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Subject Name: **Cellular Mobile Communication**

Subject Code: **EC-6001**

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EC-6001 Cellular mobile communication

Unit-V

Digital Cellular Systems: GSM- architecture, layer modeling, transmission, GSM channels and channel modes, multiple access schemes. CDMA- terms of CDMA systems, output power limits and control, modulation characteristics, call processing, hand off procedures. Miscellaneous mobile systems- TDD systems, cordless phone, PDC, PCN, PCS, non cellular systems.

5.1 Digital Cellular Systems

The digital cellular system has so many advantages over the analog system. The most significant advantages are digital signal processing techniques can be used to reduce transmission bandwidth requirement and to extract signals in poor SNR conditions. Digital cellular radio system uses different techniques for channel allocation as follows

1. Global system for mobile (GSM)
2. Cellular digital packet data(CDPD)
3. Code division multiple access(CDMA)

5.2 Global system for mobile (GSM)

The first global system for mobile (GSM) TDMA system was developed by CEPT, a European group in 1982. GSM technique is most widely used for digital cellular radio. A GSM system has maximum 200 full duplex channel per cell. Each cell has different uplink and downlink frequency. It uses digital modulation and network level architectures. GSM is a second generation (2G) cellular system. GSM can handle voice and data traffic, the voice waveform being digitally encoded before transmission. GSM transmission is done within frequency bands of 900 MHz, 1800 MHz and 1900 MHz.

5.3 GSM Architecture

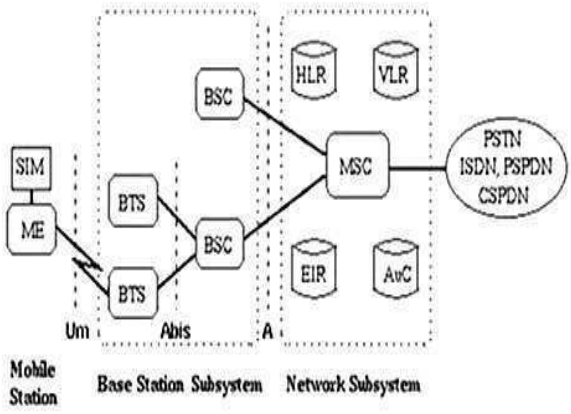

Figure 5.1 GSM architecture

GSM architecture consists of following subsystems as shown in figure 5.1

1. Mobile station (MS)
2. Base station sub system (BSS)
3. Network and switching subsystem (NSS)
4. Operation subsystem (OSS)

5.3.1 Mobile Station (MS):

The mobile station consists of mobile equipment and a subscriber identity module (SIM). Mobile equipment does not need to be personally assigned to one subscriber. All the subscriber related information is stored in the SIM. When a subscriber's SIM is inserted into mobile equipment of any MS, and that MS belongs to the particular subscriber and the call is delivered to that MS. The mobile equipment is not associated with a called number, but it is linked to the SIM. The International Mobile Equipment Identity (IMEI) is assign to mobile equipment for unique identification and SIM card contain International Mobile Subscriber Identity (IMSI).

5.3.2 Base Station Subsystem:

The base station subsystem consists of two parts:

1. Base transceiver station (BTS)
2. Base station controller (BSC)

BSS connects to the MS through a radio interface and also connects to the network and switching

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subsystem (NSS). The BTS contains reception equipment and radio transmission similar to the ME in an MS. BTS contains a trans-coder rate adaption unit (TRAU) that perform encoding and speech decoding and rate adaptation for transmitting data. The TRAU may be sited away from the BTS, usually at the MSC as a subpart of the BTS. BSC manages the radio resources for one or more BTS.

5.3.3 Network and Switching Subsystem:

The central component of network subsystem is the mobile service switching center (MSC). NSS in GSM uses an intelligent network (IN). A signaling NSS consists of main switching functions of GSM. NSS control the communication between GSM users and other telecommunications users. NSS management includes of:

- Mobile service switching center (MSC): MSC coordinates the call set-up to and from GSM users. Single MSC controls many BSCs.
- Interworking function (IWF): IWF plays the role of a gateway for MSC to interface with external networks for communication with users which are outside GSM, like circuit-switched public data network (CSPDN) or packet-switched public data network (PSPDN).The role of the IWF depends on the type network to which it interfaces and user data.
- Home location register (HLR): HLR consists of a stand-alone computer without switching capabilities, and maintain a database which contains subscriber information, and information related to the subscriber's current location, but not the actual location of the subscriber. A subdivision of HLR is the authentication center (AUC). The AUC manages the security data for subscriber authentication. Another sub-division of HLR is the equipment identity register (EIR) which stores the data of mobile equipment (ME) or ME-related data.
- Visitor location register (VLR): Links to one or more MSCs, temporarily storing subscription data currently served by its corresponding MSC, and holding more detailed data than the HLR. For example, the VLR contains more current subscriber location information than the location information at the HLR.
- Gateway MSC (GMSC): To set up a requested call, the call is firstly routed to a gateway MSC, and then GMSS finds the correct HLR by identifying the directory number of the GSM user. The GMSC has an interface with the external network for gatewaying the signal.
- Signaling transfer point (STP): STP is an essential requirement of the NSS to function itself as a stand-alone node. STP reduces the cost of the signaling transport among MSC/VLR, GMSC, and HLR.

5.3.4 Operation Subsystem:

Operation subsystem contains following three areas as shown in figure 5.1

1. Network operation and maintenance functions
2. Subscription management (charging and billing)
3. Mobile equipment management.

These tasks require interaction between some or all of the infrastructure equipment. OSS is implemented in any existing network.

5.4 Layer modeling (OSI Model)

The open system interconnection (OSI) of GSM consists of five layers as transmission (TX), radio resource (RR) management, mobility management (MM), communication management (CM) and operation administrator and maintenance (OAM) as shown in figure 5.2.

- The transmission layer make the connection between MS and BTS
- The RR Layer manages the transmission over the radio interface and provides the stable link between MS and BSC.
- MM layer manages the subscriber information and authentication activity.
- The CM layer manages call control, supplementary services management and short message service(SMS)

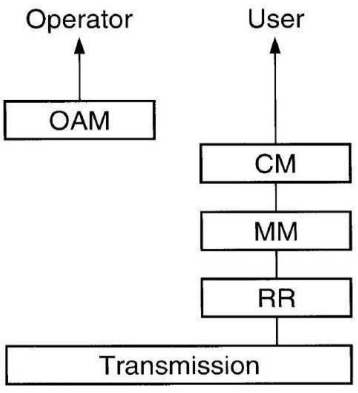

Figure 5.2 Functional planes of GSM

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5.5 GSM Channel Structure:

GSM has four radio transmission modes a speech mode and three data modes for services offered to users. The radio transmission modes use the physical channels.

➢ **Physical Channels:**

Physical channels are used to carry either digitally encoded user speech or user data in uplink and downlink direction. There are three types of physical channels and it is also called traffic channels (TCHs):

1. TCH/F (full rate): Transmits a speech code of 13 kbps or three data-mode rates, 12, 6, and 3.6 kbps.
2. TCH/H (half rate): Transmits a speech code of 7 kbps or two data modes, 6 and 3.6 kbps.
3. TCH/8 (one-eighth rate): Used for low-rate signaling channels, common channels, and data channels.

➢ **Logic channels:**

Logical channels are also known as control channels. Control channels carry signaling and synchronizing commands between base station and mobile station. Types of logic channels are as follows:

1. Common channels:

All the common channels are combined in different traffic channels. All channels are grouped by the same cycle (51 × 8 BP), where BP is the burst period i.e. time slot. The value of BP is 577 µs.

2. Downlink common channels:

There are five downlink unidirectional channels, shared or grouped by a TCH.

- Frequency correction channel (FCCH) repeats once every 51×8 BPs; used to identify a beacon frequency.
- Synchronization channel (SCH) follows each FCCH slot by 8 BPs.
- Broadcast control channel (BCCH) is broadcast regularly in each cell and received by all the mobile stations in the idle mode.
- Paging and access grant channel (PAGCH) is used for the incoming call received at the mobile station. The access grant channel is answered from the base station and allocates a channel during the access procedure of setting up a call.
- Call broadcast channel (CBCH)**:** Each cell broadcasts a short message for 2s from the network to the mobile station in idle mode. Half a downlink TCH/8 is used and special CBCH design constraints exist because of the need for sending two channels (CBCH and BCCH) in parallel.
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3. Uplink common channels:

The random-access channel (RACH) is the only one common uplink channel. RACH is the channel that the MS chooses to access the calls. There are two rates: RACH/F (full rate, one-time slot every 8 BP), and RACH/H (half rate, using 23-time slots in the 51 × 8 BP cycle, where 8 BP cycle is 4.615ms).

4. Signaling channels:

All the signaling channels have chosen one of the physical channels, and the logical channels names are based on their logical functions.

5. Slow Associated Control Channel (SACCH):

A slow-rate TCH used for signaling transport and used for non-urgent procedures, mainly handover decisions. It uses one-eighth rate. The TCH/F is always allocated with SACCH. This combined TCH and SACCH is denoted TACH/F.SACCH occupies 1-time slot (0.577 ms) in every 26 frames (4.615ms × 26).

6. Fast Associated Control Channel (FACCH):

Indicates cell establishment, authenticates subscribers, or commands a handover.

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7. Stand-alone Dedicated Control Channel (SDCCH):

Sometimes the connection between a mobile station and the network is used for passing signaling information only and not for calls. This connection may be at the user's demand or for other management operations such as updating the unit's location. SDCCH operates at a very low rate and uses a TCH/8 channel. Radio slots are assigned to users only when call penetration is required. There are two modes channel modes one is dedicated and another one idle. The use of channel mode depends on the uplink and the downlink. In GSM the uplink is the signal transmitted in the opposite direction and the downlink is the signal transmitted from the BS to the MS.

8. Voice/data channels:

Each time slot of a voice channel consists of 260 bits per block. The whole block having 316 bits. Each time slot of a data channel having 120 or 240 bits per block.

5.6 GSM Channel modes

The different types of GSM channel modes are as follows

1. Channel modes: Due to the radio spectrum limitation, individual users cannot have their own traffic control channel always.
2. Dedicated mode: In dedicated mode traffic channels are used during call establishment and SACCH to perform location updating. TCH and SACCH are dedicated channels for both uplink and downlink channels.
3. Idle mode: During non-call activities, the five downlink channels are in the idle mode: FCCH; SCH; BCCH, which is regularly broadcasting. PAGCH and CBCH, which sends one message in every 2 seconds. During idle channel mode of operation the mobile station listens to the common downlink channels, and also uses SDCCH (uplink channel) to register a mobile location associated with a particular base station to the network.

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5.7 Multiple Access Scheme:

GSM is a combination of TDMA and FDMA. The total 124 channels are present in FDMA, and each is 200 kHz. Both the 935–960MHz uplink and 890– 916 MHz downlink have been allocated 25 MHz, for a total of 50 MHz duplex separation is 45 MHz. If TDMA is used within a 200-kHz channel, 8 time slots are required to form a frame, frame duration is 4.615 ms, and the time slot duration burst period is 0.577ms.

- **Frequency Hopping:** GSM using a slow frequency-hopping spread spectrum technique for radio interface. The slow hopping is defined in terms of bits per hop. Hopping rate of CDMA is 217 hops/s, if the transmission rate is 270 kbps then hopping rate will be around 1200 bits/hop. If the PAGCH and the RACH were hopping channels, then hopping sequences could be broadcast on the BCCH. The common channel is forbidden from hopping and using the same frequency.
- **Different Types of Time Slots:** In CDMA system every cell provides a reference clock, using this reference clock the time slots are defined. Each time slot is given a number (TN) which is known by the base station and the mobile station. The time slot numbering is cyclic.
- **Bursts and Training Sequences:** In TDMA, the signal transmits in form of bursts. The time interval of the burst brings the amplitude of a transmitted signal up from a starting value of 0 to its normal value. Then a packet of bits is sent by a modulated signal and after transmission of the amplitude decreases to zero. These bursts occur only at the mobile station transmission or at the base station when the adjacent burst is not transmitted. Each burst contains tail bits and training sequence. The tail bits are three 0 bits added at the beginning and at the end of each burst which provides the guard time. The training sequence is a sequence known by the receiver that trains an equalizer, a device that reduces inter-symbol interference. The training sequence bits are inserted in the middle of a time slot to mitigate inter-symbol interference

5.8 Code-Division Multiple Access (CDMA)

CDMA is the basis for many of the commercial 2G cellular systems around the worlds and used in many types of communications systems like personal communication system (PCS), fixed wireless, global

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positioning system (GPS). CDMA is also known as IS-95. CDMA used different codes for separation. CDMA reduce the interference by using spread-spectrum modulation. The power control scheme in a CDMA system is a requirement for digital cellular application.

5.9 Terms of CDMA Systems:

- Active set: The set of pilots associated with the CDMA channels containing forward traffic channels assigned to a particular mobile station (MS).
- CDMA channel number: An 11-bit number corresponding to the center of the CDMA frequency assignment.
- Code channel: Code channel is a sub channel of a forward CDMA channel. A forward CDMA channel having 64 code channels. Some code channels are assigned to different logic channels.
- Code symbol: It is the output of an error-correcting encoder.
- Dim-and-burst: A frame in which the primary traffic is multiplexed with either secondary traffic or signal traffic. It is similar to the blank-and-burst function in AMPS.
- Forward CDMA channel: It is a channel which used for communication and having one or more code channels.
- Frame: A basic timing interval in the system. For the access channel, paging channel, and traffic channel, a frame is 20-ms long. For the sync channel, a frame is 26.666-ms long.
- Frame offset: A time skewing of traffic channel frames from system time in integer multiples of 1.25ms. The maximum frame offset is 18.75ms.
- GPS (Global Position System): System used for providing location and time information to the CDMA system.
- Handoff (HO): The act of transferring communication with a mobile station from one base station to another.
- Layering: A technique of organization of communication protocols is known as layring.
- Long code: A PN (pseudo noise) sequence with period using a tapped n-bit shift register.
- Modulation symbol: The output of the data modulator before spreading is known as modulation symbole. There are 64 modulation symbols on the reverse traffic channel. In CDMA 64-ary orthogonal modulation is used, and six code symbols are associated with one modulation symbol.

5.10 Modulation Characteristics

The reverse CDMA channel is composed of access channels and reverse traffic channels. Since the MS does not establish a system time as at the BS. The reverse channel signal received by the BS cannot use coherent detection for demodulation. So the modulation techniques for the reverse channel and forward channel are different. The modulation of the reverse channel is 64-ary orthogonal modulation at a data rate of 9600, 4800, 2400, or 1200 bps. The forward CDMA channel consists of following channels

1. Pilot Channel
2. The sync channel
3. Paging channel
4. Forward traffic channels

The actual burst transmission rate is fixed at 28,800 code symbols/ second. This results in a fixed Walsh chip rate of 307.2 thousand chips per second (kcps). Every Walsh chip is spread by 4 PN chips. The rate of the spreading PN sequence is fixed at 1.2288 million chips per second (mcps).

5.11 Call Processing

Mobile station call processing in CDMA consists of following states:

1. MS initialization state
2. MS idle state
3. System access state
4. MS control on traffic channel state

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- MS initialization state:
  - MS selects the system to be used
  - Selection of pilot channel of CDMA system within 20 ms
  - Obtain timing and system configuration information of CDMA system.

- MS idle state: In MS idle state MS performs the paging channel monitoring procedures and maintain all active registration timers.

- System access state: In this state, MS sends a message to the BS on the access channel, and from BS it receives massages through paging channel this process called access attempt.

- MS control on traffic channel state: MS communicate with BS through reverse and forward traffic channel and perform following functions
  - MS verifies the transmission and reception of traffic channels.
  - Wait for an order information message with alert
  - Wait for the answer of call by user.
  - After the completion of communication disconnects the call.

5.12 Handoff Procedures

The MS continuously searches for pilots to detect the availability of other CDMA signals that are on the same carrier frequency and measures or calculate the pilot strength. When the mobile station detects a pilot of sufficient strength which is not associated with the serving cell. Then MS sends a message to the serving base station. The cellular network decides which neighbor base stations can be involved in a handoff and selects an idle Walsh function associated with the selected site, effectively selecting a traffic channel. Types of handoff of CDMA are as follows:

- Soft Handoff

The condition where two cells are in simultaneous communication with the mobile is called Soft Handoff. MS make communication with new BS without disturbing communication with old BS. Same frequency is assigned in soft handoff between old and new BS.

- CDMA to CDMA hard handoff

Different frequency assignment is done for two BS for the transmission by MS.

- Softer Handoff

Softer Handoffs entail the simultaneous serving of a mobile unit by two sectors within same cell.

- CDMA to Analog Handoff

If no CDMA channel is available for handoff, then the call would be handed off to an available analog channel at the serving base station and switched to the analog mode of processing.MS directed to an analog channel with different frequency.

5.13 Time division duplexing (TDD) systems

TDD systems refer to digital systems where uplink is separated from downlink by the use of different time slots in same frequency band for information transfer. There are two types of TDD systems

1. TDD/FDMA: Only one user is served by each carrier
2. TDD/TDMA: the Single carrier can serve many users with different time slots.

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