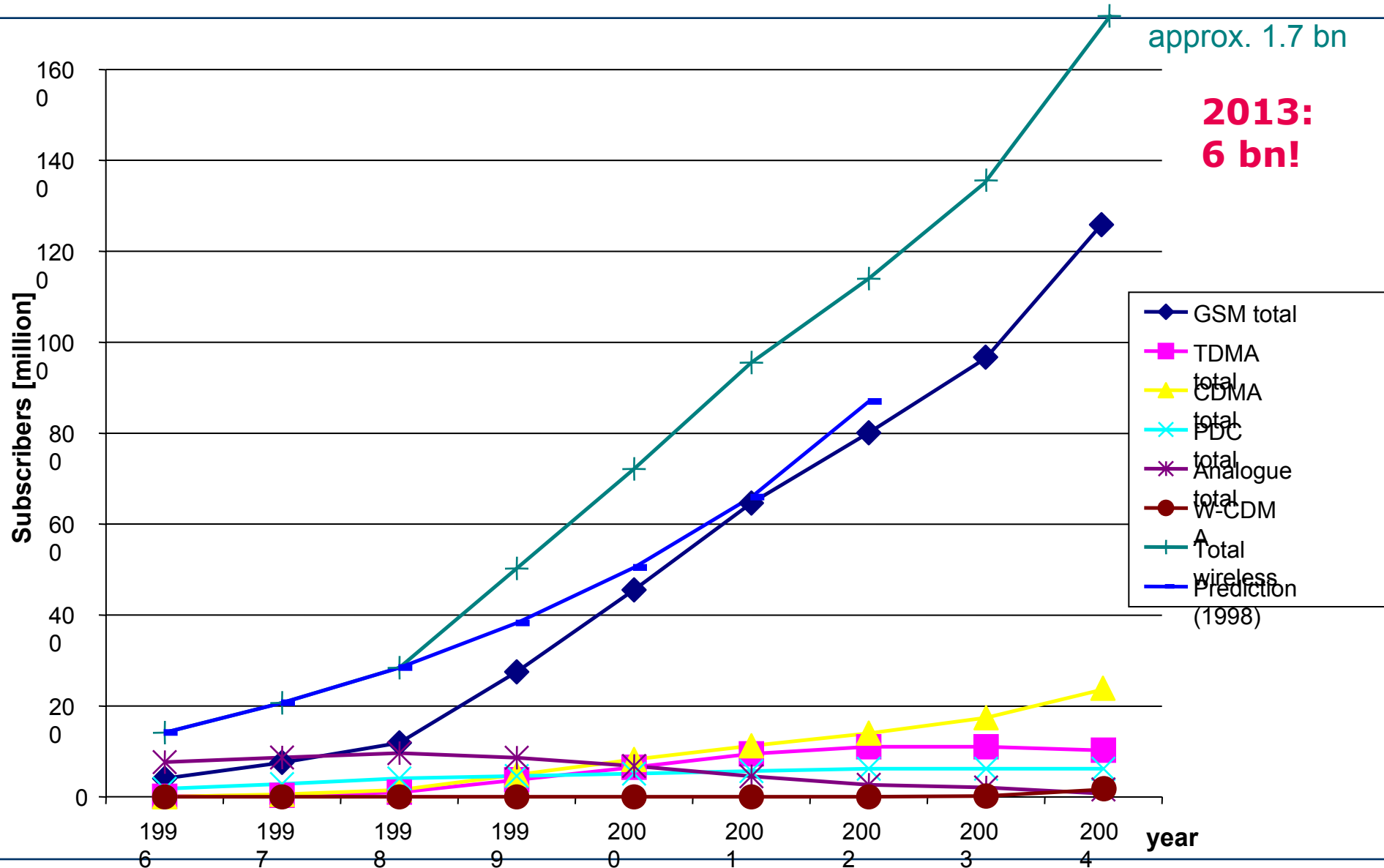

Mobile Communications

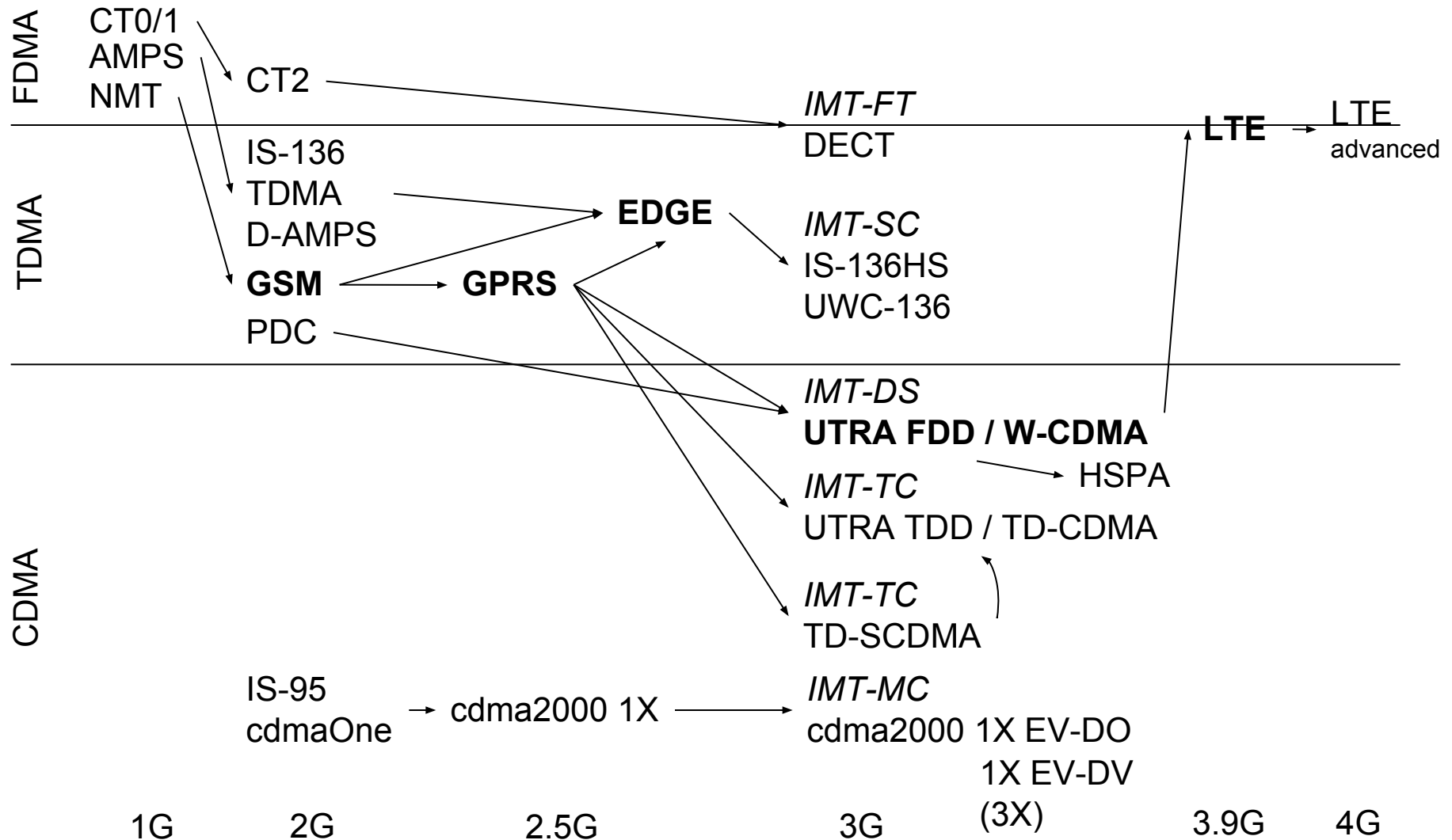
Chapter 4: Wireless Telecommunication Systems

- Market
- GSM
- UMTS

Mobile phone subscribers worldwide



Development of mobile telecommunication systems



Some press news...

- **16th April 2008:** The GSMA, the global trade group for the mobile industry, today announced that total connections to GSM mobile communications networks have now passed the **3 Billion** mark globally. The third billion landmark has been reached just four years after the GSM industry surpassed its first billion, and just two years from the second billionth connection. The 3 Billion landmark has been surpassed just 17 years after the first GSM network launch in 1991. Today more than 700 mobile operators across 218 countries and territories of the world are adding **new connections at the rate of 15 per second, or 1.3 million per day.**
- **11 February 2009:** The GSMA today announced that the mobile world has celebrated its **four billionth connection**, according to Wireless Intelligence, the GSMA's market intelligence unit. This milestone underscores the continued strong growth of the mobile industry and puts the global market on the path to reach a staggering **six billion connections by 2013.**
- By **2014 3.4bn** people will have **broadband**, 80% mobile!

GSM: Overview

- GSM
 - formerly: Groupe Spéciale Mobile (founded 1982)
 - now: Global System for Mobile Communication
 - Pan-European standard (ETSI, European Telecommunications Standardisation Institute)
 - simultaneous introduction of essential services in three phases (1991, 1994, 1996) by the European telecommunication administrations (Germany: D1 and D2)
 - seamless roaming within Europe possible
- Today many providers all over the world use GSM (>220 countries in Asia, Africa, Europe, Australia, America)
 - more than 4,2 billion subscribers in more than 700 networks
 - more than 75% of all digital mobile phones use GSM
 - over 29 billion SMS in Germany in 2008, (> 10% of the revenues for many operators) [be aware: these are only rough numbers...]
 - See e.g. www.gsmworld.com

Performance characteristics of GSM (wrt. analog sys.)

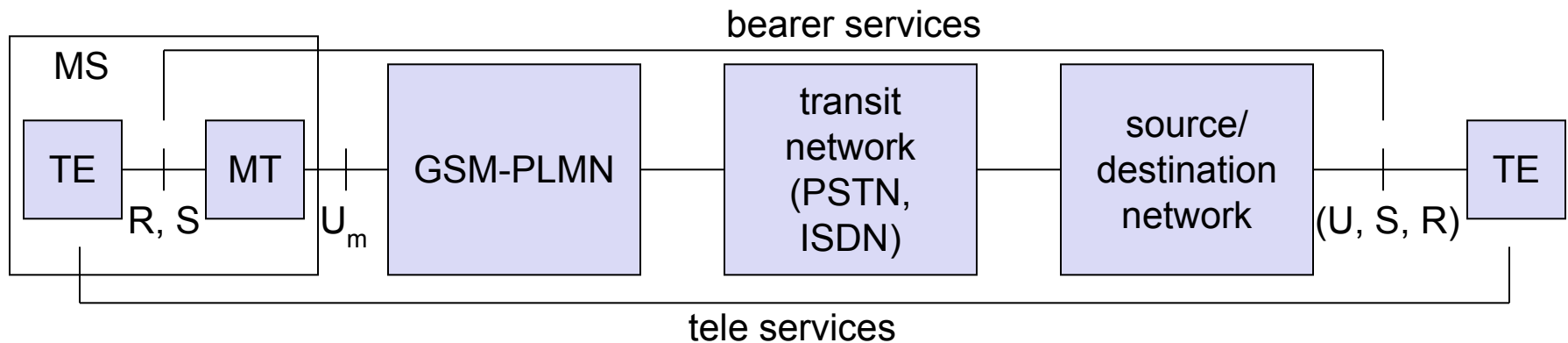
- Communication
 - mobile, wireless communication; support for voice and data services
- Total mobility
 - international access, chip-card enables use of access points of different providers
- Worldwide connectivity
 - one number, the network handles localization
- High capacity
 - better frequency efficiency, smaller cells, more customers per cell
- High transmission quality
 - high audio quality and reliability for wireless, uninterrupted phone calls at higher speeds (e.g., from cars, trains)
- Security functions
 - access control, authentication via chip-card and PIN

Disadvantages of GSM

- There is no perfect system!!
 - no end-to-end encryption of user data
 - no full ISDN bandwidth of 64 kbit/s to the user, no transparent B-channel
- reduced concentration while driving
- electromagnetic radiation
- abuse of private data possible
- roaming profiles accessible
- high complexity of the system
- several incompatibilities within the GSM standards

GSM: Mobile Services

- GSM offers
 - several types of connections
 - voice connections, data connections, short message service
 - multi-service options (combination of basic services)
- Three service domains
 - Bearer Services
 - Telematic Services
 - Supplementary Services



Bearer Services

- Telecommunication services to transfer data between access points
- Specification of services up to the terminal interface (OSI layers 1-3)
- Different data rates for voice and data (original standard)
 - Transparent bearer service (use only physical layer to transmit data – Forward error correction (FEC) only
circuit switched – constant delay and throughput
 - Non transparent bearer service (use protocols of layer 2 and 3 to implement error correction and flow control)
data service (packet switched)
- Today: data rates of approx. 50 kbit/s possible – (even more with new modulation)

Tele Services I

- Telecommunication services that enable voice communication via mobile phones
- All these basic services have to obey cellular functions, security measurements etc.
- Offered services
 - mobile telephony
primary goal of GSM was to enable mobile telephony offering the traditional bandwidth of 3.1 kHz
 - Emergency number
common number throughout Europe (112); mandatory for all service providers; free of charge; connection with the highest priority (preemption of other connections possible)
 - Multinumbering
several ISDN phone numbers per user possible

Tele Services II

- Additional services
 - Non-Voice-Teleservices
 - group 3 fax
 - voice mailbox (implemented in the fixed network supporting the mobile terminals)
 - electronic mail (MHS, Message Handling System, implemented in the fixed network)
 - ...
 - Short Message Service (SMS)
alphanumeric data transmission to/from the mobile terminal (160 characters) using the signaling channel, thus allowing simultaneous use of basic services and SMS
(almost ignored in the beginning now the most successful add-on! – but more and more replaced by IP-based messaging)

Supplementary services

- Services in addition to the basic services, cannot be offered stand-alone
- Similar to ISDN services besides lower bandwidth due to the radio link
- May differ between different service providers, countries and protocol versions
- Important services
 - identification: forwarding of caller number
 - suppression of number forwarding
 - automatic call-back
 - conferencing with up to 7 participants
 - locking of the mobile terminal (incoming or outgoing calls)
 - ...

Architecture of the GSM system

- GSM is a PLMN (Public Land Mobile Network)
 - several providers setup mobile networks following the GSM standard within each country
 - components
 - MS (mobile station)
 - BS (base station)
 - MSC (mobile switching center)
 - LR (location register)
 - subsystems
 - RSS (radio subsystem): covers all radio aspects
 - NSS (network and switching subsystem): call forwarding, handover, switching
 - OSS (operation subsystem): management of the network

GSM System Architecture

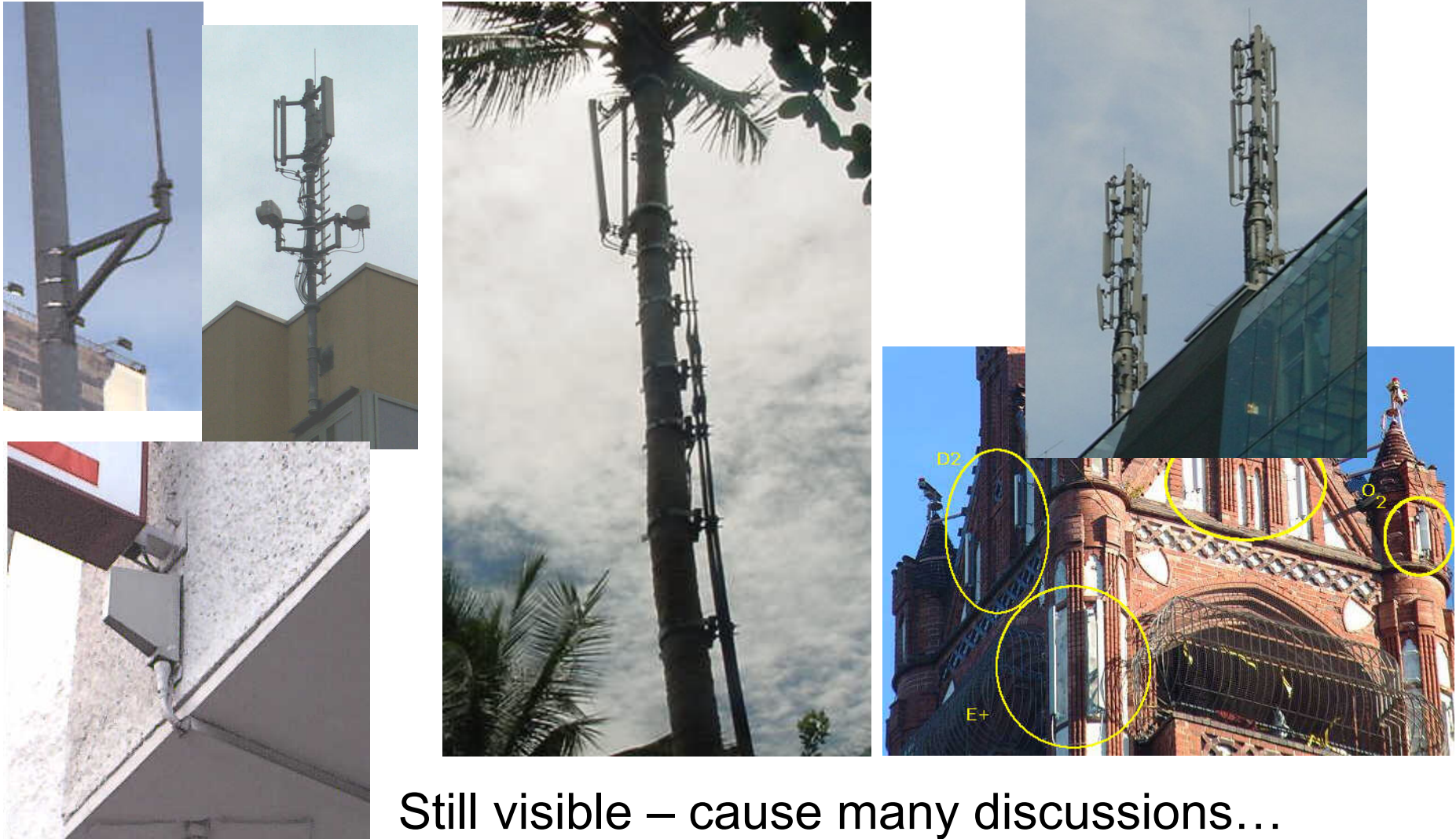
- Radio Subsystem (RSS)
 - Mobile Station (MS)
 - Mobile Equipment (ME)
 - Subscriber Identity Module (SIM)
 - Base Station Subsystem (BSS)
 - Base Transceiver Station (BTS)
 - Base Station Controller (BSC)
- Network Switching Subsystem(NSS)
 - Mobile Switching Center (MSC)
 - Home Location Register (HLR)
 - Visitor Location Register (VLR)
- Operation Subsystem (OSS)
 - Operation and Maintenance Center (OMC)
 - Authentication Center (AUC)
 - Equipment Identity Register (EIR)

Ingredients 1: Mobile Phones, PDAs & Co.



The visible but **smallest part** of the network!

Ingredients 2: Antennas



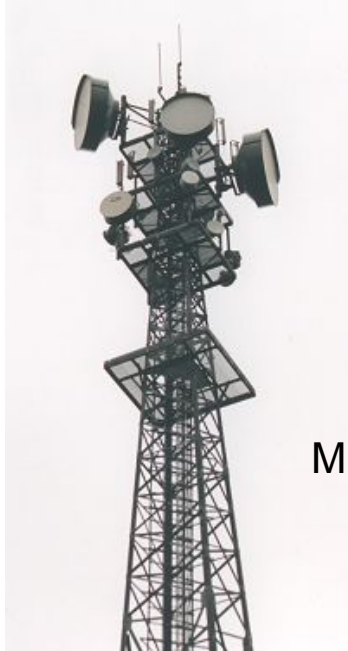
Still visible – cause many discussions...

Ingredients 3: Infrastructure 1



Base Stations

Cabling



Microwave links



Ingredients 3: Infrastructure 2



Switching units



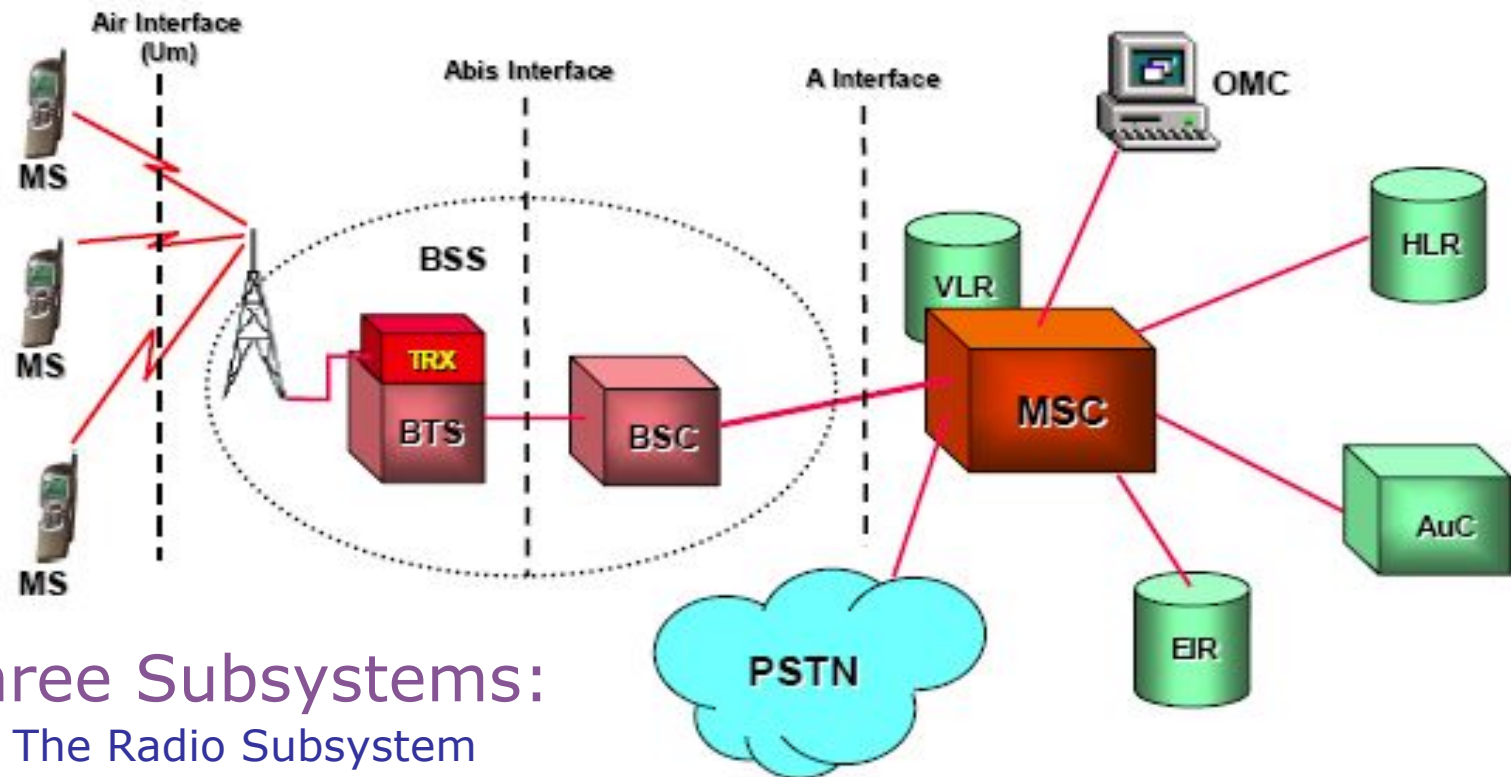
Management

Data bases

Monitoring



GSM Architecture



- **Three Subsystems:**

- The Radio Subsystem
- The Network and Switching Sub-system (NSS) – comprising an MSC and associated registers
- The Operation Subsystem

MS: Mobile Station

BSS: Base Station Subsystem

BSC: Base Station Controller

BTS: Base Transceiver Station

TRX: Transceiver

MSC: Mobile Switching Centre

VLR: Visitor Location Register

HLR: Home Location Register

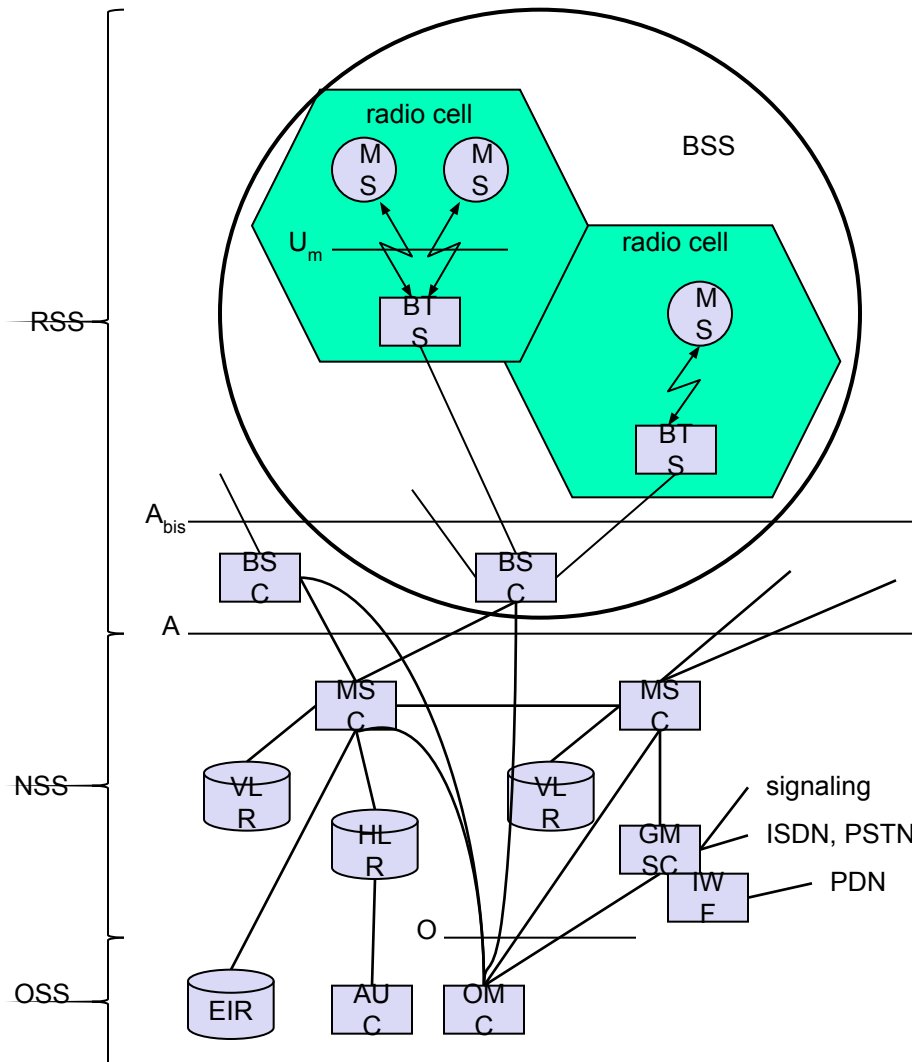
AuC: Authentication Centre

EIR: Equipment Identity Register

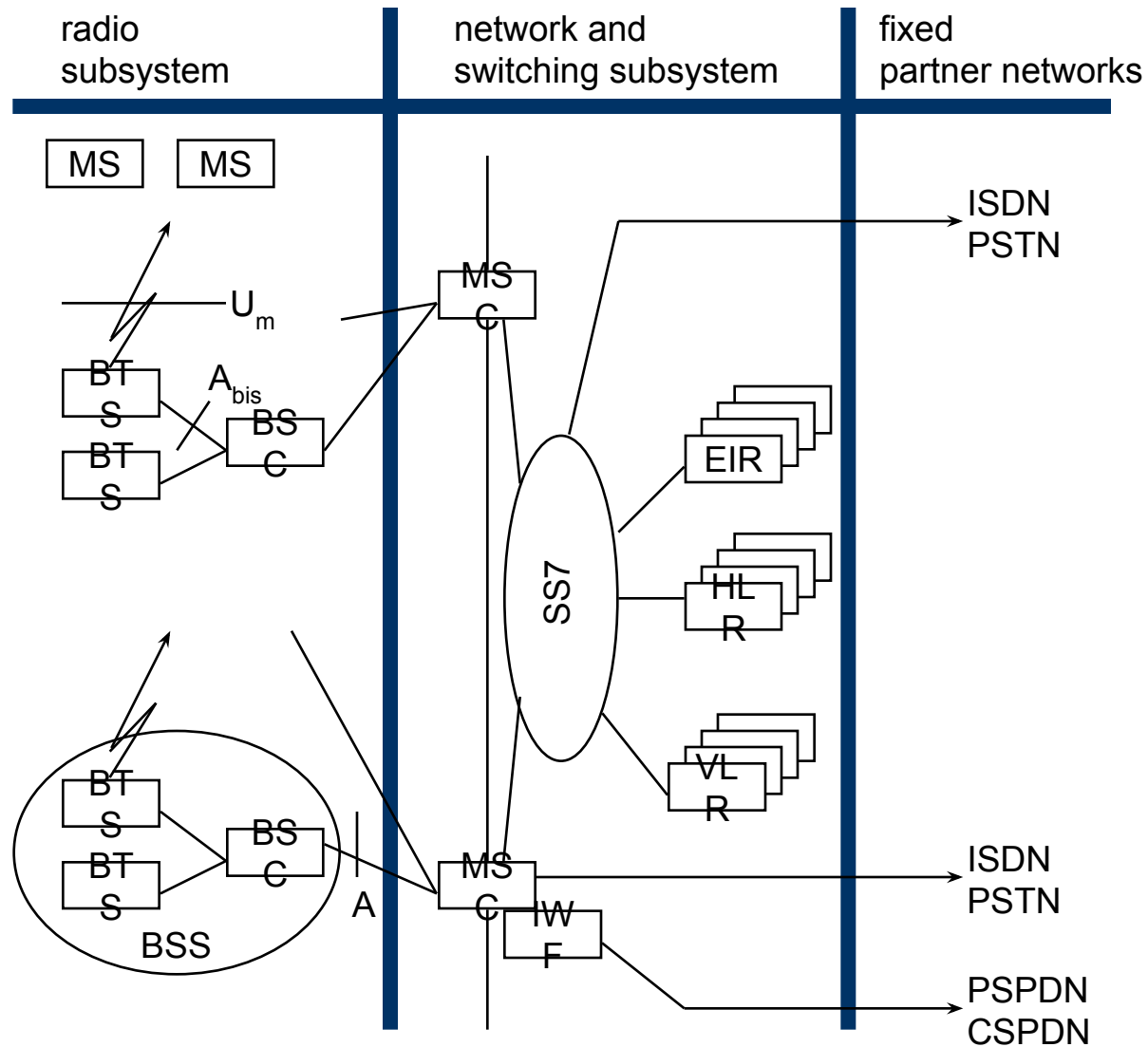
OMC: Operations and Maintenance Centre

PSTN: Public Switched Telephone Network

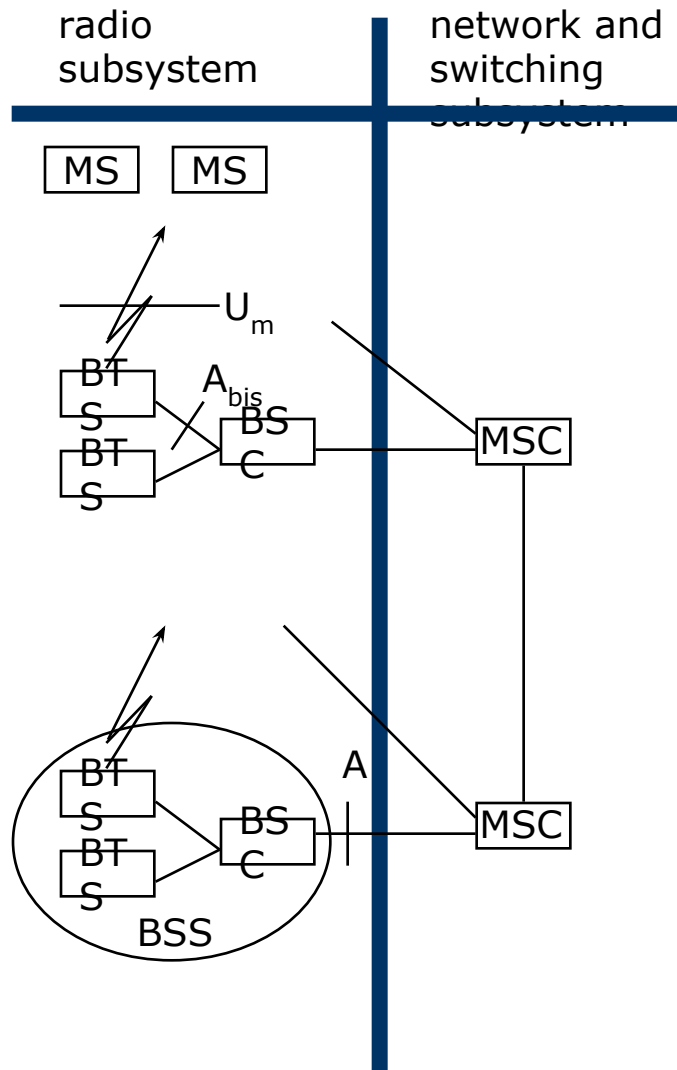
GSM: elements and interfaces



GSM: system architecture



System Architecture: Radio Subsystem



• Components

- *MS* (Mobile Station)
- *BSS* (Base Station Subsystem): consisting of
 - *BTS* (Base Transceiver Station): sender and receiver
 - *BSC* (Base Station Controller): controlling several transceivers

• Interfaces

- U_m : radio interface
- A_{bis} : standardized, open interface with 16 kbit/s user channels
- **A**: standardized, open interface with 64 kbit/s user channels

Radio Subsystem

- The Radio Subsystem (RSS) comprises the cellular mobile network up to the switching centers
- Components
 - Mobile Stations (MS)
 - Base Station Subsystem (BSS):
 - Base Transceiver Station (BTS): radio components including sender, receiver, antenna - if directed antennas are used one BTS can cover several cells
 - Base Station Controller (BSC): switching between BTSs, controlling BTSs, managing of network resources, mapping of radio channels
 - $BSS = BSC + \text{sum}(BTS) + \text{interconnection}$

RSS: The Mobile Station (MS)

- The mobile station consists of:
 - Mobile Equipment (ME)
 - Subscriber Identity Module (SIM)
- The SIM stores all specific data that is relevant to GSM - permanent and temporary data about the mobile, the subscriber and the network, including:
 - The International Mobile Subscriber Identity (IMSI)
 - MS ISDN number of subscriber (phone number)
 - Authentication key and algorithms for authentication check
 - Charging information, list of subscribed services
 - Personal identity number (PIN), and PIN unblocking key (PUK)
 - Temporary location information while logged onto GSM system
 - Temporary mobile subscriber identity (TMSI)
 - Location area identification (LAI)

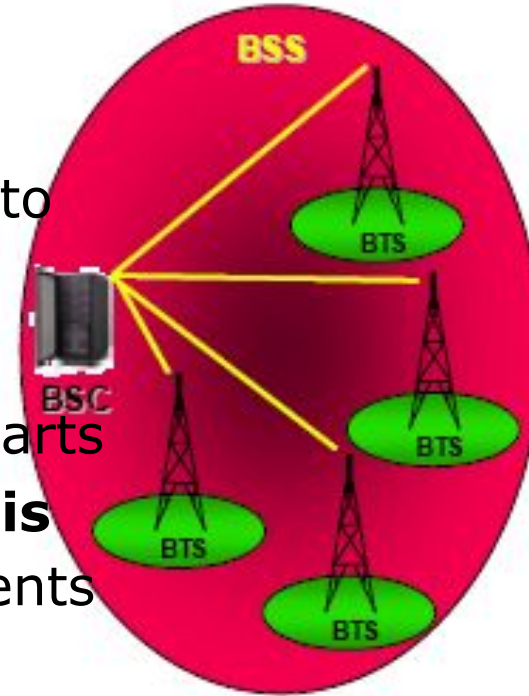


RSS: The Mobile Station (MS)

- The mobile equipment has a unique International Mobile Equipment Identity (IMEI), which is used for theft protection
- Without the SIM, only emergency calls are possible
- For GSM 900, MS transmits power of up to 2W, for GSM 1800 1W due to smaller cell-size
- MS can also have other components and services for the user (display, loudspeaker, Bluetooth interface, IrDA,...etc). These are non GSM features.

RSS: The Base Station Sub-System (BSS)

- A GSM network comprises many BSSs.
- The BSS performs all the functions necessary to maintain radio connection to an MS (coding/decoding of voice, rate adaptation,...)
- Base Station Subsystem is composed of two parts that communicate across the standardized **Abis** interface allowing operation between components made by different suppliers:
 - Base Station Controller (BSC)
 - One or more Base Transceiver Stations (BTSs)
- BTS contains:
 - Radio Transmitter/Receiver (TRX)
 - Signal processing and control equipment
 - Antennas and feeder cables



RSS: The Base Station Sub-System (BSS)

- The purpose of the BTS is to:
 - Provide radio access to the mobile stations
 - Manage the radio access aspects of the system
 - Encode, encrypt, multiplex, modulate and feed the RF signals to the antenna.
 - Frequency hopping
 - Communicates with Mobile station and BSC
- The BSC:
 - Allocates a channel for the duration of a call
 - Maintains the call:
 - Monitoring quality
 - Controlling the power transmitted by the BTS or MS
 - Generating a handover to another cell when required
- BTSs can be linked to parent BSC by microwave, optical fiber or cable

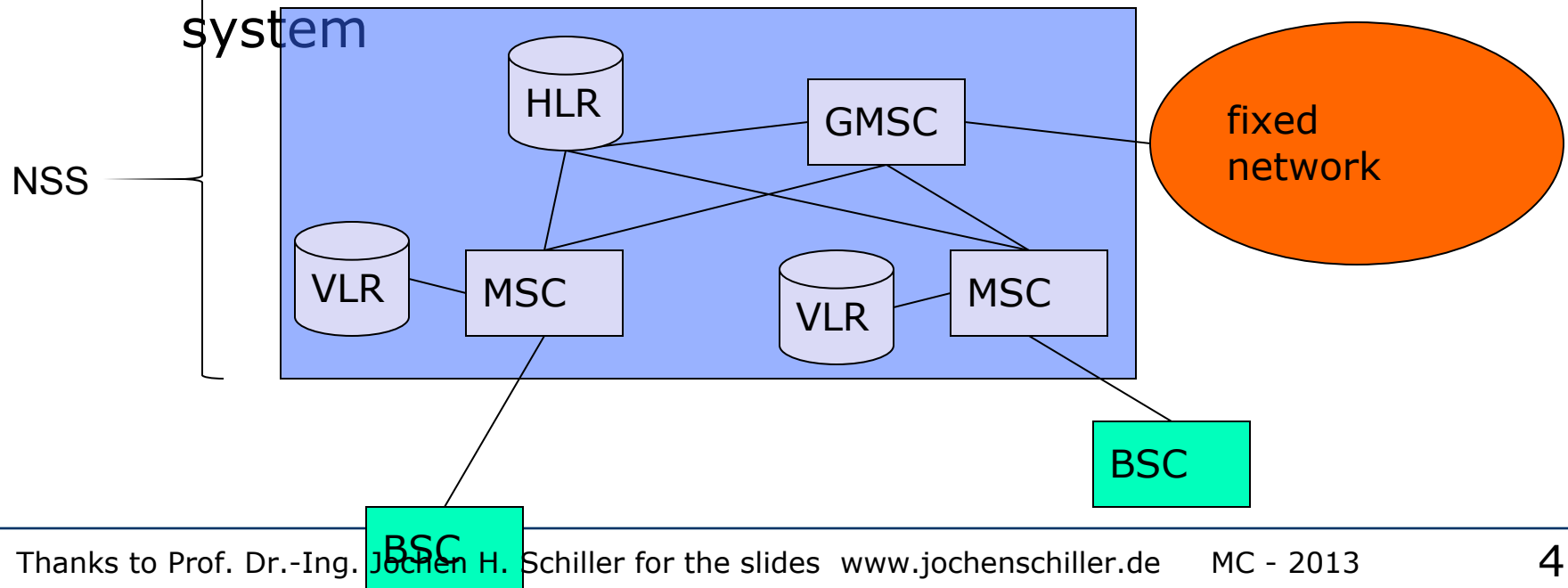
Network and switching subsystem (NSS)

- NSS is the main component and the heart of the GSM system
 - Connects the wireless network with standard public networks (manages communication between GSM and other networks)
 - Performs handover between different BSSs
 - Supports roaming of users between different providers in different countries
 - Performs functions for worldwide localization of users
 - Charging and billing information, accounting information

In summary switching, mobility management, interconnection to other networks, system control are the main functions of NSS

NSS- components

- Components
 - Mobile Services Switching Center (MSC)
 - Gateway Mobile Switching Center
 - Databases (important: scalability, high capacity, low delay)
 - Home Location Register (HLR)
 - Visitor Location Register (VLR)
- All components connect using the SS7 signaling system



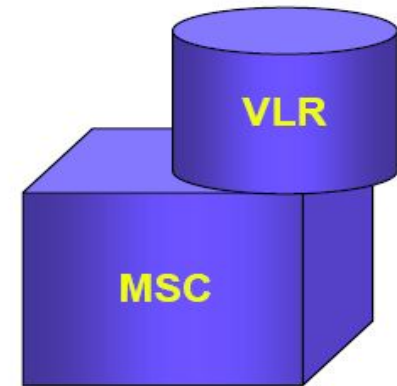
NSS - Mobile Services Switching Center

- MSCs are high-performance digital ISDN switches
- They set-up and control connections to other MSCs and to BSCs via the A-interface
- They form the backbone network of a GSM system
- Typically, an MSC manages several BSCs in a geographical region
- Controls all connections via a separated network to/from a mobile terminal within the domain of the MSC

NSS - Mobile Switching Centre (MSC)

- Functions of the MSC:

- Switching calls, controlling calls and logging call data
- specific functions for paging and call forwarding
- mobility specific signaling
- Mobility management over the radio network and interworking with other networks.
- Radio Resource management – handovers between BSCs
- Billing Information
- location registration and forwarding of location information
- provision of new services (fax, data calls)
- support of short message service (SMS)
- generation and forwarding of accounting and billing information
- Interface with PSTN, ISDN, PSPDN - interworking functions via Gateway MSC (GMSC)



NSS - MSC- Gateway Mobile Switching Centre (GMSC)

- A particular MSC can be assigned to act as a GMSC (Gateway Mobile Switching Centre)
-
- A GMSC is a device which routes traffic entering a mobile network to the correct destination
- The GMSC accesses the network's HLR to find the location of the required mobile subscriber
- The operator may decide to assign more than one GMSC



NSS- Home Location Register (HLR)

- Most important database in GSM system, stores all user-relevant information permanent and semi-permanent
 - Static information such as mobile subscriber ISDN number, subscribed services (e.g call forwarding, roaming restrictions), and the International mobile subscriber identity (IMSI))
 - Dynamic information such as the current location area (LA) of the MS, the mobile subscriber roaming number (MSRN), the current VLR and MSC.

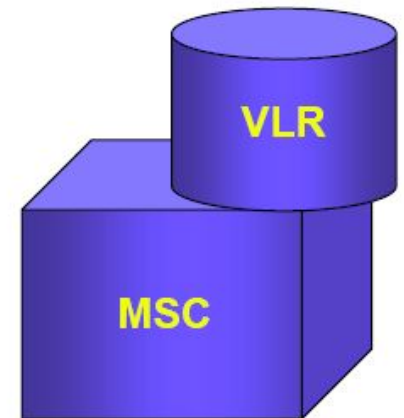
As soon as an MS leaves its current LA, the information in the HLR is updated. This information is necessary to localize a user in the worldwide GSM network
- All these user-specific information elements only exist once for each user in a single HLR which also supports charging and accounting

HLR Implementation

- There is logically one HLR in a Network, although it may consist of several separate computers
- May be split regionally
- HLRs can manage data for several million customers
- Contain highly specialised databases to fulfill real-time requirements and answer requests within certain time bounds.
- Stand alone computer – no switching capabilities
- May be located anywhere on the SS7 network
- Combine with AuC

NSS- Visitor Location Register (VLR)

- Each MSC has a VLR
- VLR is a dynamic local database which stores all important information needed for MS users currently in the LA (location area) associated to the MSC (the domain of the VLR)
- If a new MS comes into the LA of the VLR, it copies all relevant information for this user from the HLR, and stores this data temporarily.
- Information stored includes:
 - International Mobile Subscriber Identity (IMSI)
 - Mobile Station ISDN Number (MSISDN)
 - Mobile Station Roaming Number (MSRN)
 - Temporary Mobile Station Identity (TMSI)
 - Local Mobile Station Identity
 - The location area where the mobile station has been registered
 - Supplementary service parameters

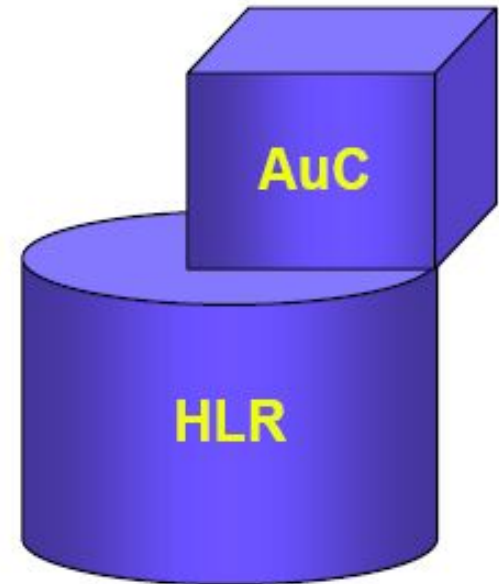


Operation Subsystem (OSS)

- The OSS (Operation Subsystem) enables centralized operation, management, and maintenance of all GSM subsystems. It accesses other components via SS7 signaling. It consists of the following three components:
 - Operation and Maintenance Center (OMC)
 - Authentication Center (AuC)
 - Equipment Identity Register (EIR)
- Operation and Maintenance Center (OMC)
 - different control capabilities for the radio subsystem and the network subsystem via the O-interface (SS7)
 - Traffic monitoring, status reports of network entities, subscriber and security management, or accounting and billing

OSS – Authentication Center (AuC)

- Authentication Center (AuC)
 - A separate AuC is defined to protect user identity and data transmission (wireless part)
 - authentication parameters used for authentication of mobile terminals and encryption of user data on the air interface within the GSM system
 - generates user specific authentication parameters on request of a VLR
 - Situated in a special protected part of the HLR



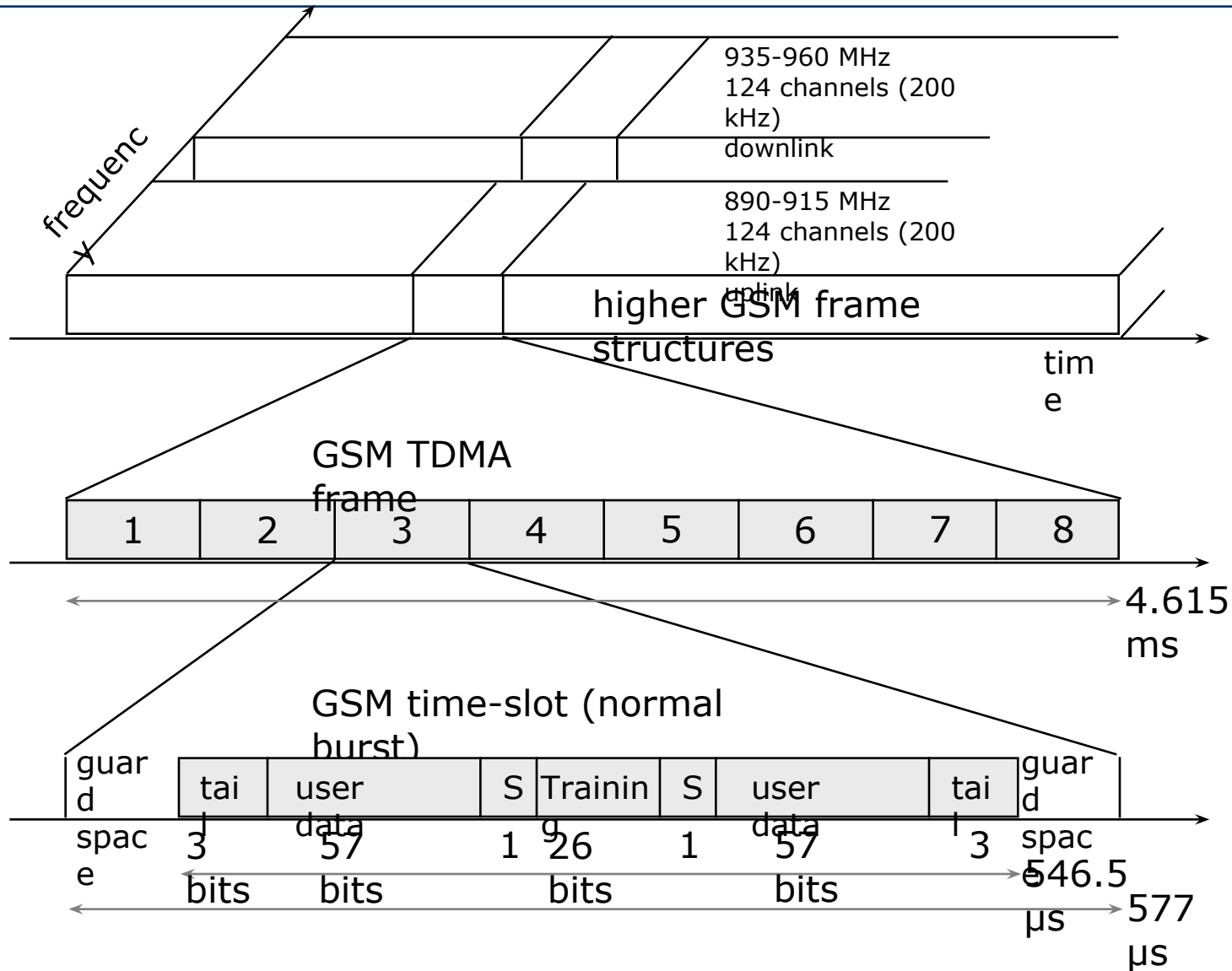
OSS – Equipment Identity Register (EIR)

- EIR is a database for all IMEI (International Mobile Equipment Identity). It stores all device identifications registered for this network
- The EIR controls access to the network by returning the status of a mobile in response to an IMEI query
- Possible status levels are:
 - White-listed - The terminal is allowed to connect to the network
 - Grey-listed - The terminal is under observation by the network for possible problems
 - Black-listed - The terminal has either been reported stolen, or is not a type approved for a GSM network. The terminal is not allowed to connect to the network.

The Radio Interface

- The most interesting interface in GSM is U_m the radio interface.
- GSM implements SDMA using cells with BTS and assigns an MS to a BTS
- FDD is used to separate uplink and downlink
- TDM is also used and media access combines TDMA & FDMA
- In GSM 900, 124 channels uplink + 124 channels downlink, each 200KHz wide, are used for FDMA
- Each of the 248 channels is further divided into frames that are repeated continuously. The duration of the frame is 4.615 ms
- Each frame is subdivided into 8 GSM timeslots, where each slot represents a physical channel and lasts for 577 μ sec. Each TDM channel occupies the 200 KHz carrier for 577 μ sec every 4.615 ms
- Data is transmitted in small portions called bursts, the burst is only 546.5 μ sec long and contains 148 bits. The remaining 30.5 μ sec are used as guard space to avoid overlapping with other

GSM - TDMA/FDMA



Cellular Networks Terminology

- Operation
 - **Initialisation**: when handset is turned on it selects a channel and connects to the switch
 - **Paging**: switch must locate a mobile by broadcasting requests from base stations
 - **Handoff**: switches must be able to move calls between cells when mobile moves
 - **Blocking/Dropping**: calls may be blocked or dropped if conditions in a cell change
 - **Interworking**: calls may be placed to other networks or may allow users to roam into other networks

GSM- Logical channels

- GSM specifies two basic groups of logical channels:
 - Traffic channels (TCH): to transmit user data (e.g., voice, fax, SMS,..)
 - Control Channel (CCH): many different CCHs are used in GSM system to control medium access, allocation of traffic channels, or mobility management. The following three groups of CCH have been defined:
 - Broadcast control channel (BCCH) : A BTS used this channel to signal information to all MSs within a cell (e.g. Cell identifier)
 - Common control channel (CCCH): All information regarding connection setup between MS and BS is exchanged via the CCCH (e.g. paging request) – random access scheme (ALOHA)
 - Dedicated control channel (DCCH): Before establishing a TCH, an MS and BTS uses this bidirectional channel for signalling (e.g. authentication)

GSM Operation: Localization & Calling

- One fundamental feature of GSM is the automatic worldwide localization of users
- The system always know 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 doesn't use the MS (still logged in GSM and not switched off).
- The HLR always contain information about the current location (the LA, not the precise geographical location)
- The VLR responsible for the MS informs the HLR about location changes.
- As soon as an MS moves into the range of a new VLR, the HLR sends all user data needed to the new VLR
- Changing VLRs with uninterrupted availability of all services is called handover - roaming

Localization & Calling (cont)

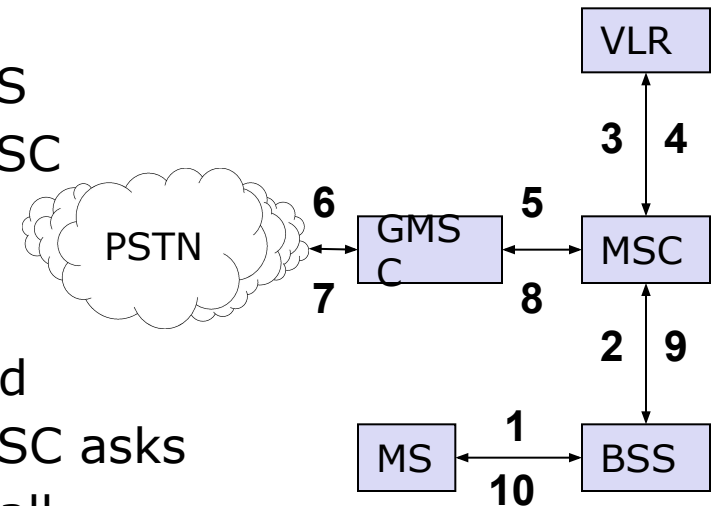
- To locate the MS and to address it several numbers are needed:
 - Mobile station international ISDN number (MSISDN). This number consists of the country code, the address of network provider and the subscriber number
 - International mobile subscriber identity (IMSI). This number is used for internal unique identification of a subscriber
 - Temporary mobile subscriber identity (TMSI): to hide the IMSI which would give away the exact identity of the user. TMSI is a four byte number selected by the current VLR and is only valid temporarily within the location area of the VLR.
 - Mobile station roaming number (MSRN). This is another temporary address that hides the identity and location of a subscriber. The VLR generates this address on request from the MSC. This address contains the current visitor country code, the visitor network provider, identification of current MSC with the subscriber number. This number is also saved in the HLR and helps the HLR to find a subscriber for an incoming call.

Localization & Calling (cont)

- All these numbers are needed to find a subscriber and to maintain the connection with a mobile station
- To describe how the calling process works we will consider two main cases for a call:
 - Outgoing call – Mobile Originated Call (MOC)
 - A GSM Mobile station calls a station outside the GSM network
 - Incoming Call - Mobile Terminating Call (MTC)
 - A station outside the GSM network calls a GSM mobile station.

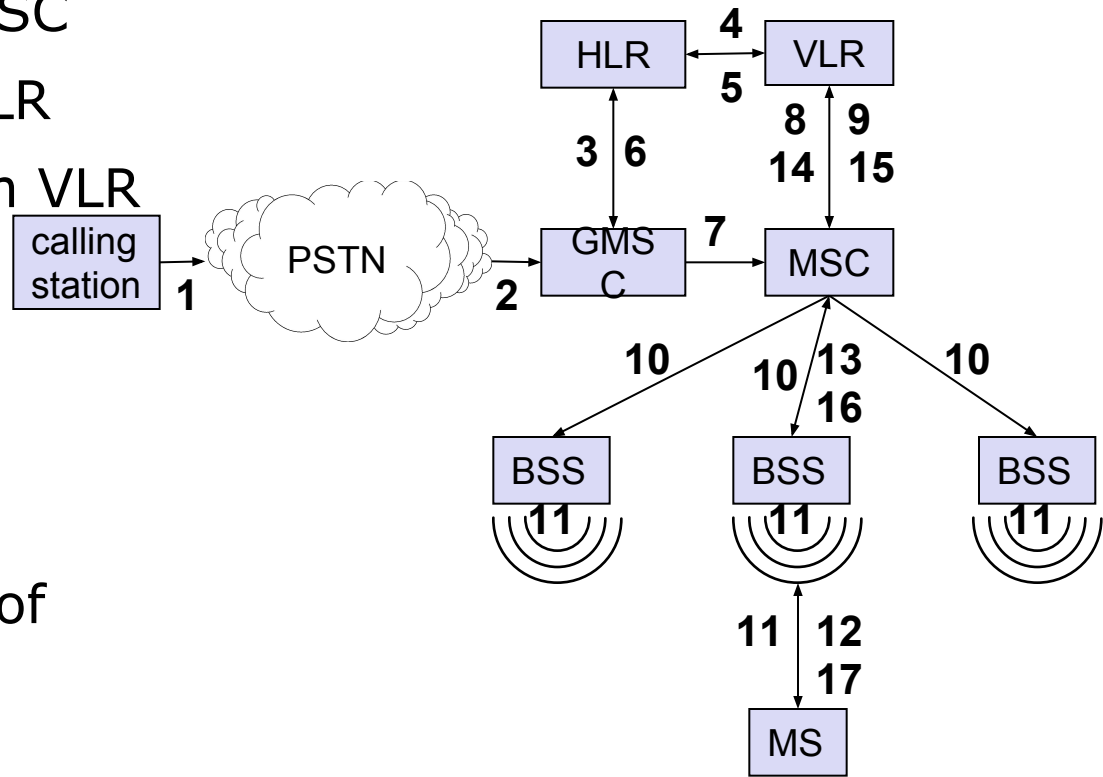
Mobile Originated Call (MOC) - outgoing call

- 1, 2: connection request
 - MS sends dialled number to BSS
 - BSS sends dialled number to MSC
- 3, 4: security check
 - MSC checks VLR if MS is allowed the requested service. If so, MSC asks BSS to allocate resources for call.
- 5-8: check resources (free circuit)
 - MSC routes the call to GMSC
 - GMSC routes the call to local exchange of called user
- 9-10: set up call
 - Answer back(ring back) tone is routed from called user to

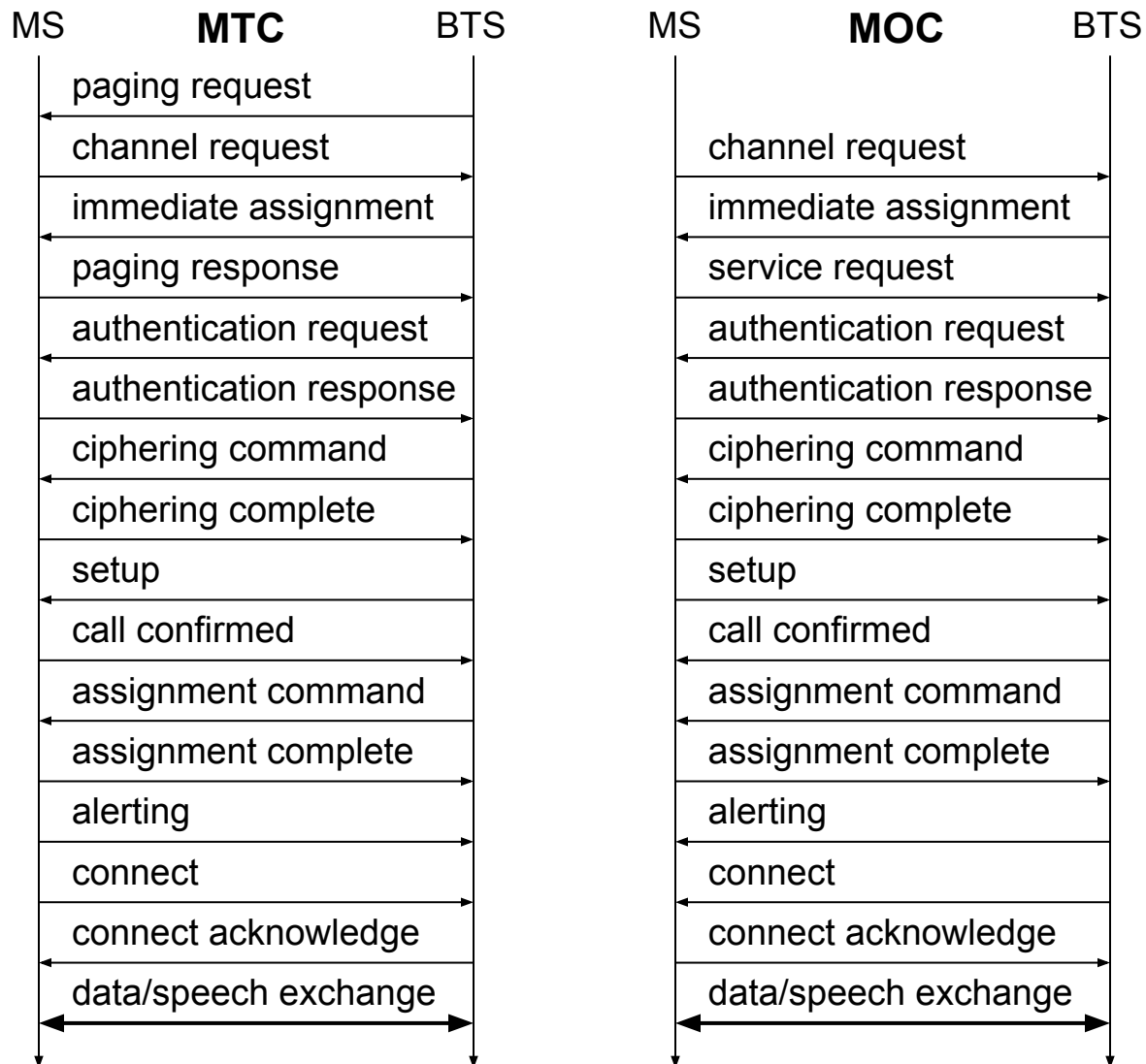


Mobile Terminated Call

- 1: calling a GSM subscriber
- 2: forwarding call to GMSC
- 3: signal call setup to HLR
- 4, 5: request MSRN from VLR
- 6: forward responsible MSC to GMSC
- 7: forward call to current MSC
- 8, 9: get current status of MS
- 10, 11: paging of MS
- 12, 13: MS answers
- 14, 15: security checks
- 16, 17: set up connection



MTC/MOC



Handover

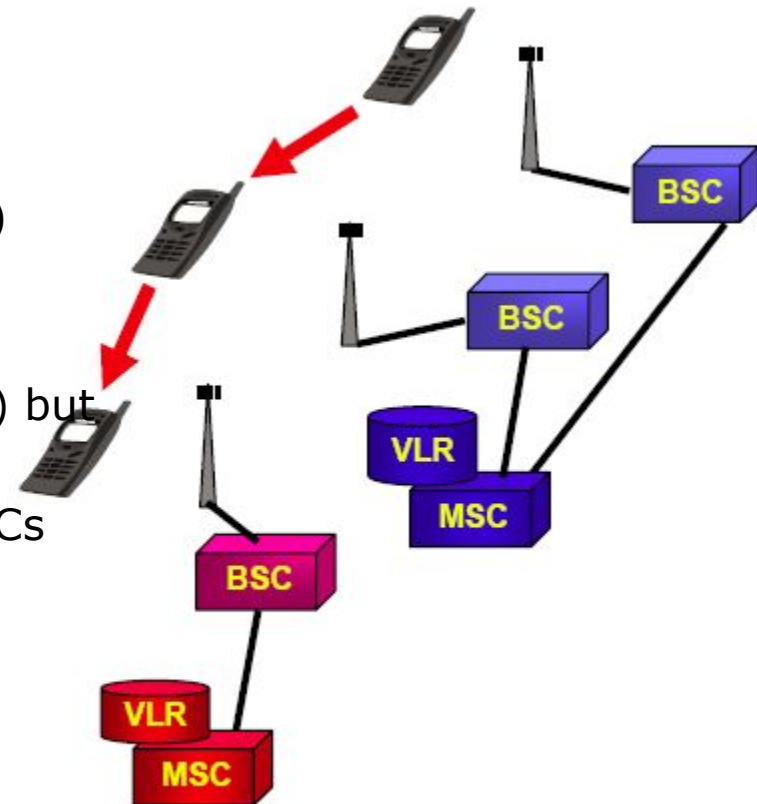
- Cellular systems require handover procedure as single cells do not cover the whole service area
 - Only up to 35 Km around each antenna on the countryside and some hundred meters in cities
- The smaller the cell-size and the faster the movement of a MS (up to 250 Km/h for GSM), the more handovers are required
- A handover should not cause a cut-off (call-drop)
- GSM aims at maximum handover duration of 60ms

Handover Causes

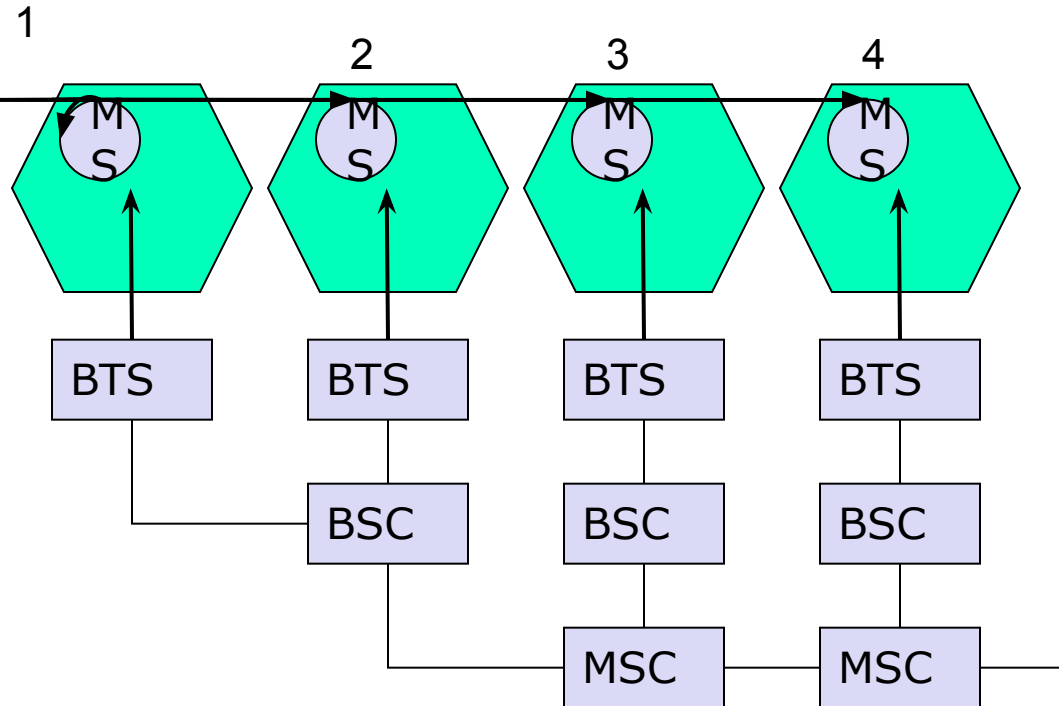
- Handover can be initiated by either MS or MSC
- Two basic reasons for a handover:
 - Mobile initiated handover: the MS moves out of the range of a BTS or a certain antenna of a BTS.
 - The received signal decreases continuously until it falls below the minimal requirements for communication
 - The error rate grows due to interference
 - The quality of the radio link is not suitable for the near future
 - Network Initiated handover: the wired infrastructure (MSC, BSC) may decide that the traffic in one cell is too high and shift some MS to other cells with a lower load; i.e.; for load balancing

Handover Types

- There are four different types of handover in the GSM system, which involve transferring a call between:
 - Internal:
 - Channels (time slots) in the same cell
 - Cells within the same BSS (same BSC)
 - External:
 - Cells in different BSSs (different BSCs) but under the control of the same MSC
 - Cells under the control of different MSCs



4 types of handover

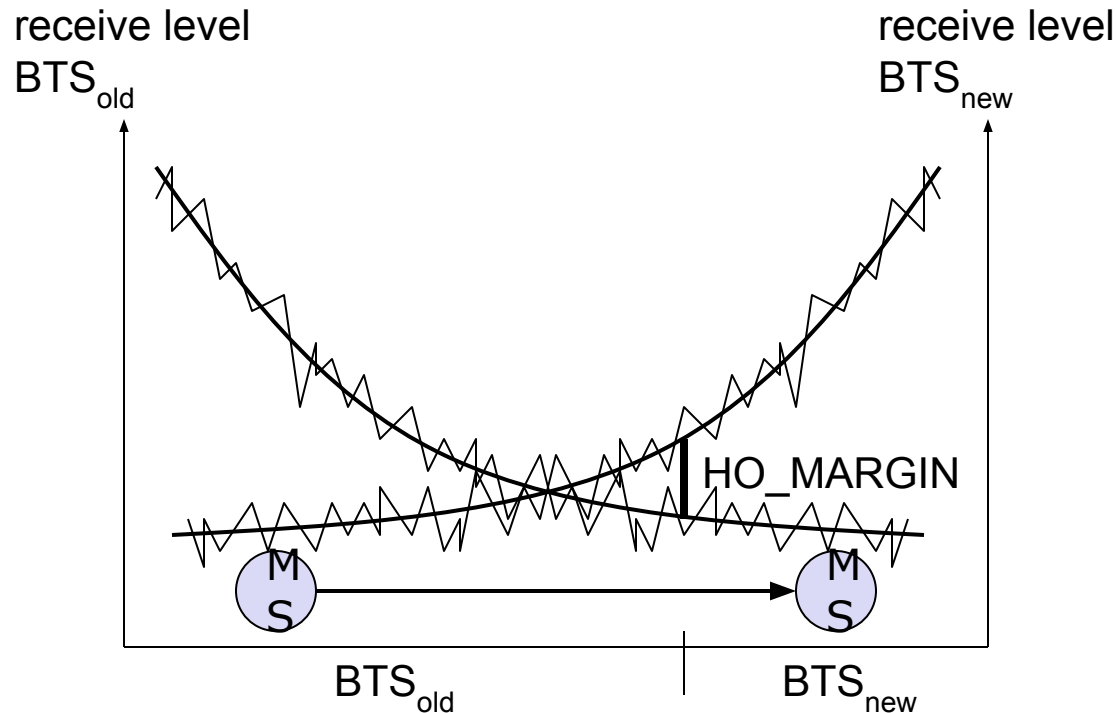


1. Intra-cell handover (channels, time-slots within the same cell – e.g. because of narrow band interference with some frequencies)
2. Inter-cell, intra-BSC handover (cells within the same BSS, BSC)
3. Inter-BSC, intra-MSC handover (cells in different BSS but under control of same MSC)
4. Inter-MSC handover (cells in different BSS and under control of different MSCs)

Handover Decision

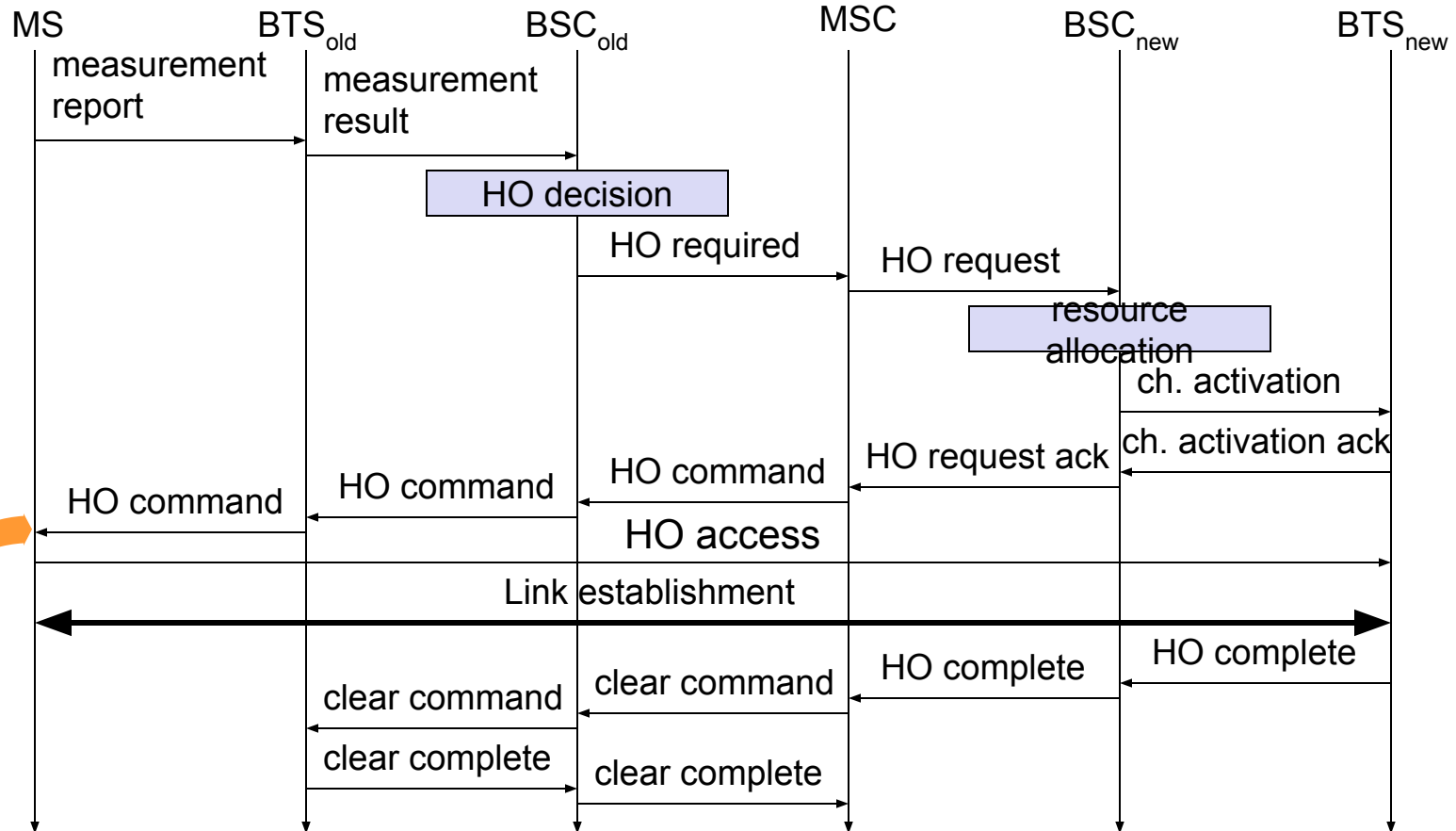
- Handover decision is based on the following parameters (in priority order):
 - Received signal quality (signal level + bit-error rate)
 - Received signal strength
 - Distance of MS from BTS
 - Drops below power budget margin
- Each operator has a operator-defined threshold and handover decisions can be based on one or a combination of the parameters
- Handover metrics:
 - Call blocking/dropping/completion probability
 - Probability of successful handoff
 - Handoff rate/delay
 - Interruption duration

Handover decision



Too high HO_Margin cause a cut-off, too low cause too many handover

Handover procedure



Hard handover

Roaming

- Allows subscriber to travel to different network areas, different operator's networks, different countries – keeping the services and features they use at home
- Billing is done through home network operator, who pays any other serving operator involved
- Requires agreements between operators on charge rates, methods of payment, etc
- Clearing house companies carry out data validation on roamer data records, billing of home network operations and allocation of payments

Roaming process

- Each mobile network has its own HLR and VLRs. When an MSC detects a mobile user's presence in the area covered by its network, it first checks the HLR database to determine if the user is in his/her home area or is roaming, i.e., the user is a visitor.
 - User in Home Area: HLR has the necessary information for initiating, terminating, or receiving a call.
 - User is Roaming: VLR contacts the user's HLR to get the necessary information to set up a temporary user profile.
- When a user receives a call while roaming within another network MSC
 - Home GMSC contacts the HLR to determine the appropriate switch in the roaming area to handle the arriving call and then transfers the call to the roaming area MSC.

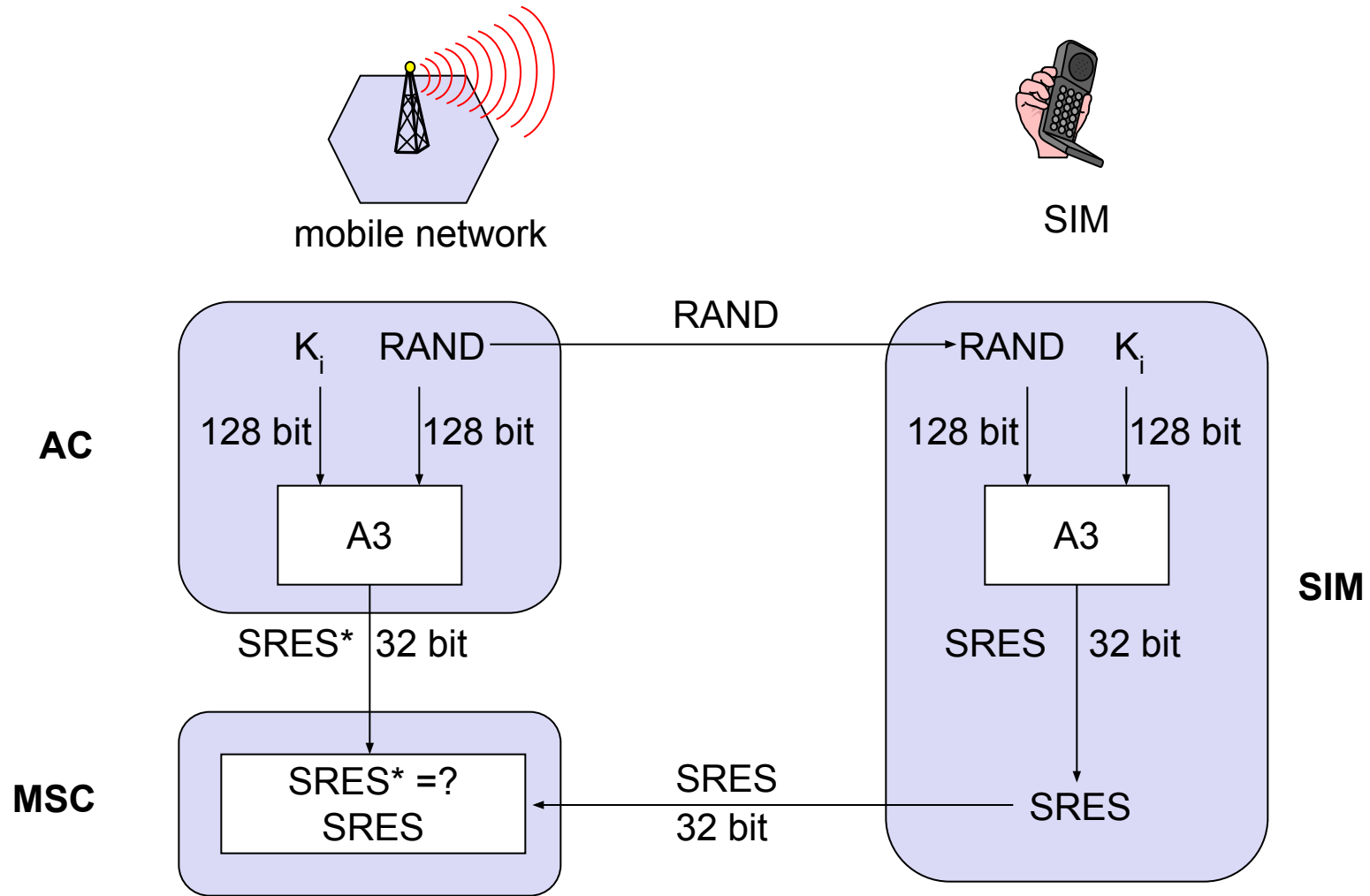
Security in GSM

- Security services
 - access control/authentication
 - user \square SIM (Subscriber Identity Module): secret PIN (personal identification number)
 - SIM \square network: challenge response method
 - confidentiality
 - voice and signaling encrypted on the wireless link (after successful authentication)
 - anonymity
 - temporary identity TMSI (Temporary Mobile Subscriber Identity)
 - newly assigned at each new location update
 - encrypted transmission
- 3 algorithms specified in GSM
 - A3 for authentication ("secret", open interface)
 - A5 for encryption (standardized)
 - A8 for cipher key generation used in A5("secret", open interface)
- Algorithms A3, A8 are located on the SIM and the AuC and can be proprietary. A5 is implemented in device and should be identical for all providers

"secret":

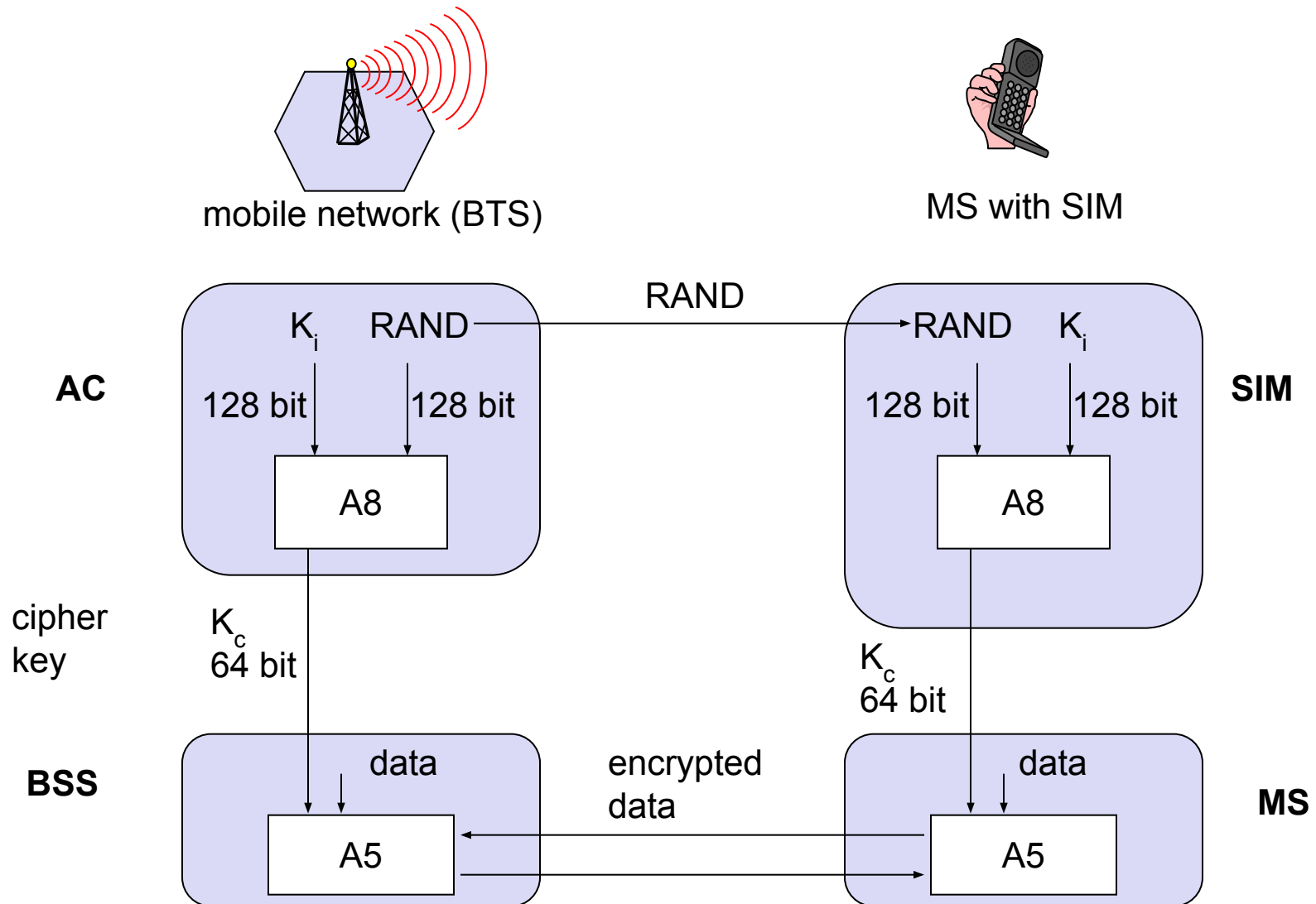
- A3 and A8 available via the Internet
- network providers can use stronger mechanisms

GSM - authentication

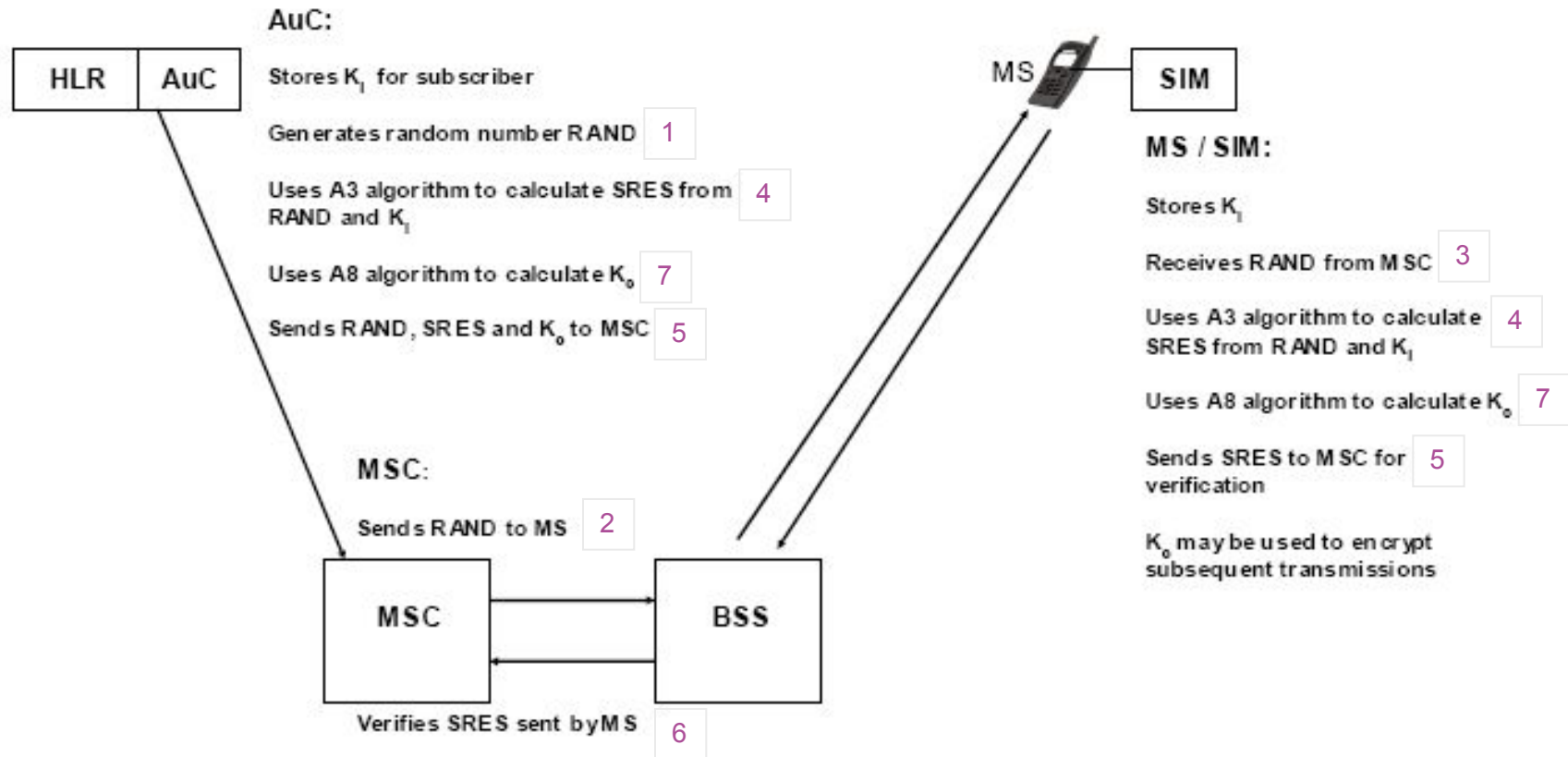


K_i : individual subscriber authentication key SRES: signed response

GSM - key generation and encryption



Authentication & Encryption



Evolution Of GSM

- 2nd Generation
 - GSM -9.6 Kbps (data rate)
- 2.5 Generation
 - HSCSD (High Speed Circuit Switched Data)
 - Data rate : 76.8 Kbps (9.6 x 8 kbps)
 - GPRS (General Packet Radio Service)
 - Data rate: 14.4 - 115.2 Kbps
 - EDGE (Enhanced Data rate for GSM Evolution)
 - Data rate: 547.2 Kbps (max)
- 3rd Generation
 - UMTS - WCDMA(Wide band CDMA)
 - Data rate : 0.348 – 2.0 Mbps

Data services in GSM

- Data transmission standardized with only 9.6 kbit/s. Advanced coding allows 14.4 kbit/s
 - not enough for Internet and multimedia applications
- GSM is circuit switching connected-oriented mechanism. This is not suitable for data transmission which is bursty in nature and requires higher bandwidth
 - Web-browsing leaves the channel idle most of the time, so allocation of channel permanently waste too much resources
 - Billing is based upon time allocation of channels which is not suitable for data services
- Two basic approaches have been proposed:
 - HSCSD (High-Speed Circuit Switched Data)
 - GPRS (General Packet Radio Service)

HSCSD (High-Speed Circuit Switched Data) – 2.5 Generation

- Higher data 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– the allocation could be asymmetrical (more slots on downlink than in uplink)
- Mainly software update in MS and MSC
- An MS can use up to 8 slots within the frame to achieve up to 115.2 Kbit/s
- advantage: ready to use, constant quality, simple
- disadvantage: Still circuit switching same problems, high price and wasting of resources– channels blocked for voice transmission –

General Packet Radio Service- GPRS (2.5 G)

- General Packet Radio Service (GPRS) is a new bearer service for GSM that greatly improves and simplifies wireless access to packet data networks,
- It uses the existing GSM network to transmit and receive TCP/IP based data to and from GPRS mobile devices.
- GPRS is a non-voice service added to existing TDMA time division multiple
- access networks, one of the 2.5G technology upgrades. TDMA is the underlying transport mechanism used by GSM networks.

General Packet Radio Service- GPRS (2.5 G)

- Fully packet-oriented switching
- Standardization 1998, introduction 2001
- Using free slots only if data packets ready to send (e.g., 50 kbit/s using 4 slots temporarily)
- Users are always ON – Charging on volume not on connection time
- Advantage: one step towards UMTS, more flexible
- Disadvantage: more investment needed (new hardware)
- GPRS network elements
 - GSN (GPRS Support Nodes): GGSN and SGSN (routers)
 - GGSN (Gateway GSN)
 - interworking unit between GPRS and PDN (Packet Data Network)
 - SGSN (Serving GSN)
 - supports the MS (location, billing, security)
 - GR (GPRS Register)
 - user addresses

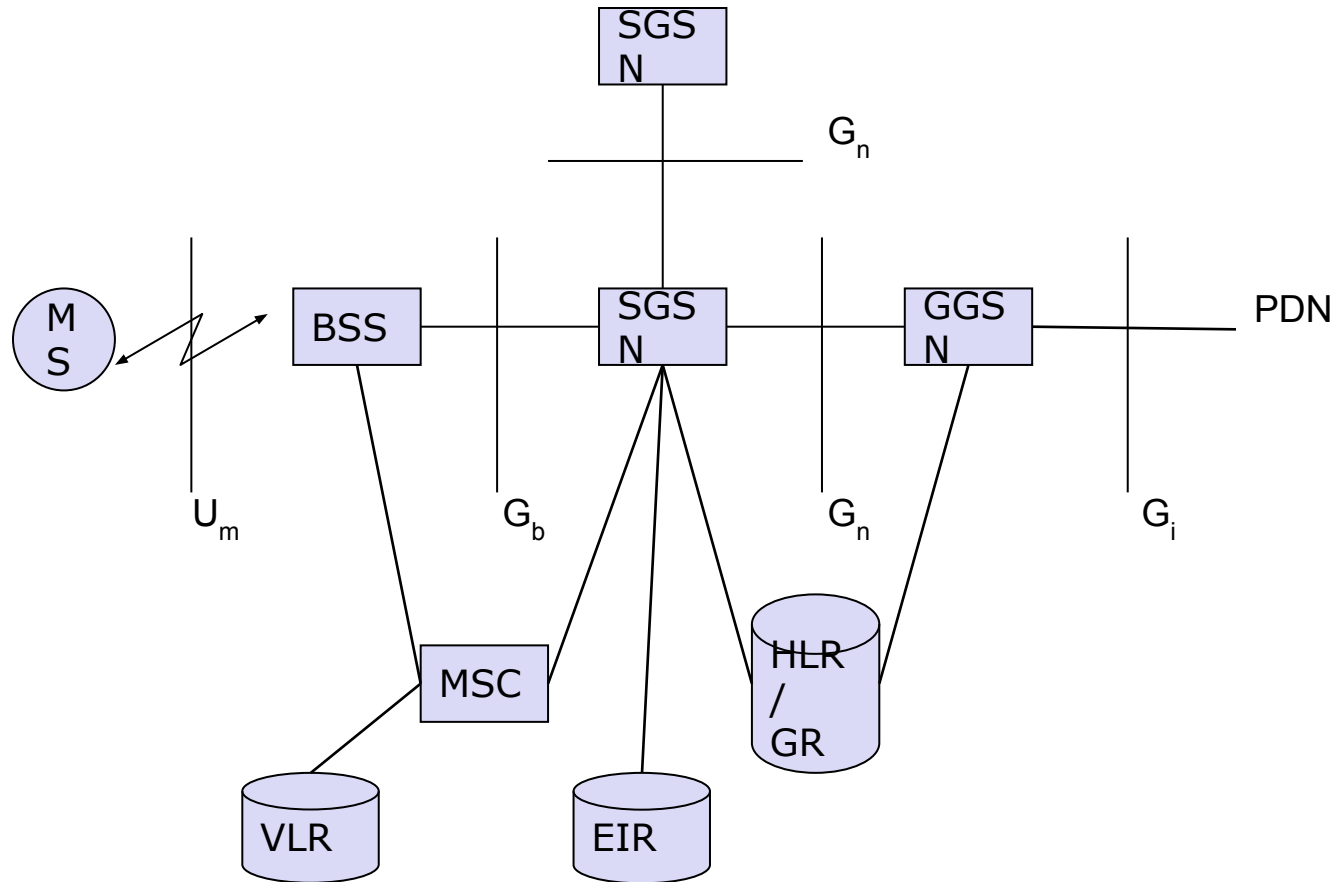
General Packet Radio Service- GPRS (2.5 G)

- High Speed (Data Rate 14.4 – 115 kbps)
- Efficient use of radio bandwidth (Statistical Multiplexing)
- Circuit switching & Packet Switching can be used in parallel
- Constant connectivity

Comparison of GSM & GPRS

	GSM	GPRS
Data Rates	9.6 Kbps	14.4 to 115.2 Kbps
TDMA	Uses one out of seven time slots	uses 4 +1 time slots
Billing	Duration of connection	Amount of data transferred
Type of Connection	Circuit – Switched Technology	Packet - Switched Technology

GPRS Architecture and Interfaces



Towards 3G: EDGE Technology

- EDGE improves the GPRS architecture by employing a new modulation method and link quality control. 8-PSK is a high-level linear modulation method that carries three times more information through an extended signal constellation.
- The link quality control dynamically selects the modulation and coding scheme for transmission of data over the air interface. Thus the EDGE user bit-rates increase with better quality.

Towards 3G: CDMA

- Capacity is CDMA's biggest asset. It can accommodate more users per MHz of bandwidth than any other technology (3 to 5 times more than GSM)
- CDMA has no built-in limit to the number of concurrent users.
- CDMA do not limit the distance a tower can cover.
- CDMA consumes less power and covers large areas so cell size in CDMA is larger.
- CDMA is able to produce a reasonable call with lower signal (cell phone reception) levels.
- CDMA uses Soft Handoff, reducing the likelihood of dropped calls.
- CDMA's variable rate voice coders reduce the rate being transmitted when speaker is not talking, which allows the channel to be packed more efficiently.
- Has a well-defined path to higher data rates.

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

UMTS

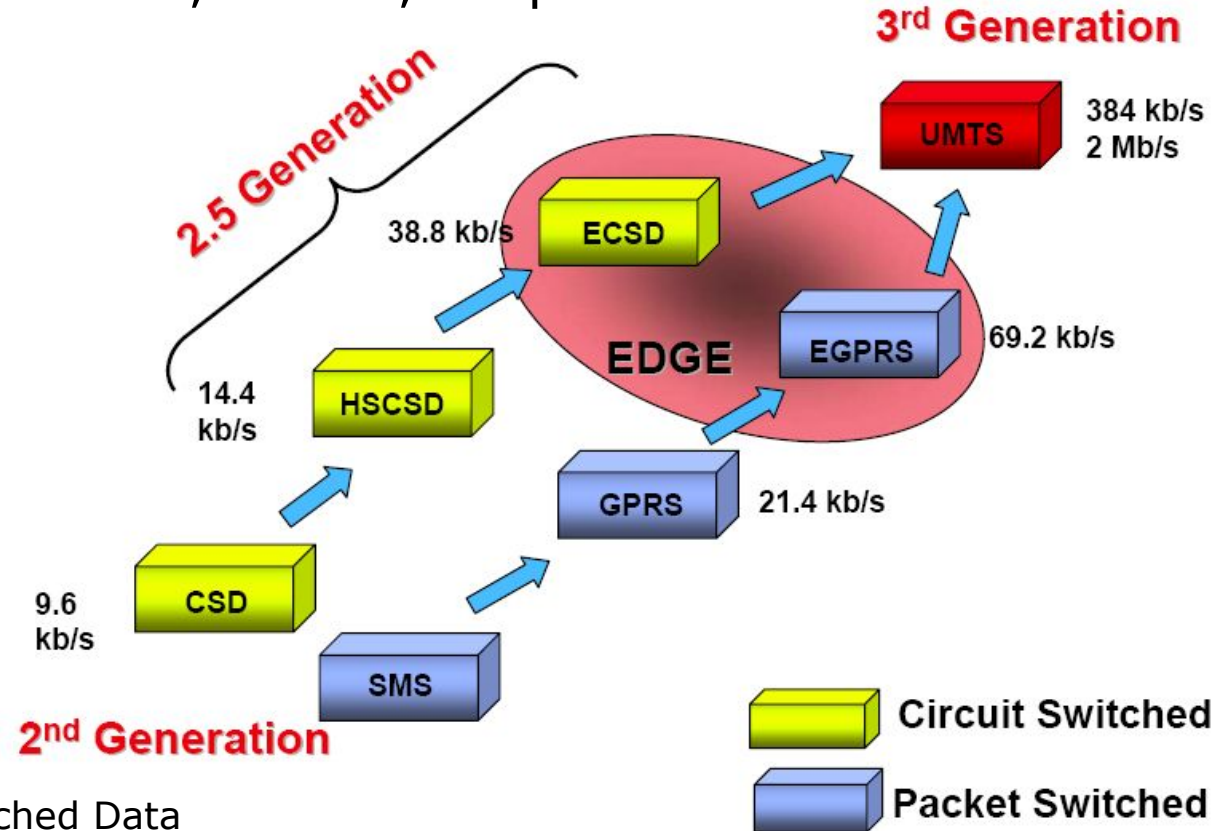
- UMTS – Universal Mobile Telephone System
- Most popular 3G wireless standard.
- Combines the infrastructure of the GSM network with superior technology of the CDMA air interface.
- UMTS was originally a European standard.
- Not just an improvement of 2G networks.
- Requires new equipment and new frequency bandwidths

UMTS Aims

- Broadband access around 2Mbit/s
- Mobile or fixed access
- Service transparency
- Mass market provision at low (?) cost
 - Variety of tariffs in 2011
- Convergence of network types
- Global (getting easier!)

UMTS Evolution

- Evolution of GSM towards 3G systems
- Main requirement is for increased data rates
- Mobile access to: Internet, E-mail, Corporate networks



HSCSD: High-Speed Circuit-Switched Data

GPRS: General Packet Radio Service

EDGE: Enhanced Data rates for GSM Evolution

Thanks to Prof. Dr.-Ing. Jochen H. Schiller for the slides www.jochenschiller.de

MC - 2013

4.75

UMTS Evolution

- How?
 - GSM won't completely evolve into UMTS
 - Additional capabilities in GSM
 - Introduce gradually in cities
 - Dual UMTS/GSM terminals

UMTS Multimedia

- Applications
 - Web browsing
 - Push techniques (news etc.)
 - Messaging & email
 - Real-time audio & video
 - E-commerce applications (banking, shopping)
 - Office applications

IP over 3G/UMTS

- Key services in 3G
 - Voice (of high quality)
 - Non-Internet Multimedia, e.g. photo/video messaging
 - Location-based Services (LBS)
 - Internet Access – Internet Multimedia Subsystem (IMS)
- IP will be a 'service' of 3G
 - This means IP runs on top of existing layers in parallel to other protocols for other services
 - Some providers will specialize in IP access to customers, possibly separately to existing providers

Internet Multimedia Subsystem

