PCC UNIT-1

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1. Explain about the mobile fading characteristics.

A. **Types of Mobile Fading**

1. Large-Scale Fading

- **Cause**: Environmental obstructions such as buildings, terrain, and foliage.
- **Components**:
    - **Path Loss**: Signal attenuation due to distance between transmitter and receiver.
    - **Shadowing (Slow Fading)**: Signal blocked or attenuated by large objects.
- **Variation Scale**: Occurs over distances of tens to hundreds of meters.
- **Modeling**: Typically modeled using log-normal distribution.

2. Small-Scale Fading

- **Cause**: Multipath propagation—signals reflect off surfaces and arrive at the receiver with different delays and phases.
- **Characteristics**:
    - Rapid fluctuations in signal amplitude and phase.
    - Occurs over distances comparable to the signal wavelength.
- **Subtypes**:
    - **Flat Fading**: All frequency components of the signal fade uniformly.
    - **Frequency-Selective Fading**: Different frequency components experience different levels of fading due to delay spread.

Doppler-Based Fading

3. Fast Fading

- **Cause**: High relative motion between transmitter and receiver, leading to Doppler shifts.
- **Effect**: Rapid changes in signal amplitude and phase.
- **Time Scale**: Microseconds to milliseconds.
- **Relevant When**: The coherence time of the channel is smaller than the symbol duration.

4. Slow Fading

- **Cause**: Gradual changes in the environment, such as moving behind a building or hill.
- **Effect**: Slow variation in average signal strength.
- **Time Scale**: Seconds or longer.
- **Relevant When**: The coherence time is larger than the symbol duration.

2. What is the need of cellular mobile communication systems?

A.

1. Overcoming Limitations of Conventional Systems

- **Traditional mobile systems** (like early analog radio) had limited capacity, poor coverage, and inefficient spectrum use.

- Cellular systems divide geographic areas into smaller cells, allowing **frequency reuse** and **higher user density** without interference.

2. Efficient Spectrum Utilization

- The radio spectrum is a finite resource.
- Cellular architecture enables **reuse of frequencies** in non-adjacent cells, maximizing spectrum efficiency and supporting more users simultaneously.

3. Support for Mobility

- Cellular systems are designed to **track and manage user movement** across cells.
- Features like **handoff** (seamless transition between cells) ensure uninterrupted service during travel.

4. Scalability and Coverage

- Cells can be **split or resized** to accommodate growing user demand.
- Hierarchical cell structures (macro, micro, pico, femto) allow coverage from national to indoor levels.

5. Integration of Voice, Data, and Multimedia

- Modern cellular systems (3G, 4G, 5G) support **high-speed data**, **video streaming**, **IoT**, and **real-time communication**.
- They enable services like mobile internet, GPS, video calls, and cloud access.

6. Economic and Social Impact

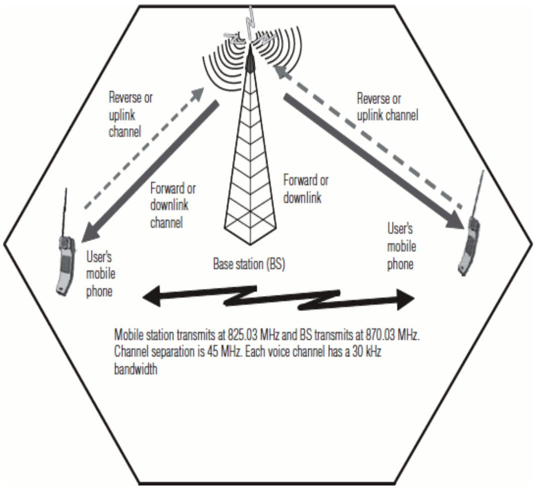
- Cellular networks support **e-commerce**, **telemedicine**, **remote education**, and **emergency services**.
- They are foundational to **digital transformation** and **smart infrastructure**.

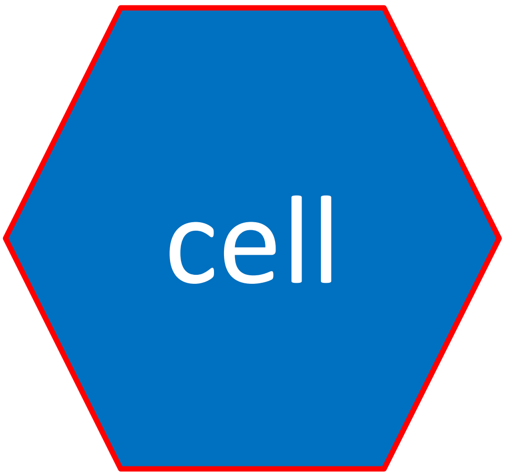
7. Advanced Network Features

- Cellular systems incorporate **intelligent switching**, **load balancing**, and **security protocols**.
- They support **adaptive modulation**, **error correction**, and **QoS management** for reliable communication.

3. Explain about Hexagonal shaped cells.

A.





1. Efficient Coverage Without Overlap

- Hexagons can **tile a plane perfectly** without gaps or overlaps, unlike circles.

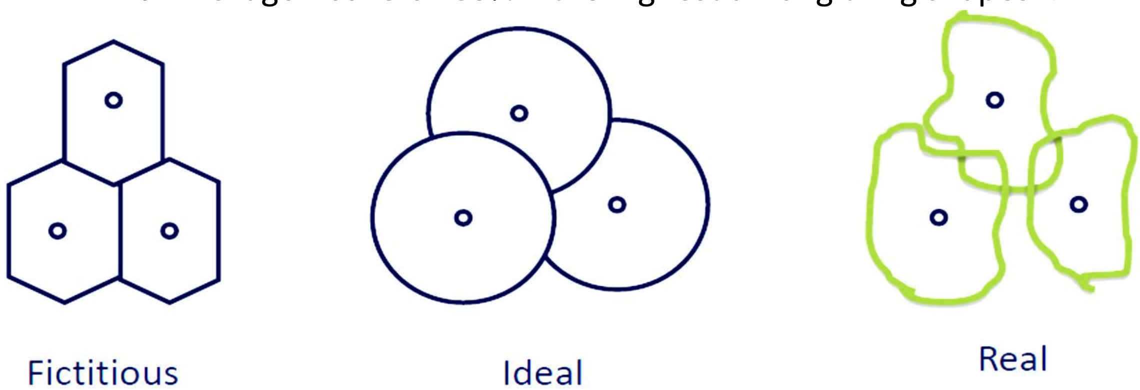
- This ensures **uniform coverage** and avoids dead zones or excessive interference between adjacent cells.

2. Approximates Circular Coverage

- The radiation pattern from a base station is roughly circular.
- A hexagon closely approximates a circle while still allowing for **seamless tiling**, making it a practical compromise between ideal coverage and geometric fit.

3. Maximizes Area Coverage

- Compared to other shapes:
  - Triangle covers ~17.7% of a circle's area.
  - Square covers ~63.7%.
  - Hexagon covers ~83%—the highest among tiling shapes2.



- This means fewer base stations are needed to cover a given area.

4. Simplifies Frequency Reuse Planning

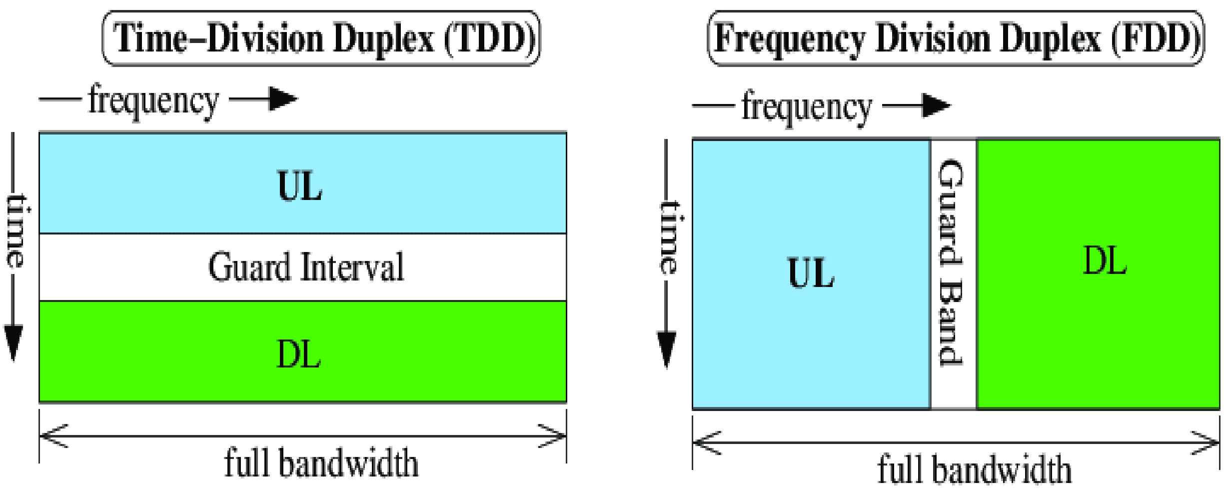
- Hexagonal cells make it easier to implement **frequency reuse patterns**.
- This helps reduce co-channel interference and improves spectrum efficiency.

5. Uniform Distance Between Centers

- The centers of adjacent hexagonal cells are equidistant.
- This uniformity simplifies **handoff algorithms** and **network planning**.

4. Write any 4 differences between FDD and TDD.

A.



Feature	FDD (Frequency Division Duplex)	TDD (Time Division Duplex)
Frequency Usage	Uses two separate frequency bands for uplink and downlink	Uses a single frequency band, alternating in time
Duplexing Method	Full-duplex (simultaneous transmission and reception)	Half-duplex (transmission and reception at different times)
Spectrum Requirement	Requires paired spectrum	Uses unpaired spectrum
Traffic Flexibility	Fixed uplink/downlink allocation	Dynamic allocation based on traffic demand
Synchronization Need	Minimal synchronization required	Requires precise timing synchronization
Interference Handling	Lower self-interference due to separate bands	Higher risk of interference; needs coordination

5. Explain uniqueness of mobile radio environment.

A.

Unique Features of Mobile Radio Environment

1. Fading and Multipath Propagation

- Signals often reach the receiver via multiple paths due to reflection, diffraction, and scattering.
- This causes **rapid fluctuations** in signal amplitude and phase, known as **small-scale fading**.
- **Rayleigh and Rician fading models** are commonly used to describe these effects.

2. Time Dispersion and Delay Spread

- Multipath signals arrive at slightly different times, causing **inter-symbol interference (ISI)**.
- This leads to **frequency-selective fading**, where different parts of the signal spectrum fade differently.

3. Doppler Shift and Mobility

- Movement of the user or surrounding objects causes **Doppler shifts**, altering the frequency of received signals.
- This results in **fast fading** and requires adaptive techniques for reliable communication.

4. Coherence Bandwidth and Coherence Time

- **Coherence bandwidth**: Range of frequencies over which the channel response is flat.
- **Coherence time**: Duration over which the channel characteristics remain stable.

- These parameters define how well a signal can be transmitted without distortion.

5. Interference Dynamics

- Mobile environments are prone to **co-channel and adjacent channel interference** due to frequency reuse.
- The interference pattern changes constantly as users move, requiring dynamic resource management.

6. Variable Channel Conditions

- Unlike fixed channels, mobile radio channels vary with location, time, weather, and user density.
- This necessitates **robust modulation, coding, and handoff strategies**.

6. Explain the operation of a cellular system.

A. **Key Components of Cellular System Operation**

1. Mobile Unit Initialization

- When a mobile device is powered on, it scans available **setup channels** to find the strongest signal.
- It locks onto the nearest **cell site** based on signal strength.
- This process is called **self-location**, and it helps the mobile unit stay connected in idle mode without burdening the network.

2. Mobile-Originated Call

- The user dials a number and presses "send."
- The mobile unit sends a **service request** via the setup channel.
- The **cell site** receives the request and forwards it to the **Mobile Telephone Switching Office (MTSO)**.
- The MTSO assigns a **voice channel** and connects the call to the destination (mobile or landline).

3. Network-Originated Call

- A landline user dials a mobile number.
- The telephone network routes the call to the MTSO.
- The MTSO initiates a **paging process** across relevant cell sites to locate the mobile unit.
- Once found, the mobile unit is instructed to tune to a voice channel and the call is connected.

4. Call Termination

- When the call ends (either party hangs up), a **signaling tone** is sent to the cell site.
- The voice channel is released and made available for other users.

5. Handoff Procedure

- If the mobile user moves from one cell to another during a call, the system performs a **handoff**.
- The call is seamlessly transferred to a new cell site with better signal strength, maintaining continuity.

7. Describe the performance criteria of Cellular mobile systems.

A.

Criterion	Description
Voice Quality	Assessed using subjective tests like Mean Opinion Score (MOS); aims for clear, intelligible audio with minimal distortion or delay.
Call Blocking Probability	Measures the likelihood that a call attempt is denied due to lack of available channels; lower values indicate better performance.
Call Dropping Rate	Indicates how often ongoing calls are terminated unexpectedly, often due to handoff failures or poor signal conditions.
Handoff Success Rate	Reflects the system's ability to maintain calls during user movement between cells; high success rate is crucial for mobility.
Coverage Area	Defines the geographic region where service is available; influenced by cell size, antenna design, and terrain.
Capacity	Refers to the maximum number of simultaneous users or calls the system can support without degradation.
Data Throughput	Measures the rate at which data is successfully transmitted; critical for modern services like video streaming and internet access.
Latency	Time delay between sending and receiving data; lower latency improves responsiveness, especially in real-time applications.
Spectral Efficiency	Indicates how efficiently the system uses available spectrum; higher efficiency supports more users with limited bandwidth.
Energy Efficiency	Evaluates power consumption relative to performance; important for both network infrastructure and mobile devices.

8. Discuss about evolution of mobile radio communications.

A. **Evolution Stages of Mobile Radio Communication**

1. Pre-Cellular Era (1930s–1960s)

- Early mobile systems used **Amplitude Modulation (AM)**.
- Limited to specific public services (e.g., police, taxis).
- No cellular concept; coverage was sparse and inefficient.

2. 1G – First Generation (1980s)

- Introduced **analog voice transmission**.
- Technologies: AMPS (USA), TACS (UK), NMT (Nordic countries).
- Features:
  - Frequency Division Multiple Access (FDMA).
  - Poor voice quality, low capacity, and minimal security.
- No support for data or roaming.

3. 2G – Second Generation (1990s)

- Shift to **digital communication**.

- Technologies: GSM, IS-95 (CDMA).
- Features:
    - Better voice quality and security.
    - Support for SMS and limited data.
    - Time Division Multiple Access (TDMA) and Code Division Multiple Access (CDMA).

4. 3G – Third Generation (2000s)

- Focused on **mobile internet and multimedia**.
- Technologies: UMTS, CDMA2000.
- Features:
    - Higher data rates (up to 2 Mbps).
    - Video calling, mobile web access.
    - Wideband CDMA (W-CDMA).

5. 4G – Fourth Generation (2010s)

- All-IP based systems for **high-speed broadband**.
- Technologies: LTE, WiMAX.
- Features:
    - Data rates up to 100 Mbps (mobile) and 1 Gbps (stationary).
    - HD video streaming, VoIP, gaming.
    - OFDMA and MIMO technologies.

6. 5G – Fifth Generation (2020s)

- Designed for **ultra-reliable, low-latency communication**.
- Features:
    - Data rates exceeding 10 Gbps.
    - Support for IoT, autonomous vehicles, smart cities.
    - Massive MIMO, beamforming, and network slicing.

9. Explain various Analog and Digital Cellular system with an example.

A.

Feature	Analog Cellular System	Digital Cellular System
Generation	1G (First Generation)	2G and beyond (Second Generation onward)
Example	AMPS (Advanced Mobile Phone System) [1]	GSM (Global System for Mobile Communications) [1]
Signal Type	Analog (Frequency Modulation for voice)	Digital (Voice encoded and compressed)
Access Method	FDMA (Frequency Division Multiple Access)	TDMA, CDMA, OFDMA (depending on generation)
Voice Quality	Lower, prone to noise and distortion	Higher, with error correction and encryption
Security	Minimal or no encryption	Strong encryption and authentication
Data Services	Not supported or very limited	Supports SMS, internet, multimedia
Capacity	Low (one user per channel)	High (multiple users per channel via multiplexing)
Compatibility	Not compatible with digital networks	Compatible with modern digital infrastructure

Example Details

- **AMPS (Analog)**:
  - Introduced in 1983 in North America.
  - Used FM modulation.
  - Operated in the 800 MHz band.
  - Limited capacity and security.
- **GSM (Digital)**:
  - Introduced in the early 1990s.
  - Used TDMA and GMSK modulation.
  - Operated in the 900/1800/1900 MHz bands.
  - Supported SMS, call encryption, and international roaming.

10. Discuss about classification of wireless systems with an example.

A.

1. Wireless Personal Area Network (WPAN)

- **Description**: Designed for short-range communication between personal devices, typically within 10 meters.
- **Use Cases**: Device pairing, wearable tech, home automation.
- **Example**: Bluetooth, ZigBee.

2. Wireless Local Area Network (WLAN)

- **Description**: Provides wireless connectivity within a limited area such as a home, office, or campus.

- **Use Cases**: Internet access, file sharing, VoIP within buildings.
- **Example**: Wi-Fi (IEEE 802.11 standards).

3. Wireless Metropolitan Area Network (WMAN)

- **Description**: Covers a city or large geographic area, often used to connect multiple WLANs or provide broadband access.
- **Use Cases**: City-wide internet, public Wi-Fi zones.
- **Example**: WiMAX (IEEE 802.16).

4. Wireless Wide Area Network (WWAN)

- **Description**: Enables long-range communication over large regions or countries using cellular infrastructure.
- **Use Cases**: Mobile telephony, mobile broadband, IoT.
- **Example**: Cellular networks (3G, 4G, 5G).

5. Satellite Communication Systems

- **Description**: Uses satellites to provide wireless communication across vast or remote areas, including global coverage.
- **Use Cases**: GPS navigation, remote internet access, disaster recovery.
- **Example**: GPS, VSAT, satellite phones.

6. Infrared Communication Systems

- **Description**: Uses infrared light for short-range, line-of-sight communication between devices.
- **Use Cases**: Remote controls, short-range data transfer.
- **Example**: TV remote controls, IR data links.

7. Microwave Communication Systems

- **Description**: Employs high-frequency microwave signals for point-to-point communication, often used for backbone links.
- **Use Cases**: Long-distance telephone and data transmission.
- **Example**: Microwave relay stations.

8. LiFi (Light Fidelity)

- **Description**: Uses visible or infrared light to transmit data wirelessly at high speeds.
- **Use Cases**: Secure indoor data transmission, optical LANs.
- **Example**: Optical wireless LANs using LED lighting.

11. Explain the various components of a basic cellular system in detail.

A.

1. Mobile Station (MS)

- **Description**: The user's mobile device that connects to the cellular network.
- **Components**:
  - **Mobile Equipment (ME)**: The physical handset or device.
  - **SIM (Subscriber Identity Module)**: Contains user identity, authentication keys, and subscription details.
- **Functions**:
  - Initiates and receives voice/data communication.
  - Sends SMS and accesses mobile services.

    - Performs handovers when moving between cells.

2. Base Station Subsystem (BSS)

This subsystem handles radio communication with mobile stations.

a. Base Transceiver Station (BTS)

- **Description**: Radio equipment that communicates directly with mobile devices.
- **Functions**:
    - Transmits and receives radio signals.
    - Handles modulation, encoding, and decoding.
    - Covers a specific geographic area known as a cell.

b. Base Station Controller (BSC)

- **Description**: Manages multiple BTS units.
- **Functions**:
    - Allocates radio channels.
    - Manages handovers between BTSs.
    - Controls power levels and frequency assignments.

3. Network Switching Subsystem (NSS)

This is the core part of the cellular network responsible for call control and mobility management.

a. Mobile Switching Center (MSC)

- **Description**: Central switch that connects calls between mobile users and external networks.
- **Functions**:
    - Call setup, routing, and termination.
    - Mobility and location management.
    - Billing and charging.
    - Interfaces with PSTN and other MSCs.

b. Home Location Register (HLR)

- **Description**: Database storing permanent subscriber information.
- **Functions**:
    - Maintains user profiles, services, and current location.
    - Supports call routing and authentication.

c. Visitor Location Register (VLR)

- **Description**: Temporary database for subscribers currently roaming in the MSC's area.
- **Functions**:
    - Retrieves data from HLR for roaming users.
    - Stores temporary location and service data.

d. Authentication Center (AUC)

- **Description**: Ensures secure access to the network.
- **Functions**:
    - Verifies SIM credentials.
    - Generates encryption keys for secure communication.

e. Equipment Identity Register (EIR)

- **Description**: Database of mobile device identities.
- **Functions**:
    - Identifies stolen or unauthorized devices.
    - Classifies devices as valid, suspect, or barred.

12. What are the limitations of conventional mobile telephone system?

A. **1. Limited Capacity**

- **Explanation**: Analog systems used frequency division multiple access (FDMA), which allocated a fixed frequency per call.
- **Impact**: Only a small number of simultaneous users could be supported in a given area, leading to congestion during peak hours.

2. Poor Voice Quality

- **Explanation**: Analog transmission was susceptible to noise, interference, and signal degradation.
- **Impact**: Users experienced static, dropped calls, and inconsistent audio clarity.

3. Lack of Security

- **Explanation**: Analog signals could be intercepted using simple radio scanners.
- **Impact**: Conversations were vulnerable to eavesdropping, and cloning of mobile devices was relatively easy.

4. No Support for Data Services

- **Explanation**: Conventional systems were designed solely for voice communication.
- **Impact**: No capability for SMS, internet access, or multimedia services.

5. Inefficient Spectrum Usage

- **Explanation**: FDMA and fixed channel allocation led to underutilization of available spectrum.
- **Impact**: Limited scalability and inefficient use of valuable radio frequencies.

6. Limited Mobility and Handover Support

- **Explanation**: Handover between cells was rudimentary and often manual.
- **Impact**: Users experienced dropped calls when moving between coverage areas.

7. No Roaming Standardization

- **Explanation**: Lack of interoperability between different networks and regions.
- **Impact**: Users couldn’t easily use their phones outside their home network or country.

8. Bulky and Power-Hungry Devices

- **Explanation**: Early mobile phones were large and consumed significant battery power.
- **Impact**: Limited portability and short battery life.

9. High Operational Costs

- **Explanation**: Infrastructure and maintenance costs were high due to analog technology.
- **Impact**: Expensive service plans and limited accessibility for the generalpublic.