WIRELESS NETWORKS

UNIT-2

Telecommunication Systems

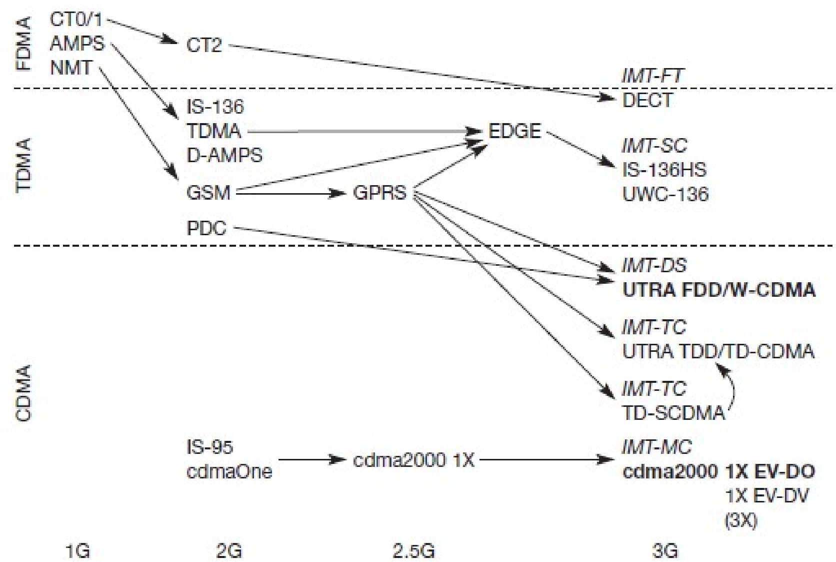
&

Satellite Systems

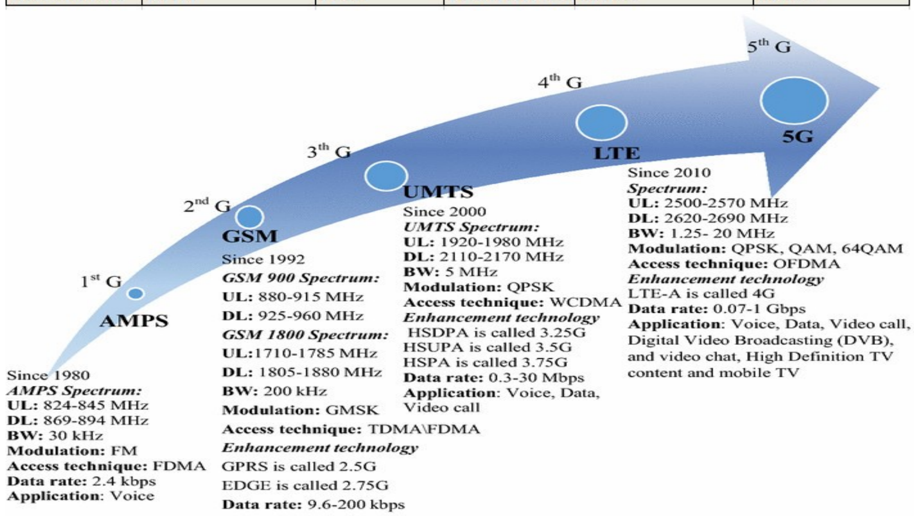
UNIT II Syllabus

- **Telecommunication Systems:** GSM, DECT, TETRA, UMTS and IMT-2000: System Architecture and Radio Interface.
- **Satellite Systems:** History, Applications, Basics, Routing, Localization, and Handover.

Telecommunication Systems



Features	1G	2G	3G	4G	5G
Start/Devlopment	1970/1984	1980/1999	1990/2002	2000/2010	2010/2015
Technology	AMPS, NMT, TACS	GSM	WCDMA	LTE, WiMax	MIMO, mm Waves
Frequency	30 KHz	1.8 Ghz	1.6 - 2 GHz	2 - 8 GHz	3 - 30 Ghz
Bandwidth	2 kbps	14.4 - 64 kbps	2 Mbps	2000 Mbps to 1 Gbps	1 Gbps and higher
AccessSystem	FDMA	TDMA/CDMA	CDMA	CDMA	OFDM/BDMA
Core Network	PSTN	PSTN	Packet Network	Internet	Internet



GSM (Global System for Mobile Communications)

- GSM is the most successful digital mobile telecommunication system in the world today.
- It is used by over **800 million people in more than 190 countries.**
- **groupe spéciale mobile (GSM) was founded in** 1982.
- This system was soon named the **Global System for Mobile communications (GSM),** with the specification process lying in the hands of **ETSI.**
- In the context of **UMTS** and the creation of 3GPP (Third generation partnership project, 3GPP, 2002a) the whole development process of **GSM was transferred to 3GPP** and further development is combined with 3G development.
- 3GPP assigned new numbers to all GSM standards.
- The goal of GSM **is to provide a mobile phone system that allows users to roam throughout Europe and provide voice services compatible to ISDN and PSTN.**

GSM -Versions

(1) GSM 900: Initially deployed in Europe. Frequency offered is

1. Uplink →890 to 915 MHz
2. Dwonlink →935 to 960 MHz

(2) GSM 1800: otherwise called as Digital Cellular System DCS 1800

1. Uplink -> 1710 to 1785 MHz
2. Downlink → 1805 to 1880 MHz

(3) GSM 1900: Otherwise called as personal communication service PLS 1990

1. Uplink -> 1850 to 1910 MHz
2. Downlink → 1930 to 1990 MHz

(4) GSM 400:

1. Uplink -> 450.4 to 478 MHz
2. Downlink → 460 to 496 MHz

(5) GSM Rail:

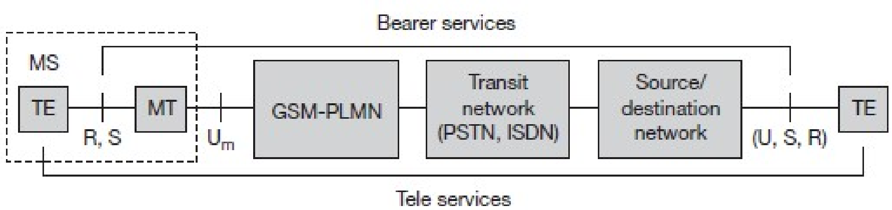
1. Used in European countries.
2. Used for railroad system.

GSM

- **Mobile services- (1) Bearer (holder) Services, (2) Tele services (3) Supplementary services**
- **System Architecture**
- **Radio Interfaces**
- **Protocols**
- **Localization and calling**
- **Handover**
- **Security**
- **New Data Services** (HSCSD,GPRS)

GSM-Mobile Services

- GSM permits the integration of **different voice and data services and the interworking with existing networks.**
- Services make a network interesting for customers.
- GSM has defined three different categories of services: **bearer, tele, and supplementary services.**



GSM-Mobile Services- Bearer services

- Bearer services comprises of all services that enable the transparent transmission of data between the interfaces to the network.
- Bearer services permit transparent (Easily understood) /non transparent, synchronous (Occurring at the same time) and asynchronous data transmission.

Transparent Bearer Services:

- This services uses the function of physical layer to transmit data.
- Data transmission has a constant delay and throughput if no error occurs but not in real time.
- FEC is used increase the transmission quality.
- Does not try to recover the lost data in case of hand over etc.

Non- Transparent Bearer Services:

- Uses the protocol of layers data link and network to transmit data.
- These services uses transparent bearer services radio link protocol (RLP).
- RLP has mechanisms of high level data link control HDLC.
- Allows retransmission of erroneous data by using selective reject mechanisms.

GSM-Mobile Services- Tele Services

- Tele services are application specific and need all the 7 layers of ISO/OSI reference model.
- Services are specified end to end. These tele services are **voice oriented tele services.**
- They are **encrypted voice transmission, messages services , and data communication with terminals (depots) from PSTN/ISDN.**
- Some of the important services are **Telephony services, Emergency Number, Short Message Services, Enhanced Message Services, Multimedia Message Services, Group 3 Fax.**

GSM-Mobile Services- Supplementary Services

- In addition to tele and bearer services, GSM providers can offer **supplementary services.**
- **Similar to ISDN networks, these services offer various enhancements for the standard telephony service, and may vary from provider to provider.**
- **Typical services are**

(1) User Identification

(2) Call Redirection/Forwarding

(3) Closed User Group.

(4) Multiparty Communication.

GSM-System Architecture

- GSM system Architecture consists of three subsystems,

➢ **Radio Sub System (RSS),**

➢ **Network and Switching Subsystem (NSS), and**

➢ **Operation Subsystem (OSS).**

- The connection between the RSS and the NSS via the **A interface** (**solid lines**) and the connection to the OSS via the **O interface** (**dashed lines**).
- **The A interface is typically based on circuit-switched PCM-30 systems (2.048 Mbit/s), carrying up to 30 64 kbit/s connections, whereas the O interface uses the Signalling System No. 7 (SS7) based on X.25 carrying management data to/from the RSS.**

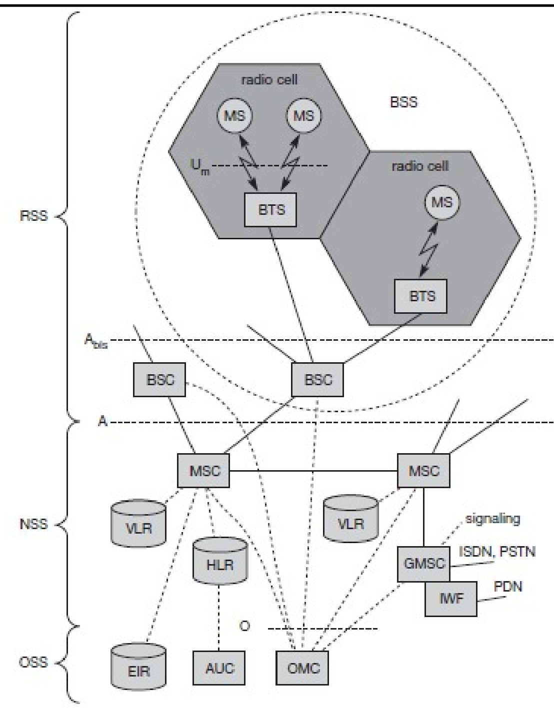


Figure 4.4 Functional Architecture of a GSM system

RSS

- As the name implies, the **Radio Sub-ystem (RSS) comprises all radio specific entities**, i.e., the **mobile stations (MS) and the base station subsystem (BSS).**
- **Base station subsystem (BSS):**

❖A GSM network comprises many BSSs, each controlled by a **base station controller (BSC).**

❖The BSS performs all functions necessary **to maintain radio connections to an MS, coding/decoding of voice, and rate adaptation to/from the wireless network part.**

❖Besides a BSC, the BSS contains several BTSs.

RSS

Base transceiver station (BTS):

- **A BTS comprises all radio equipment, i.e., antennas, signal processing, amplifiers necessary for radio transmission.**
- A BTS can **form a radio cell or, using sectorized antennas, several cells, and is connected to MS** via the **Um interface (ISDN U interface for** mobile use), and to the BSC via the **A_{bis} interface.**
- **The Um interface contains** all the mechanisms necessary for wireless transmission (TDMA, FDMA etc.).
- The **A_{bis} interface consists of 16 or 64 kbit/s connections.** A GSM cell can measure between some **100 m and 35 km** depending on the environment (buildings, open space, mountains etc.) but also expected traffic.

RSS

Base station controller (BSC):

- The BSC basically manages the BTSs**.**
- It **reserves radio frequencies, handles the handover from one BTS to another within the BSS, and performs paging of the MS.**
- The **BSC also multiplexes the radio channels onto the fixed network connections at the A interface.**

RSS

Mobile station (MS):

- **The MS comprises all user equipment and software** needed for communication with a GSM network.
- An MS consists of user independent hard- and software and of the **subscriber identity module (SIM), which stores all user-specific data that is relevant to GSM.**
- **While an** MS can be identified via the **international mobile equipment identity (IMEI), a user can personalize any MS using his or her SIM, i.e., user-specific** mechanisms like charging and authentication are based on the SIM, not on the device itself.
- **Device-specific mechanisms**, e.g., **theft protection**, use the device specific IMEI. Without the SIM, only emergency calls are possible.
- The SIM card contains many identifiers and tables, such as **card-type, serial number, a list of subscribed services, a personal identity number (PIN), a PIN unblocking key (PUK), an authentication key Ki, and the international Mobile Subscriber Identity (IMSI) (ETSI, 1991c).**
- **The PIN is used to unlock the MS**. Using the wrong PIN three times will lock the SIM.

RSS

- In such cases, the **PUK is needed to unlock the SIM**. The MS stores dynamic information while logged onto the GSM system, such as, e.g., the **cipher key Kc and** the **location information consisting of a temporary mobile subscriber identity (TMSI) and the location area identification (LAI).**
- **Typical MSs for GSM 900** have a **transmit power of up to 2 W**, whereas for **GSM 1800 1 W** is enough due to the smaller cell size.
- Apart from the telephone interface, an MS can also offer other types of interfaces to users **with display, loudspeaker, microphone, and programmable soft keys. Further interfaces comprise computer modems, IrDA, or Bluetooth.**
- Typical MSs, e.g., mobile phones, comprise many more vendor-specific functions and components, **such as cameras, fingerprint sensors, calendars, address books, games, and Internet browsers.**
- **Personal digital assistants (PDA)** with mobile phone functions are also available.

NSS

- The **"heart" of the GSM system** is formed by the **network and switching subsystem (NSS).**
- **The NSS connects the wireless network with standard public networks, performs handovers between different BSSs, comprises functions for worldwide localization of users and supports charging, accounting, and roaming of users between different providers in different countries.**
- The NSS consists of the following switches and databases:
- **Mobile services switching center (MSC)**
- **Home location register (HLR)**
- **Visitor location register (VLR)**

NSS

Mobile services Switching center (MSC):

- **MSCs are high-performance digital ISDN switches**. They set up connections to other MSCs and to the BSCs via the **A interface**, and form the fixed backbone network of a GSM system.
- Typically, an **MSC manages several BSCs in a geographical region**. A **gateway MSC (GMSC) has additional connections to other fixed networks, such as PSTN and ISDN.**
- **Using additional interworking functions (IWF), an MSC can also connect to public data networks (PDN) such as X.25.**
- **An MSC handles all signaling needed for connection setup, connection release and handover of connections to other MSCs.**
- The **standard signaling system No. 7 (SS7) is used for this purpose. SS7 covers all aspects of control signaling** for digital networks (reliable **routing and delivery of control messages, establishing and monitoring of calls).**
- Features of **SS7 are number portability, free phone/toll/collect/credit calls, call forwarding, three-way calling etc.**
- An MSC also performs all functions needed for supplementary services such as **call forwarding, multi-party calls, reverse charging etc**.

NSS

Home Location Register (HLR):

- **The HLR is the most important database in a GSM system as it stores all user-relevant information.** This comprises static information, such as the **mobile subscriber ISDN number (MSISDN), subscribed** services (e.g., call forwarding, roaming restrictions, GPRS), and the **international mobile subscriber identity (IMSI).**
- **Dynamic information is** also needed, e.g., the **current location area (LA) of the MS, the mobile subscriber roaming number (MSRN), the current VLR and MSC.**
- **As soon as an MS leaves its current LA, the information in the HLR is updated.**
- This information is necessary to localize a user in the worldwide GSM network. All these user-specific information elements only exist once for each user in a single HLR, which also supports charging and accounting.
- HLRs can manage data for several million customers and contain highly specialized data bases which must fulfill certain real-time requirements to answer requests within certain time-bounds.

NSS

Visitor Location Register (VLR):

- **The VLR associated to each MSC is a dynamic database which stores all important information needed for the MS users currently in the LA that is associated to the MSC (e.g., IMSI, MSISDN, HLR address).**
- **If a new MS comes into an LA the VLR is responsible for, it copies all relevant information for this user from the HLR.**
- This hierarchy of VLR and HLR avoids frequent HLR updates and long-distance signaling of user information.
- Some VLRs in existence, **are capable of managing up to one million customers.**

OSS

- The third part of a GSM system, the **operation subsystem (OSS),** contains the **necessary functions for network operation and maintenance.**
- The OSS possesses network entities of its own and accesses other entities via SS7 signaling.
- The following entities have been defined:

➢ **Operation and maintenance center (OMC)**

➢ **Authentication centre (AuC)**

➢ **Equipment identity register (EIR)**

OSS

Operation and Maintenance Center (OMC):

- **The OMC monitors and controls all other network entities via the O interface** (SS7 with X.25).
- Typical **OMC management functions are traffic monitoring, status reports of network entities, subscriber and security management, or accounting and billing.**
- OMCs use the concept of **telecommunication management network (TMN) as standardized by the ITU-T.**

OSS

Authentication Centre (AuC):

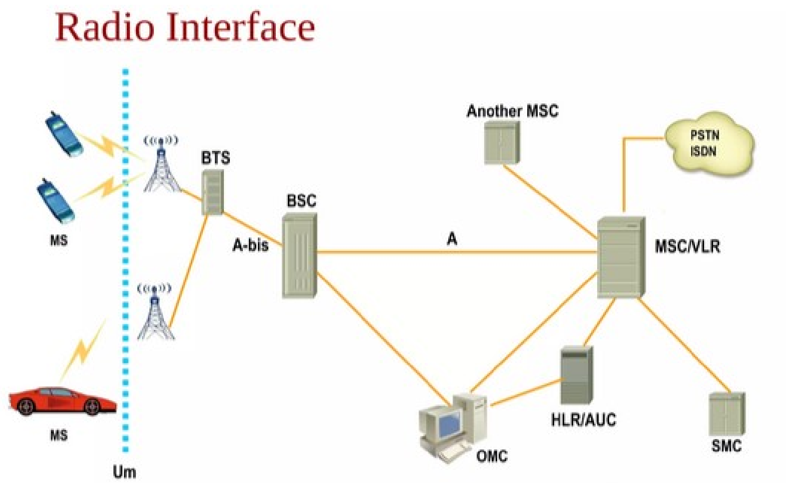
- **As the radio interface and mobile stations** are particularly vulnerable, a separate AuC has been defined **to protect user identity and data transmission.**
- The **AuC contains the algorithms for authentication as well as the keys for encryption and generates the values needed for user authentication in the HLR.**
- The **AuC may**, in fact, be situated in **a special protected part of the HLR.**

OSS

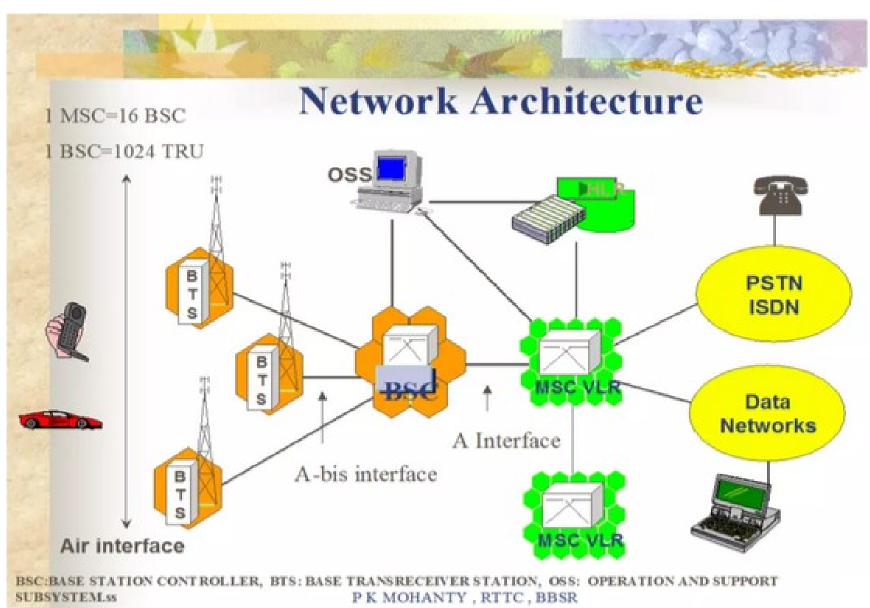
Equipment identity register (EIR):

- **The EIR is a database for all IMEIs, i.e., it stores all device identifications registered for this network.**
- As MSs are mobile, they can be easily stolen.
- With a valid SIM, anyone could use the stolen MS.
- **The EIR has a blacklist of stolen (or locked) devices. In theory an MS is useless as soon as the owner has reported a theft.**
- Unfortunately, the blacklists of different providers are not usually synchronized and the illegal use of a device in another operator's network is possible (the reader may speculate as to why this is the case).
- **The EIR also contains a list of valid IMEIs** (white list), and a **list of malfunctioning devices (gray list).**

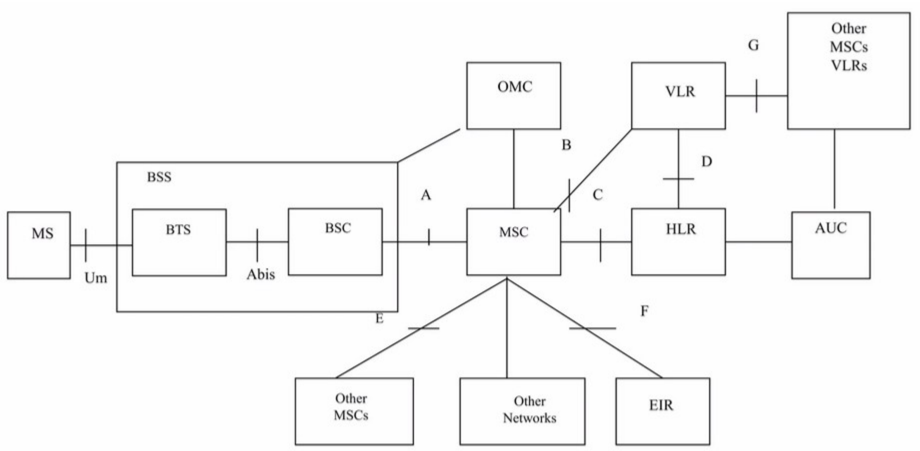
GSM Radio Interface



GSM Radio Interface



GSM Radio Interface



GSM Radio Interface

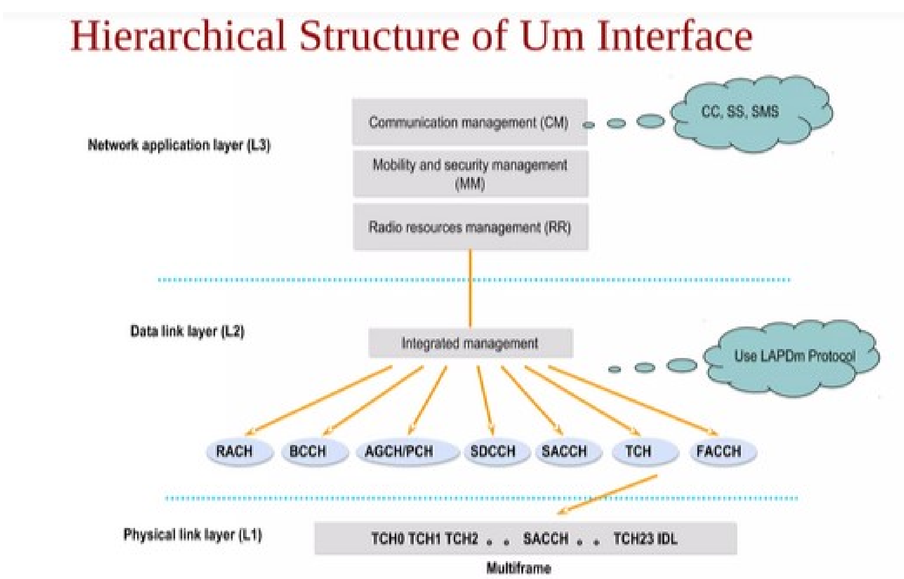
In the GSM system, there are the following interfaces:

- **Um interface**: It is the radio interface between the MS and the BTS. It is used for interworking between the MS and the fixed part of the GSM system and transmits information about radio resource management, mobility management, and connection management.
- **Abis interface**: It is the interface between the BTS and the BSC. This interface is used for remote interconnection between the BTS and the BSC. It supports all services provided to users. It also supports the control of the BTS radio equipment and the allocation of radio frequencies.
- **A interface**: the interface between the MSC and the BSC. This interface transmits information related to mobile call processing, base station management, mobile station management, channel management, etc.
- **B interface**: interface between the MSC and the VLR. The MSC sends the location information of roaming subscribers to the VLR through this interface. When setting up a call, the queries the VLR for the subscriber data of the roaming subscriber.
- **C interface**: interface between the MSC and the HLR. Through this interface, the MSC queries the HLR for the route information of the called MS and determines the connection route. When the call ends, the MSC sends the charging information to the HLR.

GSM Radio Interface

- **D interface**: interface between the MR and the HLR. This interface is used to transfer mobile subscriber data between two registers, and update the location information and routing information of the mobile station.
- **E interface**: interface between MSCs. This interface is mainly used for cross-office channel transfer. In this way, the communication is not interrupted when the subscriber moves from the service area of one MSC to the service area of another MSC during a call. In addition, the interface also transmits intermediary signaling.
- **F interface**: interface between the MSC and the EIR. The MSC checks the validity of the MS in the EIR through this interface.
- **G interface**: interface between VLRs. When a mobile station enters another VLR area from a VLR jurisdiction, the old and new VLRs exchange necessary information through this interface. This interface is used only for digital mobile communication systems.
- **H interface**: interface between the HLR and the AUC. The HLR connects to the AUC through this interface to authenticate subscribers.

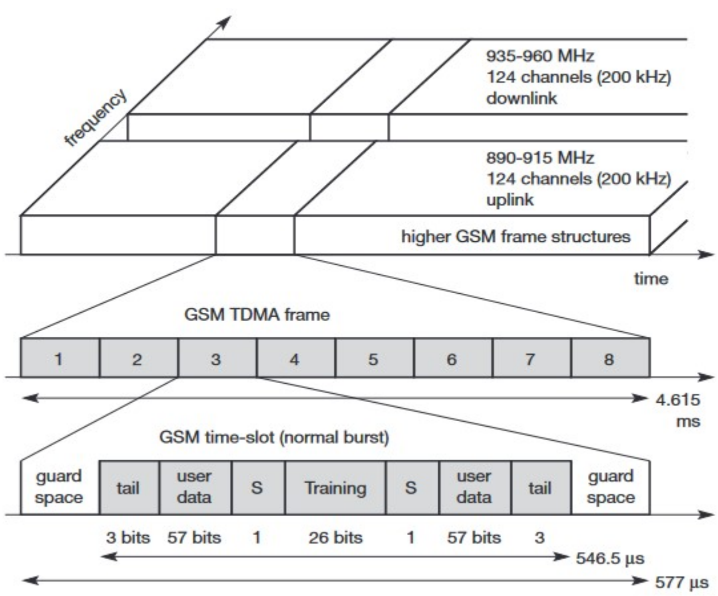
GSM Radio Interface



GSM Radio Interface

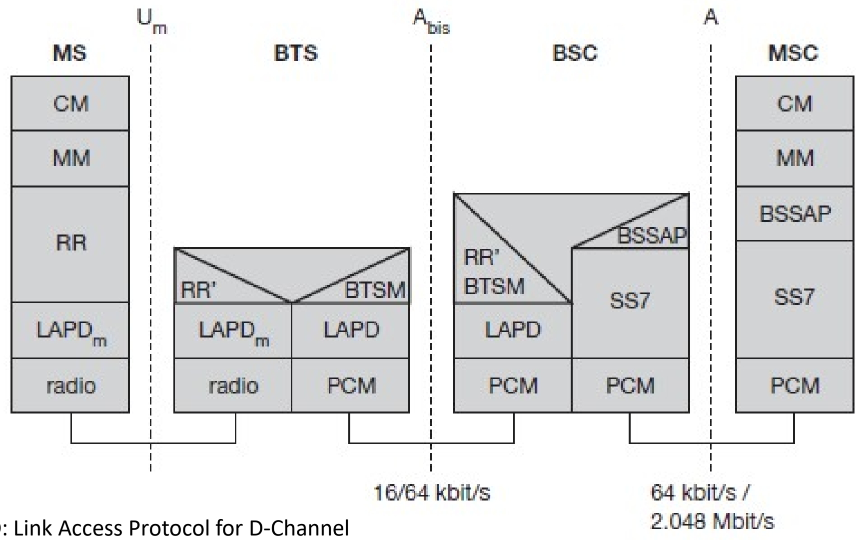
- The most interesting interface in a GSM system is U m , the radio interface, as it comprises many mechanisms for multiplexing and media access.
- GSM implements **SDMA using cells with BTS and assigns an MS to a BTS**. Furthermore, FDD is used to separate downlink and uplink.
- **Media access combines TDMA and FDMA**. In GSM 900, 124 channels, each 200 kHz wide, are used for FDMA, whereas GSM 1800 uses, 374 channels.
- Due to technical reasons, channels 1 and 124 are not used for transmission in GSM 900.
- Typically, 32 channels are reserved for organizational data; the remaining 90 are used for customers.
- Each BTS then manages a single channel for organizational data and, e.g., up to 10 channels for user data.
- The following example is based on the GSM 900 system, but GSM works in a similar way at 1800 and 1900 MHz.

GSM Radio Interface



GSM TDMA frame, slots, and bursts

GSM- Protocols



LAPD: Link Access Protocol for D-Channel
PCM: Pulse Code Modulation
RR: Radio Resource Mgt
BTSM: BTS Mgt

MM: Mobility Mgt
CM: Call Mgt
BSSAP:BSS Application Part

GSM- Protocols

Layer 1: Physical Layer

- The physical layer handles all radio specific functions.
- **Functions:**
  1) Creation of burst in any one of 5 formats.
  2) Multiplexing burst into a TDMA frame.
  3) Synchronization with BTS.
  4) Detection of idle channel.
  5) Channel quality measurement.
  6) Channel coding and Error detection and correction.
- The **Um interface uses GMSK** for modulation and performs encryption and decryption.

GSM- Protocols

Layer 2: Logical Link Layer

- **For signaling between entities in a GSM network this layer is used. The protocol used is LAPDM.**
- LAPD stands for link access procedure for D channel. **LAPDM has no buffers has to follow Um interface patterns.**
- **Functions are**
  1) **Reliable data transfer**
  2) **Resequencing of data**
  3) **Flow control.**

Layer 3: Network Layer

The Network layer has sublayers. They are

(i) Radio Resource Management: (RR)

- This is the lowest sub layer. A part of RR‟ is implemented in BTS, remaining is implemented by BSC.
- **Function of RR**
  1) **Setup**
  2) **Maintenance**
  3) **Release of Radio Channels.**
- RR directly access the physical layer. The function of RR‟ are supported by the BSC via this **BTS Management (BTSM)**

(ii) Mobility Management: (MM)

- **Functions:**
  1) **Registration**
  2) **Authentication**
  3) **Identification**
  4) **Location updating**
  5) **Providing TMSI, IMSI**

Layer 4: Call Management

- This layer contains 3 entities.
  - **1) Call control**
  - **2) SMS**
  - **3) Supplementary services.**
- **Call Control**: Provides point to point connection between two terminals. Used for call clearance, change of call parameters.
- **Short Message Services: Allows message transfer using control channels.**
- **Supplementary Services: The supplementary services discussed already are to be reproduced here.**
- **Functions: To send in band tone called Dual Tone Multiple Frequency(DTMF) over GSM.**

Localization and Calling, Int.Roaming

- One **fundamental feature of the GSM system is the automatic, worldwide localization of users.**
- **The system always knows where a user currently is, and the same phone number is valid worldwide.**
- To provide this service**, GSM performs periodic location updates even if a user does not use the mobile station (provided that the MS is still logged into the GSM network and is not completely switched off).**
- The **HLR always contains information about the current location** (only the location area, not the precise geographical location), and the **VLR currently responsible for the MS informs the HLR about location changes.**

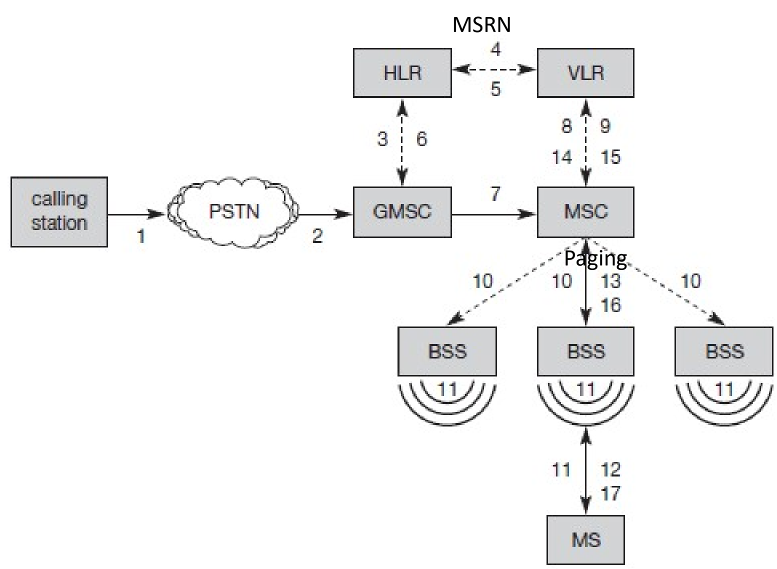
Localization and Calling, Int.Roaming

- The calling function is used to make a call to a mobile (or) a landline.
- Two possibilities are

  1.Mobile Terminated Calls

  2.Mobile Originated Calls

Mobile Terminated Call (MTC)



Mobile Terminated Call (MTC)

Step 1: The user dials a GSM subscriber phone number.

Step 2: The PSTN identifies that the number dialed belongs to GSM network and forwards the call to **Gateway MSC(GMSC)**.

Step 3: The gateway MSC identifies the HLR of the subscriber and signals the call setup to the HLR.

Step 4: The HLR checks whether the number exists and the **services are permitted services and requests MSRN from the current VLR.**

Step 5: **The HLR receives the (Mobile Subscriber Roaming Number) MSRN.**

Step 6: The HLR determines the MSC responsible for the MS forwards the information to the GMSC.

Step 7: The GMSC forwards the call setup request to the MSC indicated.

Step 8: The MSC is responsible for the steps from here after.

Step 9: The MSC requests the VLR to provide the current status of the MS. The MSC resends the request.

Step 10: If the MS is available the MSC initiates paging in all cells responsible for.

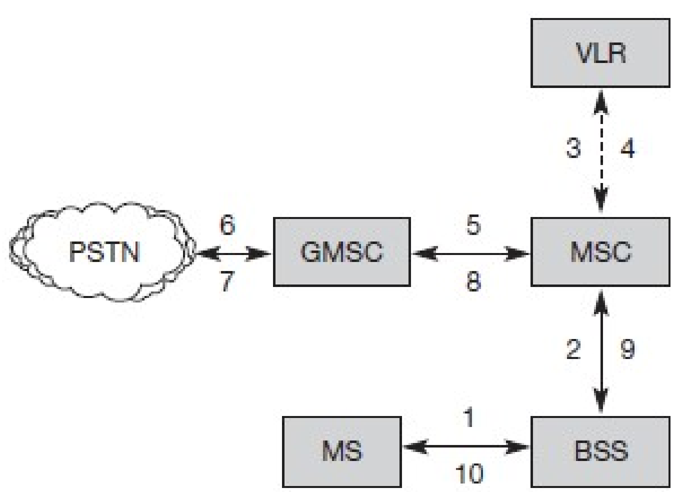
Step 11: The BTS of all the BSS transmit the paging signal.

Step 12 & 13: If the MS answers the VLR performs security check.

Step 14: The MSC response is transmitted to VLR.

Step 15 to 17: The VLR asks the MSC to setup a connection to communicate.

Mobile Originated Call (MOC)



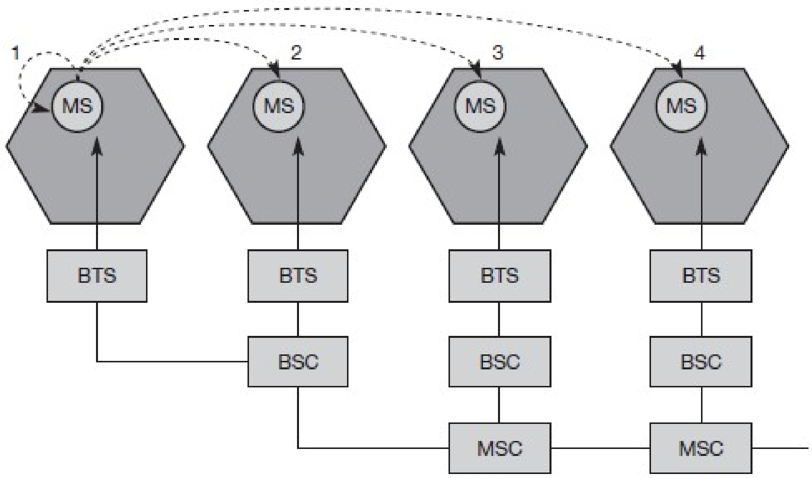
Mobile Originated Call (MOC)

Step 1: The MS transmits a request for a connection.
Step 2: The BSS forwards the request to MSC.
Step 3: The **MSC checks if the user is allowed to setup a call with the requested service and checks the availability of resources.** If all the resources are available MSC sets up a connection between MS and fixed network.

Localization and Calling, Int.Roaming

- As soon as an **MS moves into the range of a new VLR** (a new location area), **the HLR sends all user data needed to the new VLR.**
- **Changing VLRs with uninterrupted availability of all services is also called Roaming.**
- **Roaming can take place within the network of one provider, between two providers in one country** (**national roaming** is, often not supported due to competition between operators), but also between different providers in different countries (**international roaming**).
- Typically, **people associate international roaming with the term roaming as it is this type of roaming that makes GSM very attractive: one device, over 190 countries!**

Types of Handover in GSM

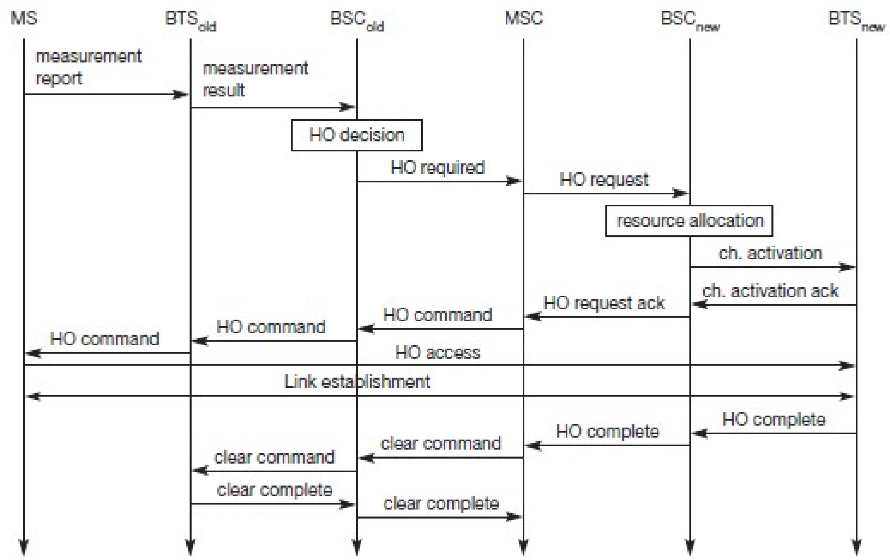


Types of handover in GSM

Four possible handover scenarios in GSM:

- **Intra-cell handover: Within a cell, narrow-band interference could make** transmission at a certain frequency impossible. The **BSC could then decide to change the carrier frequency (scenario 1).**
- **Inter-cell, intra-BSC handover: This is a typical handover scenario. The mobile station moves from one cell to another, but stays within the control of the same BSC. The BSC then performs a handover, assigns a new radio channel in the new cell and releases the old one (scenario 2).**
- **Inter-BSC, intra-MSC handover: As a BSC only controls a limited number of cells**; **GSM also has to perform handovers between cells controlled by different BSCs**. **This handover then has to be controlled by the MSC (scenario 3)**. This situation is also shown in Figure 4.13.
- **Inter MSC handover: A handover could be required between two cells belonging to different MSCs. Now both MSCs perform the handover together (scenario 4).**

Intra-MSC handover



GSM- Security

The security services offered by GSM are explained below:

- **Access control and authentication: The first step includes the authentication** of a valid user for the SIM. The user needs **a secret PIN to access the SIM**. The next step is the **subscriber authentication** .
- **Confidentiality: All user-related data is encrypted. After Authentication, BTS and MS apply encryption to voice, data, and signaling** .This confidentiality exists only between MS and BTS, but it does not exist end-to-end or within the whole fixed GSM/telephone network.
- **Anonymity: To provide user anonymity, all data is encrypted before transmission, and user identifiers** (which would reveal an identity) are not used over the air. Instead, GSM transmits a **temporary identifier (TMSI),** which is newly assigned by the VLR after each location update. Additionally, the VLR can change the TMSI at any time.

GSM Security- Subscriber Authentication

- The Access control AC generates a **random number (RAND)** as Challenge.
- The SIM in the MS answers with **SRES (Signed response) as response.**
- The **AUC performs the generation of RAND, SRES, and KC** for each IMSI **and forwards to HLR.**
- The current VLR, requests the **appropriate values from HLR. For authentication VLR sends RAND to SIM.**
- The mobile network and SIM perform the **A3 algorithm with RAND and Kj.**
- The **MS sends the SRES generated by the SIM to VLR**. The VLR compares the both.
- **If same subscriber is accepted, else rejected.**

GSM Security

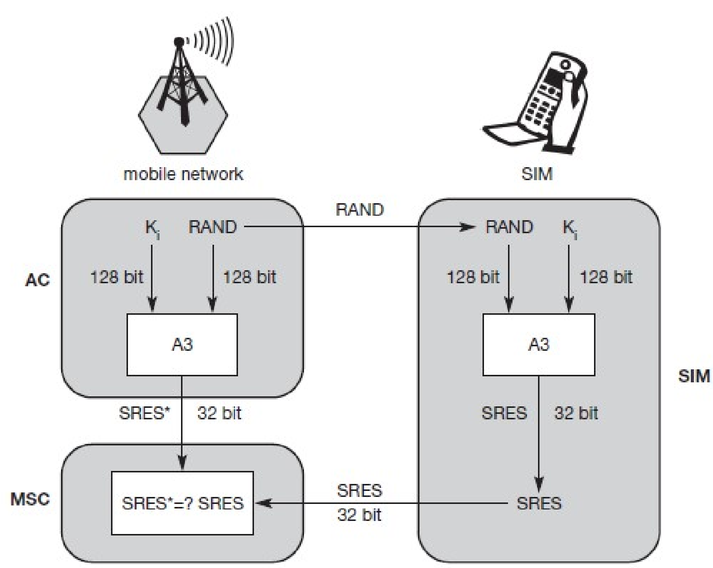


Figure 4.14 Subscriber authentication

GSM Security- Data Encryption

- To have privacy all the user related information messages are encrypted.
- After authentication MS and BSS encrypt using Kc. Kc is generated using Kj and a random value using A8.
- The Kc is not transmitted.
- Hence the SIM and the network calculate Kc, Using RAND. MS and BTS encrypt and decrypt using A5 and Kc.
- Kc is 64 bit length.
- Encryption is not strong because of 64 bits; 16 bits are always 0 in kc.

GSM Security- Data Encryption

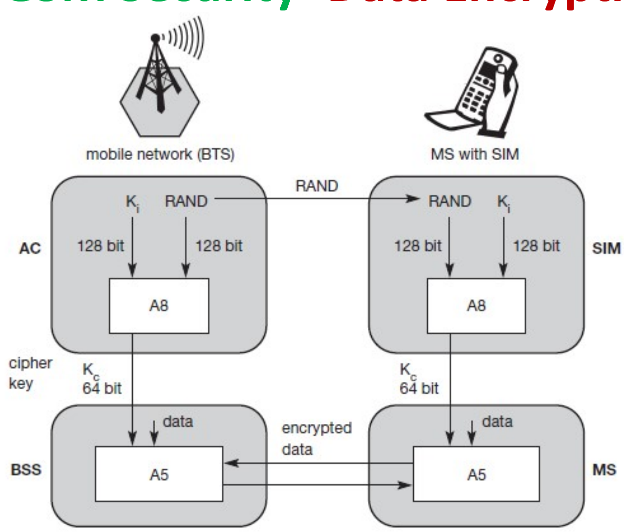


Figure 4.15 Data encryption

GSM Security- Data Encryption

- A3 is authentication algorithm,
- A8 is ciphering key generating algorithm and
- A5 is a stream cipher for encryption of user data transmitted between mobile and base station.

GSM Specifications

Multiple Access Method	TDMA / FDMA
Base station to Mobile frequencies (MHz)	935-960(basic GSM)
Mobile to Base station frequencies (MHz)	890-915(basic GSM)
Duplexing	FDD
Channel spacing, KHz	200
Modulation	GMSK
Portable TX power, Maximum/average (mW)	1000/125
Power control, handset and BSS	yes
Speech coding and rate (kbps)	RPE-LTP / 13
Speech channels per RF channel:	8
Channel rate (kbps)	270.833
Channel coding Rate	½ convolutional
Frame duration (ms)	4.615

GSM- New Data Services

New data services

- HSCSD
- GPRS

GSM- New Data Services -HSCSD

- **A straightforward improvement of GSM's data transmission capabilities is high speed circuit switched data (HSCSD), which is available with some providers.**
- **In this system, higher data rates are achieved by bundling several TCHs.**
- **An MS requests one or more TCHs from the GSM network, i.e., it allocates several TDMA slots within a TDMA frame.**
- **This allocation can be asymmetrical, i.e., more slots can be allocated on the downlink than on the uplink.**
- **Basically, HSCSD only requires software upgrades in an MS and MSC** (both have to be able to split a traffic stream into several streams, using a separate TCH each, and to combine these streams again).

GSM- New Data Services-HSCSD

- In theory, an **MS could use all eight slots within a TDMA frame** to achieve an **air interface user rate (AIUR) of, e.g., 8 TCH/F14.4 channels or 115.2 kbit/s** (ETSI, 1998e).
- One problem of this configuration is that the **MS is required to send and receive at the same time.**
- **Standard GSM does not require this capability** – uplink and downlink slots are always shifted for three slots.
- ETSI (1997a) specifies the **AIUR available at 57.6 kbit/s (duplex) using four slots in the uplink and downlink.**
- Table 4.2 shows the permitted combinations of **traffic channels and allocated slots for non-transparent services.**

GSM- New Data Services-HSCSD

AIUR	TCH / F4.8	TCH / F9.6	TCH / F14.4
4.8 kbit/s	1	–	–
9.6 kbit/s	2	1	–
14.4 kbit/s	3	–	1
19.2 kbit/s	4	2	–
28.8 kbit/s	–	3	2
38.4 kbit/s	–	4	–
43.2 kbit/s	–	–	3
57.6 kbit/s	–	–	4

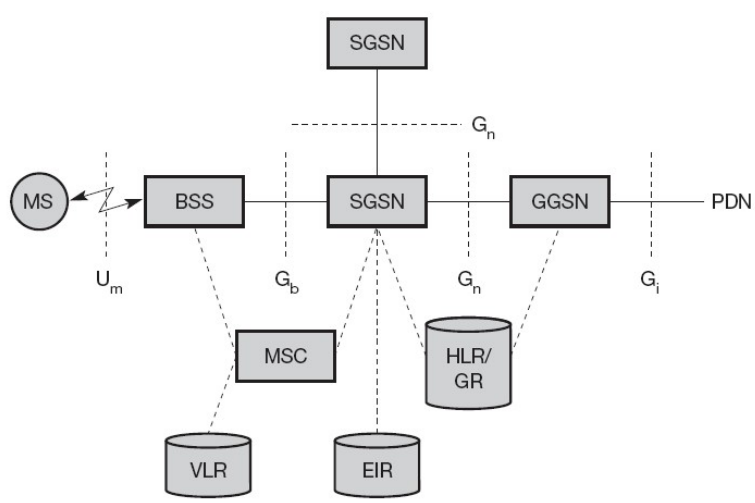
Table 4.2 Available data rates for HSCSD in GSM

GSM- New Data Services-GPRS

- **GPRS** stands for **G**eneral **P**acket **R**adio **S**ervices.
- This mechanism is flexible and powerful.
- **This method provides packet mode for data transfer for small volumes of data, to increase the data transfer.**
- **GPRS is a connectivity solution based on Internet Protocols that supports a wide range of enterprise and consumer applications.**
- With throughput **rates of up to 40 kbit/s**, users have a similar access speed to a dial up modem.
- GPRS customers enjoy advanced, **feature-rich data services such as Internet browsing-mail** on the move, **powerful visual communications such as video streaming, multimedia messages and location-based services.**

GSM- New Data Services-GPRS

GPRS- Architecture



Serving GPRS support node (SGSN) **Gateway GPRS support nodes (GGSN)**

GSM- New Data Services-GPRS

GPRS- Architecture

The GPRS architecture introduces new network elements via **Gateway GPRS support nodes (GGSN) and Servicing GPRS Support Node (SGSN).**

GSN: The GSN are routers. The GSN are integrated into the GSM architecture.

GGSN: The GGSN are the internetworking unit present between GPRS Network and packet Data Networks.

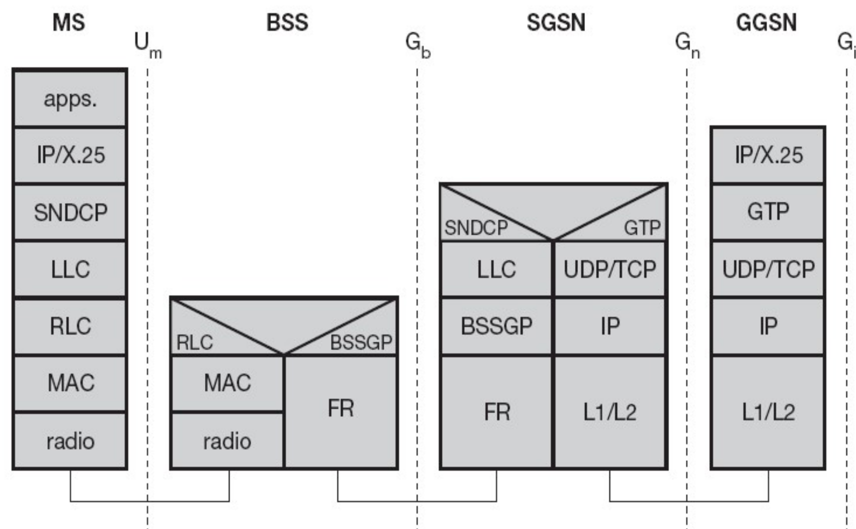
- The **GGSN contains routing information and does address conversions and tunneling.**
- The GGSN is connected to the external network via a Gi interface and transfers
- packet to SGSN via Gn interface.

Serving GPRS Support Node (SGSN):

- This node support MS via Gb interface.
- The SGSN requests the user address from GPRS (GR) and keeps track of individual MS location.
- SGSN is connected to the BSC via frame relay.
- This **node is responsible for billing and security related functions.**
- **The GR is in HLR and stores GPRS relevance –data.**

GSM- New Data Services-GPRS

GPRS –Protocol Reference Model



GPRS Tunneling Protocol(GTP) **frame relay (FR)**

Sub Network Dependent Convergence protocol (SNDCP)

GSM- New Data Services-GPRS

GPRS –Protocol Reference Model

MS:

- All the data within the GPRS back bone (i.e.)between GSN is transferred using **GPRS Tunneling Protocol(GTP)**
- GTP uses 2 different transport layer protocols
  - **(a) TCP**
  - **(b) UDP**
- The network layer protocol is IP.
- As the protocols are different to adapt to the different characteristics **Sub Network Dependent Convergence protocol (SNDCP)** is used between SGSN and MS.
- On the top of SNDCP and GTP user data is tunneled from MS to the GGSN.
- To achieve high reliability, LLC is used. **LLC has ARQ and FEC.**

GSM- New Data Services-GPRS

GPRS –Protocol Reference Model

BSS:

- The **Base Station Subsystem GPRS protocol** is based **(BSSGP)** Specify Routing and QoS related information between BSS and SGSN.
- The BSSGP does not perform error correction and works on top of **Frames Relay (FR).**
- The Radio link dependent protocols needed to transfer data over Um interface.
- The **RLC provides reliable, MAC controls the access with signaling procedure and mapping of LLC frames on to GSM physical channels.**
- The Radio interfaces at **Um** do not need any changes.
- New logical channels and mapping to the physical resources have been defined (e.g.) **Packet Data Traffic channels(PDTCH)**.
- Capacity allocation is a demand and shared between circuit switched channels.
- The important factor needed is that for any application working should not notice any details from GPRS infrastructure.
- **Tunneling takes place to keep them not informed about the hops.**

DECT

- DECT stands for **Digital Enhanced Cardless Telecommunication.**
- DECT is used in **offices, trade shows, home** etc.
- **Access points to PSTN are established with in.**
- Digital Cellular networking specialized by **ETSI** in 2002.
- **A normal DECT slot is 417 microseconds long and contains 420 bits. It is made up of the following fields:**
  - **16 bits preamble (yellow)**
  - **16 synchronization word(blue)**
  - **64 bit A field. It specifies what the content of the B field is (red).**
  - **324 bits B field. This contains the actual information: voice of data (green).**
- **Most of the DECT product on the market today use Gaussian filtered FSK (GFSK)**
- **DECT uses Dynamic Channel Allocation.**

Difference between DECT and GSM

- The difference lies in cell diameter and cell capacity.
- **GSM is designed for outdoor ,cell diameter of 70 km.**
- **DECT is designed for indoor, cell diameter of 300 m from the base station.**
- **DECT can offer service to 10,000 people within one km.**
- **DECT works at a frequency range of 1880-1990 MHz offering QD Full duplex channels.**
- **TDD is used using 10ms frames**
- **Frequency range is subdivided into 10 carries frequency using FDMA, each frames are divided into 24 slots using TDMA.**
- **12 slots are used for uplink and another 12 slots for downlink.**

DECT

Modulation Scheme:

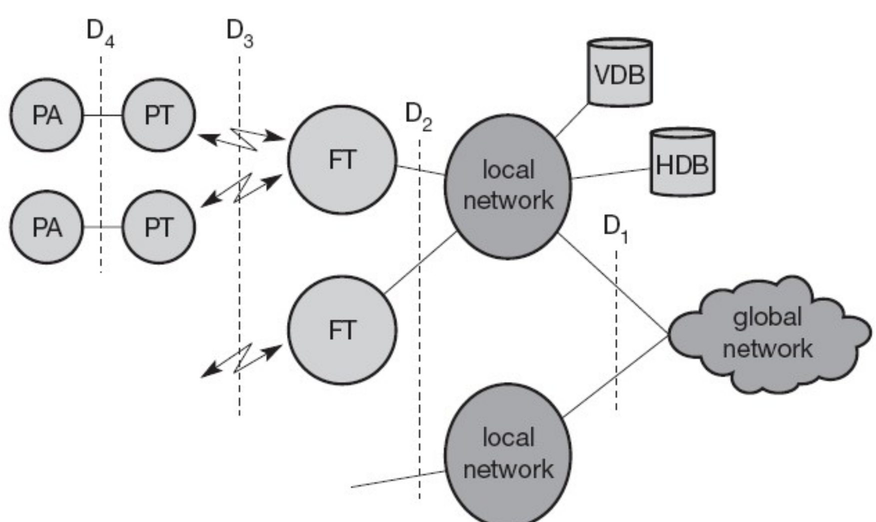
- Most of the DECT product on the market today use Gaussian filtered FSK (GFSK) as their modulation scheme.
- The advantages of GFSK can be summarized as follows.

➢ **Constant envelop nature:** this allows GFSK modulated signal to be operated with **class-C power amplifier** without introducing spectrum regeneration. Therefore, lower power consumption and higher power efficiency can be achieved.

➢ **Narrow power spectrum**: narrow main lobe and low spectral tails keep the **adjacent channel interference to low levels and achieve higher spectral** (being a phantom) efficiency.

➢ **Non-coherent detection:** GFSK modulated signal can be **demodulated by the limiter/ discriminator receiver.**

DECT-System Architecture



PA: Portable Application
PT: Portable Radio Termination
FT: Fixed Radio Termination

DECT-System Architecture

Global Networks:

- connects the local structure to the outside world, **offer services via interface *D1*, *External Network.***
- Global Network can be **ISDN/PSTN.**
- The services offered can be **transportation of data, translation of address and routing of data between networks.**

Local Network:

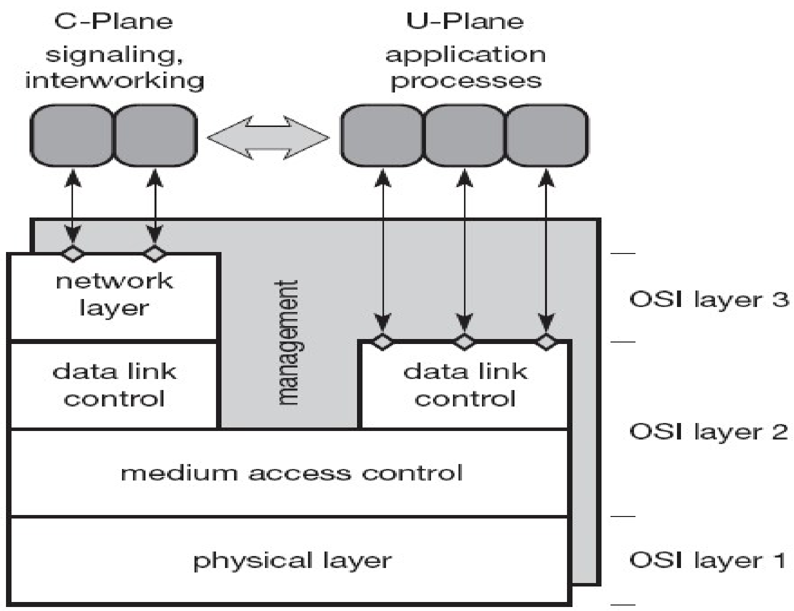
- The local networks in DECT offer local Communication Services (e.g.) call forwarding, address translation. **This is the core of the DECT system**.
- All the network functions needs to be integrated in with local or global network.
- The local network **has Home Data Base (HDB) and Visitor Data Base (VDB).**
- These data bases support mobility. They are similar to HLR and VLR.
- **Incoming calls are automatically forwarded to the current subsystem responsible for the DECT user and the VDB informs the HDB about change in location.**

DECT-System Architecture

Fixed Radio Termination(FT) and Portable Radio Termination(PT)

- They form the (FT & PT) core of DECT network.
- They provide multiplexing.
- They form layer 1 to 3 in both fixed network and mobile network.

DECT-Protocol Architecture



DECT-Protocol Architecture

- The protocol architecture follows the OSI` reference model.
- The layers are **physical Layer**, **Medium access control** and **Data Link control** for **control plane. (C-Plane)** and **user plane (U-Plane).**
- For the **C-Plane** there is an additional network layer, the user data from layer 2 is directly forwarded to the **U-plane.**
- **A management plane** vertically covers all lower layer of a DECT system.

DECT-Protocol Architecture

Physical Layer

- The functions are

(1) Modulation/demodulation.

(2) Incoming signal detection.

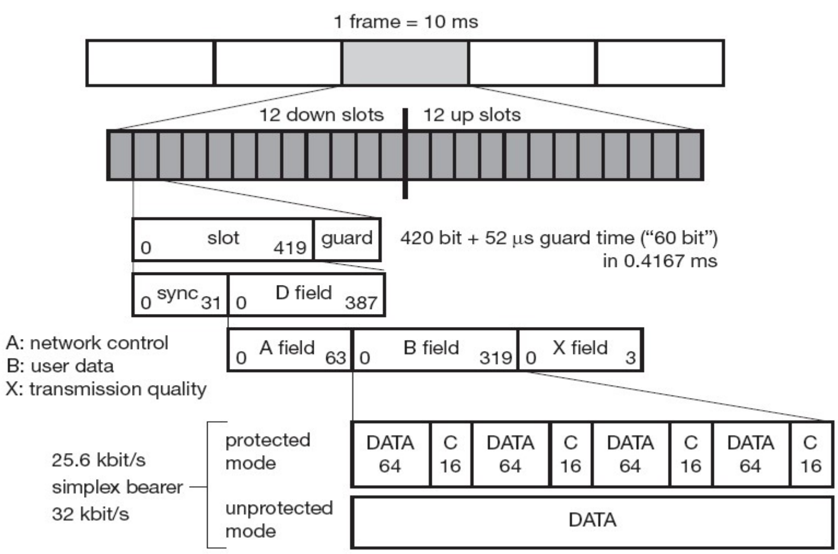
(3) Sender/receiver Synchronization.

(4) Collection of status information for the management plane.

- This layer generates the physical channel structure.
- On request from the MAC layer the physical layer assigns a channel for data transmission.

DECT-Protocol Architecture

DECT-TDMA frame structure



DECT-Protocol Architecture

DECT-TDMA frame structure

- The above figure shows TDMA frame structure.
- **The duration is 10 ms and contains 12 slots for downlink and 12 slots for uplink in basic connection mode.**
- If the **mobile node receives data in slot S, it returns data in slot S + 12.**
- An advanced connection mode allows different allocation scheme.
- **Each slot has duration of 0.4167 ms** and contain several different physical packets.
- 420 bits are used for data, **52 µS are used as guard space**.
- The **420 data bits** are divided into **32 bit synchronization pattern**, followed by the **data field D**.
- The fields for data transmission use the 388 bits for network control A field User data B field
- Transmission Quality-X field.
- Network control is transmitted at 6.4 kBPs.
- User data depends upon error correction mechanisms

DECT-Protocol Architecture

DECT-TDMA frame structure

Modes:

(1) Unprotected Mode:

- Simpler bearer service at 32 kBk

(2) Protected Mode:

- 64 bit data, 16 bit CRC
- Data rate: 25.6 kBPs.

Duplex Bearer service

- Combines 2 simplex bearer services.
- 80 kBPs Data Increases Throughput.

DECT-Protocol Architecture

Medium Access Control Layer

- **Functions**

1. Establish, maintain, release channel for higher layer by activating and deactivating physical channels.
2. Multiplex several logical channels to physical channel.
3. Logical channels are used for signaling network control, user data transmission, paging broadcast messages.
4. Services are segmentation and reassembly.
5. Error Control and Correction.

Data Link Control Layer: DLC

- **Functions:** Creates and maintains reliable connections between mobile and base station.

Services for C-Plane

1. Connection less broadcast for paging called LB.
2. Point to point protocol.

Services for U-Plane:

1. Transparent, unprotected service, FEC, Rate adaptation.

DECT-Protocol Architecture

Network Layer

- The network layer exists only for C-plane.
- Functions are to **request, check, reserve control and release resource at the fixed station and mobile terminal.**

The mobility management is responsible for identity management, authentication and to manage local data bases.

- The call control handles connection setup**, release and negotiation.**

The message services are

- **1. Connection oriented massage service (COMS).**
- **2. Connection less message service (CLMS).**
- They are responsible for **data transfer to from the Internetworking unit that connects** the DECT system to the outside world.

TETRA(TErrestrial Trunked RAdio)

- Trunked radio systems constitute **another method of wireless data transmission.**
- These systems **use many different radio carriers but only assign a specific carrier to a certain user for a short period of time according to demand.**
- While, for example, **taxi services**, **transport companies with fleet management systems** and **rescue teams all have their own unique carrier frequency in traditional systems**, they can **share a whole group of frequencies** in trunked radio systems for better frequency reuse via **FDM and TDM** techniques.
- **These types of radio systems typically offer interfaces to the fixed telephone network, i.e., voice and data services, but are not publicly accessible.**
- This system should replace national systems, such as **MODACOM, MOBITEX and COGNITO in Europe** that typically connect to an X.25 packet network.(An example system from the **US is ARDIS**.)

TETRA(TErrestrial Trunked RAdio)

TETRA offers two standards:

- The **Voice + Data (V+D) service (ETSI, 1998l) and the Packet Data Optimized (PDO) service** (ETSI, 1998m).
- While **V+D offers circuit-switched voice and data transmission**, **PDO only offers packet data transmission**, either **connection-oriented to connect to X.25** or **connectionless for the ISO CLNS (connectionless network service).**
- The latter service can be **point-to-point** or **point-to-multipoint.**
- **V+D connection modes comprise unicast and broadcast connections, group communication within a certain protected group, and a direct ad hoc mode without a base station.**
- However, **delays for short messages can be up to 500 ms or higher depending on the priority.**

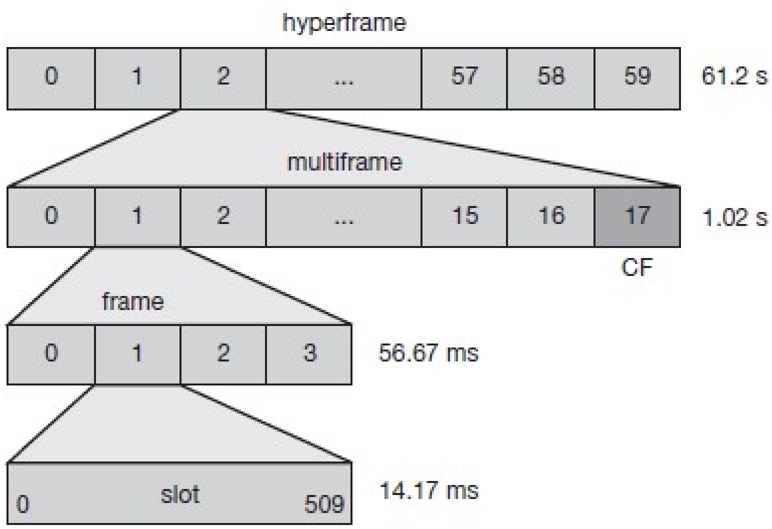
TETRA(TErrestrial Trunked RAdio)

- TETRA also offers **bearer services of up to 28.8 kbit/s for unprotected data transmission** and **9.6 kbit/s for protected transmission.**
- Examples for end-to-end services are **call forwarding, call barring, identification, call hold, call priorities, emergency calls and group joins.**
- **The system architecture of TETRA is very similar to GSM.**
  - Via the radio interface Um, the **mobile station (MS) connects to the** Switching and Management Infrastructure (SwMI), **which contains the user data bases** (HDB, VDB), the base station, and **interfaces to PSTN, ISDN, or PDN.**
  - The system itself, however, is much simpler in real implementation compared to GSM, as typically **no handover is needed**.
  - **Taxis** usually remain within a certain area which can be covered by one TETRA cell.

TETRA(TErrestrial Trunked RAdio)

- Several frequencies have been specified for **TETRA which uses FDD (e.g., 380–390 MHz uplink/390–400 MHz downlink, 410–420 MHz uplink/420–430 MHz downlink).**
- **Each channel has a bandwidth of 25 kHz and can carry 36 kbit/s.**
- Modulation is **DQPSK**. While **V+D uses up to four TDMA voice or data channels per carrier**, **PDO performs** statistical multiplexing.
- For accessing a channel, **slotted Aloha is used**.

TDMA frame structure of TETRA



TDMA frame structure of TETRA

- Each **frame** consists of four slots (**four channels in the V+D service per carrier**), with a **frame duration of 56.67 ms.**
- Each **slot carries 510 bits within 14.17 ms, i.e., 36 kbit/s. 16** frames together with one **control frame (CF) form a multiframe, and finally, a hyperframe contains 60 multiframes.**
- **To avoid sending and receiving at the same** time, TETRA shifts the uplink for a period of two slots compared to the downlink.
- TETRA offers **traffic channels (TCH) and control channels (CCH) similar** to GSM.
- Typical **TCHs are TCH/S for voice transmission**, and **TCH/7.2, TCH/4.8, TCH/2.4 for data transmission** (depending on the FEC mechanisms required).

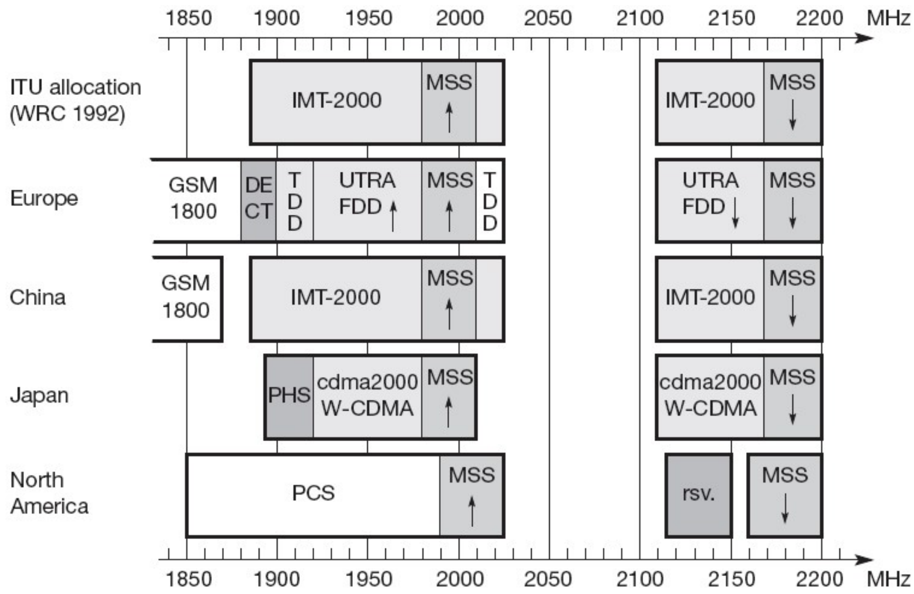
TETRA(TErrestrial Trunked RAdio)

- However, in contrast to GSM, **TETRA offers additional services like group call, acknowledged group call, broadcast call, and discrete listening.**
- **Emergency services need a sub-second group-call setup in harsh environments** which possibly lack all infrastructure.
- **These features are currently not available in GSM** or other typical mobile telephone networks, so TETRA is complementary to other systems.
- **TETRA has been chosen by many government organizations in Europe and China.**

UMTS & IMT-2000

- **UMTS (Universal Mobile Telecommunications Service)** is a third-generation **(3G) broadband, Packet-based transmission of text, digitized voice, video, and multimedia at data rates up to 2 megabits per second (Mbps).**
- **UMTS offers a consistent set of services to mobile computer and phone users**, no matter where they are located in the world.
- UMTS is based on Global System for Mobile (GSM) communication standard.
- **The higher band width of UMTS** also enables other new services like **video conferencing** or **IPTV.**
- **UMTS may allow the Virtual Home Environment (VHE)** to fully develop, **where a roaming user can have the same services to either at home**, in the office or in the field through a **combination of transparent terrestrial and satellite connections.**

Family of IMT-2000



3G Radio Access Technologies

- The ITU standardized the **5 groups of 3G radio access technologies** as

IMT-DS:

- **DS-Direct spread** technology has wide band CDMA (W-CDMA) systems.
- This is the technology specified **for ULTRA-FDD** and used by Europe and Japan.

IMT-TC:

- **TC stands for Time Code.**
- This family member is called time code contained the **UTRA-TDD** system.
- Uses TD-CDMA.
- The Chinese proposal TD synchronous CDMA (TD-SCDMA) was added.

IMT-MC:

- **CDMA -2000** is a **multicarrier** technology standardized by 3 GPP .
- Third generation partnership project 2, 3 GPP2 2002 was formed.
- Version CDMA-2000 EV-DO has been accepted as 3G standard.

IMT-SC:

- **SC – Single Carrier.**
- This is the enhancement of **US TDMA** system systems UWC-136. This is a single carrier technology originally promoted by UWCC.

IMT-FT:

- **Frequency time technology** an **enhanced version of cordless telephone standard DECT** has been selected for application that does not require high mobility.

UMTS System Architecture

- The above figure shows the simplified UMTS reference architecture.
- This is applied **to UTRA**(**U**MTS **T**errestrial **R**adio **A**ccess), 3 GPS 2000.
- The UTRA Network (**UTRAN**) handles cell level mobility and has **Radio Network Subsystem**(**RNS**)

UMTS System Architecture

Functions of RNS:

1) Channel ciphering and deciphering

2) Handover control

3) Radio Resource Management

- The UTRAN is connected to the user **equipment UE via radio interface U_u which is similar to U_m in GSM**.
- The **UTRAN is connected to core network CN via Iu interface which is similar to A in GSM**

Functions of CN (Core Network):

1) Inter system handover

2) Gateways to other network handover

3) Location management

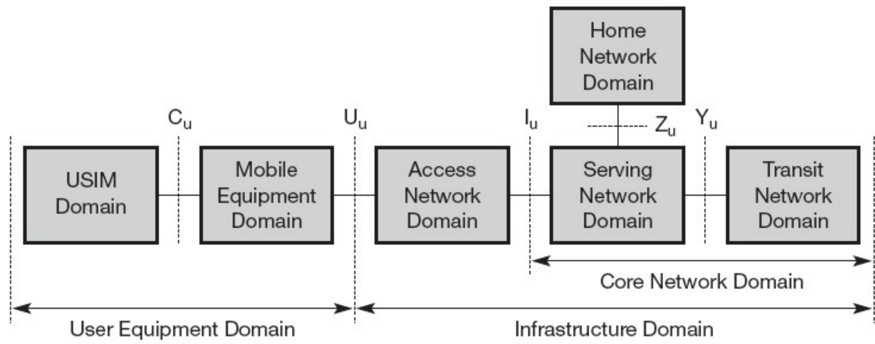
UMTS System Architecture

UMTS further subdivides the simplified architecture into domains. They are,

i. User Equipment domain

ii. Infrastructure domain

iii. Core Network domain



UMTS domains and interfaces

UMTS System Architecture

(i) User Equipment domain:

- The **User Equipment UE domain is assigned to a single user** and **has all the functions that are needed to access the UMTS services.**
- The user equipment domain has **A. USIM domain B. mobile equipment domain.**

A.USIM Domain:

- The **USIM domain contains the SIM for UMTS**, performs encryption, authentication, store user related data for UMTS.
- USIM belongs to service provider and contains micro processors for enhanced program execution.

B. Mobile Equipment Domain:

- The end device is in the mobile equipment domain functions of **Radio Transmission, interfaces are located in Mobile equipment domain.**

UMTS System Architecture

(ii) Infrastructure Domain:

- This domain is shared **among all users and offers UMTS services.**
- The domain **consist of Access network domain:** This consist the **access to network independent functions.**

(iii) Core network Domain:

- The core network domains **have 3 sub domains** with specific task.

1. **Servicing network domain**: Has **all functions currently used by the user for accessing the UMTS services.**
2. **Home network Domain**: **All functions related to home network of a user** is present.
3. **Transmit network Domain**: This domain is used **when the servicing network cannot directly contact the home network.**

UMTS Radio Interface

- The biggest difference between UMTS and GSM comes with the **new radio interface (Uu).**
- The duplex mechanisms are already well known from **GSM (FDD) and DECT(TDD).**
- However, the **Direct sequence (DS) CDMA used in UMTS** is new (for European standards, not in the US where CDMA technology has been available since the early nineties).
- **DS-CDMA technology multiplies a stream of bits with a chipping sequence.**
- This spreads the signal and, **if the chipping sequence is unique, can separate different users.**
- **All signals use the same frequency band** (in UMTS/IMT-2000 5 MHz-wide bands have been specified and licensed to network operators).
- UMTS uses a constant **chipping rate of 3.84 Mchip/s.**

UMTS Radio Interface- UMTS Modes

- There are two modes of UTRA based on FDD and TDD. They are

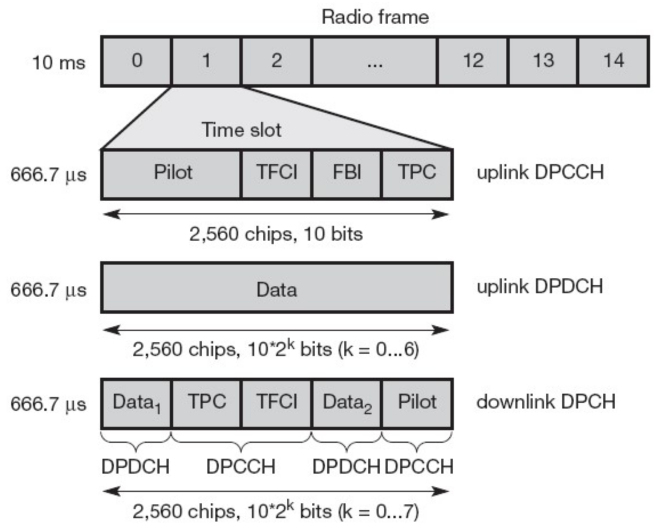
1.UTRA - FDD(W-CDMA)

2. UTRA – TDD (TD-CDMA)

UMTS Radio Interface-UTRA-FDD (W-CDMA)

- The FDD mode for UTRA uses wide band CDMA (W-CDMA) with **direct sequence spreading.**
- The figure shows the radio frame comprising **15 time slots.**
- This slot is **not used for user separation** but it is **used for support periodic function.**
- **Each frame has got logical and physical channels and their mapping.**
- The above figure shows **three physical channels** as they are **used for data transmission.**
- Of the three **two is used for uplink.**

UTRA-FDD (W-CDMA)



UTRA FDD (W-CDMA) frame structure

UTRA-FDD (W-CDMA)

Uplink Channels:

1) Dedicated Physical Data Channel:(DPDC)

- This channel conveys user/signaling data.
- The spreading facture is between 4&256.

2) Dedicated Physical control channel (DPCCH)

- In each connection layer 1 needs exactly one DPCCH.
- This channel **conveys control data for the physical layer only.**
- Spreading is constant at 256.
- **The pilot is user for channel estimation.**
- The **transfer format combination identifies (TFCI) specifies the channels transported with in DPDCH.**
- **Signaling for the soft hand over is supported by the feedback information field (FBI).**
- The last field **transmit power control(TPC) is used for controlling the transmission power of a sender.**
- Power control is performed in each slot.

UTRA-FDD (W-CDMA)

Downlink Channel:

Dedicated physical channel (DPCH):

- The down link **time multiplexes control data and user data.**
- Spreading factor is between 4&512.
- **When no collision occurs on the down links, medium access on the uplink needs to be coordinate. Physical random access channel (PRACH) is used for this**.
- **User equipment UE** starts with lowest available transmission power to avoid interfaces with other stations.
- If **no positive acknowledgement is received UE tries with other slot.**
- The number of available access slots can be defined per cell and is transmitted is a broadcast channel to UE.

UTRA-FDD (W-CDMA)

- The **UE has to perform the following steps during the search for a sale after power on.**

1) Primary synchronization:

- The **UE has to synchronize with the help of 256 primary synchronization codes.**
- This code is same for all cells and helps to synchronize with the time slow structure.

2) Secondary synchronization:

- **The UE receives a secondary synchronization code which defines the group of scrambling codes used in the cell.**
- The UE is synchronized with the frame structure.

3) Identification of the scrambling code:

- The **UE tries all scrambling codes within the group of codes to find the right code with help of correlate.**
- **Finally the UE can receive the data over broad cast channel.**

UTRA-FDD (W-CDMA)

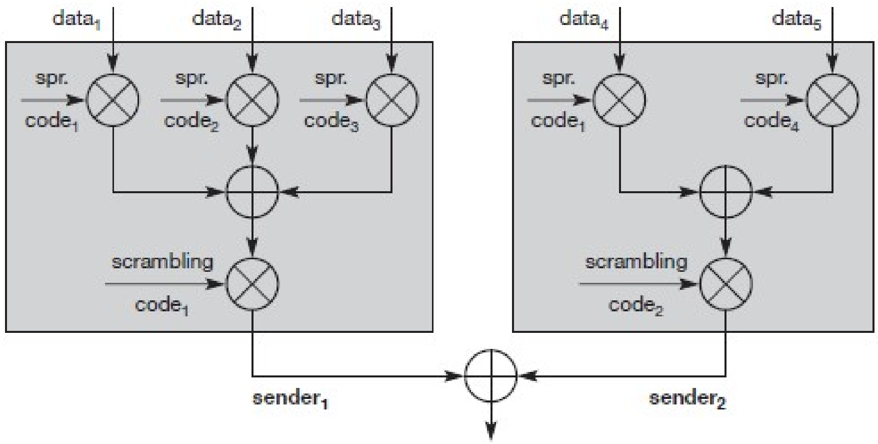


Figure 4.26 Spreading and scrambling of user date

UTRA-FDD (W-CDMA)

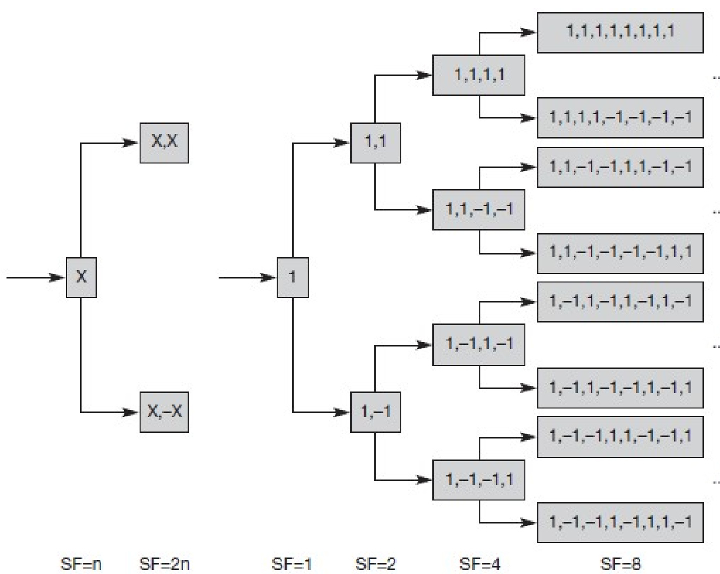


Figure 4.27 OVSF code tree used for orthogonal spreading

UMTS Radio Interface-UTRA-TDD (TD-CDMA)

- This mode **UTRA-TDD separates up and downlink using a radio frame.**
- **1 slot with 2560 chips per slot form a radio frame with duration of 10ms.**
- **Chipping rate is 3.84 M Chips/sec.**

Types of frame

❖ Symmetrical

❖ Asymmetrical

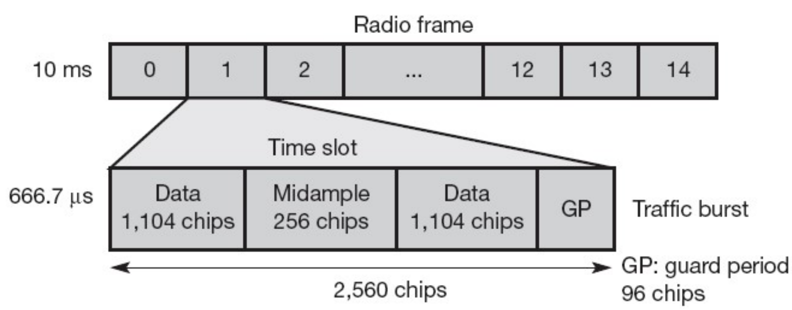
- **Symmetrical (similarity in size, shape, etc):**

➢ The frame contains same no. of uplink and downlink slots.

- **Asymmetrical:**

➢ The frames can be in arbitrary combination. The **frame can have only one switching point from uplink to down link.**

UTRA TDD (TD-CDMA) frame structure



Data rates can be 6,624/3,312/1,656/828/414KBPs.

Data:

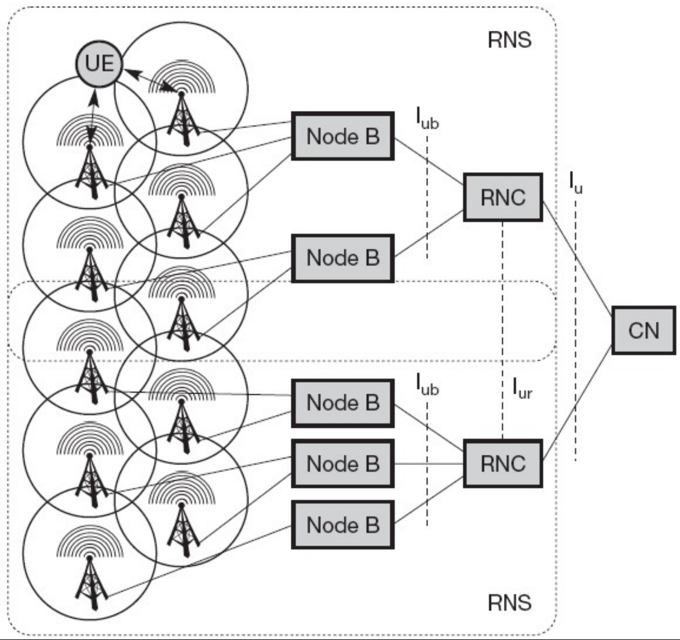
1. **2 data fields 1,104 Chips each.**
2. Spreading is applied to the data fields only.

Midample: This field is **used for training and channel estimation.**

GP: Guard Period.

The stations must be tightly synchronized and the spreading are available once per slot as it uses TDD and same scrambling code for all station. **The GP is used to loosen the synchronization.**

UTRAN- Basic Architecture



UTRAN- Basic Architecture

The following figure shows the architecture of UTRAN. It consists of

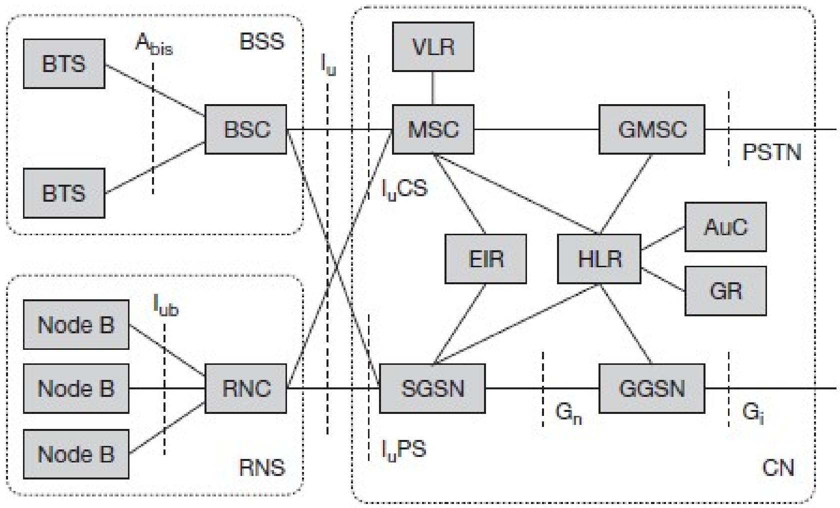
(1) Radio Subsystems RNS:

- RNS is controlled by RNC (Radio Network Controller).
- The RNS has many components called node B.
- RNC is equivalent to BSC, node B is that of BTS.
- RNC is connected to the Core Network (CN) is Iu.

(2) Node B

- The node B controls several antennas which make a radio cell via FDD/TDD.
- The Mobile device UE can be connected to one or more antenna.
- Node B is connected to RNC via I_{ub}.
- Task of node B is the inner loop power control to mitigate near and far effects.
- Node B supports a special handover called softer handover.

Core Networks



UTRAN- Basic Architecture

(3) User Equipment:

UE is the nodes.

Functions

i. Perform signal quality measurement.

ii. UE has to co-operate during handover and cell selection, encryption/decryption,resource allocation process

iii. Implements mobility management, bearer negotiation function.

UTRAN- Basic Architecture

Functions of RNC:

(1) Call Admission Control: RNC calculates the traffic within each cell and decides if additional traffic is acceptable or not.

(2) Congestion Control: RNS allocates bandwidth to each station in a cyclic fashion and considers QoS.

(3) Encryption and Decryption: RNC encrypts all data arriving the PSTN before transmission on Wireless Network.

(4) ATM Switching and Multiplexing, Protocol Conversion: The Connection are based on ATM. RNC has to switch the connections to multiplex the data.

(5) Radio Resource Control: RNC control a radio resources connected to the cells in a node B.

UTRAN- Basic Architecture

Functions of RNC:

(6) Radio Bearer Setup and Release: RNC has to setup, maintain, and release logical data connection to UE.

(7) Code Allocation: CDMA codes used by UE are selected by RNC.

(8) Power Control: RNC performs a loose power control

(9) Handover Control and RNS Relocation: Depending on the signal strength, on UE, node B, the RNC decides if handover is needed or not. If the UE moves out of range of one RNC, a new RNC is needed. This is called RNS Relocation.

(10) Management: The RNC assesses the current load, current traffic, error state to manage the network.

UMTS Protocol Structure Modes

- The UTMS Network can operate in

(i) Circuit Switched Domain (CSD)- has the Classical Circuit Switching Services.

(ii) Packet Switched Domain (PSD)- Packet Switching services.

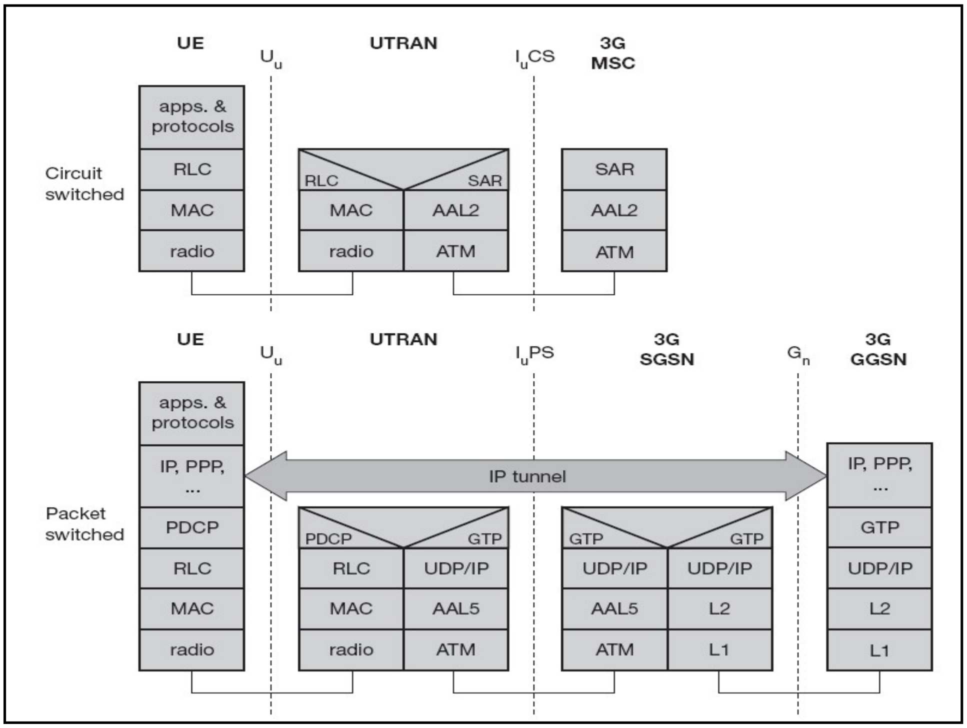
Protocol Stack for CSD and PSD

CSD Protocol Stack:

- This uses the ATM adaptation layers (**AAL2**) for user data transmission.
- RNC implements the RLC and MAC layer.
- Physical layer is located in **node B**.
- SAR- **Segmentation and reassembly layer (SAR) is used to segment and reassemble.**

PSD Protocol Stack:

- Here more protocols are needed.
- Data transport is performed by lower layer.
- All the packets destined for UE are encapsulated using **GPRS tunneling protocol(GTP).**
- RNC performs protocol conversion from **GTP/UDP/IP** to **packet data convergence protocol (PDCP).**
- The **radio layer** is the physical layer depends on UTRA mode.
- **MAC layer** co-ordinates medium access and multiplex the logical channel on to transport channel.
- **The MAC layer does encryption.**



Protocol Stack for CSD and PSD

Radio Link Control RLC: Offers three different transport mode viz.

(1) Acknowledged Mode: Transfers data using **ARQ for error detection**. Guarantee one time, in order delivery.

(2) Unacknowledge Mode: Transfers data **without ARQ**. Guarantees atleast one time delivery with the help of sequence nos.

(3) Transparent Mode: **Transfers the data without processing**. Relies upon FEC used in radio layer.

Handover

UMTS has 2 classes of handover

(1) Hard Handover:

- Switching between different antenna/system is performed at a certain point of time.
- UTRA supports this type only. **Inter frequency handover, Inter System, Inter satellite handover are hard handover.**

➢ **Inter Frequency Handover:** Change the carrier frequency.

➢ **Inter system Handover:** Handover from one GSM system to other system.

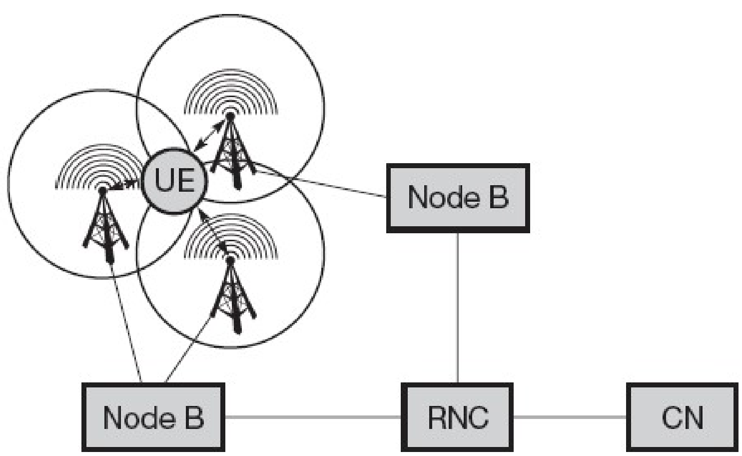
➢ **Inter segment Handover:** Satellite handover is called **Inter Segment handover.**

(2) Soft Handover:

- Here the nodes receive the signals from many stations whereby making the handover soft.
- This Mechanism is present only in FDD mode and only in UMTS.
- Soft handovers use **macro diversity ,** a property of CDMA.

Handover

Micro Diversity

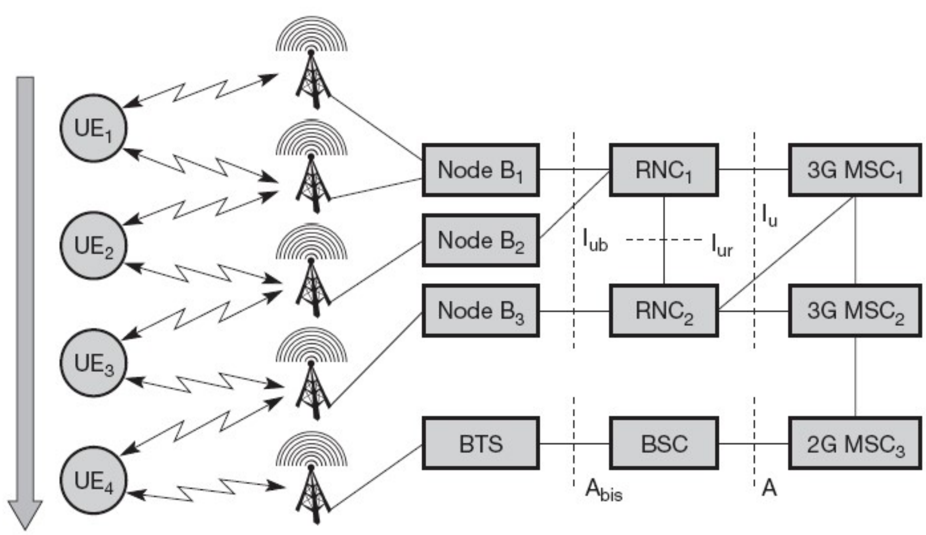


Handover

Micro Diversity

- UE can receive signals from upto three antennas which may belong to different node B.
- The UE combines the received data.
- In other direction UE sends the Data which is received by all node B involved.
- RNC combines the data stream received from node B.
- UE receives data from different antenna at the same time makes a handover soft.
- Moving from one cell to another is smooth.

Handover Types in UMTS



Handover Types in UMTS

1) **Intra Node B, Intra RNC:** UE1 moves from one antenna of node B1 to another antenna. This handover is called soft handover.
2) **Inter Node B, Intra RNC:** UE2 moves from node B1 to node B2. RNC1 supports the soft handover by combining and splitting data.
3) **Inter-RNC:** When UE3 moves from node B2 to node B3 Two types of handover can take place
   - **(i) Internal Inter RNC Handover:** This is not visible for CN. RNC1 can act as SRNC , RNC2 will be DRNC. CN communicate via Iu.
   - **(ii) External Inter RNC Handover:** As soon as the relocation of the interface Iu takes place the handover is called **External Inter RNC handover.** Communication is by the same MSC1 but handover is hard handover.

- UE4 moves from a 3G UMTS to a 2G GSM network. The handover is hard hand over. Real time usability.

Satellite Systems

- History
- Applications
- Basics
- Routing
- Localization
- Handover

Satellite Systems- Introduction

- Satellite communication introduces another system supporting mobile communications.
- Satellites offer global coverage without wiring costs for base stations and are almost independent of varying population densities.
- Three major classes of satellites are
  - GEO,
  - MEO, and
  - LEO.

Satellite Systems- History

The history of satellite systems includes the following key events:

- 1945: Arthur C. Clarke published his essay "Extra-Terrestrial Relays" in the British magazine Wireless World, describing the use of artificial satellites in geostationary orbits to relay radio signals.
- 1957: The Soviet Union launched Sputnik 1, the first artificial Earth satellite, which orbited the Earth for three months. Sputnik 1 was equipped with a radio transmitter that sent pinging sounds down to Earth.
- 1965: The launch of Intelsat 1, also known as Early Bird, marked the beginning of commercial satellite communications.
- 1972: Canada launched ANIK, the first domestic communications satellite.
- 1974: The United States launched WESTAR, the first domestic communications satellite.
- 1976: MARISAT became the first mobile communications satellite.
- 1988: TAT-8 became the first fiber-optic trans-Atlantic telephone cable.
- 2003 : The launch of Eutelsat Communication’s e-BIRD satellite. Using four ‘spot beams’ (the targeting of radio signals from the satellite to a specific point on Earth), this provided Europe with broadband and broadcast services in areas not served by ADSL and other terrestrial broadband technologies.
- In December 2010, Eutelsat launched its KA-SAT satellite, which had 82 narrow spot beams connected to 10 ground stations across Europe.
- 2020: A satellite constellation is a system of interconnected low earth orbit (LEO) satellites that work collaboratively to establish a mesh network. Iridium was among the first to develop this technology, and it is currently experiencing a resurgence with the launch of new constellations such as SpaceX’s Starlink, Telesat’s Light speed, and Amazon’s Kuiper.

Satellite Systems- Applications

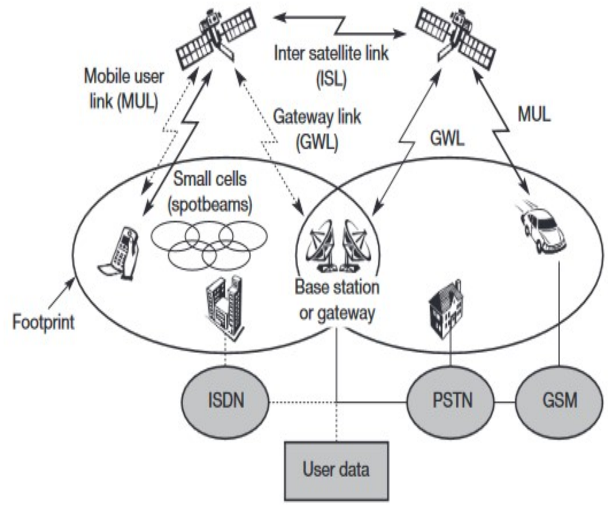
- **Weather forecasting**: Several satellites deliver pictures of the earth using, e.g., infra red or visible light. Without the help of satellites, the forecasting of hurricanes would be impossible.
- **Radio and TV broadcast satellites:** Hundreds of radio and TV programs are available via satellite. This technology competes with cable in many places, as it is cheaper to install and, in most cases, no extra fees have to be paid for this service. Today's satellite dishes have diameters of 30–40 cm in central Europe, (the diameters in northern countries are slightly larger).
- **Military satellites:** One of the earliest applications of satellites was their use for carrying out espionage. Many communication links are managed via satellite because they are much safer from attack by enemies.
- **Satellites for navigation:** Even though it was only used for military purposes in the beginning, the global positioning system (GPS) is nowadays well-known and available for everyone.

Satellite Systems- Applications

- **Global telephone backbones**: While the signal to a geostationary satellite has to travel about 72,000 km from a sender via the satellite to the receiver, the distance is typically less than 10,000 km if a fiber-optical link crossing the Pacific or Atlantic Ocean is used.
- **Connections for remote or developing areas:** Due to their geographical location many places all over the world do not have direct wired connection to the telephone network or the internet (e.g., researchers on Antarctica)
- **Global mobile communication:** Cellular phone systems, such as AMPS and GSM (and their successors) do not cover all parts of a country. Areas that are not covered usually have low population where it is too expensive to install a base station. With the integration of satellite communication, however, the mobile phone can switch to satellites offering worldwide connectivity to a customer (Jamalipour, 1998). For the UMTS system frequency bands directly adjacent to the terrestrial bands have been allocated for the satellite segment (S-Band: 1980–2010 MHz uplink, 2170–2200 MHz downlink)

Satellite Systems- Applications

- Figure 5.1 shows a classical scenario for satellite systems supporting global mobile communication



Satellite Systems- Basics

- Satellites orbit around the earth. Depending on the application, these orbits can be circular or elliptical.
- Satellites in circular orbits always keep the same distance to the earth's surface following a simple law:

- The attractive force F_g of the earth due to gravity equals $m \cdot g \cdot (R/r)^2$.
- The centrifugal force F_c trying to pull the satellite away equals $m \cdot r \cdot \omega^2$.

The variables have the following meaning:

- m is the mass of the satellite;
- R is the radius of earth with $R = 6{,}370$ km;
- r is the distance of the satellite to the centre of the earth;
- g is the acceleration of gravity with $g = 9.81$ m/s^2;
- and ω is the angular velocity with $\omega = 2 \cdot \pi \cdot f$, f is the frequency of the rotation.

Satellite Systems- Basics

To keep the satellite in a stable circular orbit, the following equation must hold:

- $F_g = F_c$, i.e., both forces must be equal. Looking at this equation the first thing to notice is that the mass *m* of a satellite is irrelevant (it appears on both sides of the equation).
- Solving the equation for the distance *r* of the satellite to the center of the earth results in the following equation:
  The distance $r = (g \cdot R^2/(2 \cdot \pi \cdot f)^2)^{1/3}$

Satellite Systems- Basics

- Important parameters in satellite communication are the **inclination and elevation angles.**
- The inclination angle δ (see Figure 5.3) is defined as the angle between the equatorial plane and the plane described by the satellite orbit.
- An inclination angle of 0 degrees means that the satellite is exactly above the equator. If the satellite does not have a circular orbit, the closest point to the earth is called the perigee.

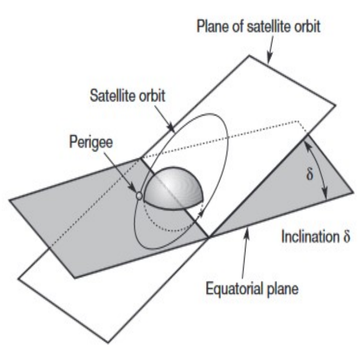


Figure 5.3 Inclination angle of a satellite

Satellite Systems- Basics

- The **elevation angle ε** (see Figure 5.4) is defined as the angle between the center of the satellite beam and the plane tangential to the earth's surface. A so called **footprint** can be defined as the area on earth where the signals of the satellite can be received.

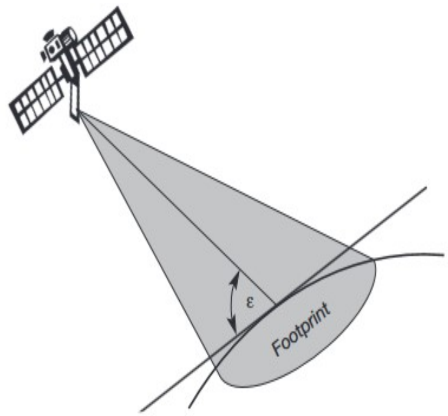


Figure 5.4 Elevation angle of a satellite

Satellite Systems- Basics

- Another effect of satellite communication is the **propagation loss of the signals.** This attenuation of the signal power depends on the distance between a receiver on earth and the satellite, and, additionally, on satellite elevation and atmospheric conditions. **The loss L depending on the distance r between sender and receiver can be calculated as:**

$$L = (4 \cdot \pi \cdot r \cdot f / c)^2,$$

with f being the carrier frequency and c the speed of light.

Satellite Systems- Basics

Four different types of orbits can be identified as shown in Figure 5.6:

- **Geostationary (or geosynchronous) earth orbit (GEO):** GEO satellites have a distance of almost 36,000 km to the earth. Examples are almost all TV and radio broadcast satellites, many weather satellites and satellites operating as backbones for the telephone network.
- **Medium earth orbit (MEO):** MEOs operate at a distance of about 5,000–12,000 km. Up to now there have not been many satellites in this class, but some upcoming systems (e.g., ICO) use this class for various reasons .
- **Low Earth Orbit (LEO):** While some time ago LEO satellites were mainly used for espionage, several of the new satellite systems now rely on this class using altitudes of 500–1,500 km.
- **Highly Elliptical Orbit (HEO):** This class comprises all satellites with noncircular orbits. Currently, only a few commercial communication systems using satellites with elliptical orbits are planned. These systems have their perigee over large cities to improve communication quality.

Satellite Systems- Basics

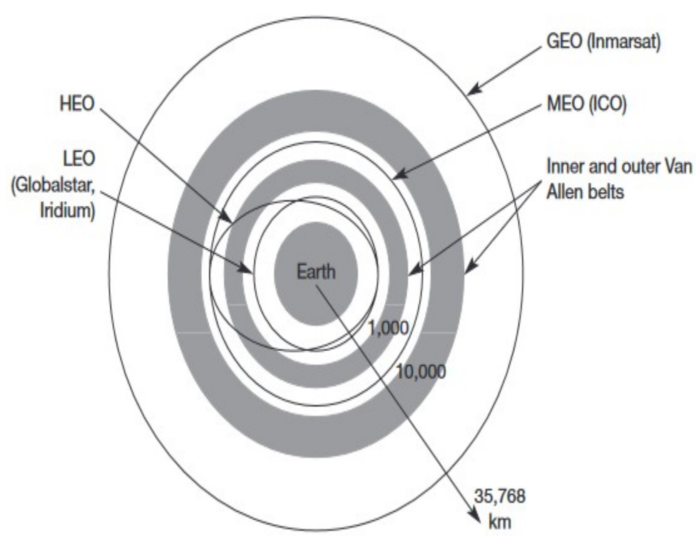
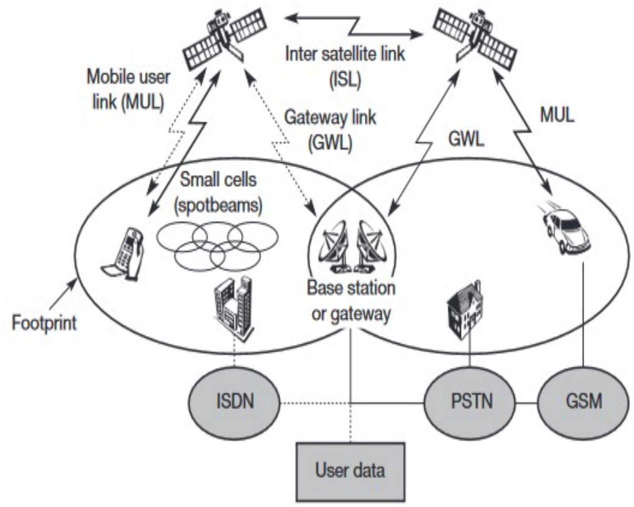


Figure 5.6 Different types of satellite orbits

Satellite Systems- Routing



Satellite Systems- Localization

- Localization of users in satellite networks is similar to that of terrestrial cellular networks.
- One additional problem arises from the fact that now the 'base stations', i.e., the satellites, move as well.
- The gateways of a satellite network maintain several registers.
- A home location register **(HLR)** stores all static information about a user as well as his or her current location.
- The last known location of a mobile user is stored in the visitor location register **(VLR).**
- Functions of the VLR and HLR are similar to those of the registers in, e.g., GSM
- A particularly important register in satellite networks is the **satellite user mapping register (SUMR).** This stores the current position of satellites and a mapping of each user to the current satellite through which communication with a user is possible.

Satellite Systems- Handover

- Intra-satellite handover
- Inter-satellite handover
- Gateway handover
- Inter-system handover

Satellite Systems- Handover

- **Intra-satellite handover:** A user might move from one spot beam of a satellite to another spot beam of the same satellite. Using special antennas, a satellite can create several spot beams within its footprint. The same effect might be caused by the movement of the satellite.
- **Inter-satellite handover:** If a user leaves the footprint of a satellite or if the satellite moves away, a handover to the next satellite takes place. This might be a hard handover switching at one moment or a soft handover using both satellites (or even more) at the same time (as this is possible with CDMA systems). Inter-satellite handover can also take place between satellites if they support ISLs. The satellite system can trade high transmission quality for handover frequency.

Satellite Systems- Handover

- **Gateway handover:** While the mobile user and satellite might still have good contact, the satellite might move away from the current gateway. The satellite has to connect to another gateway.
- **Inter-system handover:** Typically, satellite systems are used in remote areas if no other network is available. As soon as traditional cellular networks are available, users might switch to this type usually because it is cheaper and offers lower latency. Current systems allow for the use of dual-mode (or even more) mobile phones but unfortunately, seamless handover between satellite systems and terrestrial systems or vice versa has not been possible up to now.

Satellite Systems- Examples

	Iridium (orbiting)	Globalstar (orbiting)	ICO (planned)	Teledesic (planned)
No. of satellites	66 + 7	48 + 4	10(?) + 2	288(?)
Altitude [km] coverage	780 global	1,414 ±70° latitude	10,390 global	Approx. 700 global
No. of planes	6	8	2	12
Inclination	86°	52°	45°	40°
Minimum elevation	8°	20°	20°	40°
Frequencies [GHz (circa)]	1.6 MS 29.2 ↗ 19.5 ↙ 23.3 ISL	1.6 MS ↗ 2.5 MS ↙ 5.1 ↗ 6.9 ↙	2 MS ↗ 2.2 MS ↙ 5.2 ↗ 7 ↙	19 ↙ 28.8 ↗ 62 ISL
Access method	FDMA/TDMA	CDMA	FDMA/TDMA	FDMA/TDMA
ISL	Yes	No	No	Yes
Bit rate	2.4 kbit/s	9.6 kbit/s	4.8 kbit/s (144 kbit/s planned)	64 Mbit/s ↙ 2/64 Mbit/s ↗
No. of channels	4,000	2,700	4,500	2,500
Lifetime [years]	5–8	7.5	12	10
Initial cost estimate	$4.4 bn	$2.9 bn	$4.5 bn	$9 bn

UNIT II Review

Telecommunication Systems

- **GSM:** Architecture, Location tracking and call setup, Mobility management, Handover, Security, GSM, SMS, International roaming for GSM, call recording functions, subscriber and Service data management (HLR,VLR,EIR).
- DECT, TETRA, UMTS&IMT-2000.

Satellite Systems: History, Applications, Basics, Routing, Localization, and Handover.

UNIT-2

ENDS