UNIT-V

Multiple Access Techniques

- *To allow many mobile users to share simultaneously a finite amount of radio spectrum, in a most efficient way, various technologies have been developed and the goal behind these methods is to handle as many calls as possible in a given bandwidth (i.e., call-handling capacity). This concept is called "multiple access"*

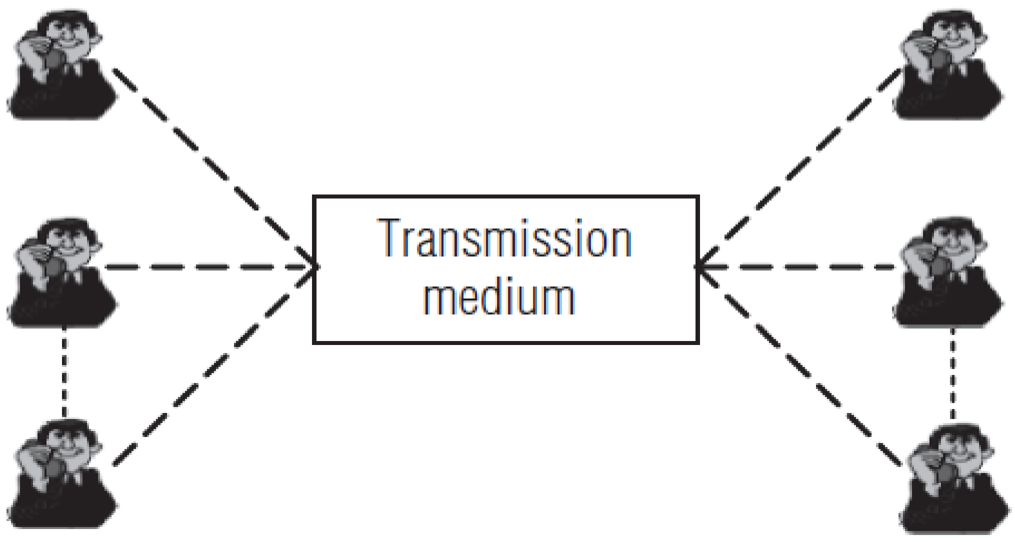


Figure 16.1 Multiple access scenario

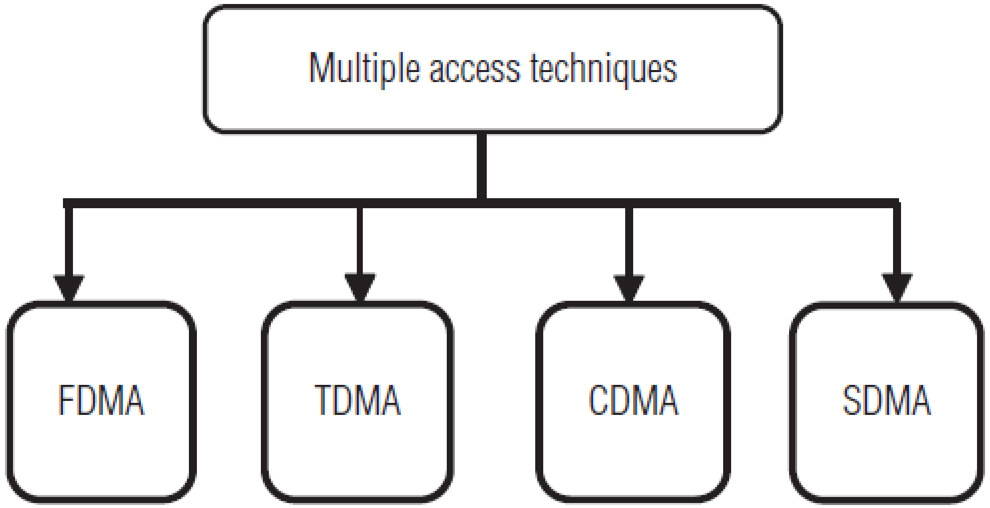
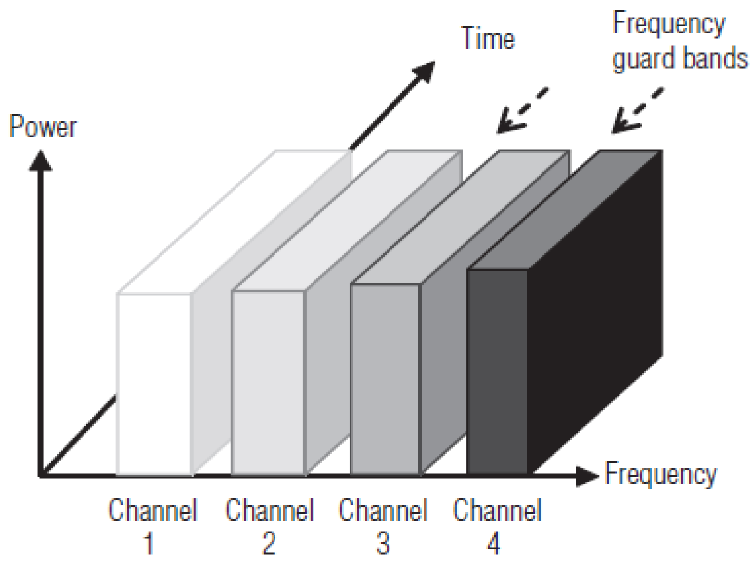


Figure 16.2 Multiple access techniques

FDMA

- *The FDMA is the simplest scheme used to provide multiple access in analogue transmission. In FDMA systems, the radio frequency spectrum is divided into several frequency bands separated by a certain guard band. Each frequency band can be used simultaneously.*
- In this technique, the bandwidth is divided into a number of channels and distributed among users with a finite portion of bandwidth for permanent use as illustrated in Figure

•FDMA permits only one user per channel because it allows the user to use the channel 100 per cent of the time.



- Frequency guard bands are provided between adjacent signal spectra to minimize crosstalk between adjacent channels.
- In FDMA, the channel has two frequencies, namely forward channel and reverse channel.
- When the FDMA technique is employed, as long as the user is engaged in “conversation,” no other user can access the same spectrum space.

Number of channels supported in FDMA system.

$$\text{Number of channels } (N) = \frac{B_t - 2B_g}{B}$$

where

B_t is the allocated frequency spectrum

B_g is the guard band allocated at the edge of frequency spectrum

B_c is the channel bandwidth

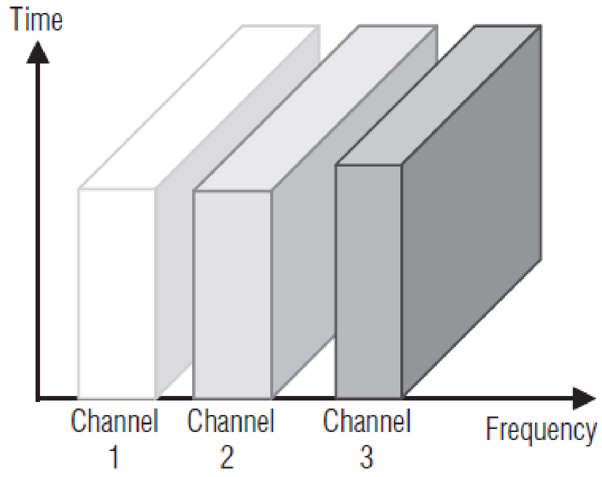


Figure : Time and bandwidth occupancy of three user signals with FDMA

Example problem:

If each cellular carrier is allocated N number of channels and *the allocated frequency spectrum is 12.5 MHz*, guard band is 10 KHz and the bandwidth of each channel is 30 KHz. Find the total number of channels provided by the cellular carrier.

Solution

From Equation (16.1)

$$\text{Number of channels } (N) = \frac{B_t - 2B_g}{B_c}$$

$$\text{Number of channels } (N) = \frac{[(12.5\times10^6) - 2(10\times10^3)]}{30\times10^3} = \mathbf{416}$$

Example problem:

In the United States, the advanced mobile phone service (AMPS) cellular operator is allocated 15 MHz for each simplex band, and if B_t is 10 MHz, B_g is 10 KHz, and B_c is 25 KHz. Find the number of channels available in an FDMA system.

Solution

The number of channels available in the FDMA system is given as

$$N = \frac{B_t - 2B_g}{B_c}$$

$$N = \frac{10 \times 10^6 - 2(10 \times 10^3)}{25 \times 10^3} \approx 399$$

In the United States, each cellular carrier is allocated **399** channels.

Advantages, disadvantages, and applications of FDMA:

Advantages:

- 1. A continuous transmission scheme, and therefore of lower complexity than TDMA scheme, for example, synchronization requirements are not severe
- 2. Simple to implement from a hardware standpoint, because multiple users are isolated by employing simple band pass filters
- 3. Fairly efficient with a small base population and when traffic is constant
- 4. No channel equalization required
- 5. Capacity can be increased by reducing the information bit rate and using an efficient digital speech coding scheme

Disadvantages

1. If an FDMA channel is not in use, then it sits idle and cannot be used by other users to increase or share the capacity. Therefore, FDMA implementation becomes *inefficient use of spectrum*.
2. FDMA requires tight RF filtering to minimize adjacent channel interference.
3. Network and spectrum planning are intensive.
4. Frequency planning is time consuming.
5. Even though no two users use the same frequency band at the same time, guard bands are introduced between frequency bands to minimize adjacent channel interference. Guard bands are unused frequency slots that separate neighbouring channels. This leads to a waste of bandwidth. When continuous transmission is not required, bandwidth goes wasted since it is not being utilized for a portion of the time.

Applications of FDMA

1. Walkie-talkies and mobile networks for closed user groups often use FDMA.
2. Another example of FDMA is AM or FM radio broadcasting, where each station has its own channel.
3. Early cellular telephony mostly used FDMA analogue transmission.

TDMA

- TDMA systems were developed as FDMA system spectrum efficiency became insufficient. In digital systems, continuous transmission is not required because users do not use the allotted bandwidth all the time. It allows several users to share the same frequency band by dividing the timescale into different time slots which are periodically allocated to each mobile user for the duration of a call.
- *TDMA systems have the capability to split users into time slots because they transfer digital data, instead of analogue data commonly used in legacy FDMA systems.*

TDMA

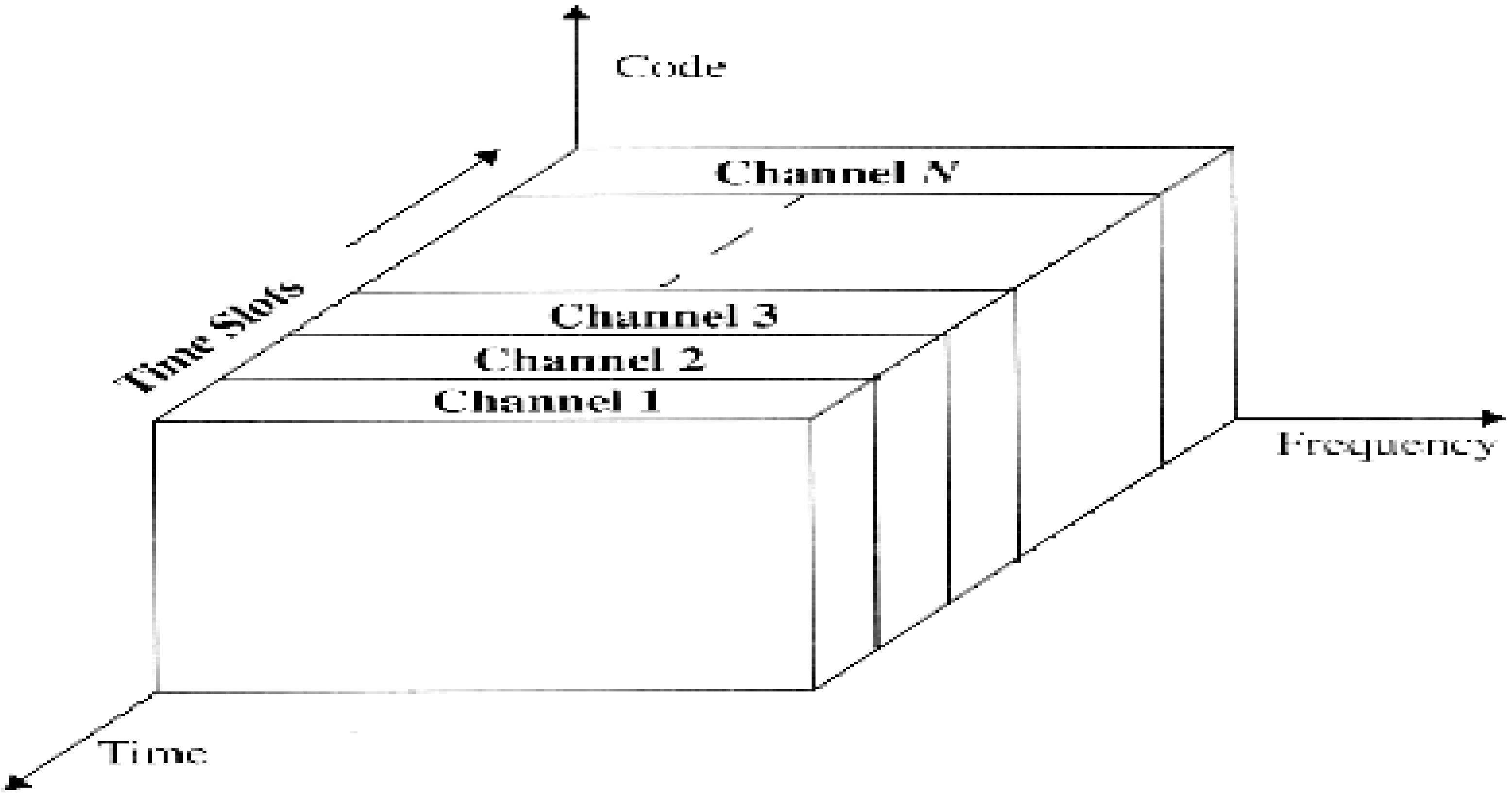


Figure 9.3 TDMA scheme where each channel occupies a cyclically repeating time slot.

TDMA principle of operation

- *TDMA systems divide the radio spectrum into time slots and each user is allowed to either transmit or receive in each time slots (i.e., different users can use the same frequency in the* same cell but at different times).

In TDMA, when the caller depresses the push-to-talk (PTT) switch, a control channel registers the radio to the closest base station. During registration, the base station assigns the user an available pair of channels, one to transmit and the other to receive. However, unlike an FDMA system registration, a TDMA system registration also assigns an available time-slot within the channel. The user can only send or receive information at that time, regardless of the availability of other time-slots. Information flow is not continuous for any user, but rather is sent and received in bursts. The bursts are re-assembled at the receiving end and appear to provide continuous sound because the process is very fast.

TDMA principle of operation

- *TDMA systems divide the radio spectrum into time slots and each user is allowed to either transmit or receive in each time slots* (i.e., different users can use the *same frequency* in the same cell but at different times).
- **Each user occupies a cyclically repeating time slot,**
- *A channel may be thought of as particular time slot that reoccurs every frame, where N time slots comprise a frame.*
- **Transmit data in a buffer-and-burst method, the transmission for any user is noncontinuous.**
- *digital data and digital modulation must be used with TDMA.*

Number of users supported by TDMA illustrates that the FDMA system supports 4 users while the TDMA system supports 12 users within the same bandwidth as the FDMA system

Number of users supported by the TDMA system

= Number of channels in the frequency spectrum × Time slots/channel = 4 × 3 = 12

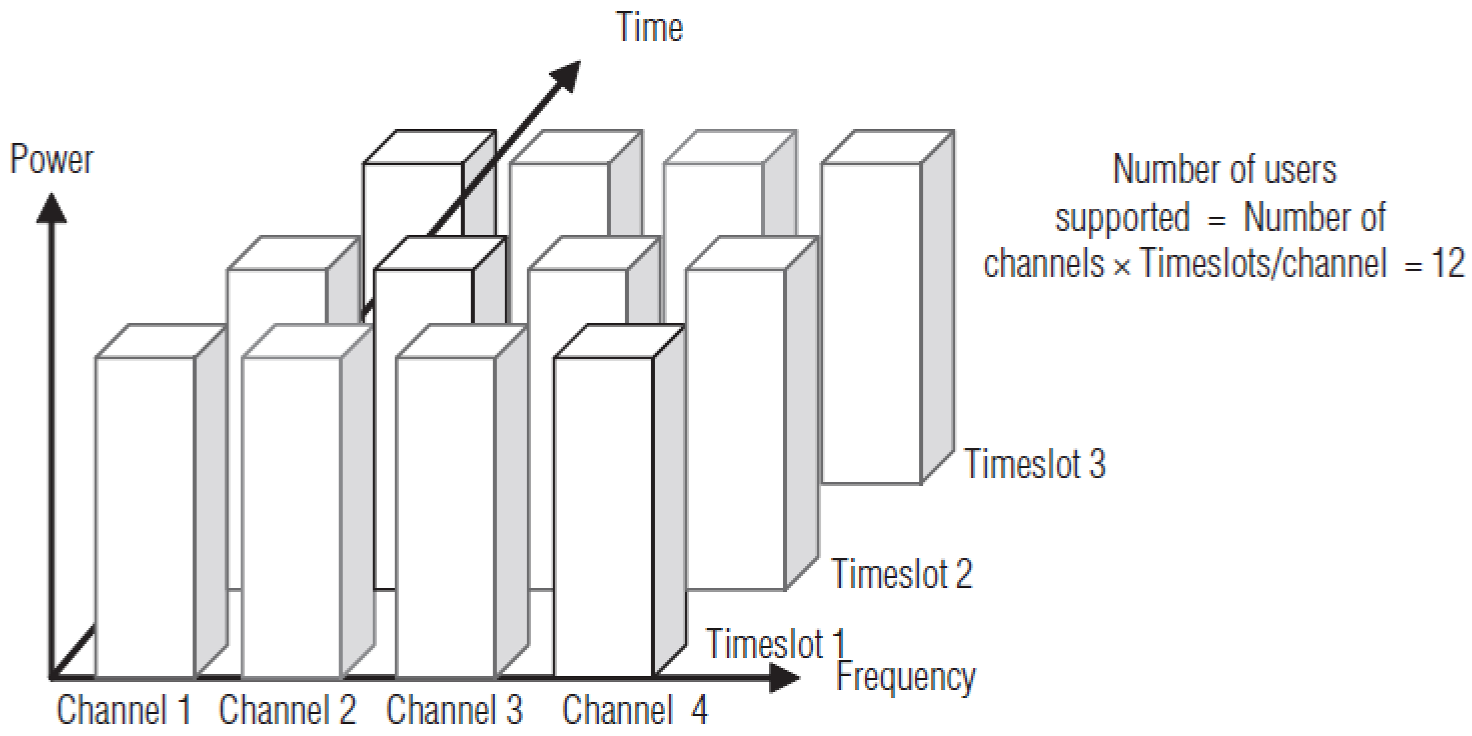


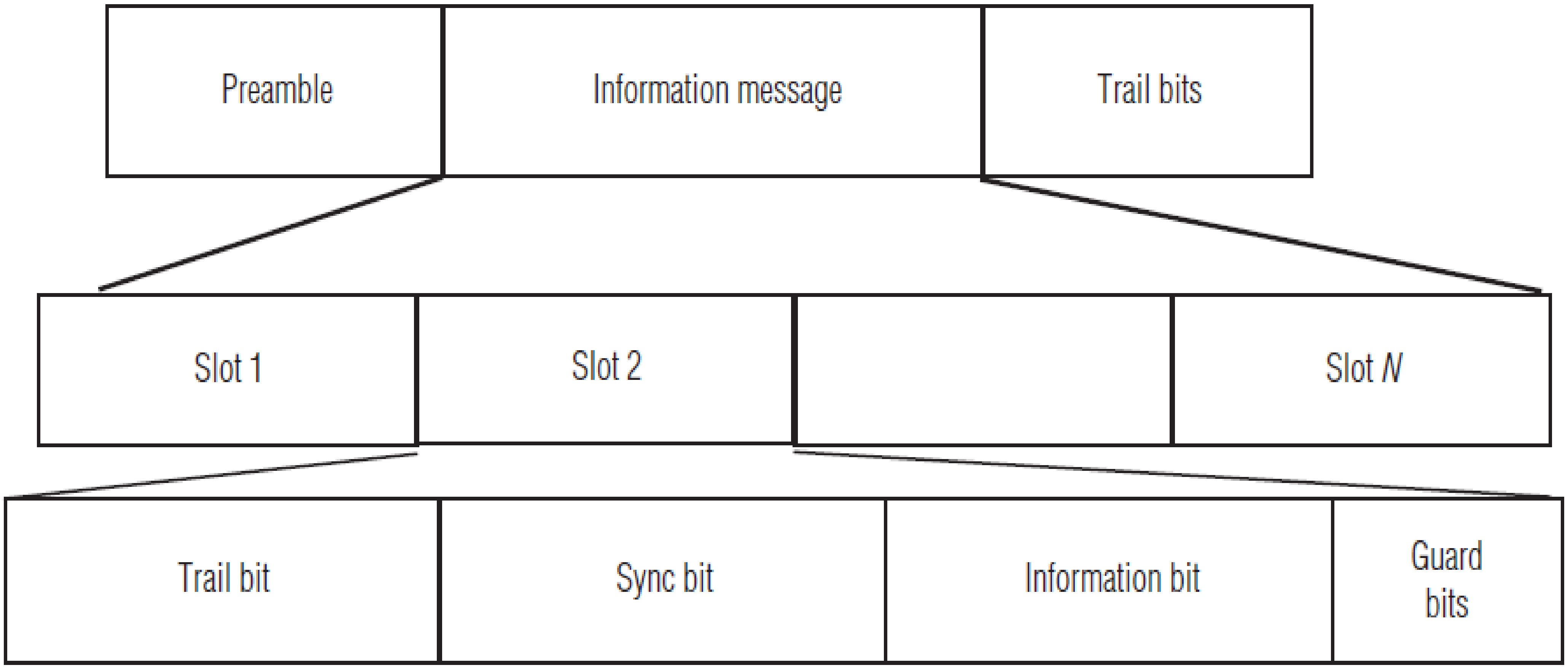
Figure: TDMA principle of operation

TDMA frame structure

In a TDMA system, time is divided into equal time intervals called *slots*. User data is transmitted in the slots. Several slots make up a frame. Guard times are used between each user's transmissions to minimize crosstalk between channels (Figure 16.17).

Each user is assigned a frequency and a time slot to transmit data. The data is transmitted via a radio-carrier from a base station to several active mobiles in the downlink. In the reverse direction (uplink), transmission from mobiles to base stations is time-sequenced and synchronized on a common frequency for TDMA. The preamble carries the address and synchronization information that both the base station and the mobile stations use for identification.

Figure: TDMA frame structure



Efficiency of TDMA

The efficiency of TDMA system is a measure of the percentage of transmitted data that contains information as opposed to providing overhead for the access scheme. The frame efficiency η is the percentage of bits per frame which contains transmitted data.

$$\text{Efficiency } (\eta) = \frac{\text{Number of bits per frame containing in the transmitted data}}{\text{Total number of bits per frame}} \qquad (16.5)$$

$$= \frac{(b_T - b_{OH})}{b_T} \times 100 = (1 - b_{OH} / b_T) \times 100$$

where

b_T is the total number of bits per frame $= T_f \times R$ (16.6)

T_f is the frame duration

R is the channel bit rate

b_{OH} is the number of overhead bits per frame $= N_r \times b_r + N_t \times b_p + N_t \times b_g + N_r \times b_g$ (16.7) where

- *Nr is the Number of reference bits per frame*
- *Nt is the number of traffi c bits per frame*
- *br is the number of overhead bits per reference burst*
- *bP is the number of overhead bits per reference in each slot*
- *bg is the number of equivalent bits in each guard time interval*

Number of channels/time slots in TDMA system

$$N = \frac{M(B_{\text{total}} - 2B_{\text{guard}})}{B_{\text{c}}} \quad (16.8)$$

where

M is the number of time slots per carrier channel or maximum number of TDMA users supported on each radio channel

B_g is the guard band to present user at the edge of the band

Advantages and disadvantages of TDMA

Advantages

- Data Transmission is in discrete bursts
  - Extended battery life over FDMA and talktime
  - Handoff process is simpler, since it is able to listen for other base stations during idle time slots
- More efficient use of spectrum, compared to FDMA
  - Will accommodate more users in the same spectrum space than an FDMA system which improves capacity in high-traffic areas, such as large metropolitan areas
  - Efficient utilization of hierarchical cell structures – pico, micro, and macro cells
- Since different slots are used for transmission and reception, duplexers are not required

Disadvantages

- TDMA requires synchronization. If the time slot synchronization is lost, the channels may collide with each other.
- For mobiles and, particularly for handsets, TDMA on the uplink demands high-peak power in transmit mode that shortens battery life. If a TDMA interface consists of n channels, then the transmitted powers are 10 log n times higher than in an FDMA system.
- Network and spectrum planning are intensive.
- Dropped calls are possible when users switch in and out of different cells.
- Higher costs due to greater equipment sophistication.
- Equalization is required, since transmission rates are generally very high as compared to FDMA channels.

Example problem

If a normal GSM timeslot consists of 6 trailing bits, 8.25 guard bits, 26 training bits, and 2 traffic bursts of 61 bits of data, find the frame efficiency

Solution

Number of bits in a time slots = 6 + 8.25 + 26 + 2(61) = 162.25 bits.
Number of bits in Frame = 8 × 162.25 = 1,298 bits/frame.
The number of overhead bits per frame is given by

$$b_{OH} = 8(6) + 8(8.25) + 8(26) = 322 \text{ bits}$$

Frame efficiency, η = (1,298 – 322)/1,298 × 100 = 75.192 per cent

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Example problem 16.5

Consider a GSM system, which is in TDMA/FDD system that uses the 30 MHz forward link, which is broken into number of channels of 240 kHz. If eight speech channels are supported on a single radio channel and if no guard band is assumed, find the number of simultaneous users that can be accommodated in GSM.

Solution

The number of simultaneous users that can be accommodated in GSM is

$$N = \frac{30\times10^6}{(240\times10^3/8)} = 1{,}000$$

Thus, GSM can accommodate 1,000 simultaneous users.

- Example problem:

If normal GSM time slot consists of 6 trailing bits, 8.50 guard bits, 28 training bits, and 2 traffic burst of 58 bits of data, find the frame efficiency.

Solution

A time slot has $6 + 8.50 + 28 + 2(58) = 158.5$ bits

A frame has $8 \times 158.50 = 1268$ bits/frame

The number of overhead bits per frame is given by $b_{OH} = 8(6) + 8(8.5) + 8(28) = 340$ bits

The frame efficiency $\eta = \left(1 - \frac{340}{1268}\right) \times 100 = 73.19\%$

Features of TDMA:

- **TDMA shares a single carrier frequency with several users, where each user makes use of nonoverlapping time slots. The number of time slots per frame depends on several factors, such as modulation technique, available bandwidth, etc.**
- **Data transmission for users of a TDMA system is not continuous, but occurs in bursts. This results in low battery consumption, since the subscriber transmitter can be turned off when not in use (which is most of the time).**
- **Because of discontinuous transmissions in TDMA, the handoff process is much simpler for a subscriber unit, since it is able to listen for other base stations during idle time slots. An enhanced link control, such as that provided by mobile assisted handoff (MAHO) can be carried out by a subscriber by listening on an idle slot in the TDMA frame.**
- **TDMA uses different time slots for transmission and reception, thus duplexers are not required. Even if FDD is used, a switch rather than a duplexer inside the subscriber unit is all that is required to switch between transmitter and receiver using TDMA.**

Features of TDMA (continued):

- **Adaptive equalization is usually necessary in TDMA systems, since the transmission rates are generally very high as compared to FDMA channels.**
- **In TDMA, the guard time should be minimized. If the transmitted signal at the edges of a time slot are suppressed sharply in order to shorten the guard time, the transmitted spectrum will expand and cause interference to adjacent channels.**
- **High synchronization overhead is required in TDMA systems because of burst transmissions. TDMA transmissions are slotted, and this requires the receivers to be synchronized for each data burst. In addition, guard slots are necessary to separate users, and this results in the TDMA systems having larger overheads as compared to FDMA.**
- **TDMA has an advantage in that it is possible to allocate different numbers of time slots per frame to different users. Thus bandwidth can be supplied on demand to different users by concatenating or reassigning time slots based on priority.**

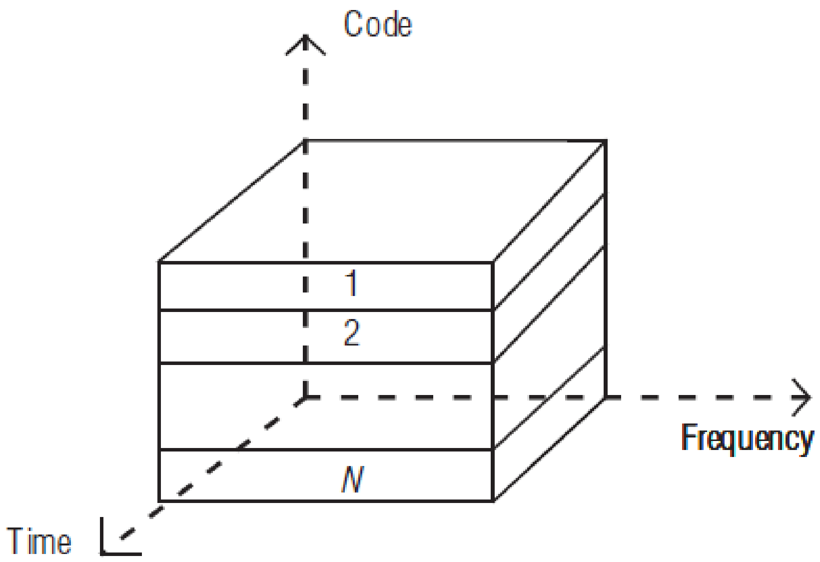
Code division multiple access

- CDMA allows transmissions to occupy the entire bandwidth at the same time without interference.
- *CDMA uses spread-spectrum technique to increase spectrum efficiency over current FDMA and TDMA systems.*
- A *spread-spectrum signal* is a signal that has an extra modulation that expands the signal bandwidth beyond what is required by the underlying data modulation. Spread-spectrum communication systems are useful for the following:

1. Suppressing interference
2. Making interception difficult
3. Accommodating fading and multipath channels
4. Providing a multiple-access capability

Code division multiple access

- CDMA cellular systems operate in the 800 MHz and 1.9 GHz PCS bands
- *QUALCOMM* is the developer of the CDMA air interface used in cellular systems
- Compared to GSM cellular systems, CDMA requires fewer cell towers and provides up to five times the calling capacity



CDMA principle of operation

- *CDMA assigns to each user a unique code sequence that is used to code data before transmission. If a receiver knows the code sequence related to a user, it is able to decode the received data.*
- The codes are called *Pseudorandom code sequences*
- A user's unique code separates the call from all other calls.
- The capacity of the system depends on the quality of current calls. *As more users are added, noise is added to the wideband frequency, therefore decreasing the quality of current calls*
- ***Types of codes used in CDMA***:

Walsh codes: These are orthogonal codes. The spreading on forward link is 1.2288 Mbps and on reverse link is 307.2 Kbps. 64-bit Walsh codes are used in IS 95A and IS 95B. 128-bit 1.Walshcodes are used in CDMA2000.

2.Short PRN code: (16 bit) are used to identify the base station and the cell.

3.Long PRN code : (42-bit code) are used to identify mobile station on reverse link.

- ***Advantages***
- Greatest spectrum efficiency: capacity increases about 8 to 10 times that of an analogue system and 4 to 5 times that of other digital systems, which makes it most useful in high traffic areas with a large number of users and limited spectrum.
- CDMA improves call quality by filtering out background noise, crosstalk, and interference.
- “Soft handoffs”: because of the multiple diversities in use, handoffs between cells are undetected by the user.
- Simplified frequency planning: all users on a CDMA system use the same radio frequency spectrum. Engineering detailed frequency plans are not necessary. Frequency re-tunes for expansion are eliminated. Fewer cells are required for quality coverage.
- Random Walsh codes enhance user privacy; a spread-spectrum advantage.
- Precise power control increases talk time and battery life for mobile phones.
- ***Disadvantages***
- Backwards compatibility techniques are costly.
- Currently, equipment is expensive.
- Difficult to optimize to maximize performance.
- Low traffic areas lead to inefficient use of spectrum and equipment resources.

Handoffs in CDMA mobile systems

- The act of transferring a call of from one base station to another is termed as handoff. Handoff occurs when a call has to be handed off from one cell to another as the user moves between cells.
- ***Hard handoff and soft handoff***
- In a traditional "hard" handoff, the connection to the current cell is broken and then the connection to the new cell is made. This is known as a "break-before-make" or hard handoff.
- Since all cells in CDMA use the same frequency, it is possible to make the connection to the new cell before leaving the current cell. This is known as a "make-before-break" or "soft handoff".
- Soft handoff requires less power, which reduces interference and increases capacity. The implementation of handoff is different in GSM and CDMA standards.

Near-far problem

- The near far problem occurs when two or more DSSS transmitters transmit the signals towards the same DSSS receiver as shown in Figure

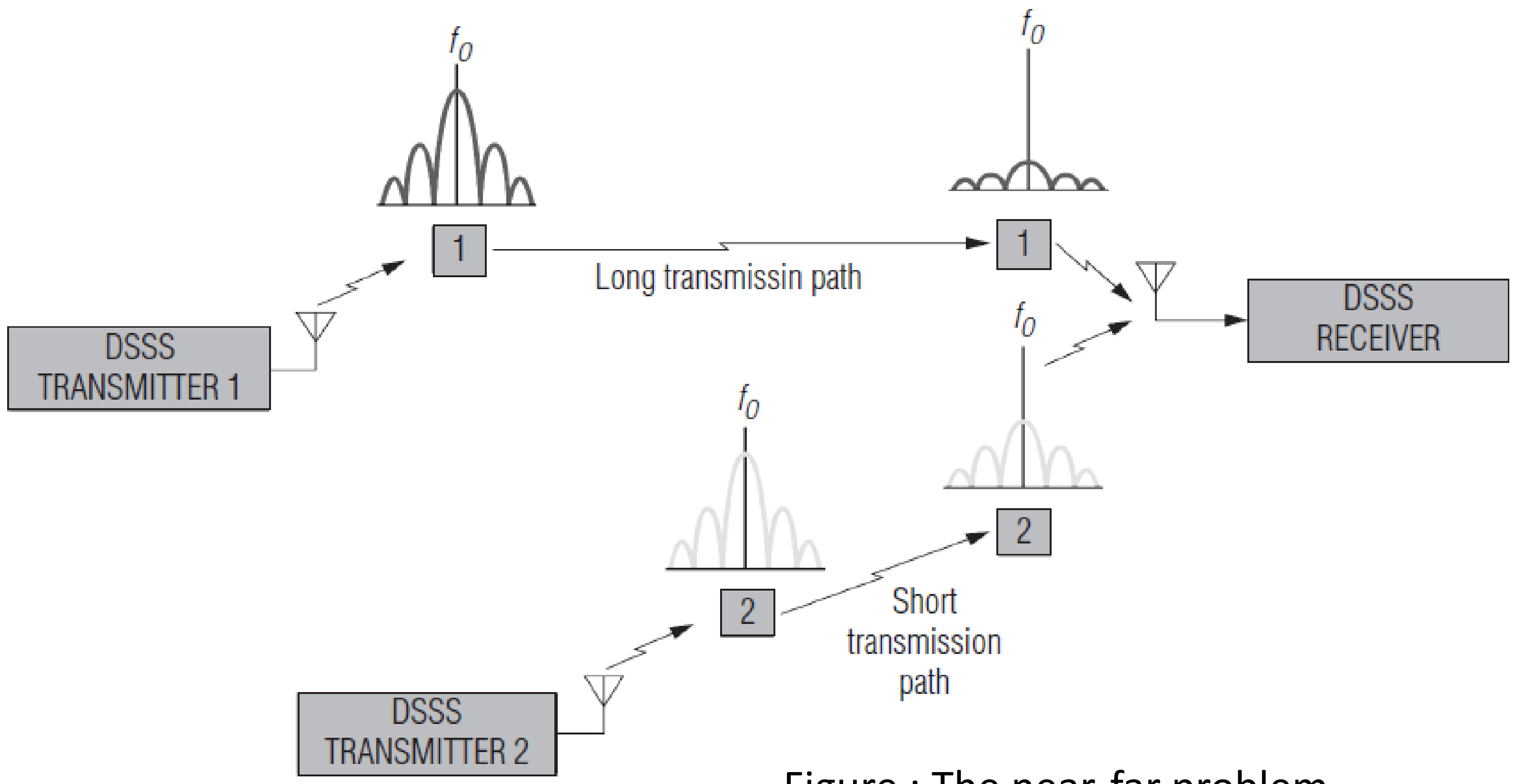


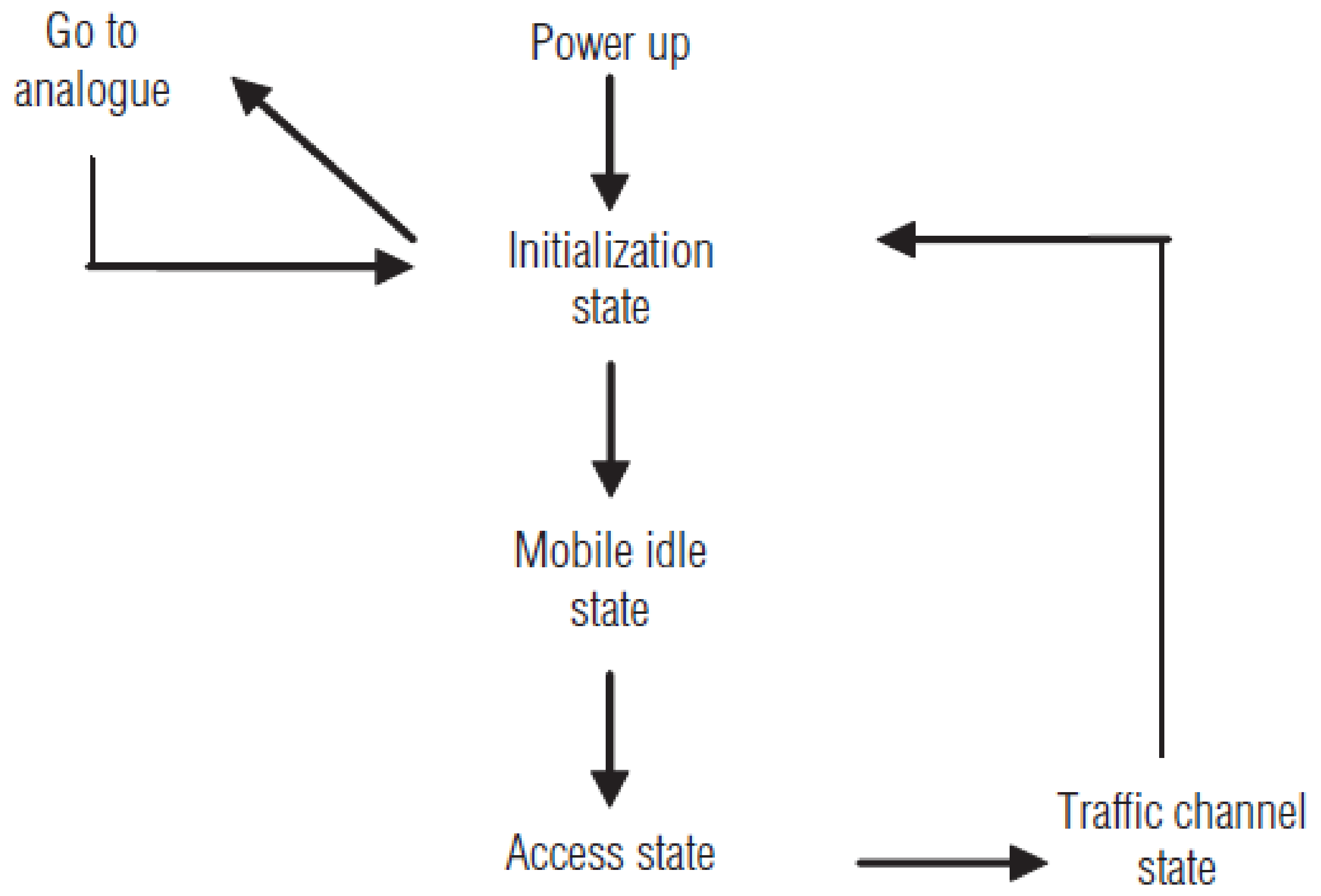
Figure : The near-far problem

Near-far problem contd------

- In this figure, two DSSS transmitters transmit the signals towards a DSSS receiver, one transmitter being closer to the receiver than the other transmitter. The power of the two spread-spectrum signals transmitter is the same at the antenna of each DSSS transmitter.
- However, the two spread-spectrum signals at the DSSS receiver antenna have different power levels because the paths between the two transmitters and the receiver are of different lengths.
- The power of the spread-spectrum signal coming from DSSS transmitter 1 is lower than that coming from DSSS transmitter 2 because transmitter 1 is farther away from the receiver than transmitter 2.
- Any spread spectrum signal other than the desired one produces interference similar to that caused by noise, this results in a rather poor *S/N ratio at the DSSS receiver input. Consequently, errors are likely* to appear in the recovered data when the process gain of the system is not sufficient to overcome the *S/N ratio deficit observed at the DSSS receiver input.*

Call processing in the CDMA mobile phones

- Figure shows the basic call-processing loop



- After power up, the initialization state determines which system to use (whether analogue or CDMA).
- If it is CDMA, it goes into sync processing. Once the system is synchronized, the system goes into the mobile station idle state, where it monitors the paging channel.
- If a call is to be originated or the mobile is paged, the system goes into the access state.
- Once a call is setup, the phone moves over to the traffic channel state, where the forward and reverse traffic channels are used to communicate voice and messaging.
- During the idle state, the mobile will monitor the paging channel. Various messages pertaining to setup and operation are on the paging channel.

- Certain situations will trigger the mobile to drop out of the traffic state (drop the call on purpose):
- *Mobile ACK failure: Certain messages require an ACK (Acknowledge signal); generally, a* mobile will retransmit the message after 400 ms, but if no ACK comes after three tries, the mobile drops the call.
- *Base station ACK failure: This is similar to the mobile ACK failure, but it is not standardized.*
- *Mobile fade timer: The timer is set to 5 s after receiving two consecutive good frames. If the* timer gets to zero, the call drops.
- *Mobile bad frames: If there are 12 consecutive bad frames, the mobile drops the call.*
- *Base station bad frames: This is similar to mobile bad frames, but not standardized (i.e.,* manufacturers can implement this, however, they choose).

Approach	SDMA	TDMA	FDMA	CDMA
Idea	Segment space into cells/sectors	Segment sending time into disjoint time slots, demand driven or fixed patterns	Segment the frequency band into disjoint sub-bands	Spread the spectrum using orthogonal codes
Terminals	Only one terminal can be active in one cell/one sector	All the terminals are active for short periods of time on the same frequency	Every terminal has its own frequency, uninterrupted	All terminals can be active at the same place at the same moment, uninterrupted
Signal separation	Cell structure directed antennas	Synchronization in the time domain	Filtering in the frequency domain	Code plus special receivers
Advantages	Very simple, increases capacity per km^2	Established fully digital, very flexible	Simple established, robust	Flexible, less planning needed, soft handover
Disadvantages	Inflexible antennas typically fixed	Guard space needed (multi-path propagation), synchronization difficult	Inflexible frequencies are as scarce resource	Complex receivers, needs more complicated power control for senders
Comment	Only combination with TDMA, FDMA, or CDMA useful	Standard in fixed networks, together with FDMA/SDMA used in many mobile networks	Typically combined with TDMA (frequency hopping patterns) and SDMA (frequency reuse)	Used in many 3G systems higher complexity, lowered expectations; integrated with TDMA/FDMA

INTRODUCTION TO DIGITAL SYSTEMS

- Many digital cellular and cordless phone systems have been developed.
- The cellular systems are GSM, NA-TDMA, CDMA, and the cordless phone systems are DECT and CT-2 schemes.
- Although analog cellular systems are limited to using frequency division multiple-access (FDMA) schemes, **digital cellular systems can use FDMA, time division multiple-access (TDMA), and code-division multiple-access (CDMA).**
- When a multiple-access scheme is chosen for a particular system, all the functions, protocols, and network are associated with that scheme.

Global system for mobile

- GSM is most widely used and globally implemented digital cellular technology. It is used for transmitting data and mobile voice services.
- In GSM, time division multiple access (TDMA) technique is used for transmitting voice and data through air interface.
- CEPT, a European group, began to develop the Global System for Mobile TDMA system in June 1982.
- GSM has two objectives: pan-European roaming, which offers compatibility throughout the European continent, and
- interaction with the integrated service digital network (ISDN), which offers the capability to extend the single-subscriber-line system to a multiservice system with various services currently offered only through diverse telecommunications networks.

Basic Features Provided by GSM

- Call Waiting
  - Notification of an incoming call while on the handset
- Call Hold
  - Put a caller on hold to take another call
- Call Barring
  - All calls, outgoing calls, or incoming calls
- Call Forwarding
  - Calls can be sent to various numbers defined by the user
- Multi Party Call Conferencing
  - Link multiple calls together

Flexibility and increased capacity:

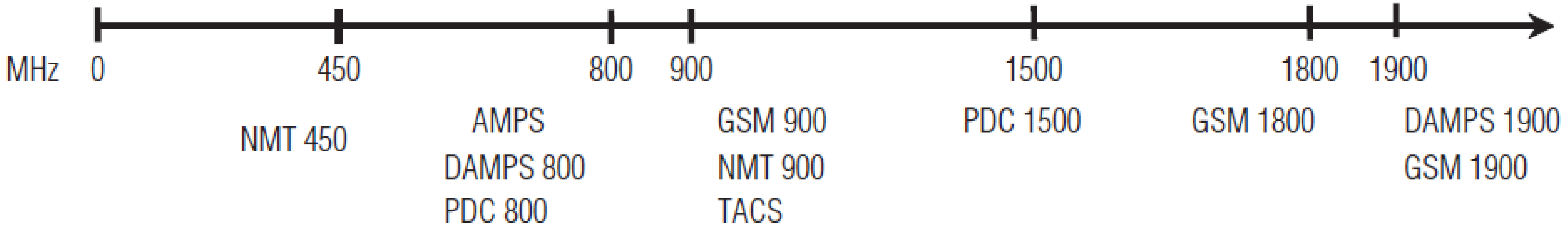
- GSM equipment is fully controlled by its software. Network re-configurations can be made quickly and easily with minimum manual intervention.
- new speech algorithms
- flexibility of *international roaming*.
- More carriers in a given area to give better frequency reuse.
- *Multi-band networks* and mobiles

Frequency, channel spacing, and transmission rate

- Television: 300 MHz approx.

 FM Radio: 100 MHz approx.

- Police radios: Country dependent
- Mobile networks: 300–2,000 MHz approx.
- The frequency used by mobile networks varies according to the standard being used.



- ***Transmission rate:-***The amount of information transmitted over a radio channel over a period of time is known as the transmission rate.In GSM, the net bit rate over the air interface is 270 kbps.
- **Improved security and confidentiality:-**With GSM, both the mobile equipment (ME) and mobile subscriber are identified. The ME has a unique number coded into it when it is manufactured.
  - This can be checked against a database every time the mobile makes a call to validate the actual equipment. The subscriber is authenticated by use of a smart card known as a SIM.
  - GSM also offers the capability to encrypt all signals over the air interface.
  - it makes it very diffi cult for the casual “hacker” to listen-in to personal calls.
  - In addition to this, the GSM air interface supports frequency hopping. This entails each “burst” of information being transmitted to/from the MS/base site on a different frequency, again making it very difficult for an observer (hacker) to follow/listen to a specific call.

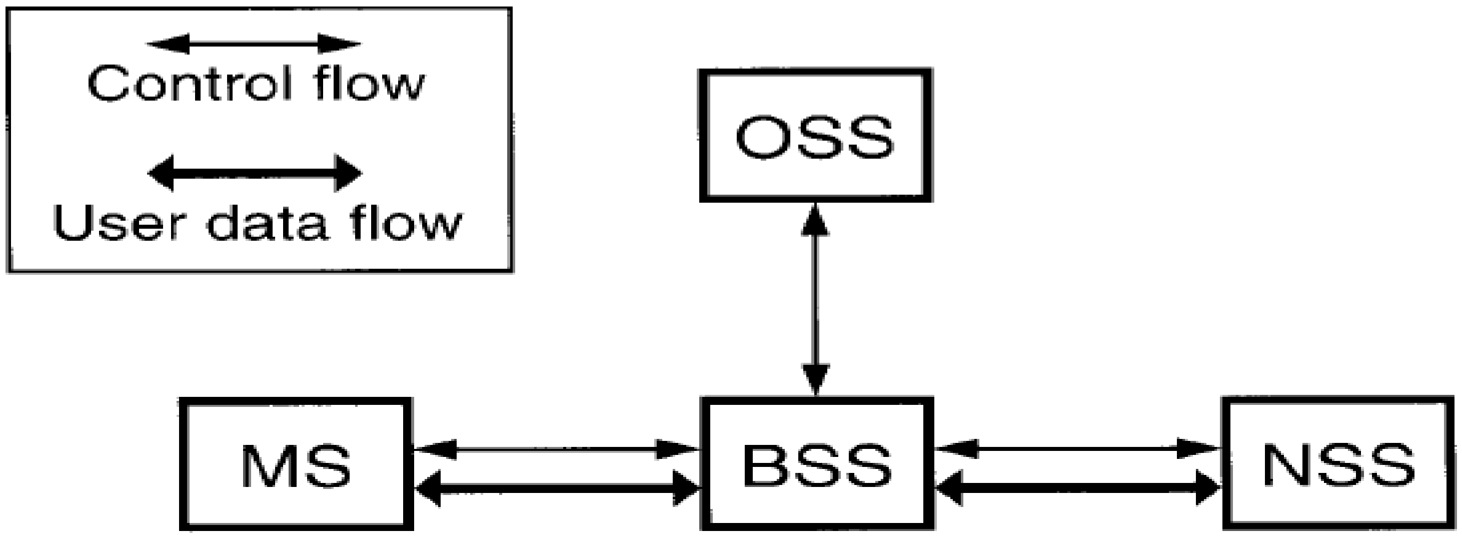
- **Flexible handover processes**
- **Switching and control**
- **Noise robust:-**In order to combat the problems caused by noise, GSM uses digital technology instead of analogue. By using digital signals, we can manipulate the data and include sophisticated error protection, detection, and correction software.
- **User services:- *Teleservices or telephony services:-***A teleservice utilizes the capabilities of a bearer service to transport data, defining which capabilities are required and how they should be set up. *Voice calls, Videotext and facsimile*
- ISDN compatibility in GSM
- ***Supplementary services***
    - *Short text messages* (SMS)*:*
    - *Multiparty service or conferencing*
    - *Call waiting*
    - *Call hold*
    - *Call forwarding*
    - *Call barring*
    - *Number identification*
    - **Advice of Charge**
    - **Closed User Groups**

Advantages of GSM over Analog system

- Capacity increases
- Reduced RF transmission power and longer battery life.
- International roaming capability.
- Better security against fraud (through terminal validation and user authentication).
- Encryption capability for information security and privacy.
- Compatibility with ISDN,leading to wider range of services

GSM Architecture

- GSM consists of many subsystems, such as the mobile station (MS), the base station subsystem (BSS), the network and switching subsystem (NSS), and the operation subsystem(OSS).



The Mobile Station.

- *The MS may be a stand-alone piece of equipment for certain* services.
- The MS includes mobile equipment (ME) and a subscriber identity module (SIM).
- ME does not need to be personally assigned to one subscriber.
- The SIM is a subscriber module which stores all the subscriber-related information.
- When a subscriber's SIM is inserted into the ME of an MS, that MS belongs to the subscriber, and the call is delivered to that MS.
- The ME is not associated with a called number—it is linked to the SIM.
- In this case, any ME can be used by a subscriber when the SIM is inserted in the ME.

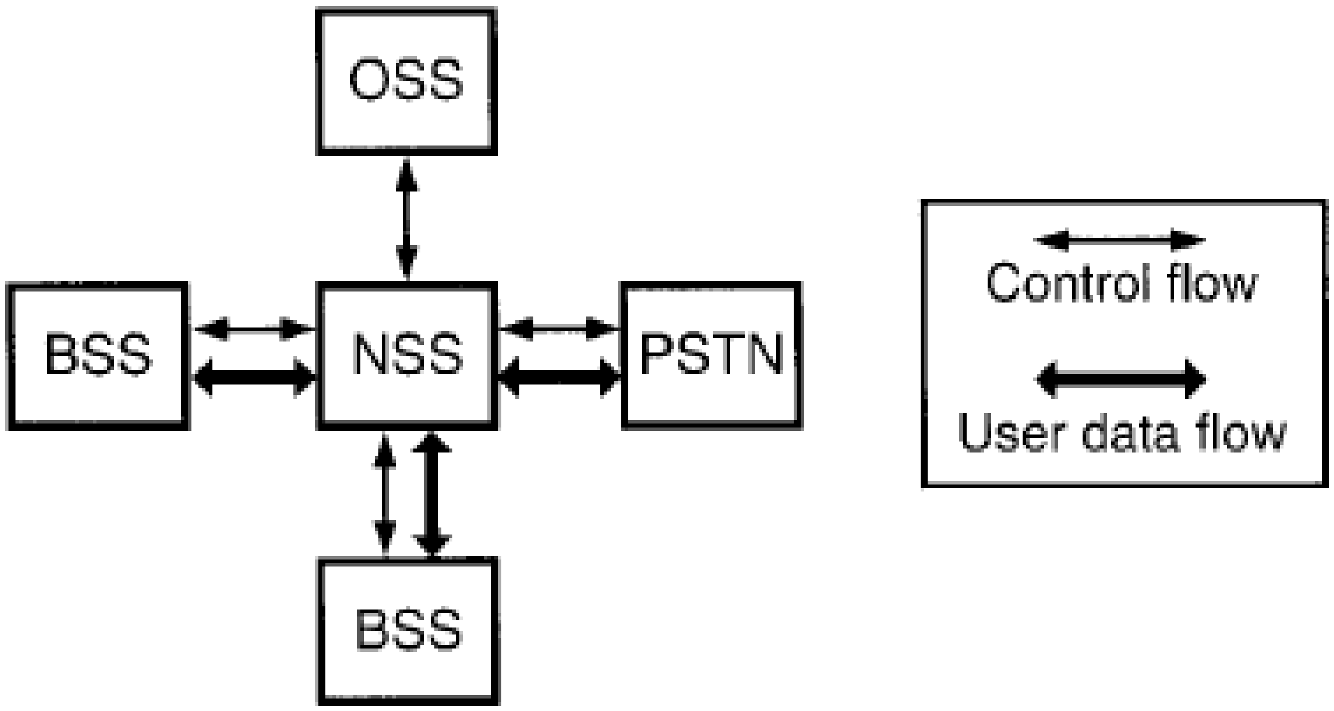
Base Station Subsystem.

- *The BSS connects to the MS through a radio interface* and also connects to the NSS.
- The BSS consists of a base transceiver station (BTS) located at the antenna site and a base station controller (BSC) that may control several BTSs.
- The BTS consists of radio transmission and reception equipment similar to the ME in an MS.
- A transcoder/rate adaption unit (TRAU) carries out encoding and speech decoding and rate adaptation for transmitting data.
- As a subpart of the BTS, the TRAU may be sited away from the BTS, usually at the MSC.
- In this case, the low transmission rate of speech code channels allows more compressed transmission between the BTS and the TRAU, which is sited at the MSC.

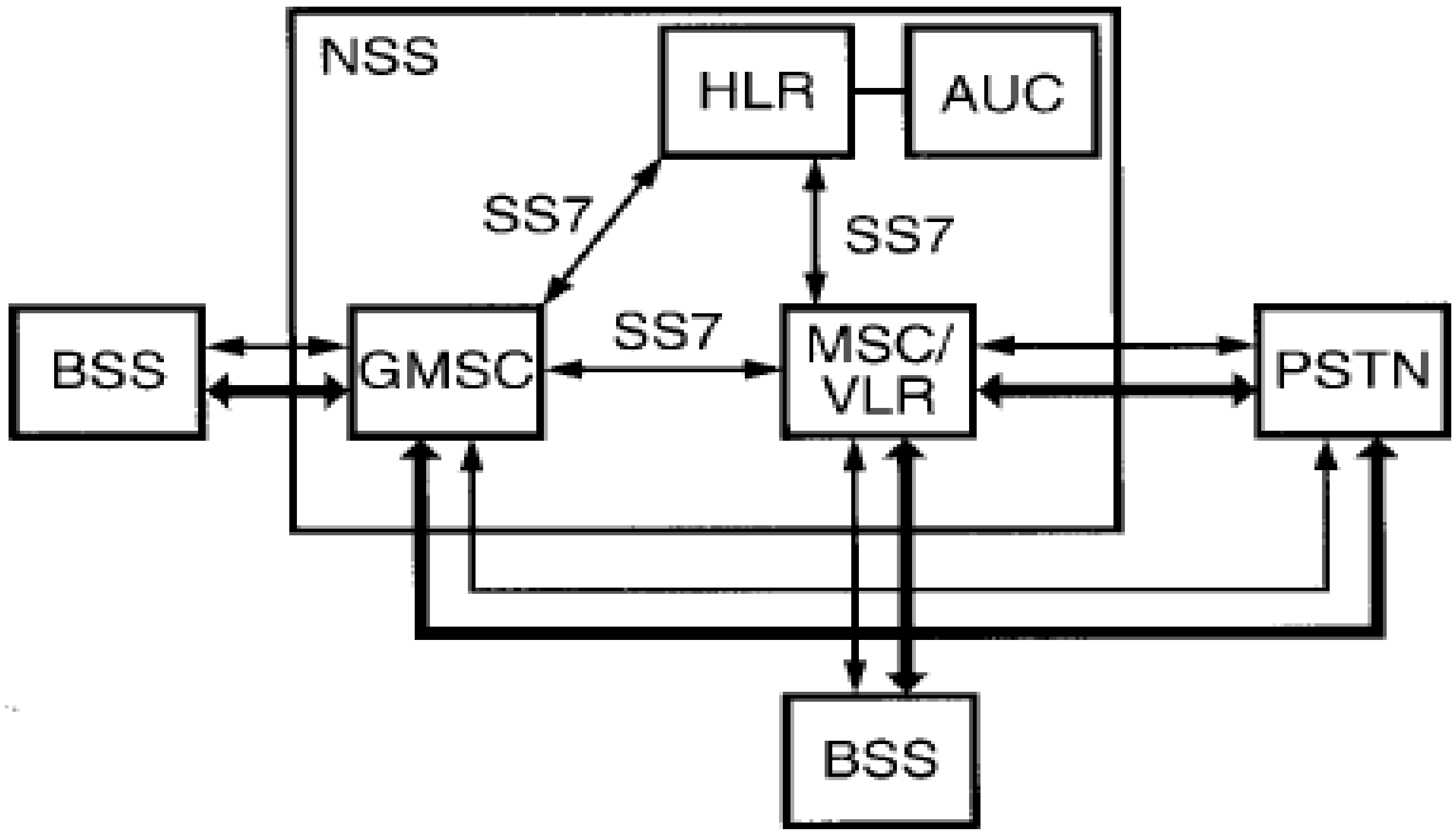
Network and Switching Subsystem.

- *NSS in GSM uses an intelligent* network (IN).
- The IN's attributes will be described later.
- A signaling NSS includes the main switching functions of GSM.
- NSS manages the communication between GSM users and other telecommunications users.
- NSS management consists of:
- ***Mobile service switching center (MSC).*** *Coordinates call set-up to and from GSM users.*
- An MSC controls several BSCs.

FIGURE .NSS and its environment. (*a*) *The external environment;*



(b) the internal structure.



(b)

Home location register (HLR).

- *Consists of a stand-alone computer without switching* capabilities,
- 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 holds more current subscriber location information than the location information at the HLR.

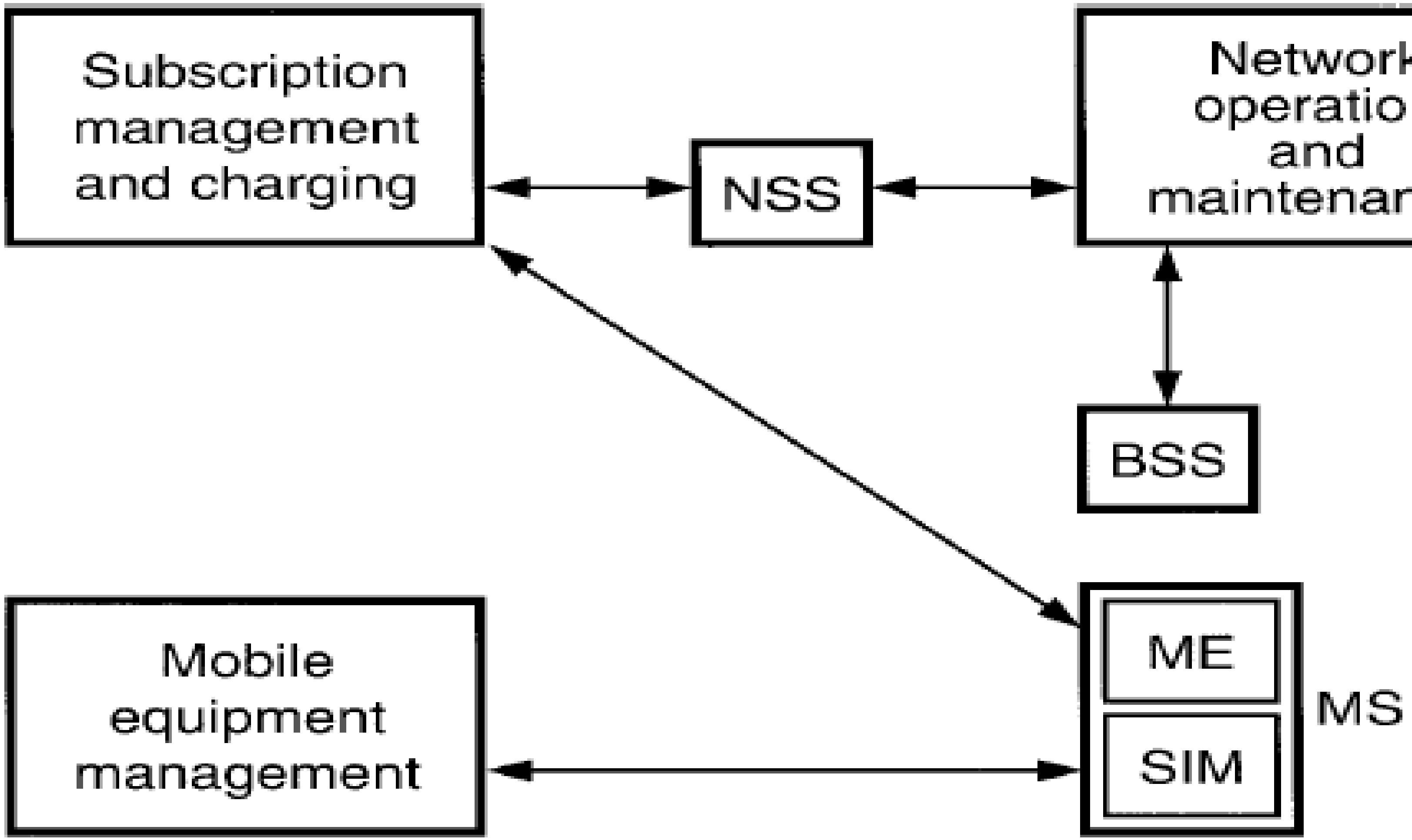
Gateway MSC (GMSC).

- *In order to set up a requested call, the call is initially routed to a* gateway MSC, which finds the correct HLR by knowing the directory number of the GSM subscriber.
- The GMSC has an interface with the external network for gatewaying, and the network also operates the full Signaling System 7 (SS7) signaling between NSS machines.

Operation Subsystem.

- ***There are three areas of OSS, as shown in Fig.***
- (1) network operation and maintenance functions,
- (2) subscription management, including charging and billing, and
- (3) mobile equipment management.
- These tasks require interaction between some or all of the infrastructure equipment.
- OSS is implemented in any existing network.

Operation Subsystem.



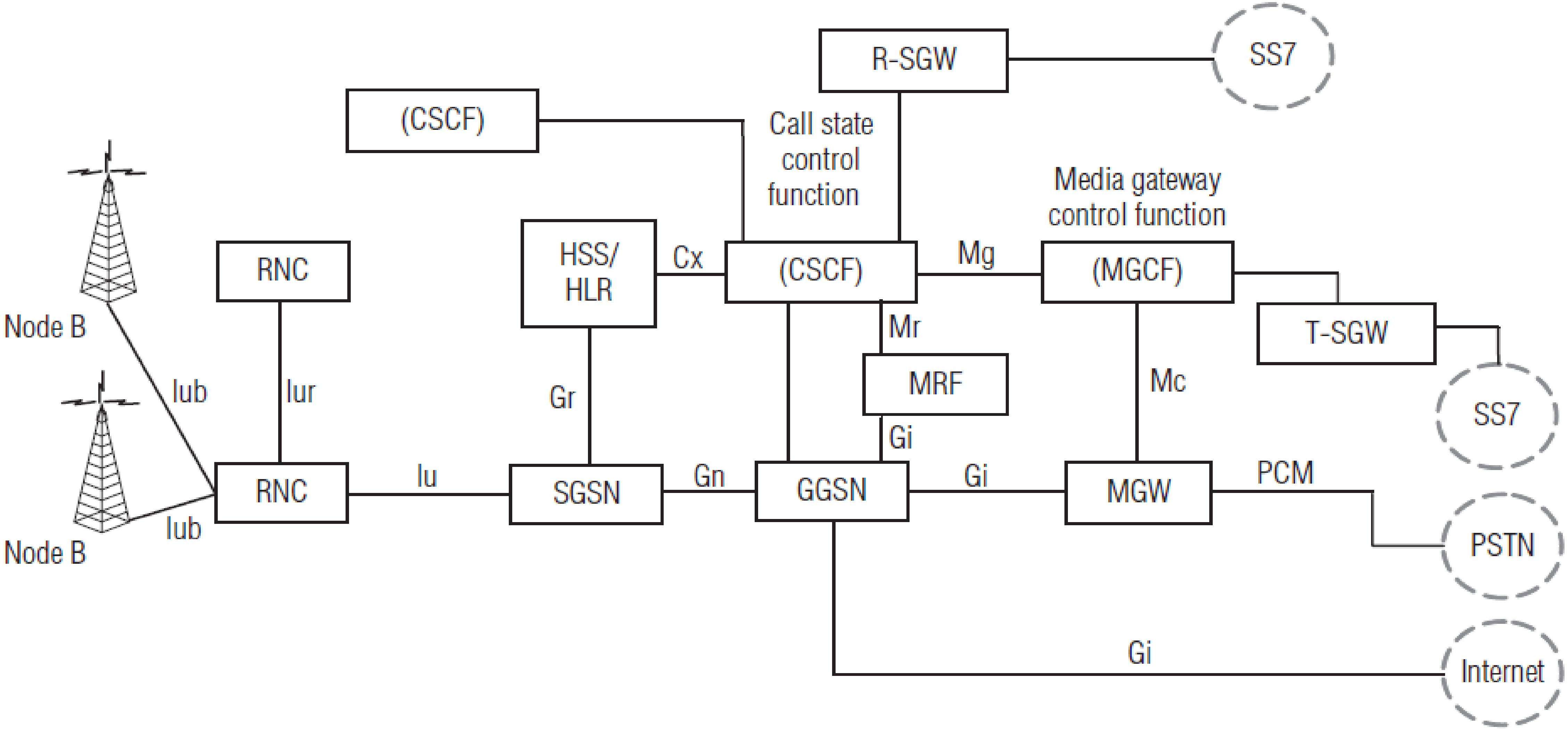
3G Systems

- 3G mobile systems offer high bit rate services, high-quality videos, images, and fast web access. They differ significantly from the 2G technologies (global system for mobile communication [GSM] and CDMA1). The aim of 3G is to provide communication services from person to person at any place and at any time through any medium using a compact lightweight terminal with guaranteed quality of service (QoS) and security. The two standards of 3G technology that are most popular in the world are
- Wideband code division multiple access (WCDMA)
- Code division multiple access 2000 (CDMA2000).

UMTS network architecture

- UMTS is evolved from GPRS to replace the radio access network (RAN). The UMTS terrestrial radio access network (UTRAN) consists in B Node the 3G term for BTS, and RNCs connected by ATM network. The 3G mobile network evolved from the 2G systems such as GSM and GPRS. *Some of the UMTS elements in the networks are: (i) The UMTS subscriber identity module similar to* the GSM SIM card, (ii) the *Node B, analogous to the GSM BTS, (iii) the RNC, analogous to the GSM* BSC, (iv) the *call state control function, (v) the multimedia resource function, (vi) the media gateway* (MGW), (vii) the *transport media gateway, (viii) the roaming signaling gateway, and (ix) the media gateway control function. The above network elements communicate in the following predefined* interfaces: (i) the *Iub interface, between RNC and Node B, (ii) the Iur interface, between RNCs, (iii)* the *Gr interface, between HLR and GGSN, and (iv) the Gi interface, between GGSN and MGW or* other packet-based networks. Figure presents the UMTS release five network topology.

Figure: UMTS network architecture



- Salient features of WCDMA

- WCDMA uses a new spectrum with a 5 MHz carrier and uses the DS-CDMA radio access (multiple access) technology. It provides 50 times higher data rate than in present GSM networks and 10 times higher data rate than in GPRS networks.
- WCDMA is a technology for wideband digital radio communications of Internet, multimedia,

video, and other capacity demanding applications.

- WCDMA is the demanding 3G technology providing higher capacity for voice and data at higher data rates.
- The wider band makes it possible to divide and combine reception signals propagated through

multipath-fading channels into more multipath components, which helps to improve the

reception quality through RAKE time diversity.

- Its merits include the ability to accommodate a greater number of users who communicate

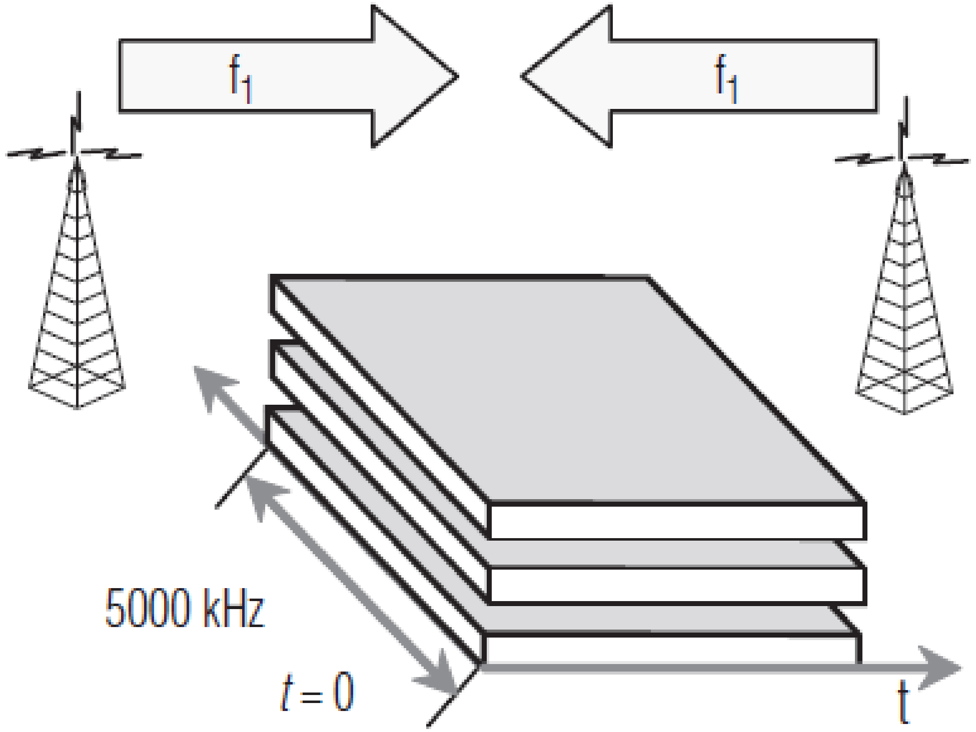
at high speed (e.g., at 64 and 384 Kbps). It has also been verified in experiments that high quality data transmission at 2 Mbps can be implemented using the 5 MHz bandwidth.

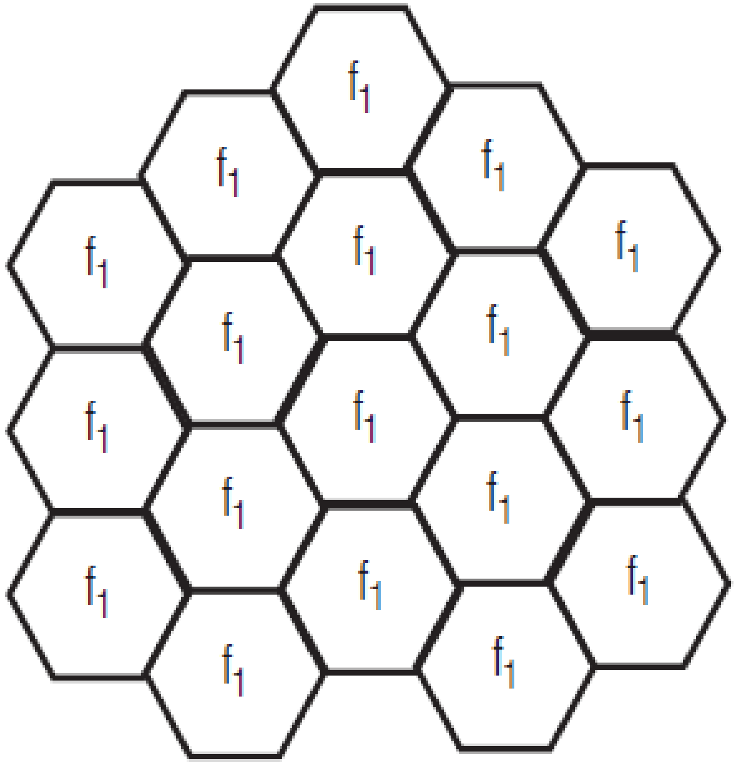
- The wide bandwidth of WCDMA gives an inherent performance gain over the previous

cellular systems and it reduces the fading of the radio signal thus improving the performance.

- WCDMA uses dual mode packet access scheme. Packet transfer can take place on both the common and dedicated channels. Owing to this phenomenon, packet access can be optimized for fast access response as well as for maximum throughput.
- The advance form of WCDMA is high-speed downlink packet access (HSDPA). HSDPA is a technology that leads to the cost-effective delivery of the most advance data services and significantly improves the network capacity.

Figure : WCDMA system features





Difference between WCDMA and 2G

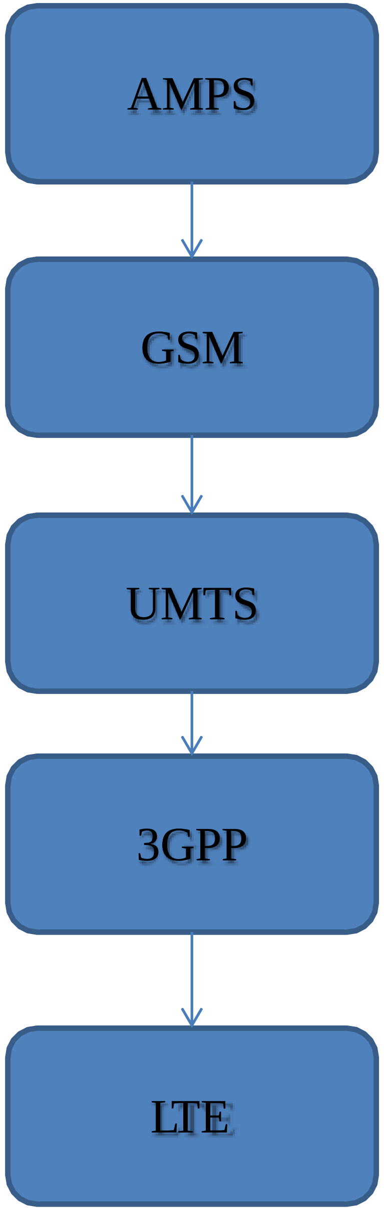
Characteristic	WCDMA	Second generation
Carrier spacing	5 MHz	200 kHz
Frequency reuse factor	1	1–18
Power control frequency	1600 Hz	2 Hz or lower
Quality control	Radio resource management algorithms	Frequency hopping
Packet data	Load-based packet scheduling	Time slot based scheduling with GPRS
Downlink transmit diversity	Supported for improving downlink capacity	Not supported by the standard but can be applied

Parameters of WCDMA

Multiple access method	WCDMA
Duplexing method	Frequency division duplex/time division duplex
Channel bandwidth	5 MHz
Base station synchronisation	Asynchronous operation
Spreading modulation	Balanced QPSK (downlink) Dual-channel QPSK(uplink) Complex spreading circuit
Data modulation	QPSK (downlink) BPSK (uplink)
Chip rate	3.84 Mcps
Frame length	10 ms
Service multiplexing	Multiple services with different quality of service requirements multiplexed on one connection
Multirate concept	Variable spreading factor and multicode
Detection	Coherent using pilot symbols or common pilot
Multiuser detection, smart antennas	Supported by the standard, optional in the implementation

INTRODUCTION to 4G

- LTE stands for “Long Term Evolution”
- It’s the 4th generation of mobile network Evolution
- Started as a project in 2004 by Telecommunication Body 3GPP
- Successor of not only UMTS but also CDMA 2000
- All LTE devices have to support for MIMO
- Provides the services like
    - Voice Over IP(VOIP)
    - Streaming Multimedia
    - Video Conferring
- LTE is a new technology which provides Triple play services like MBB
- Goals:
    - To Provide High data rate
    - Low latency
    - Packet Optimization



LTE Basic Parameters

- Frequency Range: 1.4MHz to 20MHz
- Mobility: 350km/Hr
- Coverage: 5 to 100 Km with the slight degradation after 30Km
- Latency: End user latency < 10ms
- Data Rates
- Duplexing

Data Rates

- DOWNLINK:
  - 300 Mbps peak
  - at 20MHz
  - (4x4 MIMO)

- UPLINK:
  - 75 Mbps peak
  - at 20MHz
  - (4x4 MIMO)

Duplexing And Accessing Techniques

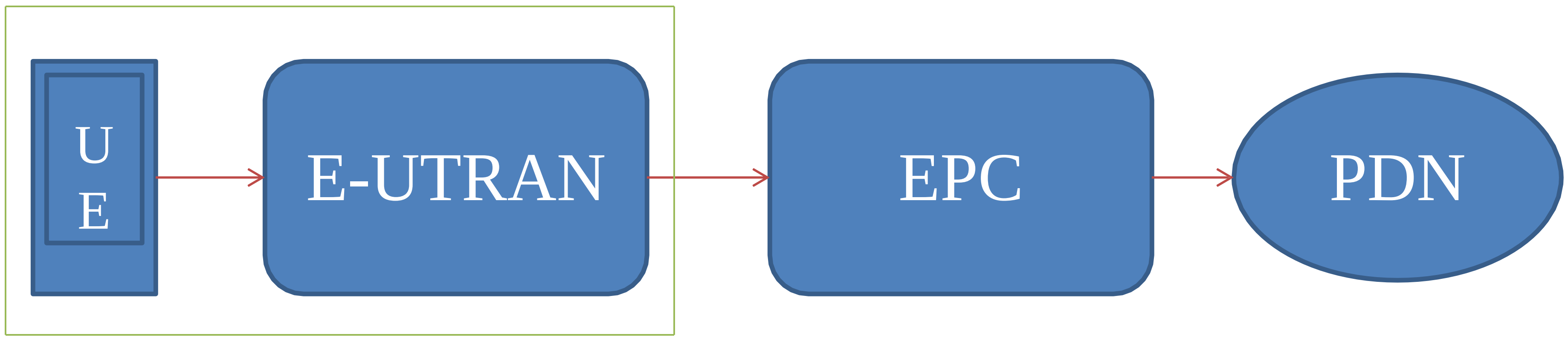
- Duplexing:
  - FDD
    - Both UL & DL can reach peak traffic simultaneously
  - TDD
    - Both the UL & DL cannot reach peak traffic simultaneously

- Accessing Techniques:
  - OFDMA for DL
  - SC-FDMA for UL

Modulation, Coding & MIMO

- Downlink Modulations: QPSK, 16-QAM and 64 QAM modulation
- Uplink Modulations: QPSK 16-QAM modulation
- Coding: Turbo Code
- MIMO:
  - ✓ Uplink → 1x2, 1x4
  - ✓ Downlink → 2x2, 4x2, 4x4

LTE Architecture Overview

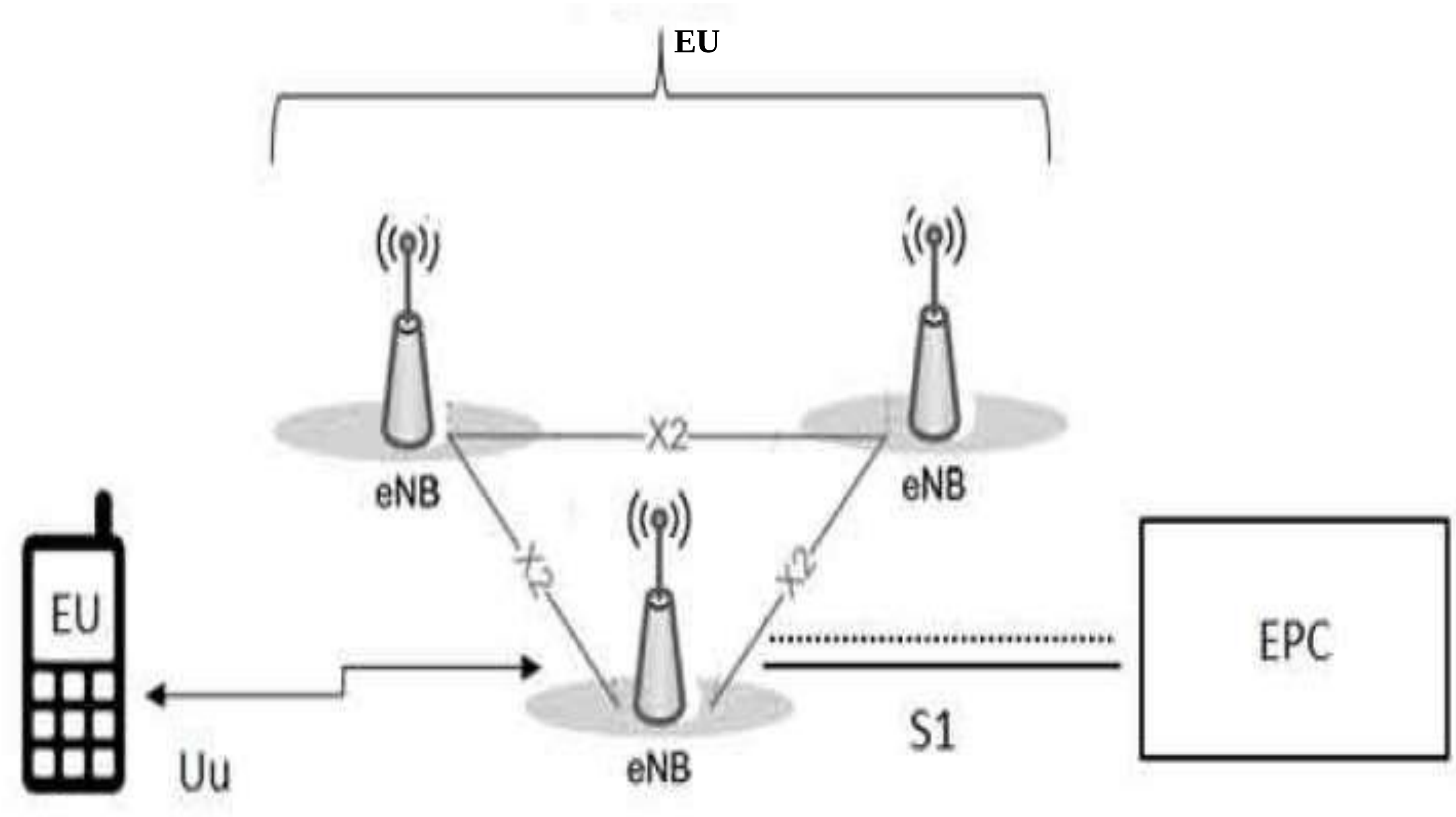


User Equipment(UE):

Consists of the following important modules

1. Mobile Termination(MT)
2. Terminal Equipment(TE)
3. SIM
   - User Ph. No.
   - Home Network Identity
   - Security Keys

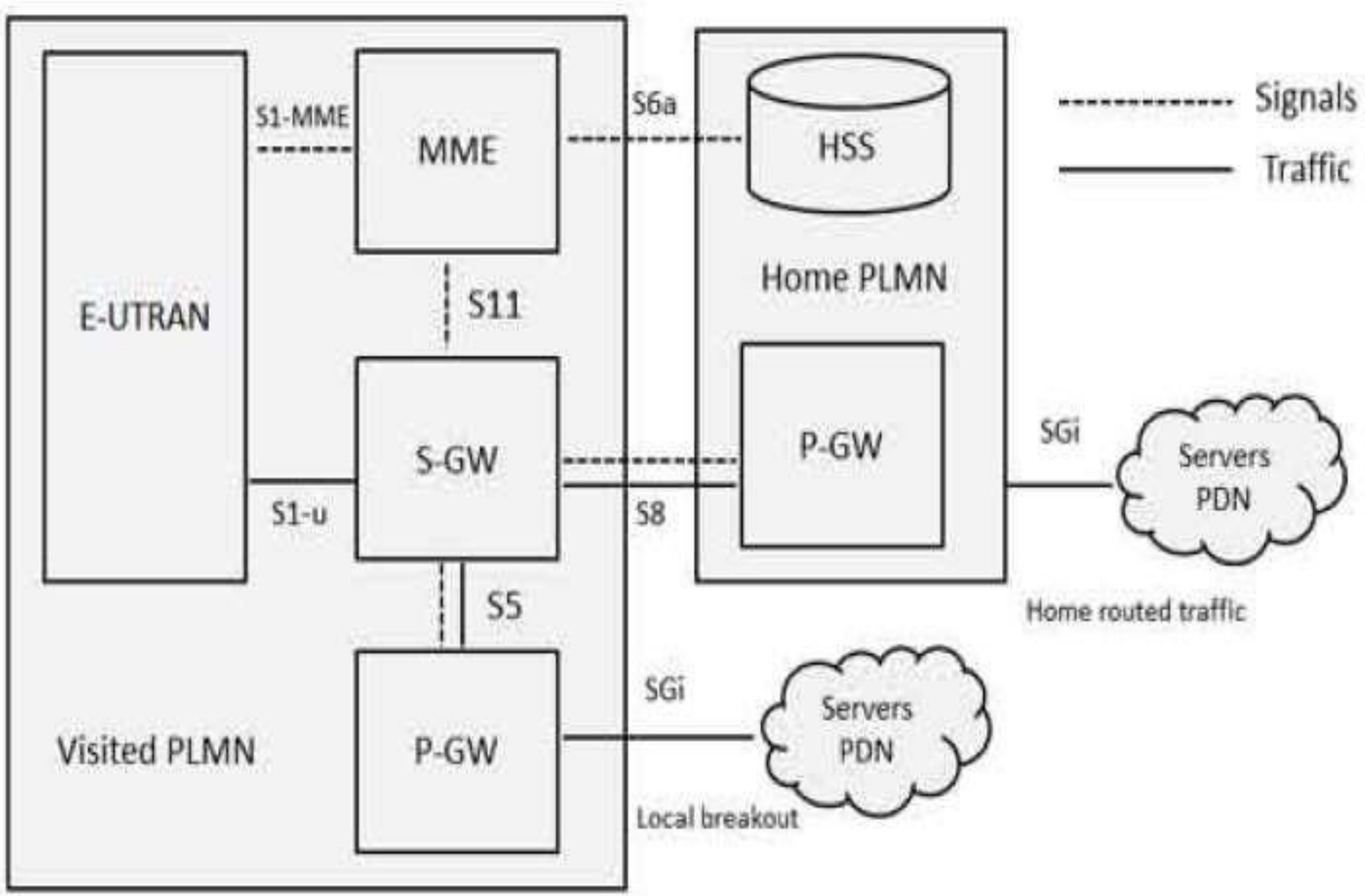
E-UTRAN(EU):



eNodeB(eNB):

- Scheduling and Dynamic allocation of resources to UE (After every 1ms)
- State transition from IDLE mode to Connected mode and vice versa
- Controlling the mobility of the UE in connected mode
- Buffering of data at handover
- Admission and Congestion control

Evolved Packet Core



MME:

- Mobility Management Entity
- Similar to VLR in GSM
- NAS signaling
- NAS signaling security
- Authentication
- Authorization
- PDN GW and Serving GW selection

HSS:

- Home Subscriber server
- Similar to HLR in GSM
- It is a central database that contains information about the network operator's subscribers.

S-GW:

- Serving Gateway
- Packet routing and forwarding
- S5/S8 interface

P-GW

- Communicates with the outside world using SGi interface

  (Each PDN is identified by APN)

- Deep Packet Inspection
- Lawful Interception
- UE IP address allocation

Advantages Of LTE

- ✓ High Throughput
- ✓ Low Latency
- ✓ FDD & TDD in a same platform
- ✓ Seamless connections
- ✓ Decreases network traffic sending and receiving data at a more rapid rate
- ✓ Allows more users to utilize the same frequency, increasing the overall number of users who are able to access the technology

Disadvantages Of LTE

- ✓ Networks need additional antennas for data transmission
- ✓ End users need the correct cell phones to make use of the network

Introduction to 5G Technology

Contents...

- Introduction to 5G
- Evolution from 1G to 5G
- COMPARISON OF 1G TO 5G TECHNOLOGIES
- Key concepts
- Architecture
- Hardware & Software of 5G
- Features
- Advantages
- Applications
- Conclusion

What is 5G?

- 5G Wireless: 5th generation wireless technology
- Complete wireless communication with almost no limitations
- Can be called REAL wireless world
- Has incredible transmission speed

What does it offer?

- Worldwide cellular phones
- Extraordinary data capabilities
- High connectivity
- More power & features in hand held phones
- Large phone memory, more dialing speed, more clarity in audio & video

Evolution from 1G to 5G

- 1G
- 2G
- 3G
- 4G
- 5G

1G

- Developed in 1980s & completed in early 1990s
- Based on analog system
- Speed up to 2.4 kbps
- AMPS (Advance Mobile Phone System) was launched by the US & it was the 1G mobile system
- Allows user to make voice calls in 1 country

2G

- Developed in late 1980s & completed in late 1990s
- Based on digital system
- Speed up to 64 kbps
- Services such are digital voice & SMS with more clarity
- Semi global facility
- 2G are the handsets we are using today, with 2.5G having more capabilities

3G

- Developed between late 1990s & early until present day
- Transmission speed from 125 kbps to Mbps
- Superior voice quality
- Good clarity in video conference
- E-mail, PDA, information surfing, line shopping/ banking,
- Global roaming

4G

- Developed in 2010
- Faster & more reliable
- Speed up to 100 Mbps
- High performance
- Easy roaming
- Low cost

5G

- Next major phase of mobile telecommunication & wireless system
- 10 times more capacity than others
- Expected speed up to 1 Gbps
- More faster & reliable than 4G
- Lower cost than previous generations

COMPARISON OF 1G TO 5G TECHNOLOGIES

Technology	1G	2G/2.5G	3G	4G	5G
Deployment	1970/1984	1980/1999	1990/2002	2000/2010	2014/2015
Bandwidth	2kbps	14-64kbps	2mbps	200mbps	>1gbps
Technology	Analog cellular	Digital cellular	Broadbandwidth/cdma/ip technology	Unified ip &seamless combo of LAN/WAN/WLAN/PAN	4G+WWWW
Service	Mobile telephony	Digital voice,short messaging	Integrated high quality audio, video & data	Dynamic information access, variable devices	Dynamic information access, variable devices with AI capabilities
Multiplexing	FDMA	TDMA/CDMA	CDMA	CDMA	CDMA
Switching	Circuit	Circuit/circuit for access network&air interface	Packet except for air interface	All packet	All packet
Core network	PSTN	PSTN	Packet network	Internet	Internet
Handoff	Horizontal	Horizontal	Horizontal	Horizontal& Vertical	Horizontal& Vertical

Key concepts

- Real wireless world with no more limitations with access & zone issues
- Wearable devices
- IPv6, where a visiting care of mobile IP address is assigned according to location & connected network
- One unified global standard
- Smart radio
- The user can simultaneously be connected with several wireless access technology
- Multiple concurrent data transfer path

Basic Architecture of 5G

Application Layer	Application(Service)
Presentation layer	
Session Layer	Open Transport Protocol (OTP)
Transport Layer	
Network Layer	Upper network layer
	Lower network layer
Datalink Layer	Open Wireless Architecture (OWA)
Physical Layer	

Open Wireless Architecture (OWA)

- OSI layer 1 & OSI layer 2 define the wireless technology
- For these two layers the 5G mobile network is likely to be based on Open Wireless Architecture (OWA)
- Physical layer + Data link layer = OWA

Network Layer

- All mobile networks will use mobile IP
- Each mobile terminal will be FA (Foreign Agent)
- A mobile can be attached to several mobiles or wireless networks at the same time
- The fixed IPv6 will be implemented in the mobile phones
- Separation of network layer into two sub-layers:

  (i) Lower network layer (for each interface)

  (ii) Upper network layer (for the mobile terminal)

Open Transport Protocol (OTP)

- Wireless network differs from wired network regarding the transport layer
- In all TCP versions the assumption is that lost segments are due to network congestion
- In wireless, the loss is due to higher bit error ratio in the radio interface
- 5G mobile terminals have transport layer that is possible to be downloaded & installed – Open Transport Protocol (OTP)
- Transport layer + Session layer = OTP

Application (service) Layer

- Provides intelligent QoS (Quality of Service) management over variety of networks
- Provides possibility for service quality testing & storage of measurement information in information database in the mobile terminal
- Select the best wireless connection for given services
- QoS parameters, such as, delay, losses, BW, reliability, will be stored in DB of 5G mobile
- Presentation layer + Application layer = Application

Hardware & Software of 5G

- 5G Hardware:
  - Uses UWB (Ultra Wide Band) networks with higher BW at low energy levels
  - BW is of 4000 Mbps, which is 400 times faster than today's wireless networks
  - Uses smart antenna
  - Uses CDMA (Code Division Multiple Access)

- 5G Software:
  - 5G will be single unified standard of different wireless networks, including LAN technologies, LAN/WAN, WWWW- World Wide Wireless Web, unified IP & seamless combination of broadband
  - Software defined radio, encryption, flexibility, Anti-Virus

Features of 5G

- High resolution for crazy cell phone users
- Bi-directional large BW
- Less traffic
- 25 Mbps connectivity speed
- Enhanced & available connectivity just about the world
- Uploading & Downloading speed of 5G touching the peak (up to 1 Gbps)
- Better & fast solution

Features (Conti…)

- High quality service based on policy to avoid error
- Support virtual private networks
- More attractive & effective
- Provides subscriber supervision tools for fast action

Advantages of 5G

- Data BW of 1 Gbps or higher
- Globally accessible
- Dynamic information access
- Available at low cost

Applications of 5G

- Wearable devices with AI (Artificial Intelligence) capabilities
- Pervasive (Global) networks
- Media independent handover
- Radio resource management
- VoIP (Voice over IP) enabled devices
- With 6th sense technology

Conclusion

- 3G- Operator Centric,
  4G- Service Centric whereas
  5G- User Centric
- We have proposed 5G wireless concept designed as an open platform on different layers
- The new coming 5G technology will be available in the market at affordable rates, high peak future & much reliability than preceding technologies