of channels.

Comparison of Multiple Access Schemes

Parameter	SDMA (Space Division Multiple Access)	TDMA (Time Division Multiple Access)	FDMA (Frequency Division Multiple Access)	CDMA (Code Division Multiple Access)
Basis	Separates users by **space/position**	Separates users by **time slots**	Separates users by **frequency bands**	Separates users by **unique codes**
Resource Allocation	Different beams/antennas for each user	Same frequency, but different time slots	Different frequency for each user	Same frequency & time, but different codes
Synchronization	Not critical	Strict synchronization needed	Less synchronization required	Synchronization important
Bandwidth Usage	Depends on spatial channels	Shared among time slots	Fixed for each user	Shared by all using spread spectrum

Parameter	SDMA (Space Division Multiple Access)	TDMA (Time Division Multiple Access)	FDMA (Frequency Division Multiple Access)	CDMA (Code Division Multiple Access)
Example	Satellite beams, sector antennas	GSM, 2G systems	Analog systems, radio broadcasting	3G (W-CDMA), 4G LTE
Advantages	High capacity using directional antennas	Efficient for burst traffic	Simple, less delay	High capacity, good security
Disadvantages	Needs advanced antenna tech	Delay if slot missed	Poor efficiency if user inactive	Complex receiver design

Packet Reservation Multiple Access (PRMA):
PRMA is a **multiple access protocol** used in wireless communication to efficiently share a channel among multiple users, especially for voice and data transmission.
It is a combination of **TDMA (Time Division Multiple Access)** and **reservation-based access**.

Working of PRMA:

1. **Time Slots:**
   - The channel is divided into fixed time slots.
   - These slots are grouped into frames.
2. **Initial Access:**
   - When a user wants to send data, it transmits in the next available free slot.
   - If no collision occurs, the slot is **reserved** for that user in upcoming frames.
3. **Reservation:**
   - Once a slot is reserved, the same user can keep using it for sending data (like voice packets) without competing again.
4. **Collision Handling:**
   - If two users try to access the same free slot, a collision occurs.
   - Colliding users retry in later slots using a random backoff time.
5. **Release of Slot:**
   - If the user has no more data to send, the reservation is released and becomes available to others.

Advantages:

- Efficient for voice communication, as it maintains a fixed slot for active users.
- Reduces delay once a slot is reserved.
- Good for both real-time (voice) and non-real-time (data) traffic.

Disadvantages:

- Reservation overhead in low-traffic situations.
- Collisions possible during initial access.

Conclusion:
PRMA improves channel efficiency by combining the benefits of TDMA and reservation methods, making it ideal for wireless networks carrying mixed voice and data traffic.

i) Hidden Terminal Problem

- **Definition:** Occurs when two stations **cannot hear each other** but both are within range of a common receiver.
- **Effect:** Causes **collisions** at the receiver.
- **Example:**
  Station A and Station C cannot detect each other but both send to Station B at the same time → collision at B.

Exposed Terminal Problem

- **Definition:** Occurs when a station is **unnecessarily prevented** from sending because it senses another station's transmission, even though its transmission would not cause interference.
- **Effect:** Leads to **wasted channel capacity**.
- **Example:**
  Station B sends to A; Station C hears B and thinks it can't send to D (but it actually can).

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ii) Far and Near Terminal Problem

- **Definition:**
  In wireless communication, signals from **near terminals** are stronger and may overpower signals from **far terminals**, causing reception issues.
- **Effect:**
  - The base station might miss data from a far terminal because the near terminal's stronger signal dominates.
- **Solution:**

- Use **power control** so all terminals send with just enough power to reach the base station.

Telecommunication Generations:
Telecommunication generations refer to the different stages of mobile network technology, from the first generation (1G) to the latest (5G), each improving speed, capacity, and services.

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1. 1G (First Generation):
- Introduced in the 1980s.
- **Technology:** Analog communication.
- **Speed:** ~2.4 kbps.
- **Service:** Only voice calls.
- Example: AMPS.

2. 2G (Second Generation):
- Introduced in the 1990s.
- **Technology:** Digital communication (GSM, CDMA).
- **Speed:** 64–128 kbps.
- **Service:** Voice, SMS, basic data.

3. 3G (Third Generation):
- Introduced in the 2000s.
- **Technology:** WCDMA, HSPA.
- **Speed:** 384 kbps to a few Mbps.
- **Service:** Voice, video calls, mobile internet.

4. 4G (Fourth Generation):
- Introduced in late 2000s.
- **Technology:** LTE, LTE-Advanced.
- **Speed:** Up to 100 Mbps (mobile), 1 Gbps (stationary).
- **Service:** HD video streaming, online gaming, VoIP.

5. 5G (Fifth Generation):
- Introduced in late 2010s.
- **Technology:** mmWave, Massive MIMO.
- **Speed:** Up to 10 Gbps.
- **Service:** Ultra-low latency, IoT, smart cities, autonomous vehicles.

Conclusion:
Each new generation in telecom has brought higher speeds, better connectivity, and advanced services, transforming the way we communicate and use mobile devices.

ISMA (Idle Sense Multiple Access):
ISMA is a **multiple access technique** where a station transmits data only when it senses the channel is idle.
It is mainly used in wireless communication to reduce collisions and improve efficiency.

Working of ISMA:

1. The station **listens** to the channel before transmitting.
2. If the channel is idle, transmission starts immediately.
3. If the channel is busy, the station waits until it becomes free.
4. This avoids unnecessary collisions by ensuring only one station transmits at a time.

Importance of ISMA:

- **Collision Reduction:** Minimizes chances of two stations sending data at the same time.
- **Efficient Channel Use:** Idle time is reduced, improving bandwidth utilization.
- **Energy Saving:** Devices transmit only when required, saving battery power.
- **Improved Performance:** Works well in networks with moderate traffic.

Conclusion:
ISMA improves wireless network efficiency by sending data only when the channel is idle, reducing collisions and saving resources.

UNIT-2

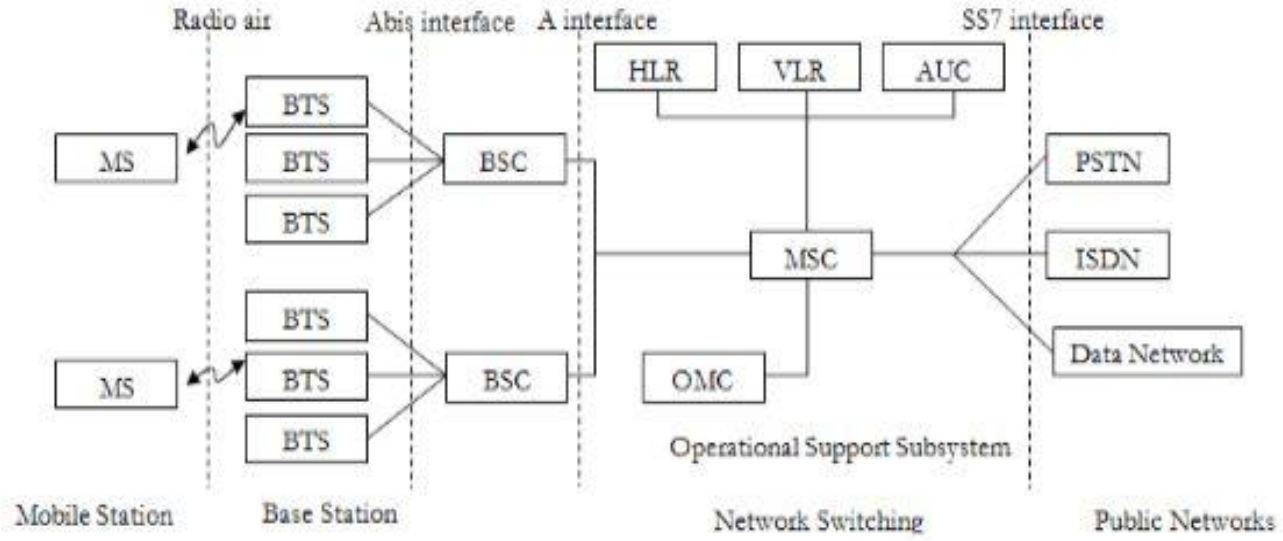

Fig: GSM Architecture

GSM Architecture:
The GSM (Global System for Mobile Communication) architecture is divided into **three main subsystems**:

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1. Mobile Station (MS)

- **Components:** Mobile Equipment (ME) + SIM card.
- **Function:**
  - ME handles communication with the network through the Base Station.
  - SIM stores subscriber details (IMSI, authentication key).

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2. Base Station Subsystem (BSS)

- **Base Transceiver Station (BTS):**
  - Handles **radio communication** with the MS.
  - One BTS covers a **cell** area.
- **Base Station Controller (BSC):**
  - Controls multiple BTS units.
  - Manages **handover** between BTSs.
  - Allocates radio channels.
- **Interfaces:**
  - **Radio interface:** Between MS and BTS.
  - **Abis interface:** Between BTS and BSC.

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3. Network Switching Subsystem (NSS)

- **Mobile Switching Centre (MSC):**
  - Main switching unit that connects calls between mobile and other networks.
- **Home Location Register (HLR):**
  - Stores permanent subscriber data and service profiles.
- **Visitor Location Register (VLR):**
  - Stores temporary data of roaming users.
- **Authentication Centre (AUC):**
  - Provides authentication and encryption keys for security.
- **Operation and Maintenance Centre (OMC):**
  - Manages network monitoring and maintenance.

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4. Public Networks

- **PSTN:** Public Switched Telephone Network (landline network).
- **ISDN:** Integrated Services Digital Network.
- **Data Network:** For internet and other data services.

Working Flow:

1. The MS communicates with BTS using radio signals.
2. BTS sends data to BSC through Abis interface.
3. BSC connects to MSC via A interface.
4. MSC routes the call/data to the right network (PSTN, ISDN, or data).

Conclusion:

GSM architecture works by dividing functions into subsystems for mobile access, radio control, and switching, ensuring **efficient communication, security, and service delivery**.

Network and Switching Sub-System (NSS) in GSM:

The NSS is the core of the GSM network.
It is responsible for **call switching, subscriber management, mobility management, and connecting GSM to other networks**.

Main Components:

1. **Mobile Switching Centre (MSC):**
    - Main switching element of GSM.
    - Routes calls between mobile users and to/from other networks (PSTN, ISDN, Internet).
    - Handles call setup, release, and mobility management.
2. **Home Location Register (HLR):**
    - Database storing **permanent subscriber information** (IMSI, authentication key, service plan).
    - Stores the current location of the subscriber.
3. **Visitor Location Register (VLR):**
    - Temporary database for subscribers currently roaming in an MSC area.
    - Stores temporary IDs and current cell location for faster call handling.
4. **Authentication Centre (AUC):**

    - Provides security by authenticating subscribers.
    - Generates encryption keys for secure communication.
5. **Equipment Identity Register (EIR) –** *(optional)*
    - Stores information about mobile devices.
    - Helps block stolen or unauthorized devices.

Functions of NSS:

- Call switching and routing.
- Subscriber authentication and security.
- Mobility management (handover, roaming).
- Interfacing with other public and private networks.

Conclusion:
The NSS forms the **brain of the GSM system**, managing user data, authentication, and call routing to ensure smooth and secure mobile communication.

Relationship between Base Station and Mobile Switching Centre (MSC):

- The **Base Station Subsystem (BSS)**, which includes **BTS** and **BSC**, handles **radio communication** with mobile stations.
- The **Mobile Switching Centre (MSC)** is part of the **Network Switching Subsystem (NSS)** and is responsible for **call switching, routing, and mobility management**.
- **Connection:**
    - The **BSC** connects to the MSC through the **A interface**.
    - The BSS sends call setup requests, location updates, and data to the MSC.
    - MSC instructs the BSS for **handover, channel allocation, and call control**.

In short:
BSS provides the **radio link**, MSC provides the **call control and routing** — both work together to connect the mobile user to the right destination.

Role of Equipment Identity Register (EIR) in GSM:

- **EIR** is a database that stores **IMEI (International Mobile Equipment Identity)** numbers of mobile devices.

- **Functions:**
    1. Identifies valid, stolen, or faulty mobile devices.
    2. Classifies devices into three lists:
        - **White List:** Allowed devices.
        - **Black List:** Stolen or blocked devices.
        - **Grey List:** Devices with issues but allowed temporarily.
    3. Prevents stolen or unauthorized devices from accessing the network.

Conclusion:
The BSS and MSC work in coordination for call handling, while the EIR ensures only authorized devices operate in the GSM network, improving security.

Frequency Allocation in GSM:
GSM uses specific frequency bands allocated for mobile communication.
The allocation depends on the **uplink** (mobile to base station) and **downlink** (base station to mobile) channels.

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1. GSM Frequency Bands:

- **GSM 900 (Primary band):**
    - **Uplink:** 890 – 915 MHz
    - **Downlink:** 935 – 960 MHz
    - Duplex spacing: **45 MHz** (gap between uplink and downlink)
- **GSM 1800 (DCS 1800):**
    - **Uplink:** 1710 – 1785 MHz
    - **Downlink:** 1805 – 1880 MHz
    - Duplex spacing: **95 MHz**
- **GSM 1900 (PCS 1900):**
    - **Uplink:** 1850 – 1910 MHz
    - **Downlink:** 1930 – 1990 MHz
    - Duplex spacing: **80 MHz**

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2. Channel Spacing:

- GSM divides each frequency band into **200 kHz channels**.
- Each channel can carry **8 time slots** using TDMA (Time Division Multiple Access).

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3. Allocation Process:

- Frequencies are assigned to different cells to avoid interference.
- **Frequency reuse** is applied, meaning the same frequency can be used in distant cells.
- Guard bands are used to prevent overlapping signals between channels.

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4. Example of GSM 900:
Uplink: 890 MHz → 915 MHz (Mobile → BTS)
Downlink: 935 MHz → 960 MHz (BTS → Mobile)
Spacing: 45 MHz between uplink & downlink

Security in GSM:
Security in GSM means protecting user identity, calls, and data from unauthorized access, eavesdropping, and misuse.
GSM uses authentication, encryption, and identity protection to keep communication secure.

Main Security Features in GSM:

1. **Authentication:**
    - The network verifies the subscriber using the **IMSI** (International Mobile Subscriber Identity) stored in the SIM.
    - A random number is sent to the mobile, which uses a secret key (Ki) to generate a response.
    - If the response matches, the user is authenticated.
2. **Encryption:**
    - Data between the mobile and BTS is encrypted using a ciphering key (**Kc**).
    - Encryption algorithm **A5** is used to protect voice and data from eavesdropping.
3. **Temporary Mobile Subscriber Identity (TMSI):**
    - Instead of sending IMSI over the air, a **temporary ID** (TMSI) is used.
    - This hides the real identity of the subscriber from hackers.
4. **Equipment Identity Check:**
    - The **EIR** (Equipment Identity Register) checks the device's IMEI.
    - Stolen or blacklisted devices are blocked.

Importance:

- Prevents fraud and unauthorized access.
- Protects user privacy and identity.
- Secures communication against interception.

Characteristics of SIM (Subscriber Identity Module):

1. **Stores Subscriber Information** – Contains IMSI, authentication key (Ki), and user profile.
2. **Portable** – Can be removed and used in another mobile device.
3. **Security** – Provides authentication and encryption keys for secure communication.
4. **Memory Storage** – Can store phonebook contacts, SMS, and network settings.
5. **Unique Identification** – Every SIM has a unique **ICCID** (Integrated Circuit Card Identifier).

Conclusion:

A SIM card is essential for identifying the subscriber, providing security, and storing limited user data in GSM communication.

UMTS (Universal Mobile Telecommunications System):

UMTS is a **third generation (3G) mobile communication system** developed as an upgrade to GSM.

It is based on **W-CDMA (Wideband Code Division Multiple Access)** technology and provides both **voice** and **high-speed data** services.

Features of UMTS:

1. **High Data Rate:**
    - Up to **2 Mbps** for stationary users.
    - Around **384 kbps** for mobile users.
2. **Multimedia Support:**
    - Video calling, mobile TV, online gaming, multimedia messaging, and internet browsing.
3. **Wide Coverage:**
    - Works in urban, rural, and international roaming scenarios.
4. **Efficient Spectrum Use:**

- Uses **5 MHz wide channels**, allowing more users and higher capacity.

5. **Global Roaming:**
   - Operates in multiple countries with common international standards.

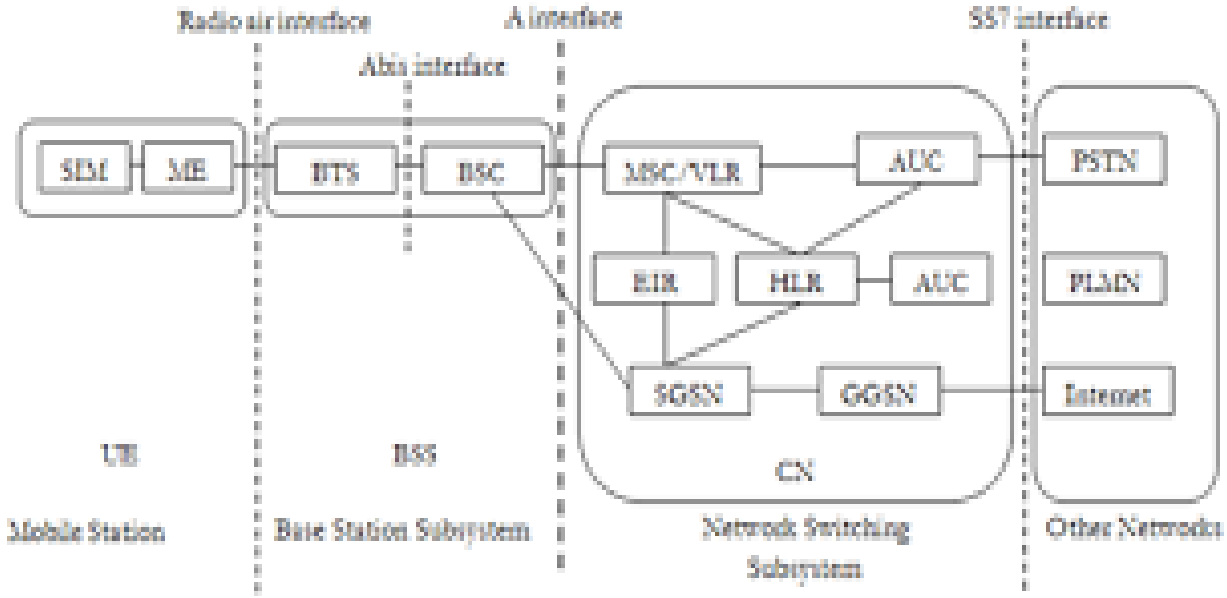

Fig: GPRS Architecture

GPRS Architecture

Introduction:

GPRS (General Packet Radio Service) is an enhancement of GSM that provides **packet-switched data services** for mobile devices, enabling internet access, multimedia messaging, and other data applications.

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1. Components of GPRS Architecture:

A. Mobile Station (MS):

- Consists of **SIM** and **Mobile Equipment (ME)**.
- Used to access GPRS services through applications like browsing or email.

B. Base Station Subsystem (BSS):

- **BTS (Base Transceiver Station):** Handles radio communication with MS.
- **BSC (Base Station Controller):** Controls multiple BTS and manages resources.

C. Network Switching Subsystem (NSS) / Core Network:

- **MSC/VLR:** Handles call control, mobility management, and switching.
- **HLR (Home Location Register):** Stores subscriber profiles and service information.

- **EIR (Equipment Identity Register):** Checks if the device is valid or blacklisted.
- **AUC (Authentication Center):** Provides authentication and encryption keys.

D. GPRS-Specific Nodes

- **SGSN (Serving GPRS Support Node):**
  - Tracks location of MS.
  - Performs authentication, packet routing, and mobility management.
- **GGSN (Gateway GPRS Support Node):**
  - Connects GPRS network to external packet data networks like **Internet, Intranet, X.25**.
  - Assigns IP addresses to MS.

E. External Networks:

- **PSTN (Public Switched Telephone Network)** for voice.
- **Internet/PLMN** for data services.

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2. Working of GPRS:

- MS sends/receives data in **packets** instead of continuous channels.
- SGSN manages communication inside the GPRS network.
- GGSN routes packets to/from external networks.

Advantages of GPRS

1. **Always-On Connectivity** – No need to dial for connection.
2. **Higher Data Rates** – Up to 171.2 kbps (practical ~40–60 kbps).
3. **Efficient Resource Use** – Uses packet switching, so bandwidth is shared.
4. **Supports Internet Services** – Web browsing, email, multimedia messaging.
5. **Global Roaming** – Works wherever GSM coverage is available.

Authentication and Privacy in GSM

1. **Authentication:**
   - Verifies that the user is genuine before allowing network access.
   - Uses a secret key **Ki** stored in SIM and **AUC** (Authentication Center).
   - Network sends a random number (**RAND**) to MS.
   - MS calculates a response (**SRES**) using RAND and Ki through **A3 algorithm**.

    - Network compares SRES from MS with its own — if they match, user is authenticated.
2. **Privacy:**
    - Protects user data and identity during transmission.
    - Uses **encryption key (Kc)** generated during authentication.
    - **A5 algorithm** encrypts voice/data so it cannot be easily intercepted.
    - Temporary Mobile Subscriber Identity (**TMSI**) is used instead of real IMSI to hide user identity.

UMTS Definition

UMTS (Universal Mobile Telecommunications System) is a **third-generation (3G) mobile communication system** developed by 3GPP.
It provides **high-speed voice, video, and data services** using **W-CDMA (Wideband Code Division Multiple Access)** as the radio access technology.

Main Elements of UMTS

1. **User Equipment (UE)**
    - Mobile device with USIM (Universal Subscriber Identity Module).
    - Connects to UMTS network for voice and data.
2. **UMTS Terrestrial Radio Access Network (UTRAN)**
    - **Node B:** Similar to BTS in GSM; handles radio communication.
    - **Radio Network Controller (RNC):** Controls multiple Node Bs and manages radio resources.
3. **Core Network (CN)**
    - **Circuit-Switched Domain:** Handles voice calls (MSC, GMSC).
    - **Packet-Switched Domain:** Handles data services (SGSN, GGSN).
    - **Databases:** HLR, VLR, AUC, EIR for subscriber and security management.

Protocol Architecture for Signaling in GSM

The **GSM signaling system** is used for call setup, location update, authentication, and control of radio channels.
It follows a layered structure similar to the OSI model.

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1. Layer 1 – Physical Layer

- Responsible for sending and receiving bits over the physical medium.

- In GSM, this includes the **air interface** between Mobile Station (MS) and Base Transceiver Station (BTS) and wired links (E1 lines) between network elements.

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2. Layer 2 – Data Link Layer

- Ensures **error-free transmission** of signaling data between two points.
- Uses **LAPDm** protocol (a modified LAPD from ISDN) over the air interface.
- Provides **framing, error detection, and retransmission** if needed.

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3. Layer 3 – Network Layer *(Divided into three sublayers)*

a) Radio Resource Management (RR)

- Manages allocation and release of radio channels.
- Controls **handover** when MS moves between cells.

b) Mobility Management (MM)

- Handles **location updating** when a subscriber changes location.
- Manages **authentication** and **security functions**.

c) Call Control (CC)

- Responsible for **call setup, maintenance, and termination**.
- Works with MSC to connect calls between users.