Mobile/Cellular Wireless Networks

Based on:

- 3GPP specifications
- W. Stallings (2010): Wireless Communications and Networks, Chapter 10.
- Wikipedia
- Youtube videos

https://www.youtube.com/watch?v=KWlLOJNH88Q

https://www.youtube.com/watch?v=zlXP8pUx07E#t=48.107744

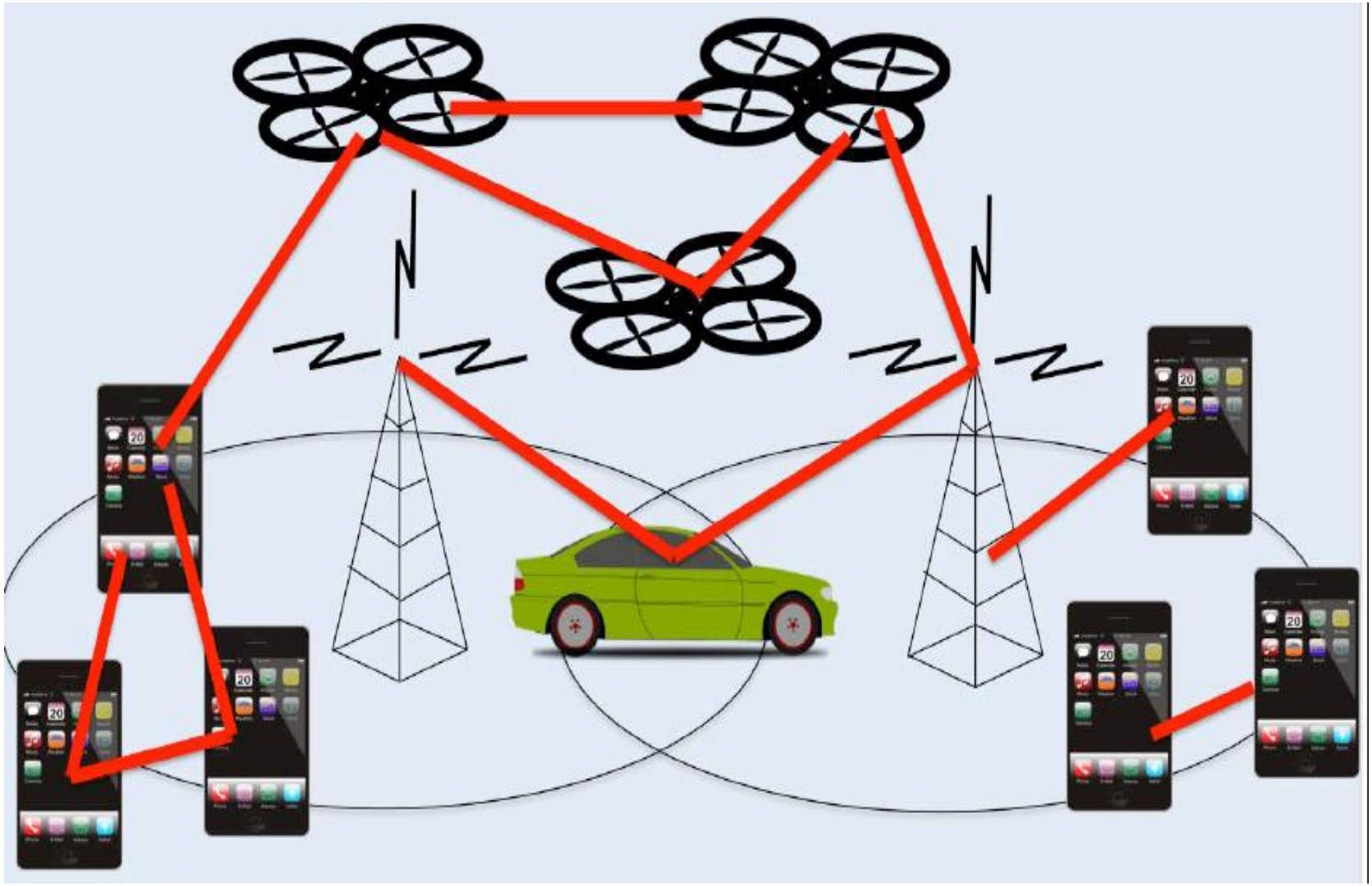
https://www.youtube.com/watch?v=mv9z_L3RQp4

https://www.youtube.com/watch?v=ud5WZuBcKU8

- C. Beard and W. Stallings (2016), Wireless networks and systems, Chapter 13, Cellular Wireless Networks

Learning Outcomes

- Understand of Mobile Network Evolution: from GSM to UMTS and 4G LTE networks
- Understand the principles used in Mobile Station, Radio Access Network, Core Network
- Describe fundamentals of Cellular System Structure and Functions, and procedures on how calls are set up and maintained
- Explain 3G Universal Mobile Telecommunications System (UMTS).
- Understand 3GPP Technical Specifications and the General structure of the 3GPP Public Land Mobile Network (PLMN)



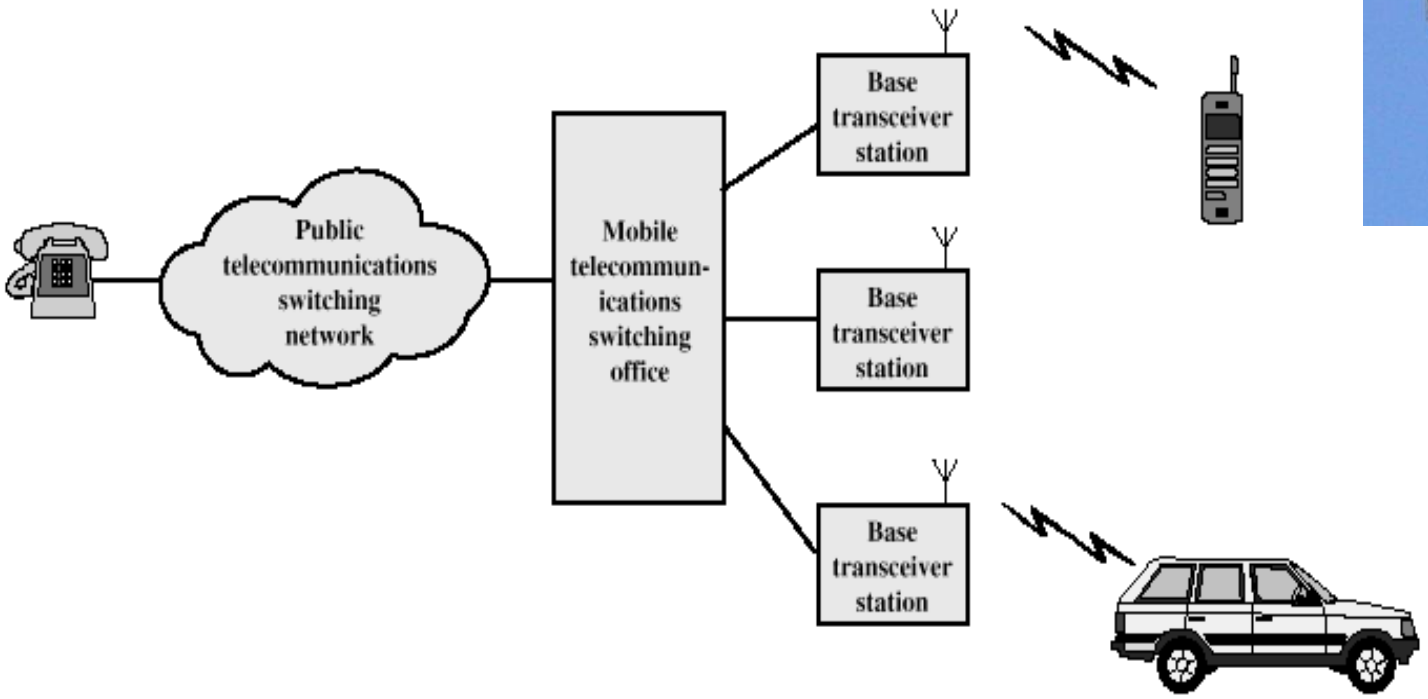
A general view of mobile cellular wireless architecture

Cellular Wireless Networks

Chapter 13

C. Beard & W. Stallings (2016), Wireless Communications Networks and Systems

Cellular System Overview



Principles of cellular networks

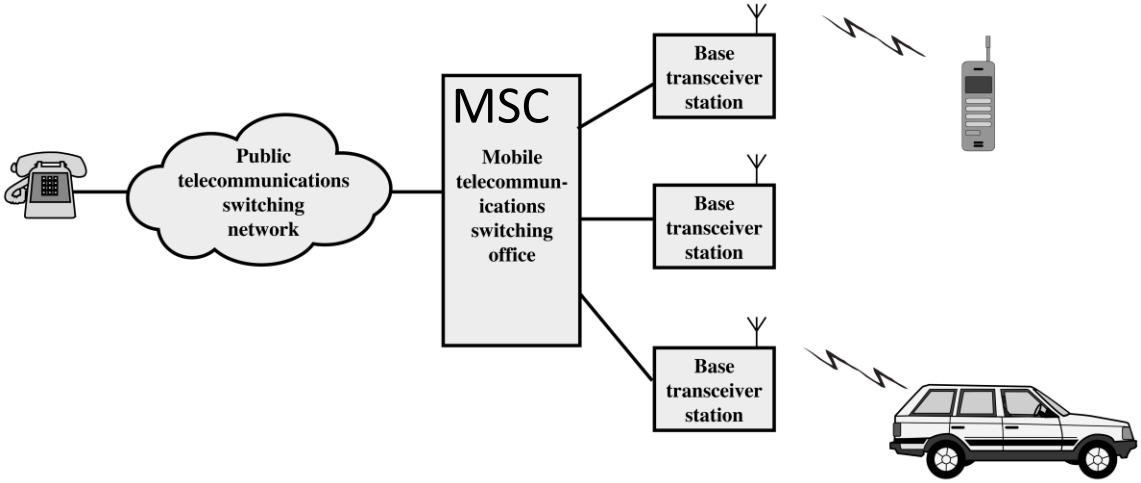
- Modern cellular networks provide mobile wireless access between
  - mobile devices including smart phones
  - land-line phones
  - the Internet
- Early mobile phones were used primarily for voice communications
- Now, the prime application seems to be access to the internet and its services
- Mobile/Cellular network standards/**specifications** are developed by by the **3GPP** (3rd Generation Partnership Project) consortium of companies
- The **3GPP specifications** are arranged into **Releases**

Base Station Subsystem (BSS)

- BSS consists of base station controller and one or more base transceiver stations (BTS)
- Each BTS defines a single cell
  - Includes radio antenna, radio transceiver and a link to a base station controller (BSC)
- BSC reserves radio frequencies, manages handoff of mobile unit from one cell to another within BSS, and controls paging

Mobile Switching Centre

GSM, or pre-Internet version



- The Mobile Switching Centre (MSC) is connected to the public telecommunication network hence allowing calls between the landline and the mobile subscribers.
- The MSC:
  - **Assigns the voice channel** to each mobile station
  - Performs **handoffs**
  - Monitors calls for **billing information**

Cellular Network Organization

- Use multiple low-power transmitters (100 W or less)
- Areas divided into cells
  - Each served by its own antenna
  - Served by base station consisting of transmitter, receiver, and control unit
  - Band of frequencies allocated
  - Cells set up such that antennas of all neighbors are equidistant (hexagonal pattern)

Frequency Reuse

- Adjacent cells assigned different frequencies to avoid interference or crosstalk
- Objective is to reuse frequency in nearby cells
  - 10 to 50 frequencies assigned to each cell
  - Transmission power controlled to limit power at that frequency escaping to adjacent cells
  - The issue is to determine how many cells must intervene between two cells using the same frequency

Approaches to Cope with Increasing Capacity

- Adding new channels
- Frequency borrowing – frequencies are taken from adjacent cells by congested cells
- Cell splitting – cells in areas of high usage can be split into smaller cells
- Cell sectoring – cells are divided into a number of wedge-shaped sectors, each with their own set of channels
- Microcells – antennas move to buildings, hills, and lamp posts

Control and Traffic Channels

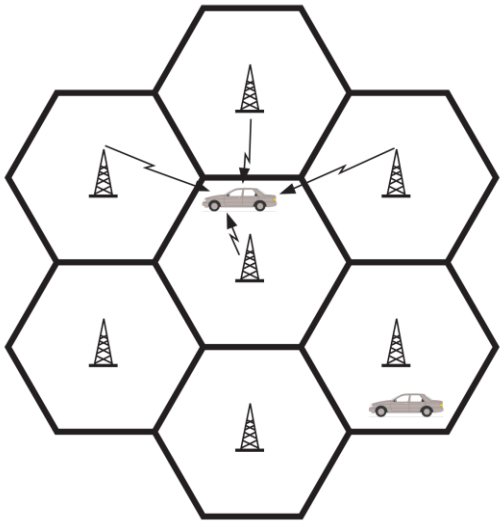
- Two types of channels are available between the mobile unit and the base station:
- **Control channels** are used to
  - **establish connection** with the BS
  - exchange information related to **setting up** and **maintaining the call**
- **Traffic channels** carry the voice or data connections between users.

Setting up and maintaining the calls

Steps and functions related to a typical call in an area controlled by a **single MSC**:

- Mobile unit initialization
- Mobile-originated call
- Paging
- Call accepted
- Ongoing call
- Handover
- Call blocking
- Call termination
- Call drop
- Calls to/from fixed and remote mobile subscriber

Mobile unit initialization



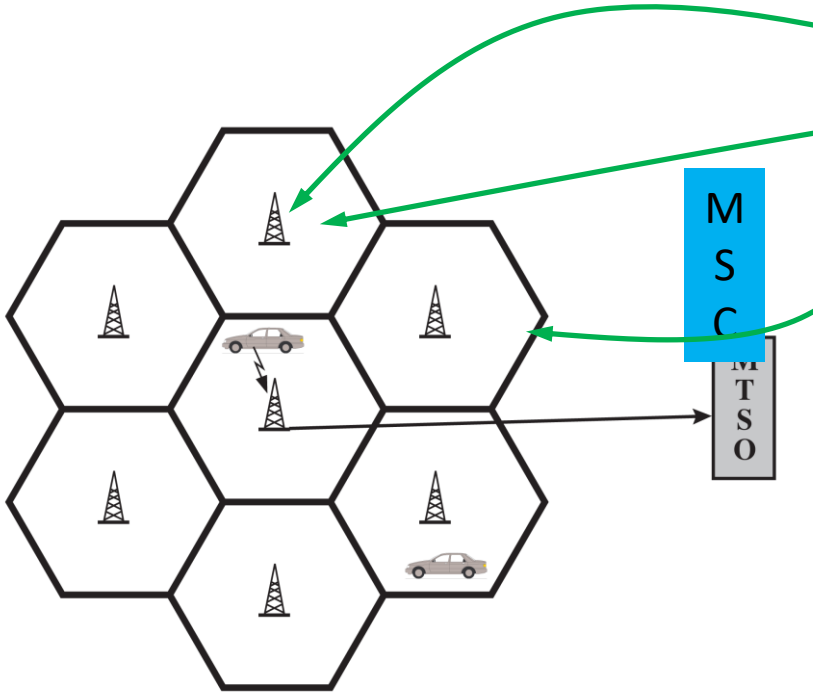
(a) Monitor for strongest signal

M
S
C

- When the mobile unit is switched on, it **scans and selects** the strongest **setup control channel**
- **Cells** with different frequency bands repetitively broadcast on different setup channels.
- The receiver selects and monitors the strongest setup channel.

- Subsequently, the **handshake** takes place between the mobile unit and the MSC controlling this cell through the cell's BS.
- The handshake is used to **identify the user** and register its **location**
- As long as the mobile unit is on, this **scanning procedure** is repeated periodically to account for the motion of the unit.

Mobile-originated call

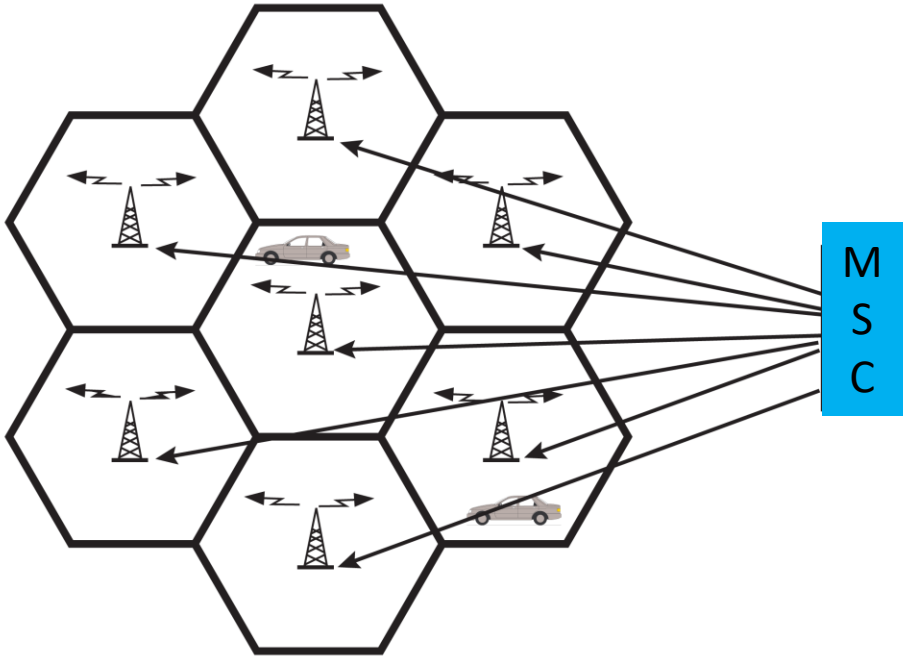


(b) Request for connection

- A **mobile unit** originates a call by sending the number of the **called unit** on the preselected **setup channel**.
- The receiver at the mobile unit first checks that the channel is idle by examining information in the channel from the BS (forward).

- When an idle channel is detected, the mobile unit may transmit on the channel to BS.
- The BS sends the **request for connection to the MSC**.

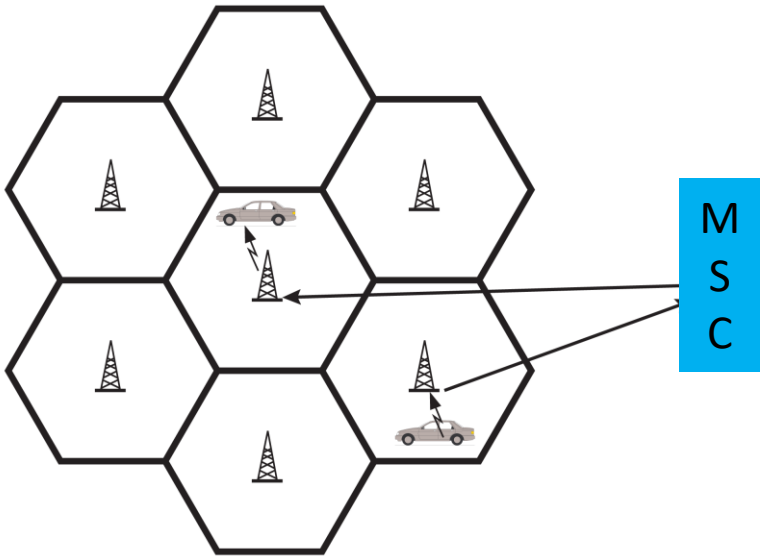
Paging



(c) Paging

- The MSC attempts to complete connection to the called unit.
- The MSC sends a paging message to certain BSs depending on the called mobile unit number.
- Each BS transmits the paging signal on its own assigned setup channel.

Call accepted

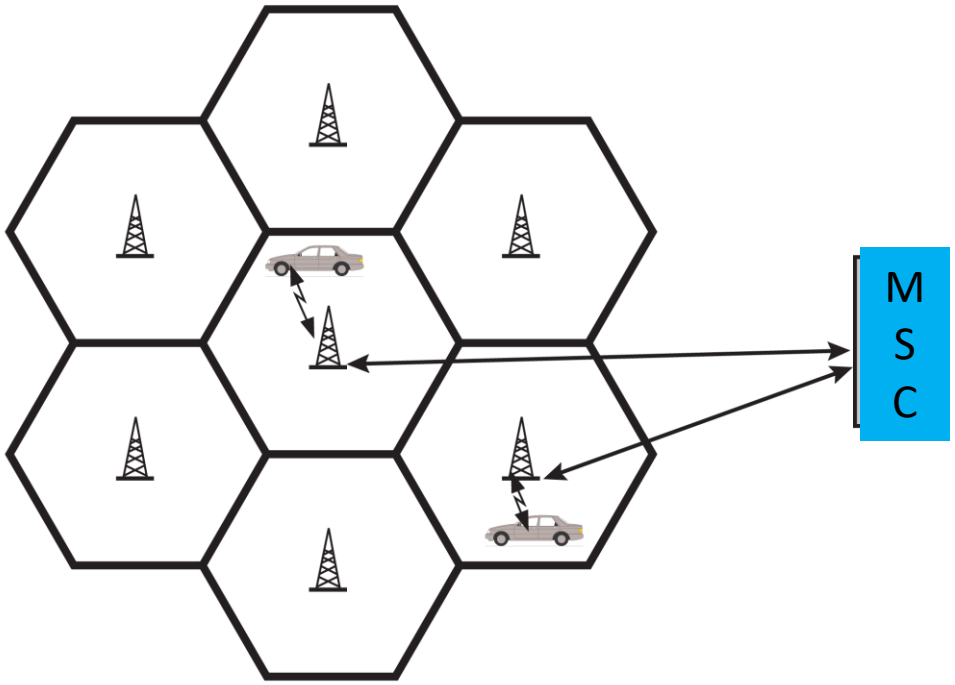


(d) Call accepted

- The called mobile unit recognizes its number on the setup channel being monitored and responds to its BS
- The BS sends the response to the MSC

- The MSC sets up a connection between the calling and a called base stations.
- The MSC also selects an available **traffic channel** within each BS, which in turns notifies its mobile unit
- The two units tune to their respective assigned channels.

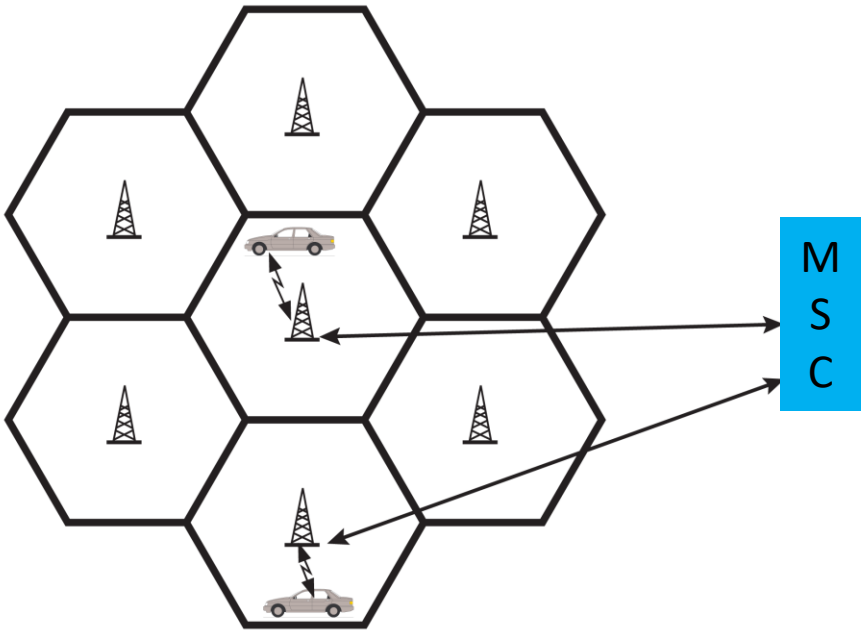
Ongoing call



(e) Ongoing call

- While the connection is maintained, the two mobile units exchange voice or data signals, going through their respective BSs and MSC

Handover



(f) Handoff

- If, during the connection, a mobile unit

  moves out of range of one BS and into the range of another one,

  the **traffic channel** has to change to one assigned to the BS in the new cell.

- The system makes this change without either interrupting the call, or alerting the user.

Mobile Radio Propagation Effects

- Signal strength
  - Must be strong enough between base station and mobile unit to maintain signal quality at the receiver
  - Must not be so strong as to create too much cochannel interference with channels in another cell using the same frequency band
- Fading
  - Signal propagation effects may disrupt the signal and cause errors

Handoff Performance Metrics

- Cell blocking probability – probability of a new call being blocked
- Call dropping probability – probability that a call is terminated due to a handoff
- Call completion probability – probability that an admitted call is not dropped before it terminates
- Probability of unsuccessful handoff – probability that a handoff is executed while the reception conditions are inadequate

Handoff Performance Metrics

- Handoff blocking probability – probability that a handoff cannot be successfully completed
- Handoff probability – probability that a handoff occurs before call termination
- Rate of handoff – number of handoffs per unit time
- Interruption duration – duration of time during a handoff in which a mobile is not connected to either base station
- Handoff delay – distance the mobile moves from the point at which the handoff should occur to the point at which it does occur

Handoff Strategies Used to Determine Instant of Handoff

- Relative signal strength
- Relative signal strength with threshold
- Relative signal strength with hysteresis
- Relative signal strength with hysteresis and threshold
- Prediction techniques

Power Control

- Design issues making it desirable to include dynamic power control in a cellular system
  - Received power must be sufficiently above the background noise for effective communication
  - Desirable to minimize power in the transmitted signal from the mobile
    - Reduce cochannel interference, alleviate health concerns, save battery power
  - In SS systems using CDMA, it's desirable to equalize the received power level from all mobile units at the BS

Types of Power Control

- Open-loop power control
  - Depends solely on mobile unit
  - No feedback from BS
  - Not as accurate as closed-loop, but can react quicker to fluctuations in signal strength
- Closed-loop power control
  - Adjusts signal strength in reverse channel based on metric of performance
  - BS makes power adjustment decision and communicates to mobile on control channel

Traffic Engineering

- Ideally, available channels would equal number of subscribers active at one time
- In practice, not feasible to have capacity handle all possible load
- For *N* simultaneous user capacity and *L* subscribers
  - $L < N$ – nonblocking system
  - $L > N$ – blocking system

Blocking System Performance Questions

- Probability that call request is blocked?
- What capacity is needed to achieve a certain upper bound on probability of blocking?
- What is the average delay?
- What capacity is needed to achieve a certain average delay?

Traffic Intensity

- Load presented to a system:

$$A = \lambda h$$

  - λ = mean rate of calls attempted per unit time
  - h = mean holding time per successful call
  - A = average number of calls arriving during average holding period, for normalized λ

Factors that Determine the Nature of the Traffic Model

- Manner in which blocked calls are handled
  - Lost calls delayed (LCD) – blocked calls put in a queue awaiting a free channel
  - Blocked calls rejected and dropped
    - Lost calls cleared (LCC) – user waits before another attempt
    - Lost calls held (LCH) – user repeatedly attempts calling
- Number of traffic sources
  - Whether number of users is assumed to be finite or infinite

Some evolution of mobile radio systems

Watch these youtube videos

https://www.youtube.com/watch?v=mv9z_L3RQp4

https://www.youtube.com/watch?v=ud5WZuBcKU8

First-Generation Analog

- Advanced Mobile Phone Service (AMPS)
  - In North America, two 25-MHz bands allocated to AMPS
    - One for transmission from base to mobile unit
    - One for transmission from mobile unit to base
  - Each band split in two to encourage competition
  - Frequency reuse exploited

AMPS Operation

- Subscriber initiates call by keying in phone number and presses send key
- MTSO verifies number and authorizes user
- MTSO issues message to user's cell phone indicating send and receive traffic channels
- MTSO sends ringing signal to called party
- Party answers; MTSO establishes circuit and initiates billing information
- Either party hangs up; MTSO releases circuit, frees channels, completes billing

Differences Between First and Second Generation Systems

- Digital traffic channels – first-generation systems are almost purely analog; second-generation systems are digital
- Encryption – all second generation systems provide encryption to prevent eavesdropping
- Error detection and correction – second-generation digital traffic allows for detection and correction, giving clear voice reception
- Channel access – second-generation systems allow channels to be dynamically shared by a number of users

Mobile Wireless TDMA Design Considerations

- Number of logical channels (number of time slots in TDMA frame): 8
- Maximum cell radius (R): 35 km
- Frequency: region around 900 MHz
- Maximum vehicle speed (V_m):250 km/hr
- Maximum coding delay: approx. 20 ms
- Maximum delay spread (Δ_m): 10 μs
- Bandwidth: Not to exceed 200 kHz (25 kHz per channel)

Steps in Design of TDMA Timeslot

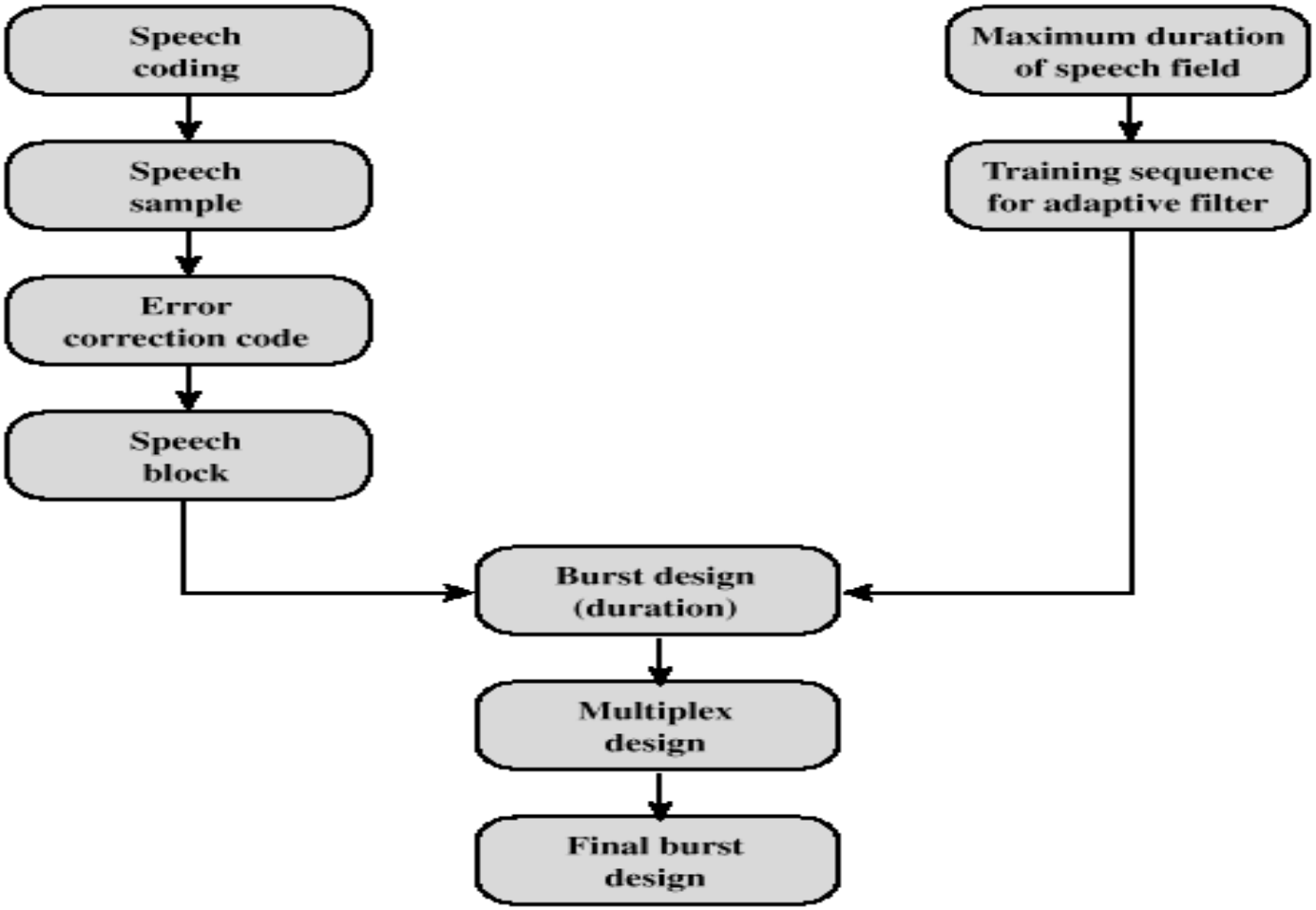


Figure 10.12 Steps in Design of TDMA Timeslot

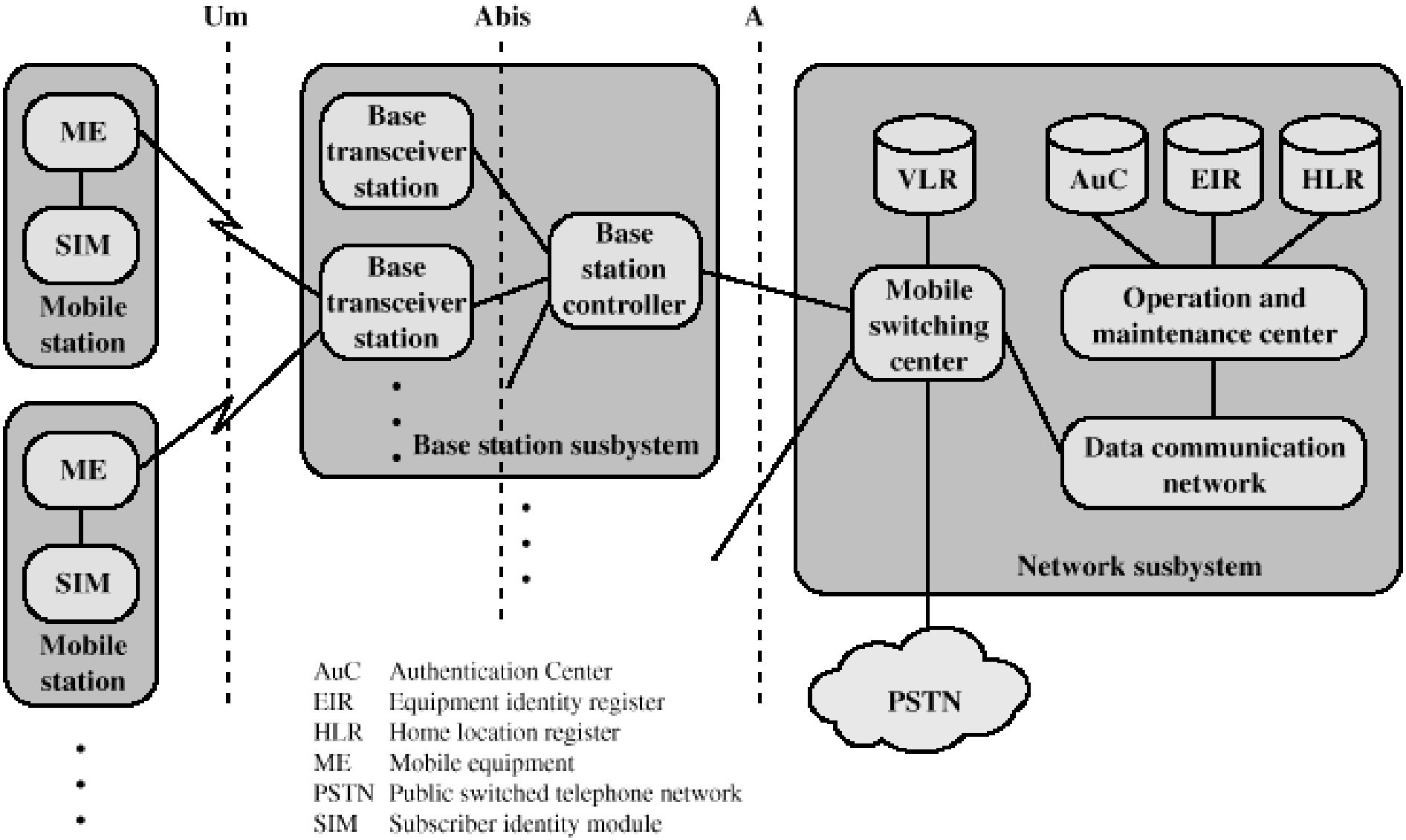


Figure 10.14 Overall GSM Architecture

Mobile Station under GSM Architecture

- Mobile station communicates across Um interface (air interface) with base station transceiver in same cell as mobile unit
- Mobile equipment (ME) – physical terminal, such as a telephone or PCS
  - ME includes radio transceiver, digital signal processors and subscriber identity module (SIM)
- GSM subscriber units are generic until SIM is inserted
  - SIMs roam, not necessarily the subscriber devices

Base Station Subsystem (BSS)

- BSS consists of base station controller and one or more base transceiver stations (BTS)
- Each BTS defines a single cell
  - Includes radio antenna, radio transceiver and a link to a base station controller (BSC)
- BSC reserves radio frequencies, manages handoff of mobile unit from one cell to another within BSS, and controls paging

Network Subsystem (NS)

- NS provides link between cellular network and public switched telecommunications networks
  - Controls handoffs between cells in different BSSs
  - Authenticates users and validates accounts
  - Enables worldwide roaming of mobile users
- Central element of NS is the mobile switching center (MSC)

Mobile Switching Center (MSC) Databases

- Home location register (HLR) database – stores information about each subscriber that belongs to it
- Visitor location register (VLR) database – maintains information about subscribers currently physically in the region
- Authentication center database (AuC) – used for authentication activities, holds encryption keys
- Equipment identity register database (EIR) – keeps track of the type of equipment that exists at the mobile station

TDMA Format – Time Slot Fields

- Trail bits – allow synchronization of transmissions from mobile units
- Encrypted bits – encrypted data
- Stealing bit - indicates whether block contains data or is "stolen"
- Training sequence – used to adapt parameters of receiver to the current path propagation characteristics
  - Strongest signal selected in case of multipath propagation
- Guard bits – used to avoid overlapping with other bursts

GSM Speech Signal Processing

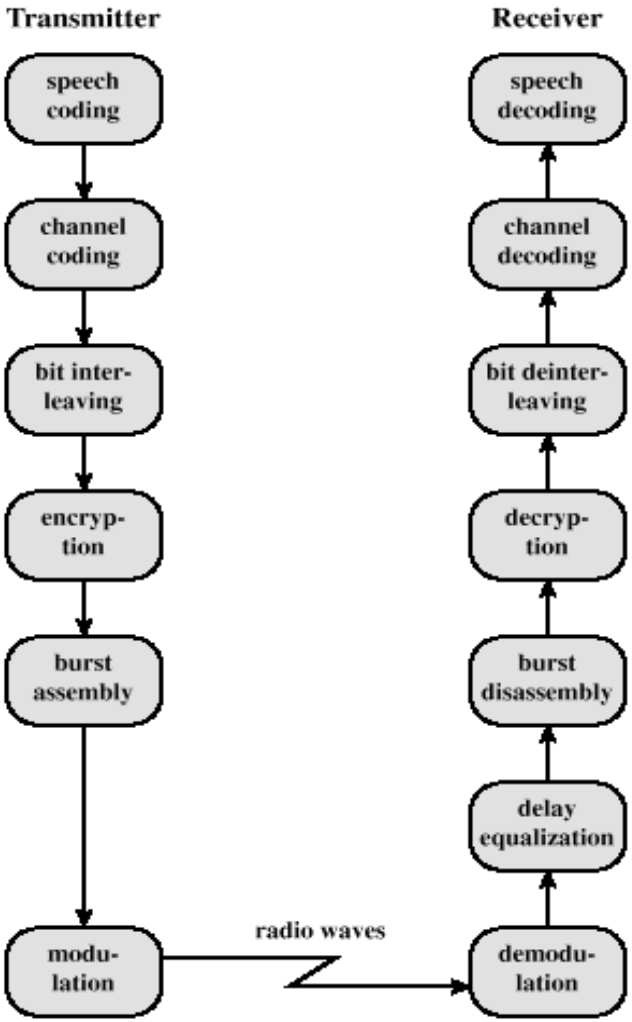
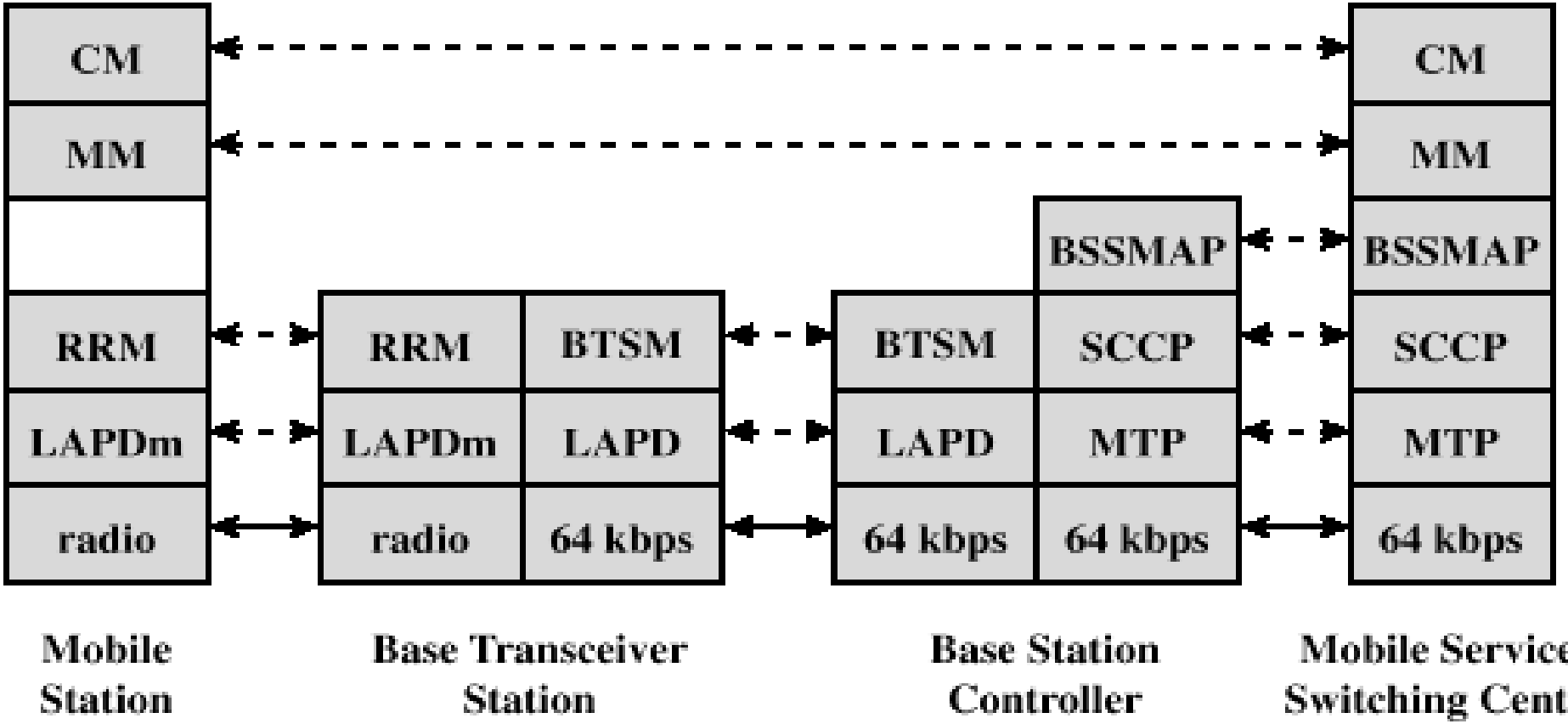


Figure 10.16 GSM Speech Signal Processing



BSSMAP = BSS mobile application part
BTSM = BTS management
CM = connection management
LAPD = link access protocol, D channel
MM = mobility management
MTP = message transfer part
RRM = radio resources management
SCCP = signal connection control part

Figure 10.17 GSM Signaling Protocol Architecture

Functions Provided by Protocols

- Protocols above the link layer of the GSM signaling protocol architecture provide specific functions:
  - Radio resource management
  - Mobility management
  - Connection management
  - Mobile application part (MAP)
  - BTS management

Advantages of CDMA Cellular

- Frequency diversity – frequency-dependent transmission impairments have less effect on signal
- Multipath resistance – chipping codes used for CDMA exhibit low cross correlation and low autocorrelation
- Privacy – privacy is inherent since spread spectrum is obtained by use of noise-like signals
- Graceful degradation – system only gradually degrades as more users access the system

Drawbacks of CDMA Cellular

- Self-jamming – arriving transmissions from multiple users not aligned on chip boundaries unless users are perfectly synchronized
- Near-far problem – signals closer to the receiver are received with less attenuation than signals farther away
- Soft handoff – requires that the mobile acquires the new cell before it relinquishes the old; this is more complex than hard handoff used in FDMA and TDMA schemes

Mobile Wireless CDMA Design Considerations

- RAKE receiver – when multiple versions of a signal arrive more than one chip interval apart, RAKE receiver attempts to recover signals from multiple paths and combine them
  - This method achieves better performance than simply recovering dominant signal and treating remaining signals as noise
- Soft Handoff – mobile station temporarily connected to more than one base station simultaneously

Principle of RAKE Receiver

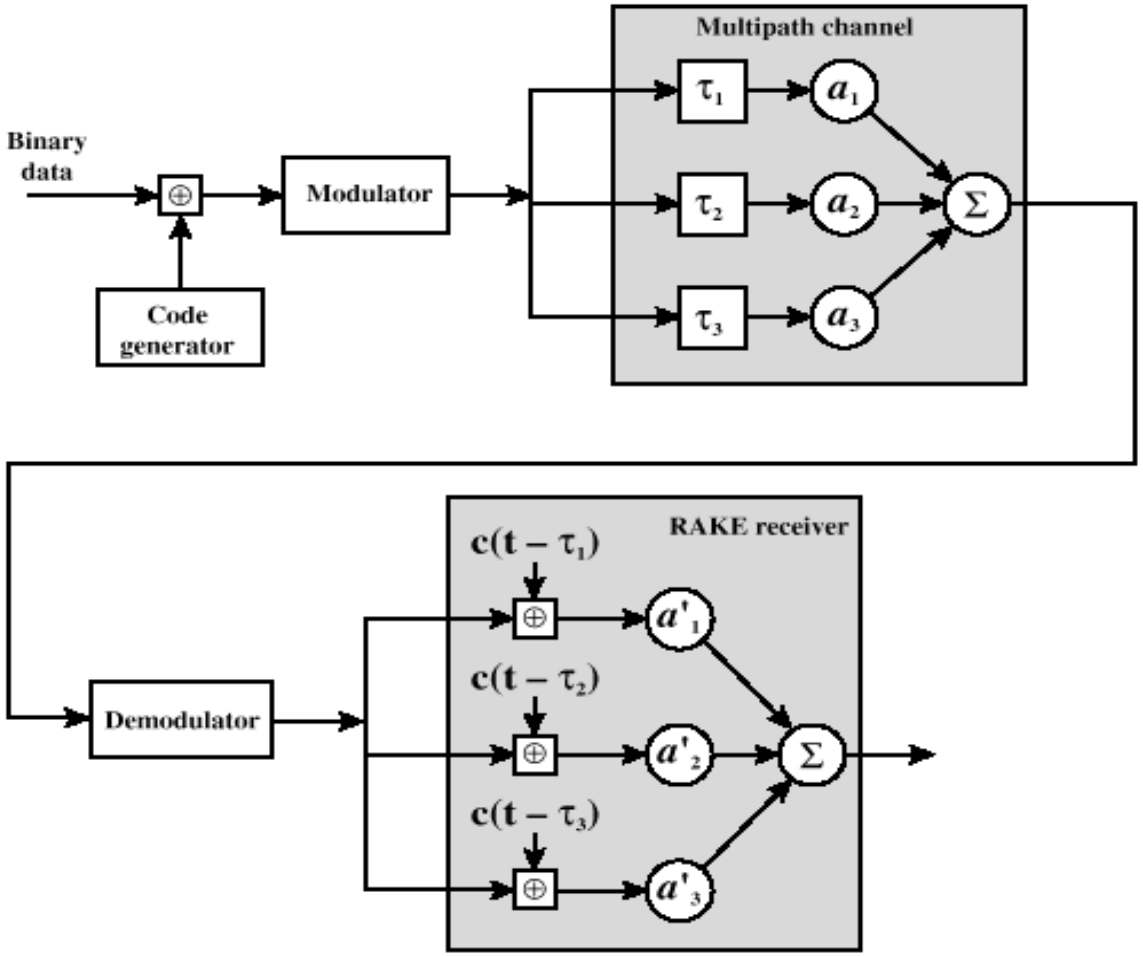


Figure 10.18 Principle of RAKE Receiver [PRAS98]

Types of Channels Supported by Forward Link

- Pilot (channel 0) - allows the mobile unit to acquire timing information, provides phase reference and provides means for signal strength comparison
- Synchronization (channel 32) - used by mobile station to obtain identification information about cellular system
- Paging (channels 1 to 7) - contain messages for one or more mobile stations
- Traffic (channels 8 to 31 and 33 to 63) – the forward channel supports 55 traffic channels

Forward Traffic Channel Processing Steps

- Speech is encoded at a rate of 8550 bps
- Additional bits added for error detection
- Data transmitted in 2-ms blocks with forward error correction provided by a convolutional encoder
- Data interleaved in blocks to reduce effects of errors
- Data bits are scrambled, serving as a privacy mask

Forward Traffic Channel Processing Steps (cont.)

- Power control information inserted into traffic channel
- DS-SS function spreads the 19.2 kbps to a rate of 1.2288 Mbps using one row of 64 x 64 Walsh matrix
- Digital bit stream modulated onto the carrier using QPSK modulation scheme

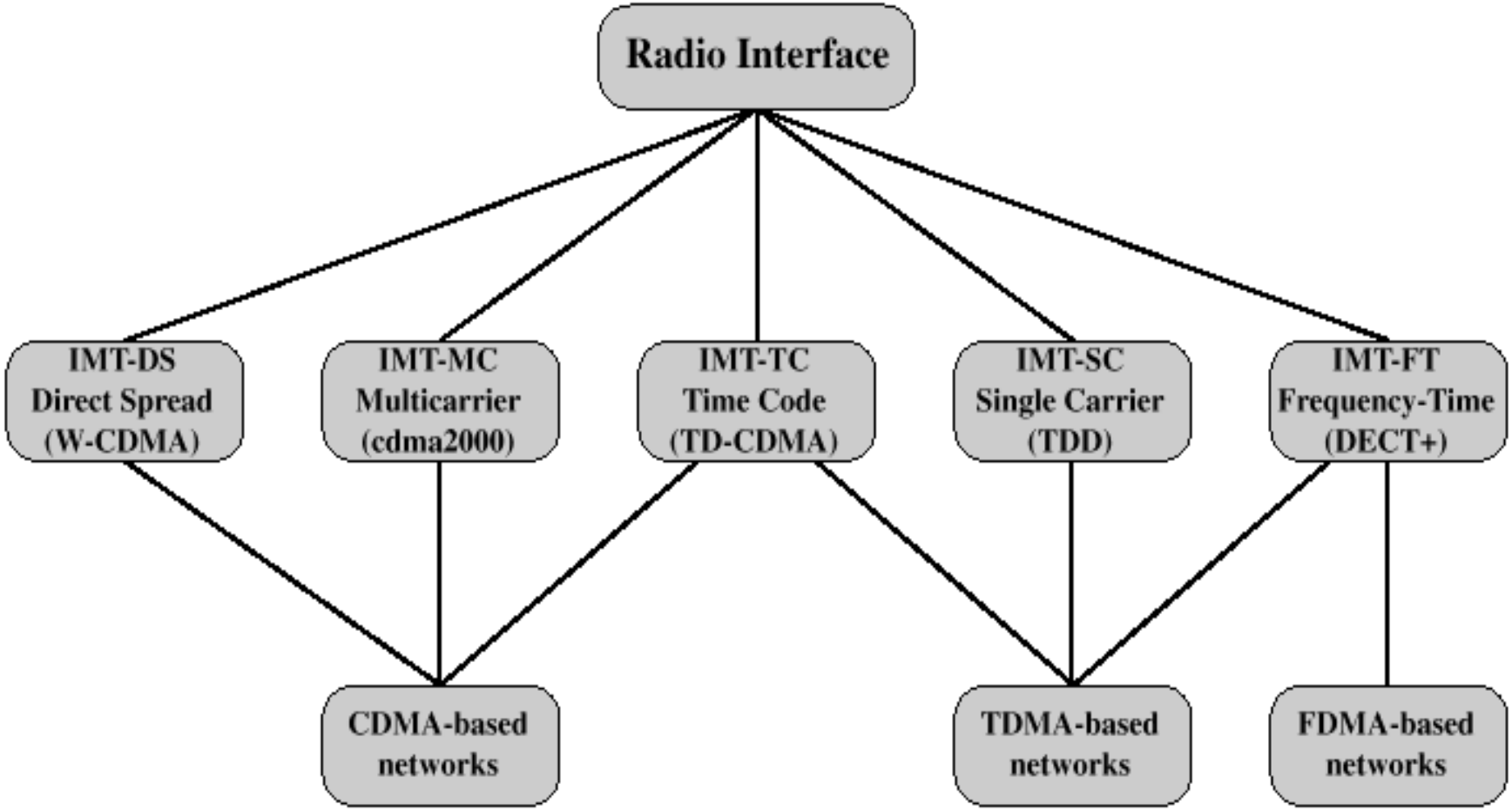
ITU's View of Third-Generation Capabilities

- Voice quality comparable to the public switched telephone network
- 144 kbps data rate available to users in high-speed motor vehicles over large areas
- 384 kbps available to pedestrians standing or moving slowly over small areas
- Support for 2.048 Mbps for office use
- Symmetrical / asymmetrical data transmission rates
- Support for both packet switched and circuit switched data services

ITU's View of Third-Generation Capabilities

- An adaptive interface to the Internet to reflect efficiently the common asymmetry between inbound and outbound traffic
- More efficient use of the available spectrum in general
- Support for a wide variety of mobile equipment
- Flexibility to allow the introduction of new services and technologies

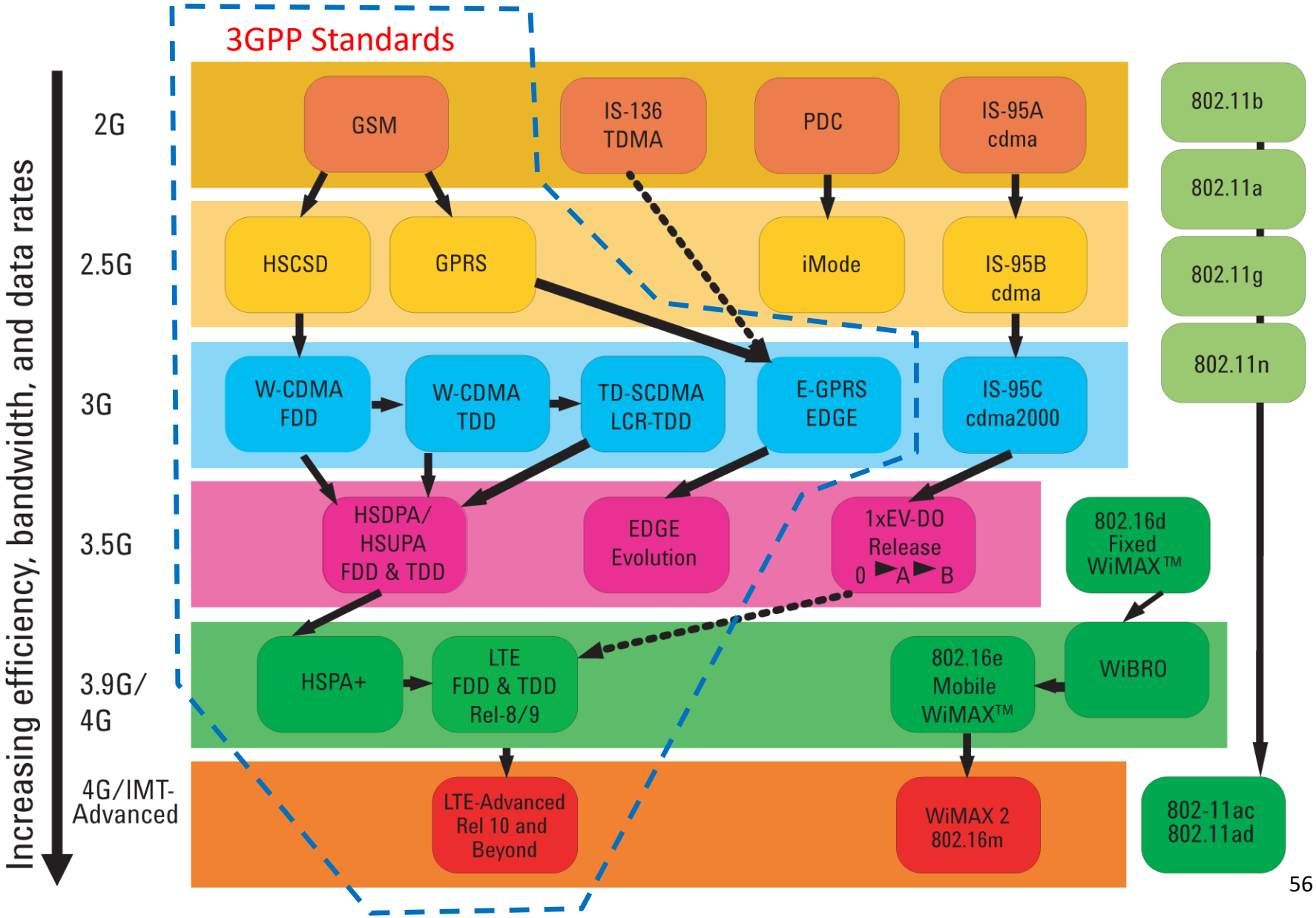
Alternative Interfaces



CDMA Design Considerations

- Bandwidth – limit channel usage to 5 MHz
- Chip rate – depends on desired data rate, need for error control, and bandwidth limitations; 3 Mcps or more is reasonable
- Multirate – advantage is that the system can flexibly support multiple simultaneous applications from a given user and can efficiently use available capacity by only providing the capacity required for each service

Mobile Communications Standards – Evolution



Evolution of Mobile Communications Standards 1

- **GSM –** Global System for Mobile Communications. The de facto global standard for mobile communications with over 90% market share.
- **GPRS –** General Packet Radio Service (GPRS) is a packet oriented mobile data service added to GSM. It provides data rates of 56–114 kbit/s
- **EDGE –** Enhanced Data rates for GSM Evolution or Enhanced GPRS (EGPRS), is digital mobile phone technology that allows improved data transmission rates as a backward-compatible extension of GSM. EDGE is considered a pre-3G radio technology and is standardized by **3GPP**
- **Evolved EDGE** continues in **Release 7** of the 3GPP standard to complement High-Speed Packet Access (HSPA). Peak bit-rates of up to 1Mbit/s and typical bit-rates of 400kbit/s can be expected.
- All the above standard are still evolving and are often referred to as GSM/EDGE family

Evolution of Mobile Communications Standards 2

- **HSCSD –** High-speed **circuit-switched** data, is an enhancement to Circuit Switched Data (CSD) of the GSM mobile phone system, four to six times faster than GSM, with data rates up to 57.6 kbit/s.

UMTS standards:

- **W-CDMA –** Wideband Code Division Multiple Access, is a family of 3G standards known as Universal Mobile Telecommunications System **(UMTS**).

  It uses the same **core network** as the 2G GSM networks allowing dual mode mobile operation along with GSM/EDGE.

- **HSPA –** High Speed Packet Access is an amalgamation of two mobile telephony protocols, High Speed Downlink/Uplink Packet Access (HSDPA/HSUPA), which extends and improves the performance of existing 3G networks utilizing the **W-CDMA** protocols.

- **HSPA+** Evolved HSPA is a further improved HSPA. 3GPP **Release 7** and **8** (2008). Worldwide adoption beginning in 2010. The newer standard allows bit rates up to 168 Mbit/s in the downlink and 22 Mbit/s in the uplink.

Evolution of Mobile Communications Standards 3

- **LTE –** Long Term Evolution (**Release 7)** and
- **LTE Advanced** (**Release 10)** are the 3.9/4G mobile communication standards aiming at the 1Gbit/s speed.
- **WiMAX 2 –** Worldwide Interoperability for Microwave Access is a mobile communication standard similar to LTE
- Note the development column related to IEEE 802.11

UMTS and 3GPP standards

- **UMTS,** Universal Mobile Telecommunications System is a third and fourth (and fifth?) generation mobile cellular technology for networks evolved from the **GSM** (Global System for Mobile Communications) standard.
- Developed by the **3GPP** (3rd Generation Partnership Project), UMTS is a component of the International Telecommunications Union ITU standard set (IMT).
- 3GPP specifications have three main parts
  - **Radio Access Network**, (TSG RAN and TSG GERAN)
  - **Core Network,** (TSG CT)
  - **Service architecture**. (TSG SA)
- 3GPP should not be confused with 3rd Generation Partnership Project 2 (3GPP2), which specifies standards for another 3G technology based on IS-95 (CDMA), commonly known as CDMA2000

3GPP Technical Specifications

- 3GPP Technical Specifications are structured as ***Releases***. See table, next slide

Each release:

- introduces new functionalities
- incorporates hundreds of individual standards documents, each of which may have been through many revisions.
- Current 3GPP standards incorporate also the latest revisions of the GSM standards.

3GPP standards – Technical Specifications

Version[7]	Released[8]	Info
Phase 1	1992	GSM Features
Phase 2	1995	GSM Features, EFR Codec,
Release 96	1997 Q1	GSM Features, 14.4 kbit/s User Data Rate,
Release 97	1998 Q1	GSM Features, GPRS
Release 98	1999 Q1	GSM Features, AMR, EDGE, GPRS for PCS1900
Release 99	2000 Q1	Specified the first UMTS 3G networks, incorporating a CDMA air interface[9]
Release 4	2001 Q2	Originally called the **Release 2000** - added features including an all-IP Core Network[10]
Release 5	2002 Q1	Introduced IMS and HSDPA[11]
Release 6	2004 Q4	Integrated operation with Wireless LAN networks and adds HSUPA, MBMS, enhancements to IMS such as Push to Talk over Cellular (PoC), GAN[12]
Release 7	2007 Q4	Focuses on decreasing latency, improvements to QoS and real-time applications such as VoIP.[13] This specification also focus on HSPA+ (High Speed Packet Access Evolution), SIM high-speed protocol and contactless front-end interface (Near Field Communication enabling operators to deliver contactless services like Mobile Payments), EDGE Evolution.
Release 8	2008 Q4	First **LTE** release. All-IP Network (SAE). New OFDMA, FDE and MIMO based radio interface, not backwards compatible with previous CDMA interfaces. Dual-Cell HSDPA.
Release 9	2009 Q4	SAES Enhancements, WiMAX and LTE/UMTS Interoperability. Dual-Cell HSDPA with MIMO, Dual-Cell HSUPA.
Release 10	2011 Q1	**LTE Advanced** fulfilling IMT Advanced 4G requirements. Backwards compatible with release 8 (LTE). Multi-Cell HSDPA (4 carriers).
Release 11	2012 Q3	Advanced IP Interconnection of Services. Service layer interconnection between national operators/carriers as well as third party application providers. Heterogeneous networks (HetNet) improvements, Coordinated Multi-Point operation (CoMP). In-device Co-existence (IDC).
Release 12	Planned to March 2015	Enhanced Small Cells (higher order modulation, dual connectivity, cell discovery, self configuration), Carrier Aggregation (2 uplink carriers, 3 downlink carriers, FDD/TDD carrier aggregation), MIMO (3D channel modeling, elevation beamforming, massive MIMO), New and Enhanced Services (cost and range of MTC, D2D communication, eMBMS enhancements)[14]
Release 13	Planned to March 2016	LTE in unlicensed, LTE enhancements for Machine-Type Communication. Elevation Beamforming / Full-Dimension MIMO, Indoor positioning[15]

Evolution of the mobile networks: Summary

- Three existing generations of mobile communication systems resulted in amalgamation of three cooperating parts loosely identified as:
  - 2G – GSM – Global System(s) for Mobile Communications
  - 3G – UMTS – Universal Mobile Telecommunications Systems
  - 4G – LTE/LTE-A – Long Term Evolution systems
- The above systems have different **Radio interfaces**, and share components of **Core Networks** and **Service architecture** to allow exchange of basic **voice and SMS services**
- We start with the general description of functions related the “classical” voice services.

3GPP Technical Specification Groups (TSG)

- **TSG RAN** Radio Access Network is responsible for the definition of the functions, requirements and interfaces of the E-UTRA (Evolved Universal Terrestrial Radio Access) networks (UMTS and LTE)
- **TSG GERAN** GSM/EDGE Radio Access Network
- **TSG SA** The TSG Service and System Aspects is responsible for the overall architecture and service capabilities of systems based on 3GPP specifications
- **TSG CT** Core Network and Terminals is responsible for specifying terminal interfaces (logical and physical), terminal capabilities and the Core network part of 3GPP systems.

General structure of the 3GPP Public Land Mobile Network (PLMN)

- The architecture of the mobile network, aka Public Land Mobile Network (PLMN), is specified in the 3GPP Technical Specifications **TS 23.002** Network architecture (local copy). Also available on Moodle.
- The TS 23.002 specification describes elements and interfaces between components belonging to three generations of mobile networks loosely identified as:
  - 2G – GSM/Edge – Global System(s) for Mobile Communications
  - 3G – UMTS – Universal Mobile Telecommunications Systems
  - 4G – LTE/LTE-A – Long Term Evolution systems
- The above systems have different **Radio interfaces**, and share components of **Core Networks** and **Service architecture** to allow exchange of **voice**, **SMSs** and the Internet access

Figure 1b: Basic Configuration of a 3GPP Access PLMN supporting CS and PS services (using GPRS and EPS) and interfaces

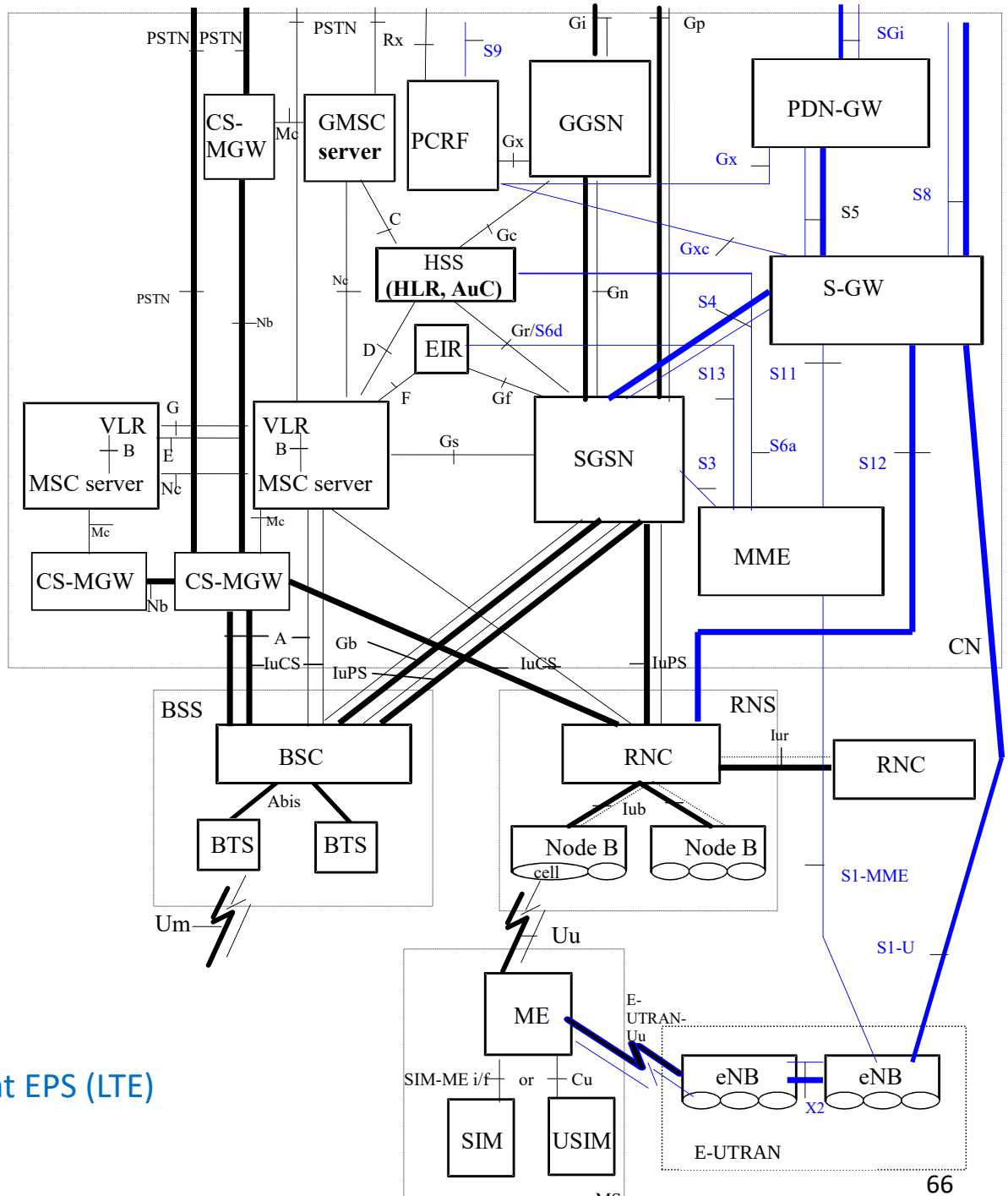
Identify: (local pdf)

- CN the core network
- BSS – the Base Station System (GSM)
- RNS aka UTRAN – the Radio Network System (UMTS)
- E-UTRAN – LTE Evolved Universal Terrestrial Radio Access Network
- MS – Mobile Station

Note:

- Interfaces
- How the components of PLMN are shared between the three generations

NOTE: The interfaces in blue represent EPS (LTE) functions and reference points.

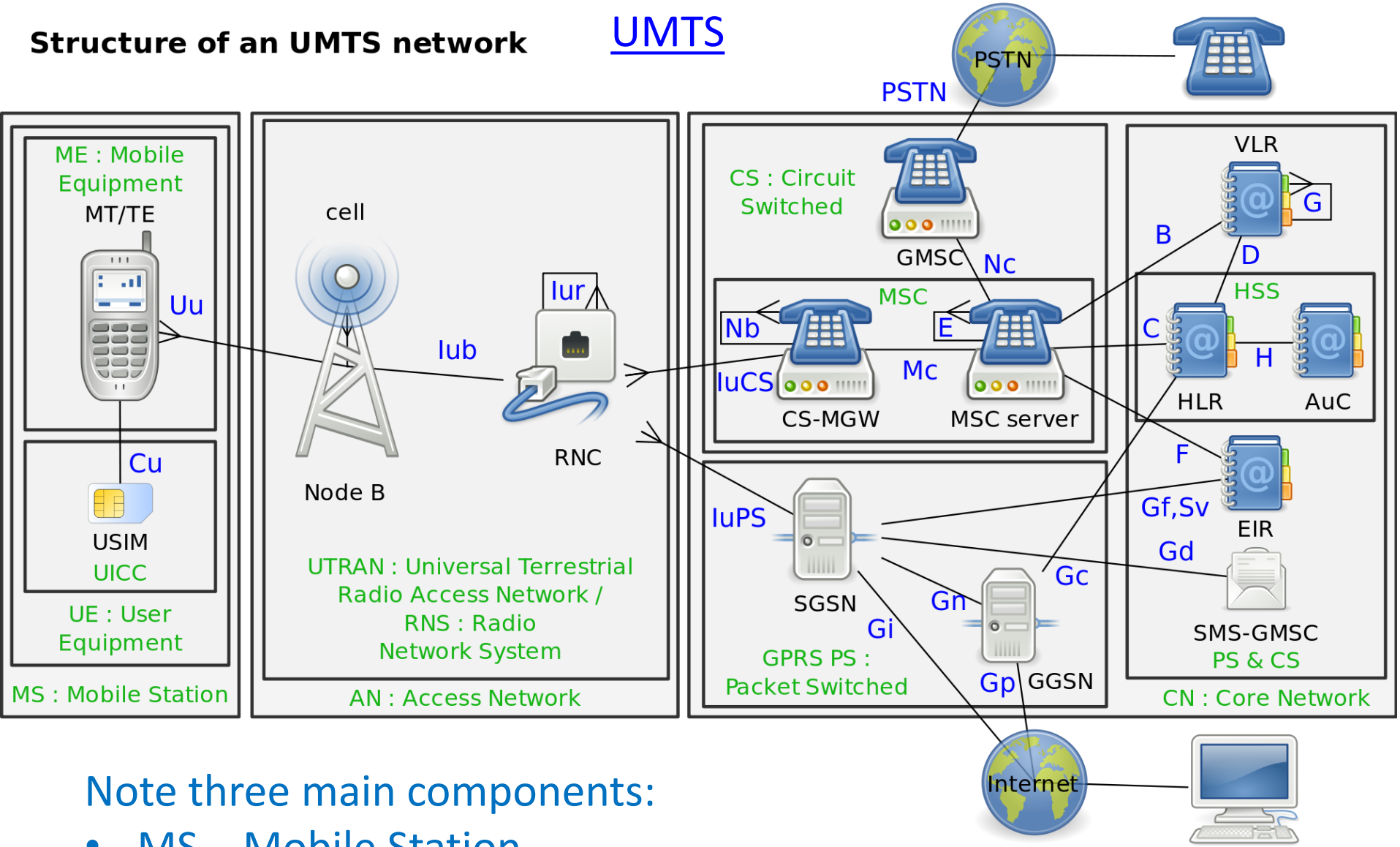


Universal Mobile Telecommunications System – **UMTS**:

- is a 3G mobile cellular system able to cooperate with networks based on the **GSM** and **LTE** standards
- developed (since 2000) and maintained by the **3GPP**
- The most recent version is **HSPA+ (Release 7** and **8)**
- uses Wideband Code Division Multiple Access (**W-CDMA**) radio technology that offers greater spectral efficiency and bandwidth
- specifies a the radio access network different form GSM,
  - UTRAN (UMTS Terrestrial **Radio Access Network**),
- Shares the **core network** with GSM
- the authentication of users via SIM (subscriber identity module) or USIM cards
- requires **different base stations** called **Node B** and new frequency allocations

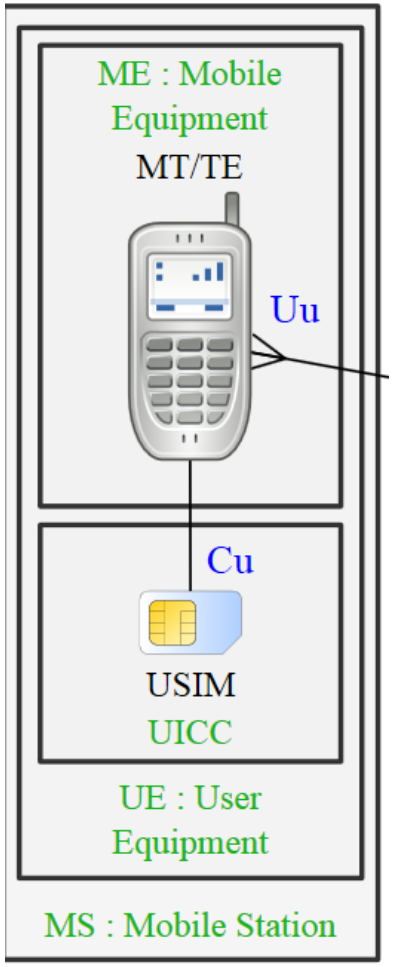
Structure of an UMTS network

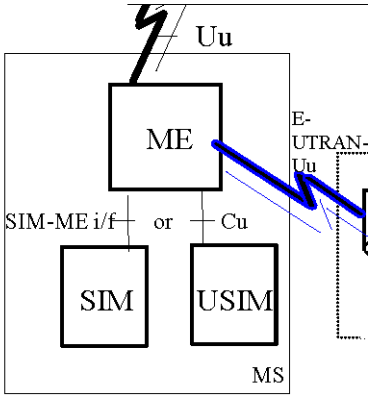
UMTS



Note three main components:

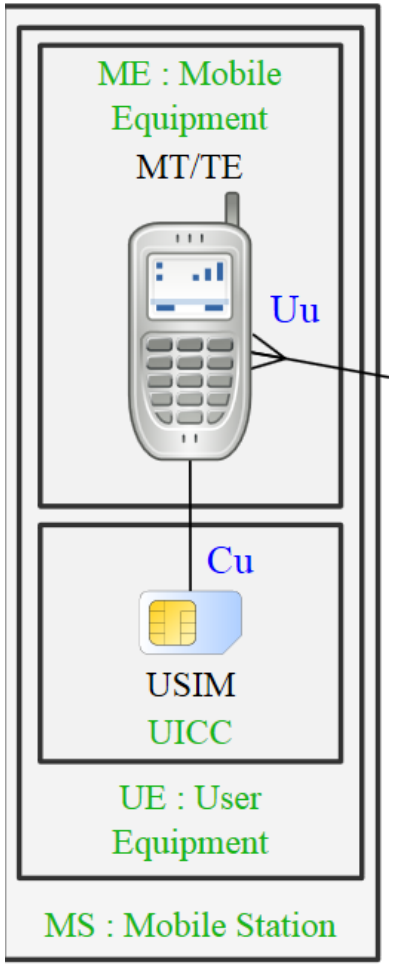
- MS – Mobile Station
- AN – Access Network
- CN – Core Network





Mobile station (MS) – Radio

- A **Mobile station** communicates across the **Uu interface** aka UTRA or E-UTRA with a cell's base station: **Node B** or **eNB** (LTE)
- The **mobile equipment** (ME) includes Mobile Telephone (MT) or a terminal equipment (TE)
- The most popular radio interface in the **UMTS (3G)** systems is commonly called W-CDMA and its variants TD-CDMA and TD-SCDMA
- W-CDMA uses FDD – frequency division duplexing
- TD-CDMA, TD- SCDMA employ the time division duplexing
- We will concentrate on the **OFDMA** system used in the LTE/A 4G systems.

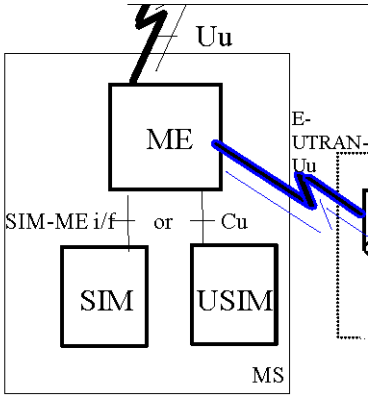


Mobile station (MS) – SIM

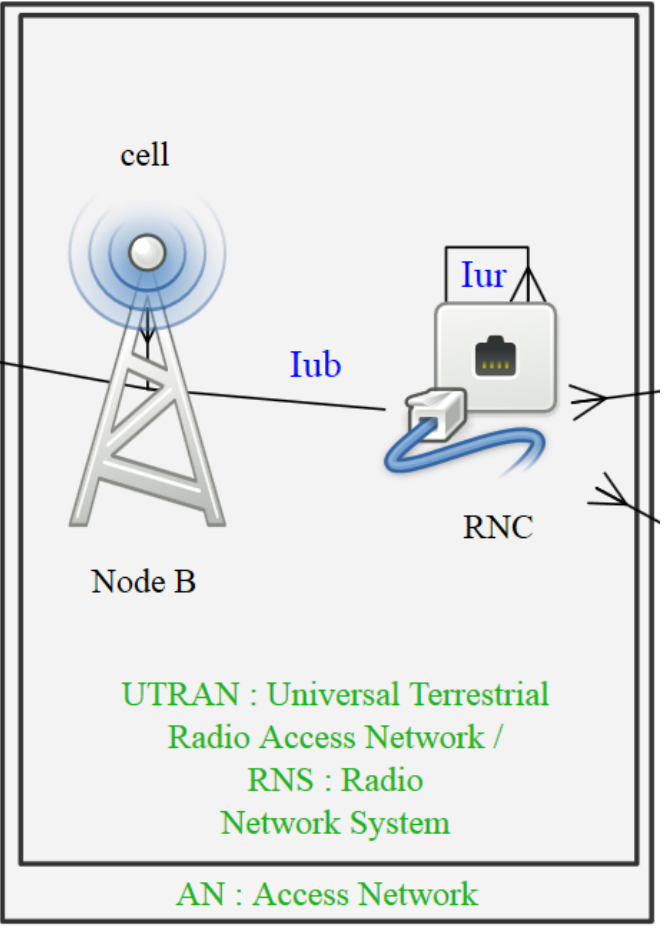
- Two versions of the **subscriber identity module:** SIM – inherited from GSM and USIM designed for UMTS (and LTE)

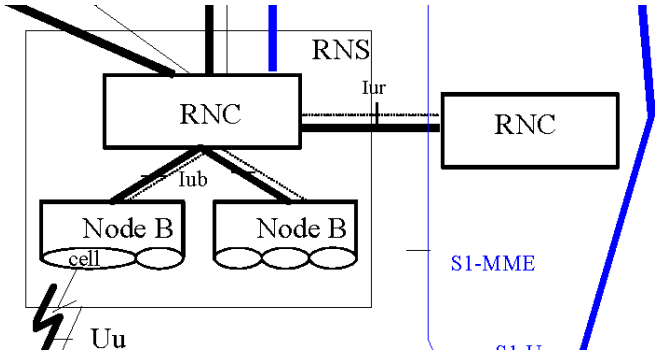
The SIM stores:

- the subscriber's identification number,
- the networks the subscriber is authorized to use,
- encryption keys,
- other information specific to the subscriber.
- Details of USIM in TS31.102 or pdf



UMTS Radio Network System



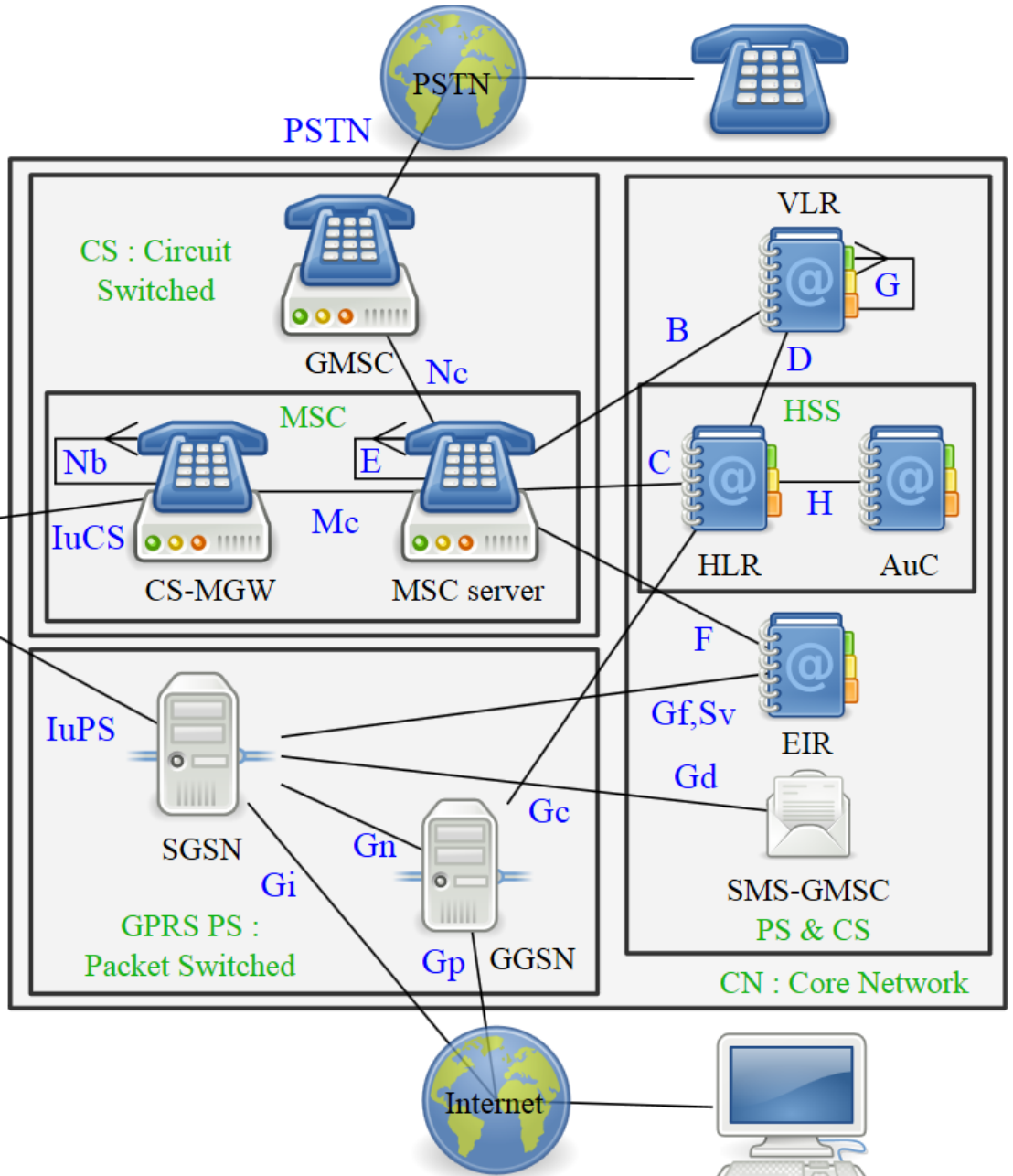


- UMTS RNS (UTRAN) consists of two main parts:
  - The Base Station aka the **Node B**
  - **RNC** – Radio Network Controller
- The RNC defines an area of **radio coverage** consisting of **one or more cells** controlled by one RNC.

The interfaces

- **Uu** – to a Mobile Station
- **Iub** – between the Node B and the RNC
- **Iur** – between two RNCs
- **IuCS** – between RNC and the "Circuit Switched" part of the systems (to PSTN)
- **IuPS** – between RNC and the "Packet Switched" part (Internet and CN)

The Core Network CN

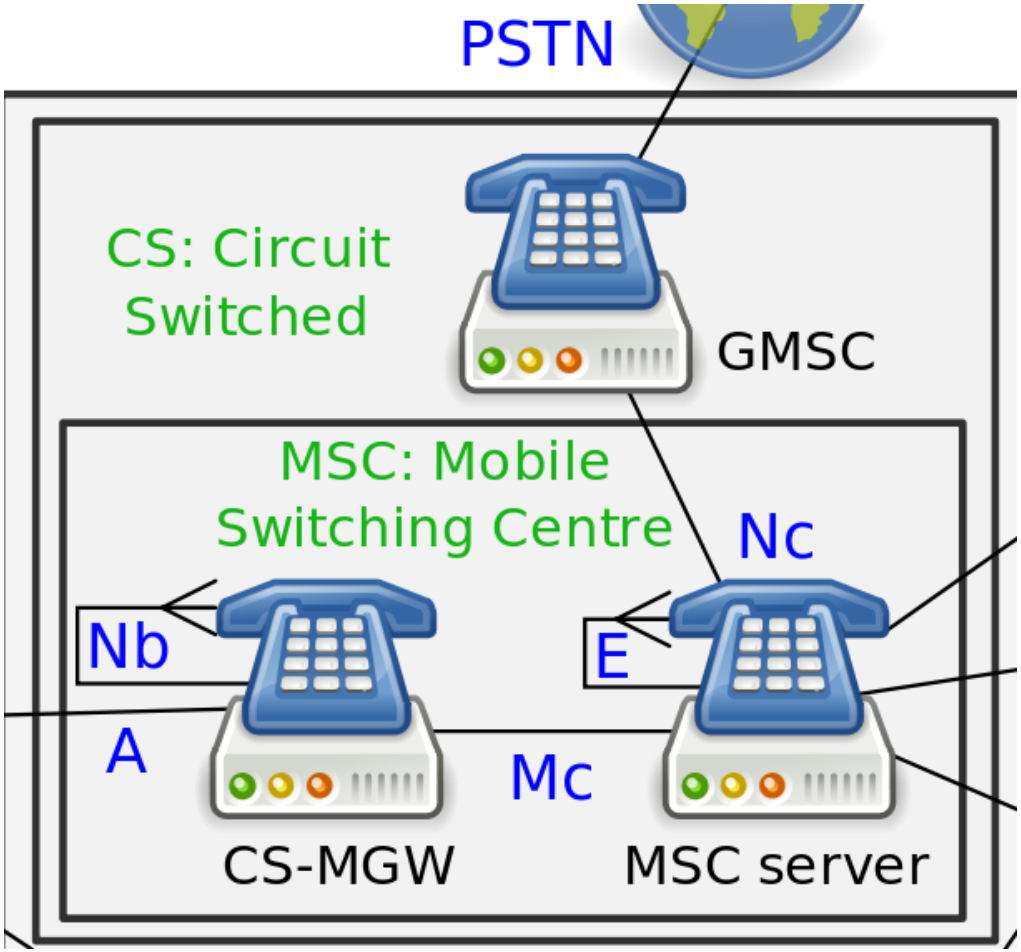


- **The Core Network** of the UMTS systems is the same as for GSM/EDGE systems

The CN consists of three main parts:

- The **Circuit Switched** part of the system controls the connections to the **PSTN** (landline phones) and contains the MSC (Mobile Switching Centre) server.
- The **Packet Switched** part aka GPRS controlling connection to the Internet
- System Databases, HSS – **Home Subscriber Server** being the most important

MSC: Mobile Switching Centre



- **Circuit Switched** part of the system (like in the Public Switched Telephone Network PSTN)
- GMSC – Gateway MSC connects to PSTN (if required)
- MSC server
- CS-MGW Circuit Switched Media Gateway
- MSC connects to the databases and servers of the Core Network

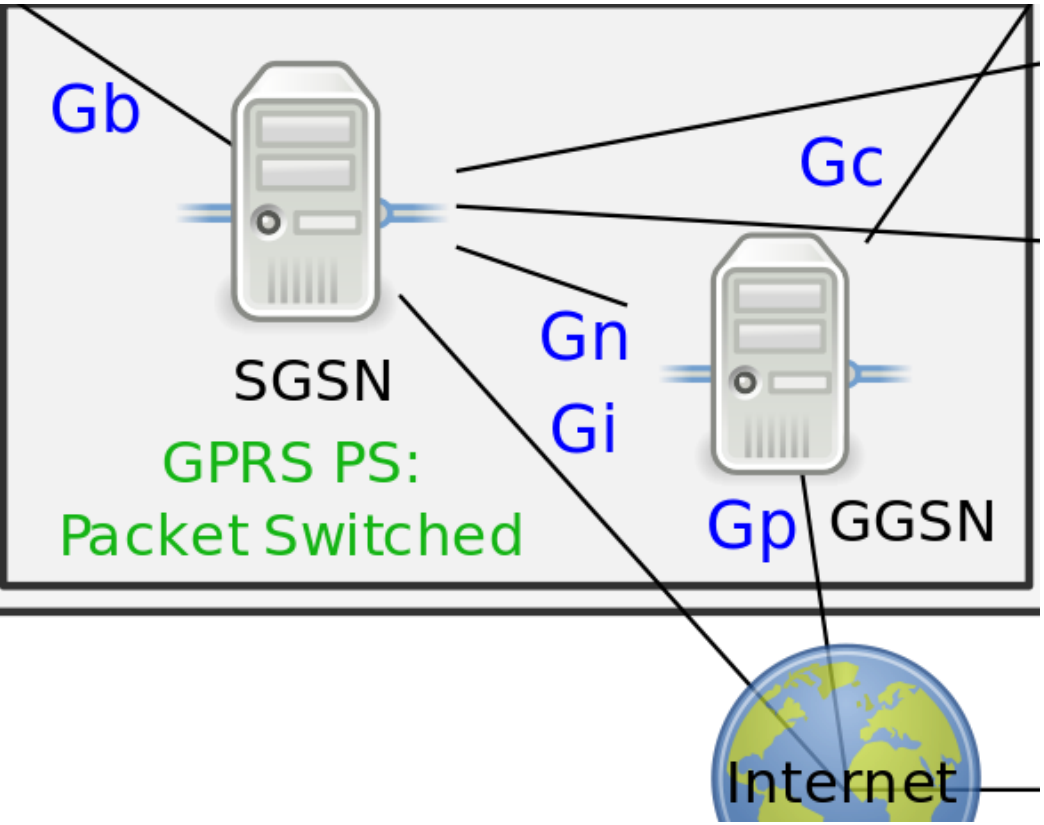
- controls handoffs between cells in different BSSs,
- authenticates users
- validates their accounts,

GPRS Services

GPRS extends the GSM Packet circuit switched data capabilities and makes the following services possible (selection):

- SMS messaging and broadcasting
- "Always on" internet access
- Multimedia messaging service (MMS)
- Instant messaging and presence
- Internet applications for smart devices through wireless application protocol (WAP)
- If SMS over GPRS is used, a higher SMS transmission speed of about 30 SMS messages per minute may be achieved.

GPRS subsystem



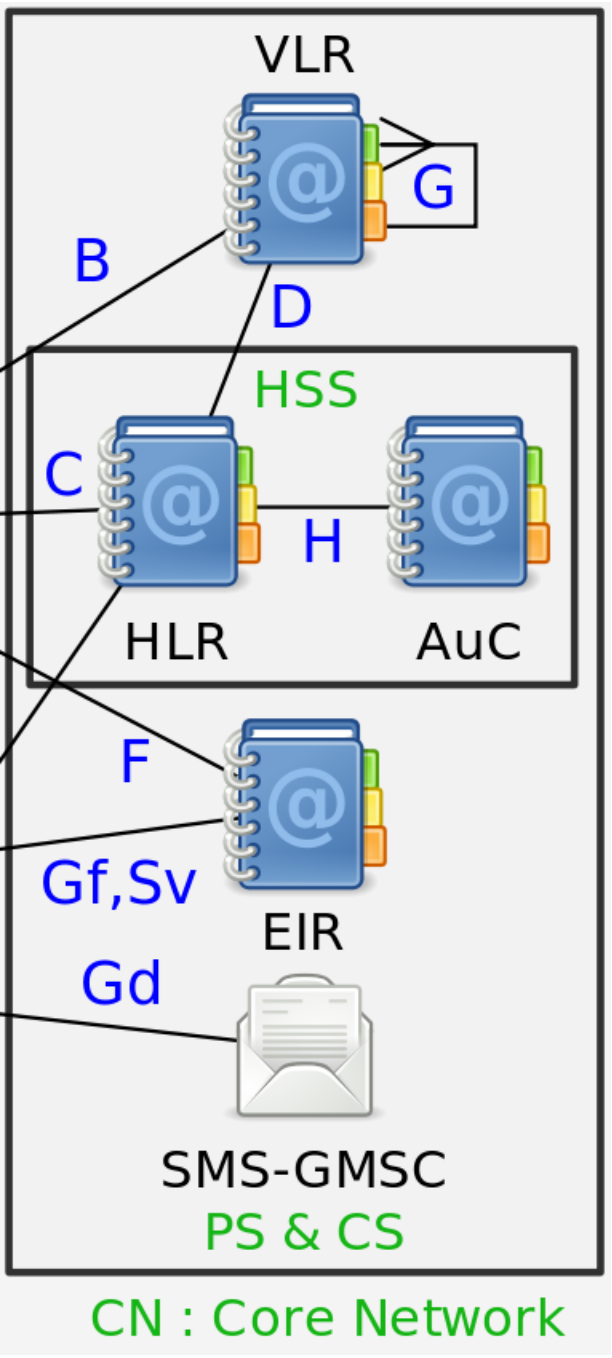
The GPRS subsystem provides

- mobility management,
- session management
- transport

for Internet Protocol packet services in GSM.

- SGSN/GGSN Serving/ Gateway GPRS Support Node

- **GPRS tunnelling protocol** (GTP) allows end users of a GSM network to move from place to place while continuing to connect to the Internet as if from one location at the **Gateway GPRS Support Node** (GGSN).
- It does this by carrying the subscriber's data from the subscriber's current **Serving GPRS Support Node** (SGSN) to the GGSN which is handling the subscriber's session.



Core network servers and databases

HSS – Home Subscriber Server operates with two fundamental databases:

- **HLR** – Home Location Register
- **AuC** – Authentication Centre database

Two other fundamental databases are:

- **VLR** – Visitor Location Register
- **EIR** – Equipment Identity Register

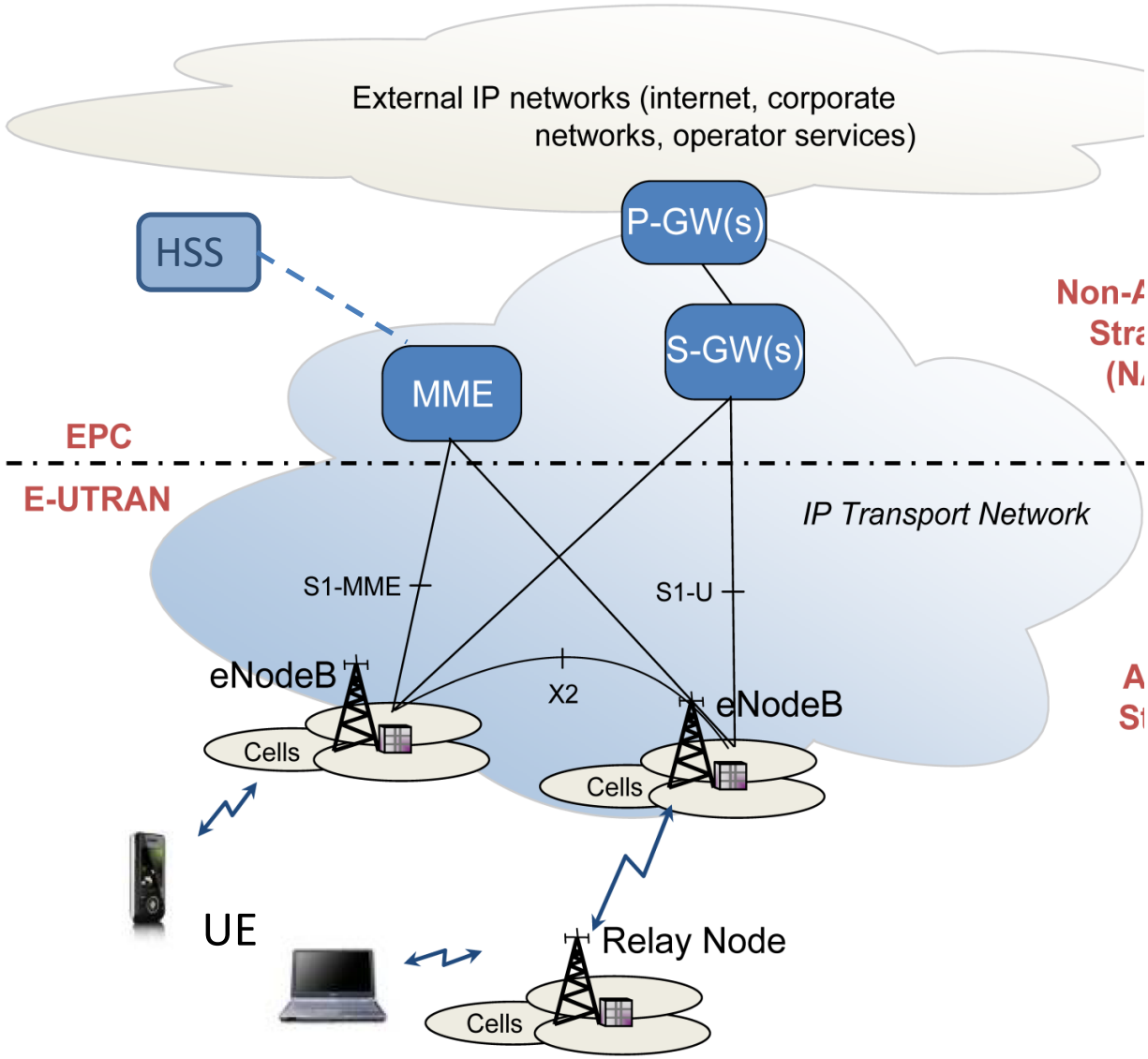
We will discuss details of the databases in the next lecture

4G Networks: LTE Long Term Evolution

- LTE (3GPP Release 8) and LTE-Advanced (3GPP Release 10) are new mobile communication standards evolved from GSM/EDGE and UMTS/HSPA network technologies.
- LTE-A targets the peak data rates of 1Gb/s using a long list of advanced technologies (e.g., OFDM, MIMO, …) in a full-duplex modes (FDD and TDD)
- LTE is an **all-IP packet-based** network with the protocol stack being:
- L1 (Layer 1) → L2 → IP → {TCP, UTP, RTP} → applications
- 3GPP standards ensure collaboration between LTE and previous technologies.

LTE: EPC + E-UTRAN architecture

Evolved Packet Core + Evolved Universal Terrestrial Radio Access Network



- Flat all-IP multi-access core network
- Enhanced NodeB (**eNB**) (former base station/NodeB)
- **UE** – User Equipment
- **MME** – Mobility Management Entity (Control Plane)
- **S-GW** – Serving Gateway (User Plane)
- **P-GW** – Packet Network Gateway
- HSS – Home Subscriber Server

Summary

Reflect on:

- Understand principles of mobile cellular wireless systems
- Understand of Mobile Network Evolution: from GSM to UMTS and 4G LTE networks
- Understand the principles used in Mobile Station, Radio Access Network, Core Network
- Describe fundamentals of Cellular System Structure and Functions, and procedures on how calls are set up and maintained
- Explain 3G Universal Mobile Telecommunications System (UMTS).
- Understand 3GPP Technical Specifications and the General structure of the 3GPP Public Land Mobile Network (PLMN)

Tutorials 8 to 10: team work for assignment 2 (30%) on research-based paper

Lecture 9 on –LTE part I on MAC layer design