MIDTERM (SHORT NOTES)

2024 - 2025

CS314 [Important Definitions]

Contact Us: 03126968553

LECTURE # 01 to 04

Cellular Network Evolution
Wireless communication began in the 1930s, primarily used for public safety. It evolved from push-to-talk systems and single-channel radio to advanced mobile telephony. The first commercial cellular service was launched in 1979 by Nordic Mobile Telephone.

Wired vs. Wireless Medium
Wired medium transmits data using cables. Wireless medium uses electromagnetic or radio waves for data transmission.

Cellular System Overview
A cellular network divides a service area into cells, each served by a base station (BS) comprising a transmitter, receiver, and control unit. These BSs connect to a fixed network (PSTN).

Components of a Cellular System
BTS (Base Transceiver Station): Handles transmission/reception and connects subscribers to the network.
BSC (Base Station Controller): Interfaces with BTSs and routes calls.
MSC (Mobile Switching Center): Central coordinator; connects BSCs and links to external networks like PSTN.

Operational Channels
Forward Voice Channel (FVC): BS to mobile voice transmission.
Reverse Voice Channel (RVC): Mobile to BS voice transmission.
Forward Control Channel (FCC): Used for call setup and call routing.
Reverse Control Channel (RCC): Mobile to BS control communication.

Common Air Interface (CAI)
Defines the communication between a BS and a mobile station using the above four channels.

Network Cells and Cluster
A cell is a basic unit of a cellular network represented by a hexagon (ideally). A cluster is a group of adjacent cells (e.g., 7 cells) with no frequency reuse within it. Cells are categorized as:

- Macro cell: Large area coverage (~6 miles), used in rural areas.
- Micro cell: Small coverage (~0.5 miles), used in urban settings.
- Pico cell: Very small areas (e.g., inside buildings).

Cell Sectorization
Dividing a cell into sectors (3–6) with directional antennas to increase frequency reuse and capacity.

Cellular Concept and Frequency Reuse
The same frequency channels are reused in non-adjacent cells to enhance capacity. The cluster size (K) affects reuse distance and interference.

Frequency Reuse Formula
$D/R = \sqrt{3K}$
Where D is the distance between co-channel cells, R is the cell radius, and K is the cluster size.

Call Setup Process

1. Phone scans for the strongest control channel.
2. It registers with BTS and receives a dedicated channel.
3. To make a call: Phone sends number → BTS → BSC → MSC → Receiver's MSC → BSC → BTS → receiver.
4. To receive a call: Receiver's phone monitors control channel and responds upon match.

Mobility Management
Ensures ongoing communication as users move. Requires BSs to track mobile users and trigger handovers if necessary.

Handover / Handoff
Transfers an ongoing call to a new BS as the user moves. Mobile Assisted Handover (MAHO) uses signal strength reports from the mobile device to assist handover decisions.

Umbrella Cell Concept
Used to manage high-speed and low-speed users differently: macro cells serve fast-moving users, and micro cells serve slow-moving users to reduce frequent handoffs.

First Generation Networks (1G)
AMPS (Advanced Mobile Phone Service): Analog, used FDMA, divided areas into cells, allowed frequency reuse. Operated at 824–894 MHz, each channel 30 kHz wide.

Second Generation Networks (2G)
Digital communication with support for encryption, error correction, and dynamic channel access. Key standards:

- GSM: 8 users per 200 kHz channel (Europe, Asia, parts of US).
- IS-136: 3 users per 30 kHz (North America).
- PDC: Used in Japan.
- IS-95 (CDMA): 64 users per 1.25 MHz (US – Sprint, Verizon).

FDMA/FDD (First Gen AMPS)
Frequency Division Multiple Access with Frequency Division Duplexing separates uplink/downlink using constant frequency separation. Each AMPS channel is 30 kHz, with total 832 channels (416 per operator).

AMPS Logical Channels
Consists of 395 voice and 21 control channels per operator. Control data is also transmitted during voice communication via FSK-encoded bursts.

Decibel (dB)
A logarithmic unit to express signal strength ratio:
dB = 10 log (P2/P1)

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2G Networks Introduction
Second Generation (2G) systems introduced digital transmission to improve voice quality, capacity, coverage, and security. Examples include D-AMPS (US), PDC (Japan), IS-94 (Korea), and GSM (Global System for Mobile Communication).

GSM (Global System for Mobile Communication)
A digital cellular standard developed by ETSI. First deployed in 1991 in Finland. Uses narrowband TDMA for communication. Provides voice and data services, including international roaming.

Advantages of GSM
High spectrum efficiency
International roaming capability
Low-cost mobile devices and base stations
High-quality voice transmission
Compatibility with ISDN and other services

GSM Network Architecture
Divided into three subsystems:

- Switching System (SS): Handles call processing and subscriber management.
- Base Station System (BSS): Manages radio functions (includes BTS and BSC).
- Operation and Support System (OSS): Monitors, controls, and maintains network operations.

Switching System Components
MSC (Mobile Switching Centre): Core switching unit linking RAN and external networks.
HLR (Home Location Register): Stores permanent subscriber info and service profiles.
VLR (Visitor Location Register): Stores temporary data for roaming subscribers.
AUC (Authentication Centre): Verifies user identity and secures communication.
EIR (Equipment Identity Register): Prevents access from stolen/unauthorized devices.

Base Station System (BSS)
BTS (Base Transceiver Station): Radio hardware serving a cell.
BSC (Base Station Controller): Manages multiple BTSs, handles handovers, power control, and frequency allocation.

GSM Network Areas

- Cell: Area covered by one BTS; uniquely identified by CGI.
- Location Area (LA): Group of cells, managed by one MSC; used for paging.
- MSC/VLR Area: Area managed by one MSC.
- PLMN Area: Network operated by a single operator, identified by MCC and MNC.

GSM Specifications

- Uplink: 890–915 MHz
- Downlink: 933–960 MHz
- Duplex spacing: 80 MHz

- Channel bandwidth: 200 kHz
- Modulation: GMSK
- Bitrate: 270 kbps
- Speech coding: LPC at 13 kbps
- Access method: TDMA.

PLMN (Public Land Mobile Network)
A mobile network run by a licensed operator. Each operator's PLMN is identified by Mobile Country Code (MCC) and Mobile Network Code (MNC). PLMNs connect to other PLMNs and networks like PSTN or ISPs for voice and data services.

Objectives of GSM PLMN

- Offer both voice and non-voice services
- Ensure compatibility with ISDN and PSTN
- Enable roaming and subscriber location updates
- Efficient spectrum usage
- Support various mobile terminals
- Maintain low infrastructure and service costs.

GSM Services

1. Teleservices: Voice calls, emergency calls, SMS, videotext, facsimile.
2. Bearer Services: Data services enabling mobile internet and file transfer (e.g., via GPRS, HSCSD).
3. Supplementary Services: Call forwarding, call waiting, conferencing, caller ID, USSD, etc..

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GSM Mobility
GSM enables roaming by separating switching functionality (in MSC/GMSC) from subscription data (in HLR). The HLR resides in the user's home network (HPLMN) and stores the subscriber profile.

Mobile Station (MS)
Consists of:

- Mobile Equipment (ME): The actual mobile phone or device.
- SIM (Subscriber Identity Module): A chip containing subscriber information like IMSI, used to authenticate and register with the GSM network.

Identifiers in GSM

- IMSI (International Mobile Subscriber Identity): Uniquely identifies a subscriber and is stored on the SIM and in the HLR.
- IMEI (International Mobile Equipment Identity): Identifies the device itself.
- MSRN (Mobile Station Roaming Number): Temporarily assigned for routing incoming calls during roaming.
- MSISDN: The phone number used to dial the subscriber; stored in HLR, not on the SIM.

Call Routing in GSM
Uses identifiers like IMSI, MSISDN, and MSRN to locate the subscriber and route the call through the appropriate MSC and base station.

GPRS (General Packet Radio Service)
An enhancement of GSM that adds packet-switched capabilities, enabling data services like mobile internet. It introduces GSNs (GPRS Support Nodes), such as:

- SGSN (Serving GSN): Tracks location and handles packet delivery to/from MS.
- GGSN (Gateway GSN): Connects GPRS network to external data networks (e.g., the Internet).

Goals of GPRS

- Efficient use of bandwidth for bursty traffic (e.g., web browsing)
- Higher data rates than GSM
- New charging models (based on data volume)
- Compatibility with 2G and 3G cores (A/Gb and Iu interfaces).

GPRS Modes of Operation

- Class A: Simultaneous circuit- and packet-switched services.
- Class B: Either circuit or packet services at one time.
- Class C: Only packet-switched services.

GPRS Mobility States

- Idle: No PDP context; cannot send/receive data except multicast.
- Standby: Known by routing area only.
- Active: Known by exact cell; can transmit/receive data.

GPRS Control Channels

PCCCH (Packet Common Control Channel): Used by GPRS mobiles to camp and initiate sessions.

- PRACH: Random access.
- PPCH: Paging channel.
- PAGCH: Access grant.
- PNCH: Multicast notifications.

PBCCH (Broadcast Control): Syncs frequency and sends general info.

PDCCH, SACCH, FACCH, SDCCH: Various control and signaling functions.

GPRS Air Interface
Uses dynamic allocation of time slots (PDCHs) with master-slave structure. Packet Data Channels can be scaled based on demand. Load management is handled at the MAC layer.

GPRS Data Transfer Procedures
Uplink and downlink include steps like random access, channel assignment, data block transmission, error handling (retransmissions), and acknowledgements.

Quality of Service (QoS) in GPRS
QoS ensures reliable data delivery with configurable parameters:

- Service precedence (3 classes)
- Reliability (3 classes)
- Delay (4 classes)
- Throughput (max and mean bit rates)

QoS profiles are negotiated during PDP (Packet Data Protocol) context activation