

Architecture and Signaling

GSM & UMTS

Part I.

Mobile Communication Systems

1. Introduction

19th Century

- **Appearance** of radio equipments

20th Century

- True **expansion** of mobile systems and market
 - Development of compact and cheap radio terminals
 - Advances in software technology
 - Advances in wireless communication theory

Explosive growth throughout the world

Service
Mobility

- Service accessible to a given user, even when if the user changes its mobile device or its mobile network

Terminal
Mobility

- Capability of a device to ensure continuity of communication when **roaming** within or across different networks

User
Mobility

- Users can access their subscribed services when moving to a different network or when changing terminals

Network
Mobility

- Mobility for entire networks (bus or airplane)

Mobility

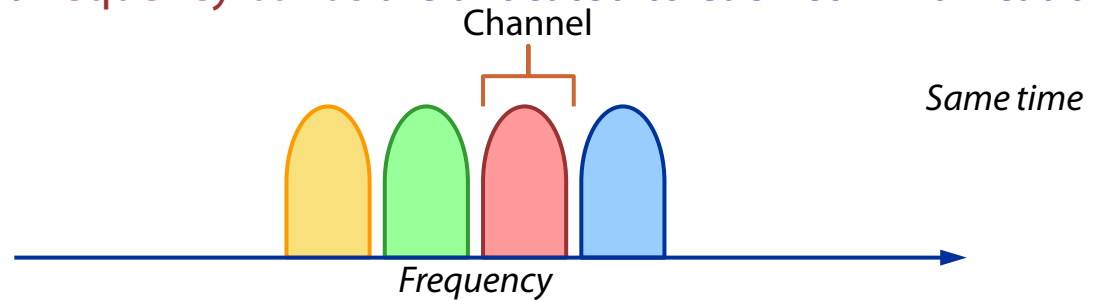
1.1. Classification

Depending upon how communication channels are set up (multiplexed) on the **radio interface**

FDMA

Frequency Division Multiple Access

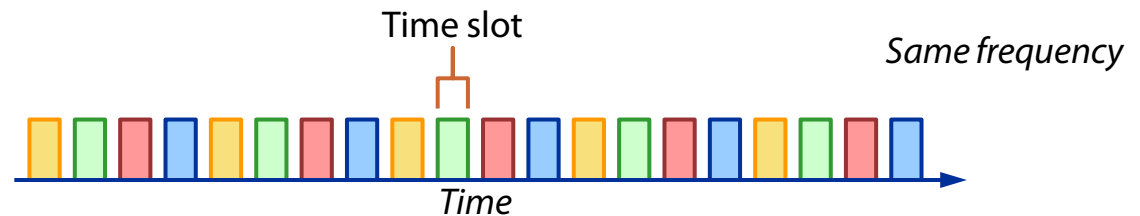
- Different **frequency bands** are allocated to each communication



TDMA

Time Division Multiple Access

- Different **timeslots** are allocated to each communication



CDMA

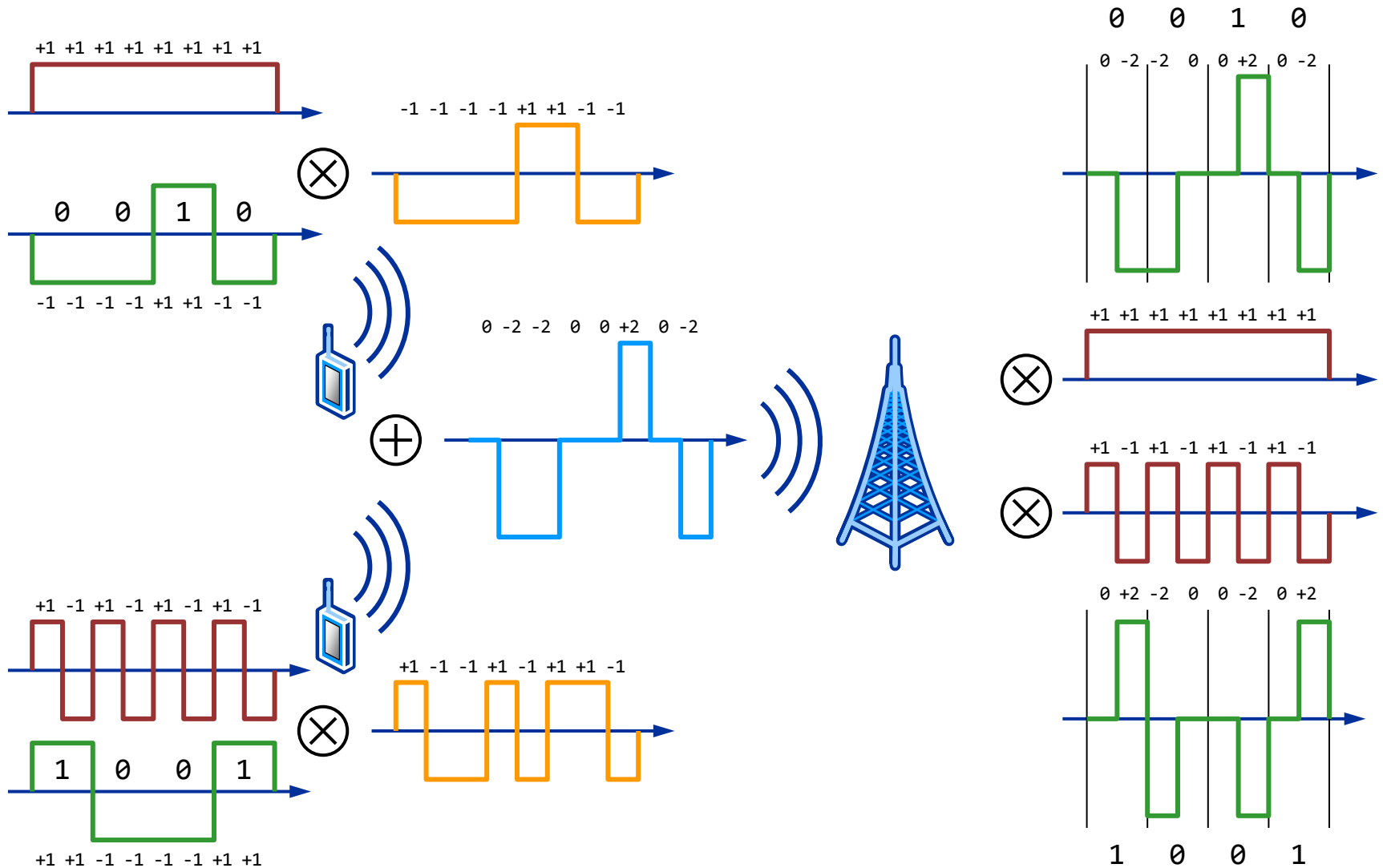
Code Division Multiple Access

- Uses **spread spectrum techniques**: the energy is spread in a wider band using **orthogonal codes**

Same time

Same frequency

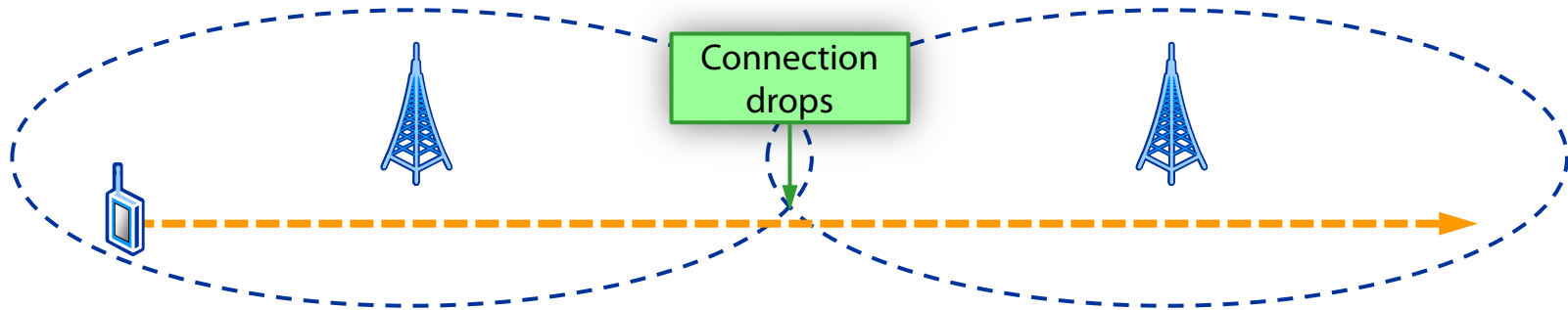
1.1.0. Code Division Multiple Access



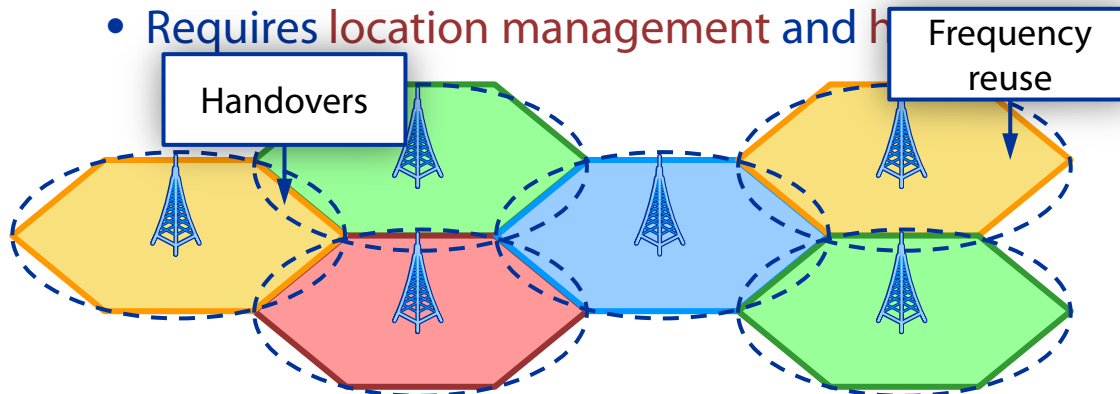
1.1. Classification

Depending on the land **radio coverage**

- Non-cellular
- Uses **one** (or few) **base stations** to cover a large geographical area
 - Calls are **dropped** and **re-established** when changing base stations



- Cellular
- Uses **many** low-power **base stations** to cover small areas called **cells**
 - **Reuses** radio frequencies in cells that are far apart
 - Requires **location management** and **handoffs** (Frequency reuse)



1.2. Major Standards

1G

Design	1970
Implementation	Late 1970s
Services	Analog voice Data
Standards	AMPS TACS NMT
Data rate	1.9 kbps
Multiple access	FDMA

Advanced Mobile Phone System

- Introduced in the US in 1978
- 800 MHz frequency band

Total Access Communication System

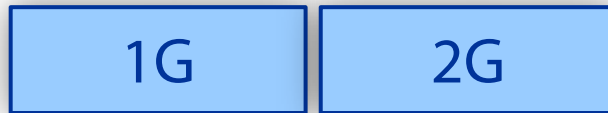
- Introduced in the UK and Ireland in 1983
- Similar to AMPS
- 900 MHz frequency band

Nordic Mobile Telephony

- Introduced in the Northern countries
- NMT-450 and NMT-950
- 900 MHz frequency band



1.2. Major Standards



	1G	2G
Design	1970	1980
Implementation	Late 1970s	1991
Services	Analog voice Data	Digital voice Data Short messages
Standards	AMPS TACS NMT	D-AMPS IS-95 GSM
Data rate	1.9 kbps	9.6 kbps (14.4 kbps)
Multiple access	FDMA	FDMA TDMA CDMA

Digital-AMPS

- Backward compatible with AMPS
- IS-54: digital voice TDMA channels, analog control
- IS-136: fully digital
- Frequency bands: 850 and 1900 MHz

Interim Standard 95

- Also known as **cdmaOne**
- Uses CDMA

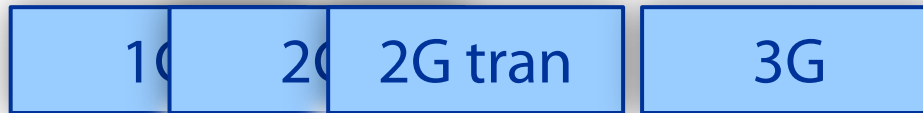
Global System for Mobile Comm.

- Most successful and widely used
- Originally an European standard

1.2. Major Standards

	1G	2G	2G tran
Design	1970	1980	1985
Implementation	Late 1970s	1991	1999
Services	Analog voice Data	Digital voice Data Short messages	Voice Packet data
Standards	AMPS TACS NMT	D-AMPS IS-95 GSM	HSCSD GPRS EDGE
Data rate	1.9 kbps	9.6 kbps (14.4 kbps)	57.6 kbps (384 kbps)
Multiple access	FDMA	FDMA TDMA CDMA	FDMA TDMA CDMA

1.2. Major Standards



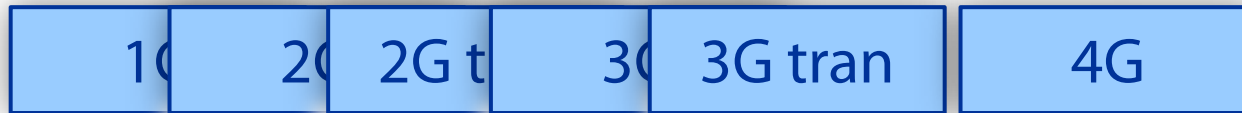
	1G	2G	2G tran	3G
Design	1979	1982	1985	1990
Implementation	Late 1980s	1991	1999	2002
Services	Analog Data Short message	Digital Data Short message	Voice Packet data	Higher capacity Multimedia
Standards	AMPS TACS NMTS	D-AMPS IS-95 GSM	HSCSD GPRS EDGE	UMTS CDMA2000 UWC-136
Data rate	1.9 kbps	9.6 kbps (14.4 kbps)	57.6 kbps (384 kbps)	144 kbps (2Mbps)
Multiple access	FDM	FDM TDM CDMA	FDMA TDMA CDMA	CDMA

1.2. Major Standards



	1G	2G	2G tran	3G	3G tran
Design	1979	1982	1985	1990	1990
Implementation	Late 1980s	1991	1999	2002	2002
Services	Analog Data Short message	Digital Data Short message	Voice Packet data	Higher capacity Multimedia	
Standards	AMPS TACS NMT	D-AMPS IS-95 GSM	HSCSD GPRS EDGE	UMTS CDMA2000 UWC-136	HSPA HSPA+
Data rate	1.9 kbps	9.6 kbps (14.4 kbps)	57.6 kbps (384 kbps)	144 kbps (2Mbps)	168 Mbps 22 Mbps
Multiple access	FDM	FDM TDM CDMA	FDMA TDMA CDMA	CDMA	CDMA

1.2. Major Standards



	1G	2G	2G t	3G	3G tran	4G
Design	1979	1982	1988	1995	1990	1990
Implementation	Late 1980s	1991	1993	2001	2008	2012
Services	Analog Data Short me	Digital Data	Voi Packet	Higher ca Multim		
Standards	AMPS TACS NMT	D-AMPS IS-95 GSM	HSCSD GPRS EDGE	UMTS CDMA2000 UWC-	HSPA HSPA+	LTE LTE-Advanced
Data rate	1.9 kb/s	9.6 kb/s (14.4 kb/s)	57.6 kb/s (384 kb/s)	144 kb/s (2 Mb/s)	168 Mbps 22 Mbps	168 Mbps 22 Mbps
Multiple access	FDM	FDM TDM CDMA	FDM TDM CDMA	CDMA	CDMA	CDMA

Part II. 2G

Global System for Mobile Communications

1. Introduction

GSM A second generation (2G) digital cellular system for mobile communications (voice and data)

1982

- Initial vision stated by GSM (Groupe Spéciale Mobile)
 - Working group established at *Conférence Européenne des Administrations des Poste et des Télécommunications* (CEPT)
 - Initial frequency bands: 890-915 MHz (uplink) and 935-960 MHz (downlink)
- Later standardization confined to ETSI (European Telecommunications Standards Institute)

1991

- GSM becomes Global System for Mobile Communications
 - Standard evolves toward 3G – 3GPP (Third Generation Partnership Project)

GSM
Standards

01	General	06	Speech coding
02	Service aspects	07	Terminal adaptors
03	Network aspects	09	Network interworking
04	MS – BS interface	10	Service interworking
05	Radio physical layer	11	Equipment and type approval

1.1. Features

- A telecommunication system offering the following services:

1 Telephony services

2 Data services

3 Access to other data networks

- Access to circuit switched public data networks (SC-PDN)
- Access to packet switched public data networks (PS-PDN)

4 Telematic services

- Short Message Service, fax, etc.

A GSM network is a **Public Land Mobile Network (PLMN)**

1.2. Mobility Concepts

- 1 Roaming
- 2 Location Updating
- 3 Handovers

1.2.1. Roaming

Roaming is possibility for a mobile subscriber to receive **service** even when it is not on the **coverage** area of its network

National
Roaming

- The user can switch between two mobile network operators

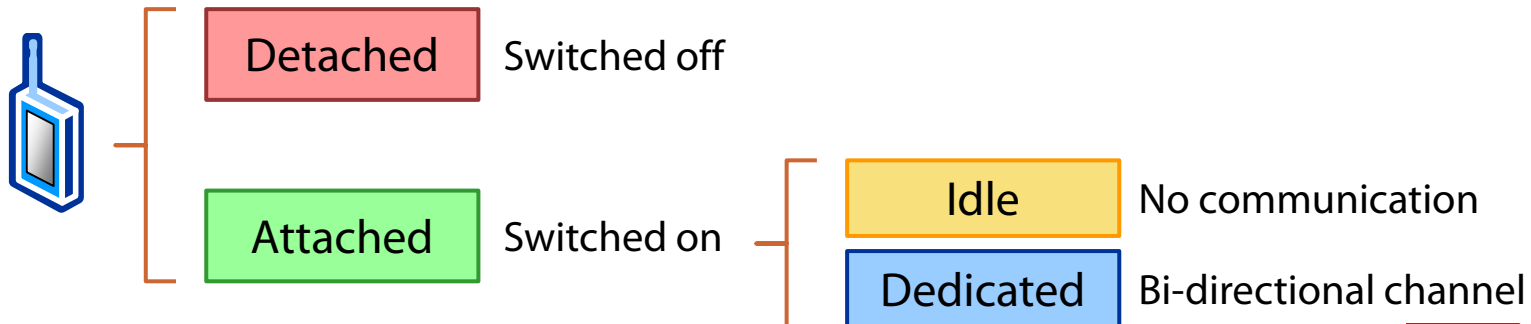
International
Roaming

- The user receives service from the PLMN of a different country

Non-GSM
Roaming

- Provided with compatible terminals

- Roaming is made possible by **changing connections** while the mobile station (MS) is in **idle state**



1.2.1. Roaming

Roaming is possibility for a mobile subscriber to receive **service** even when it is not on the **coverage** area of its network

- Roaming agreements are necessary
 - Mobile subscriber data (identity, billing etc) is transferred between the **home PLMN** and the **visited PLMN**

1.2.2. Location Updating

The procedure used by an MS in **idle mode** to communicate its **position** when it roams to another **location area**

- Methods for locating the position of a mobile subscriber

Network Level

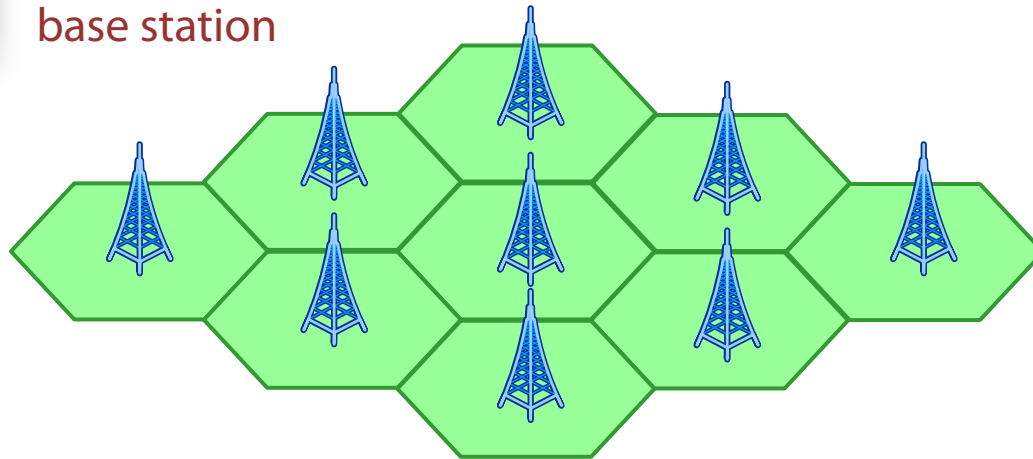
- Position known with respect to the **PLMN**

Location Area Level

- Position known with respect to several cells sharing a common identifier (a **Location Area Identifier**)

Cell Level

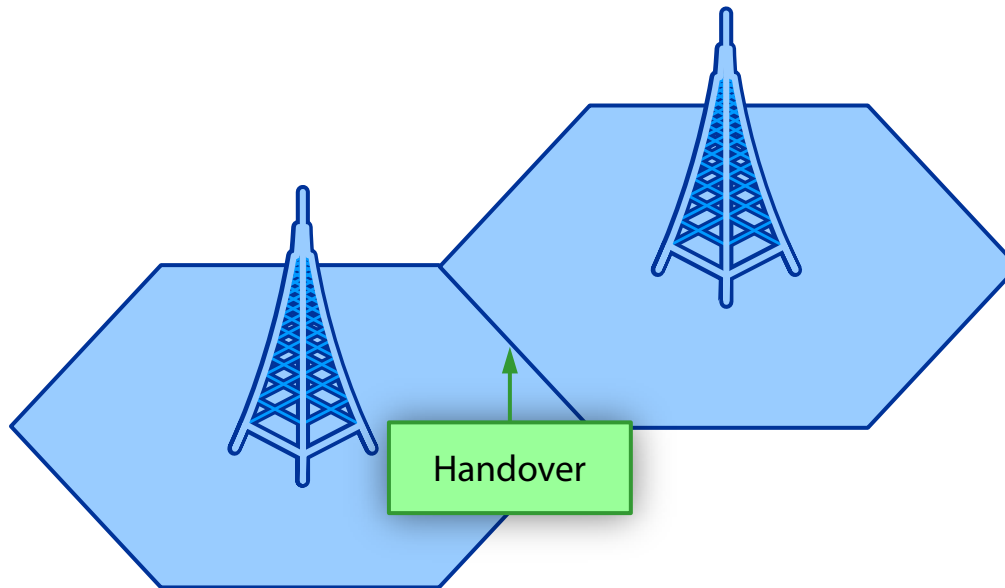
- Position known with respect to the geographic area covered by a **base station**



1.2.3. Handover

The procedure used to automatically transfer an ongoing call from a cell to another cell in a way not noticeable for the user

- Its purpose is to ensure continuity for ongoing calls in attached mode
- It can be used also for transferring a call between different radio channels of the same cell



1.3. GSM Services

- GSM offers three categories of services

1

Teleservices

- Complete communication services (e.g. telephony, SMS)
- No additional equipment is needed

2

Bearer Services

- Services used for transporting data between access points of a GSM PLMN
- Additional equipment might be needed for using a bearer service

3

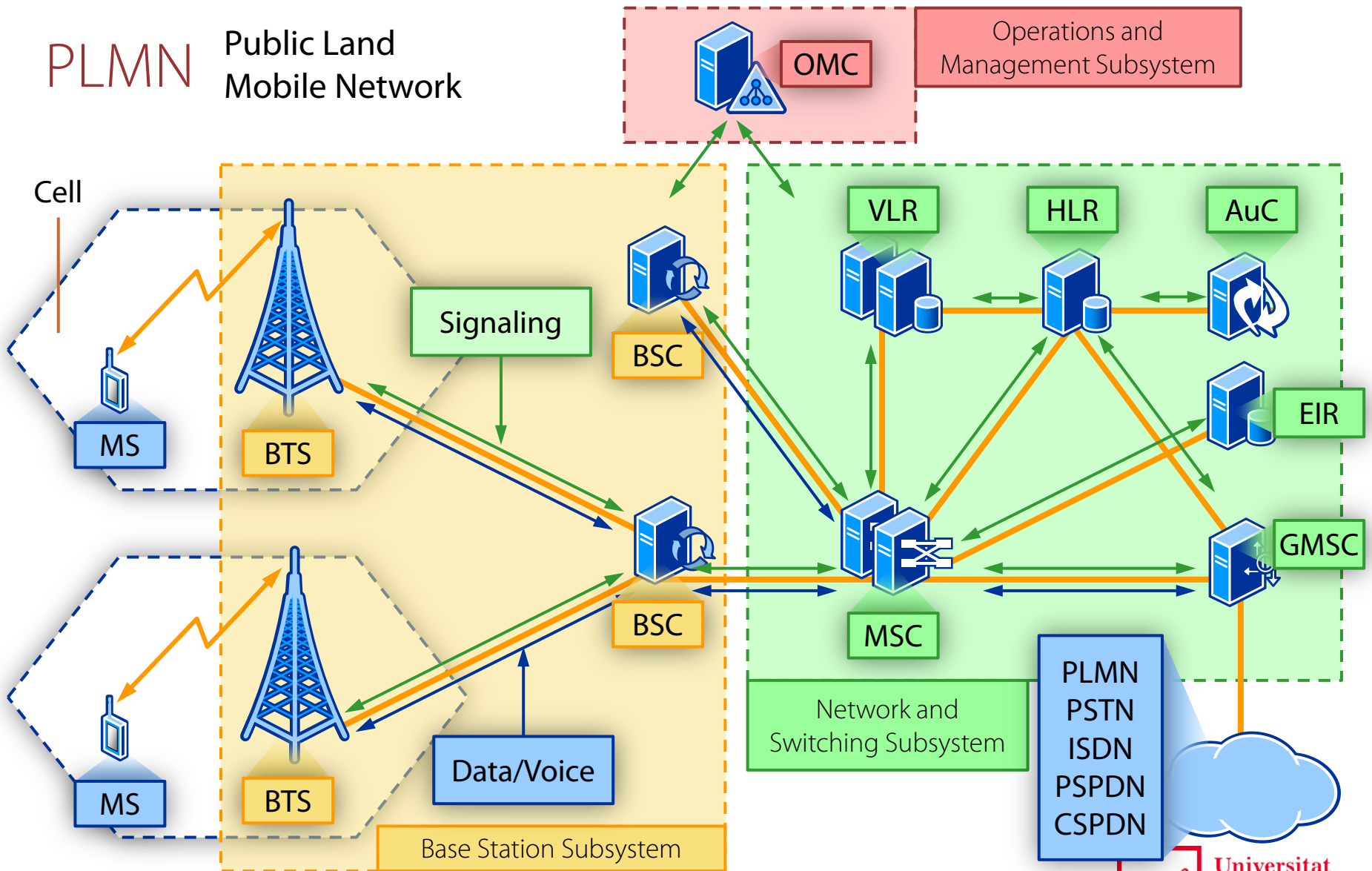
Supplementary Services

- Additional features available or not (operator's choice) free of charge or paid

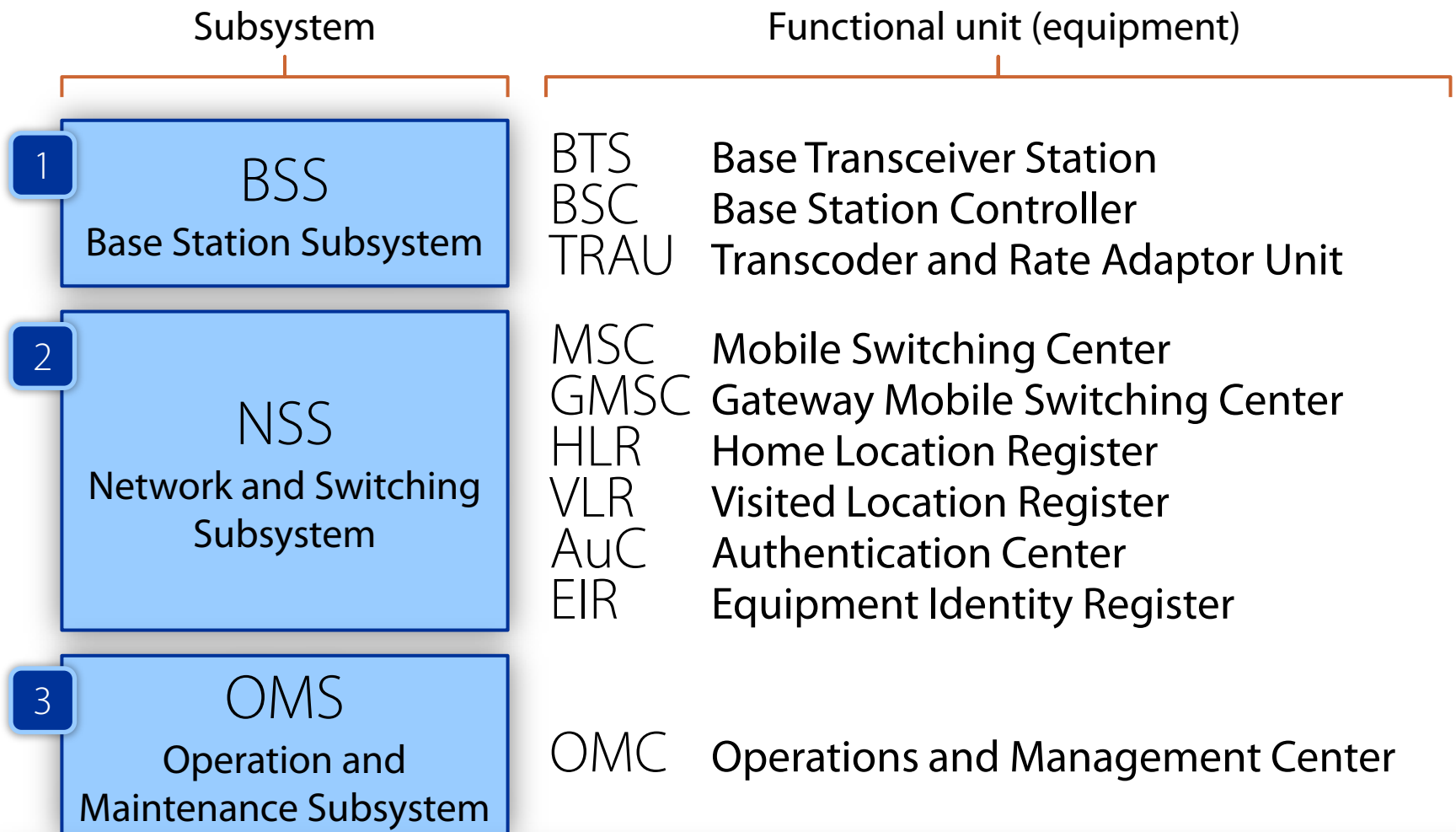
1.4. Technical Characteristics

Type	GSM 900	DCS 1800
Frequency bands (MHz)	890 – 915 (uplink) 935 – 960 (downlink)	1710 – 1785 (uplink) 1805 – 1880 (downlink)
Number of carriers	124	374
Carrier spacing	200 kHz	200 kHz
Multiple access scheme	Combined FDMA/TDMA (8 time slots)	
Duplex distance	45 MHz	95 MHz
Traffic channels gross data rate	22.8 kbps (full rate) / 11.4 kbps (half rate)	
Speech data rate	13 kbps (full rate) / 6.5 kbps (half rate)	
User data rate	9.6 kbps (14.4 kbps)	
Cell radius	100 m – 30 km (up to 70 km for extended cells)	
Modulation	Gaussian Minimum Shift Keying (GMSK)	

2. The Architecture of a GSM Network

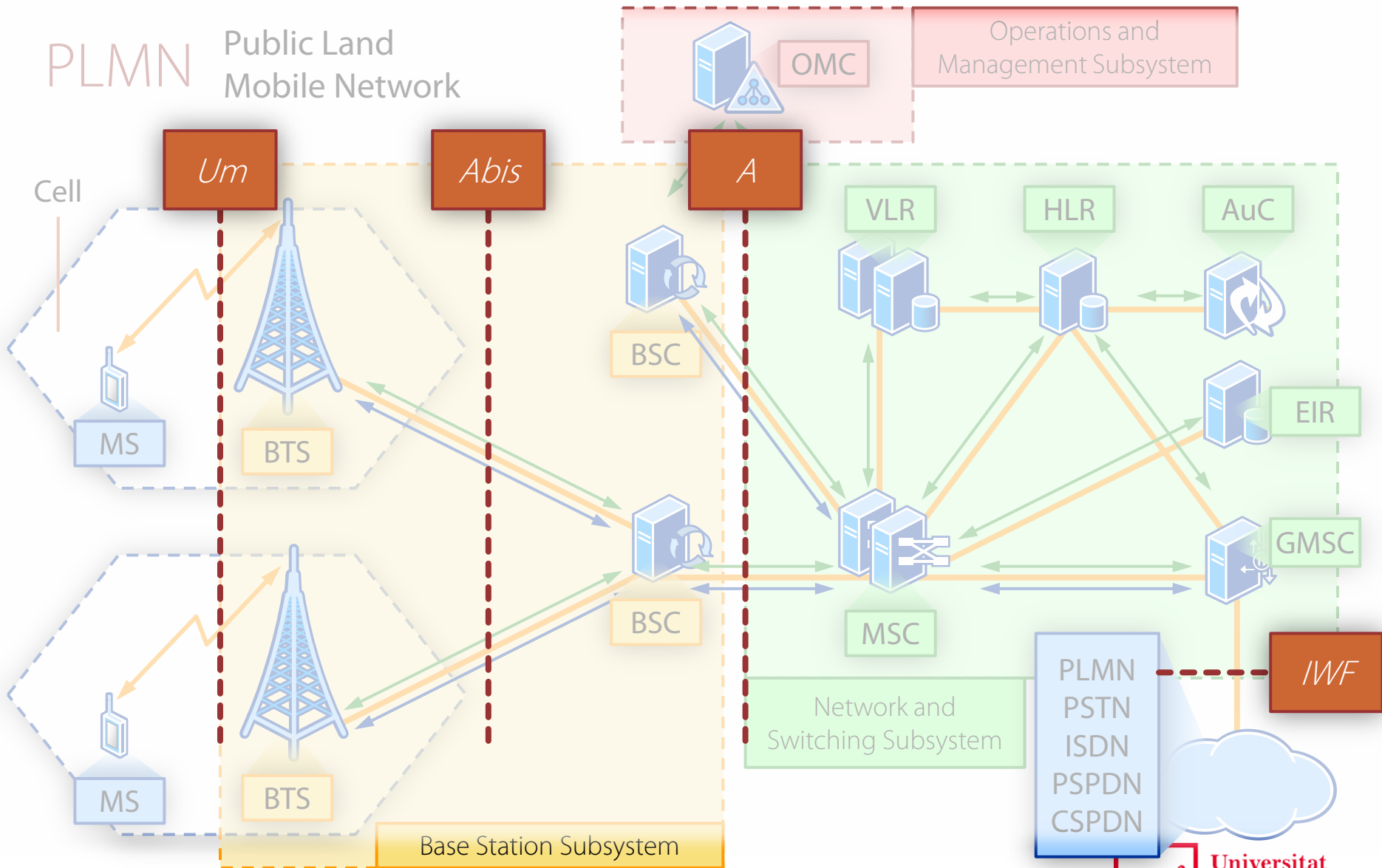


2. The Architecture of a GSM Network



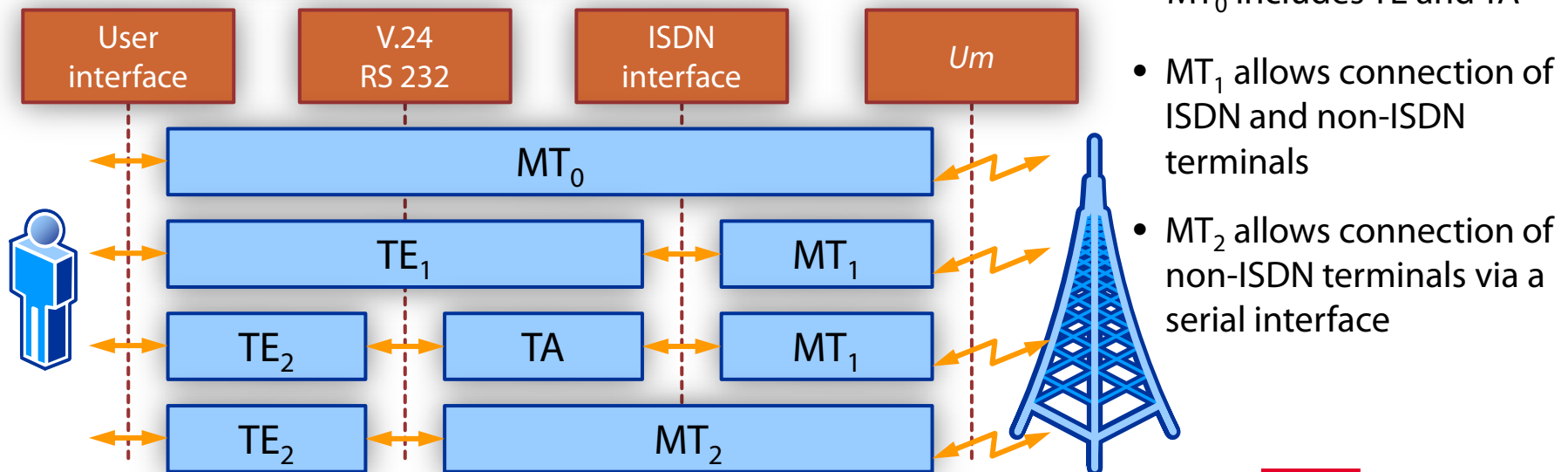
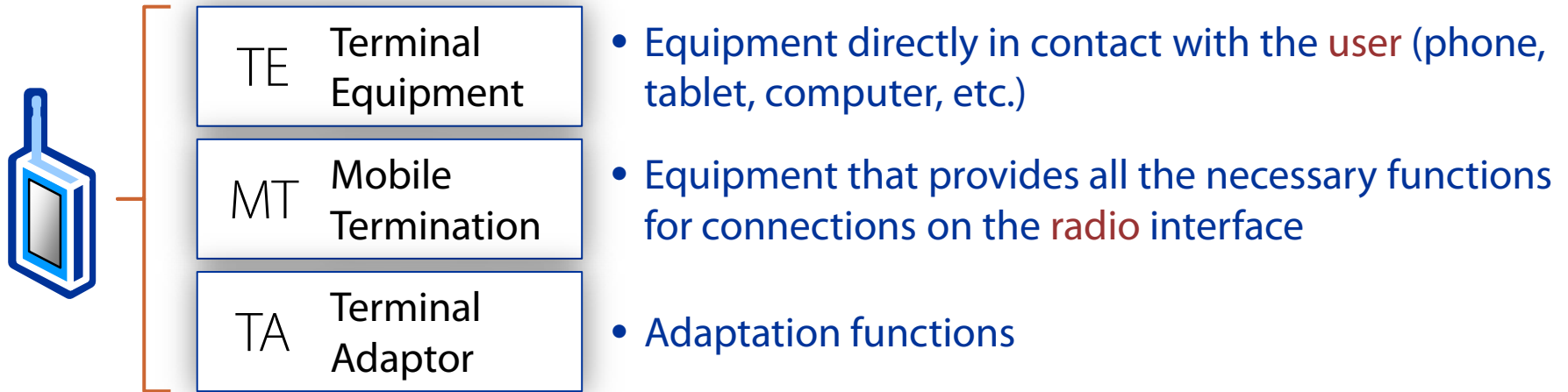
The functional units are connected through **standardized interfaces**

2. The Architecture of a GSM Network



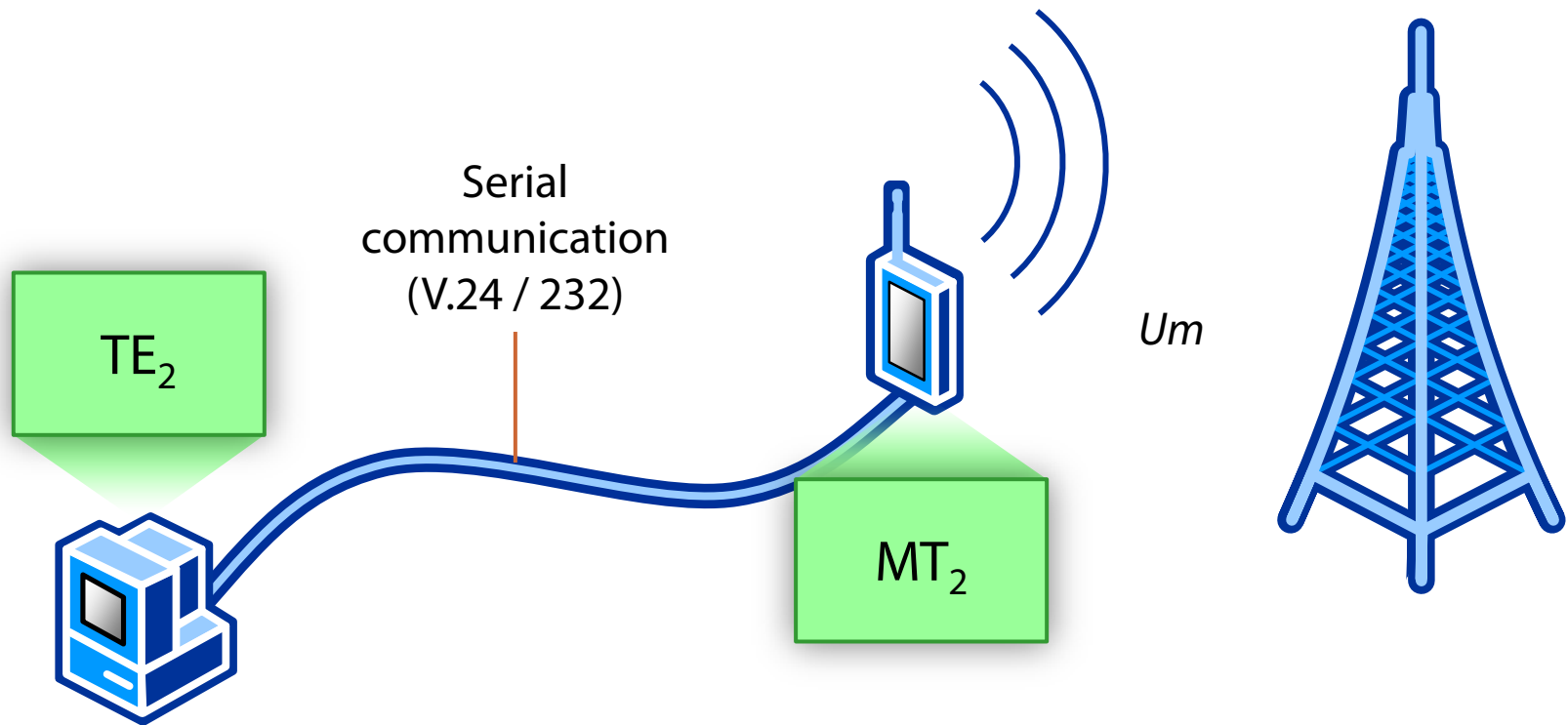
2.1. The Mobile Station

- A mobile station is composed of the following functional units



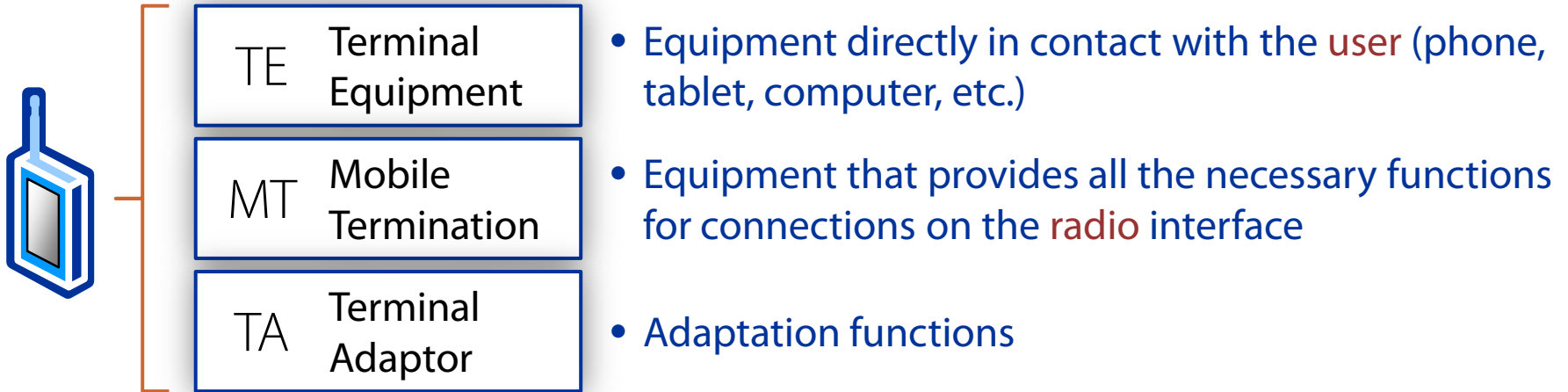
2.1. The Mobile Station

Implementations of mobile terminations MT_1 and MT_2 allows us to use the mobile station as a **data modem**



2.1. The Mobile Station

- A mobile station is composed of the following functional units



Key functions

- **Emission** and **reception** on the allocated radio channel
- **Measurements** of received signal strength
- **Transmission** of measurements to the BSC (*measurement reports*)
- **Emission advancing** (*timing advance*)
- **Signal processing** (*voice coding, channel coding, modulation*)
- Encryption , burst formatting, equalization, data compression

2.1. The Mobile Station

- A mobile station is composed of the following functional units



TE Terminal Equipment

- Equipment directly in contact with the **user** (phone, tablet, computer, etc.)

MT Mobile Termination

- Equipment that provides all the necessary functions for connections on the **radio** interface

TA Terminal Adaptor

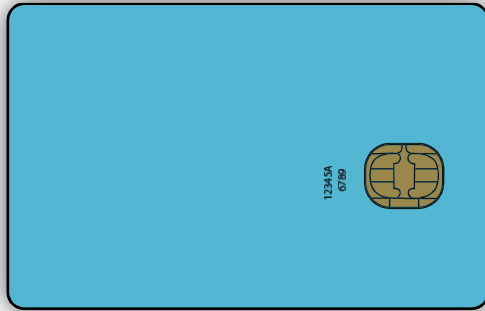
- Adaptation functions

- **Emission** and **reception** on the allocated radio channel
- **Measurements** of received signal strength
- **Transmission** of measurements to the BSC (*measurement reports*)
- Emission advancing (*timing advance*)
- **Signal processing** (*voice coding, channel coding, modulation*)
- Encryption , burst formatting, equalization, data compression

SIM Card

- Subscriber identity module

2.1.1. The SIM Card



Full size SIM (1FF)



Mini-SIM (2FF)



Micro-SIM (3FF)



Nano-SIM (4FF)

- Uniquely associated with a **user/subscription**, not MS
- Contains non-volatile **information**

IMSI International Mobile Subscriber Identity

TMSI Temporary Mobile Subscriber Identity

MSISDN Mobile Station ISDN number

Secret authentication key

PIN codes (PIN1, PIN2, PUK1, PUK2)

List of subscribed services

Location information & list of forbidden PLMNs

Memory for phone number, text messages, etc.

- Implements **encryption** and **authentication** algorithms

2.2. Base Station Subsystem

BSS All the BTSs, all the BSCs, all the TRAUs

Key functions

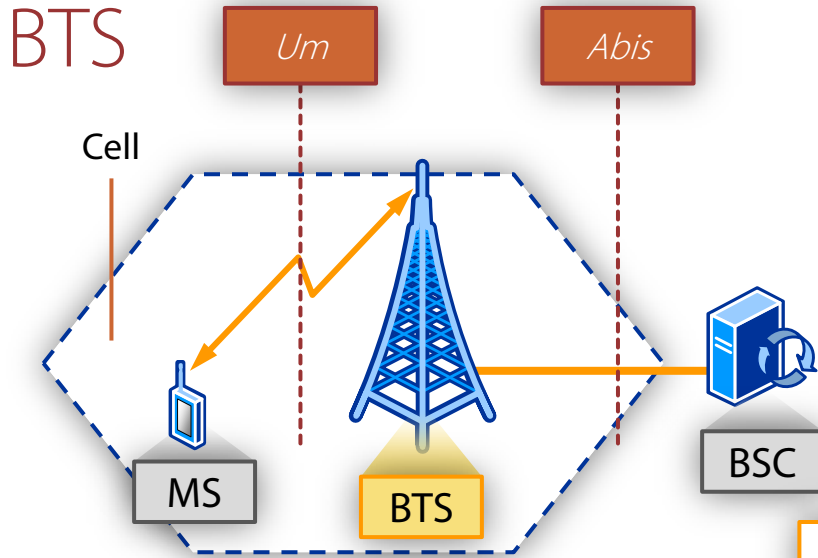
- Responsible for all radio interface related functions
 - Manages radio communications with the MS (signal processing, resource allocation/deallocation, paging etc.)
 - Manages handovers based on measurement reports
 - Voice transcoding, rate adaptations for data services
- Handles traffic/signaling between MS and MSC

1 BTS Base Transceiver Station

2 BSC Base Station Controller

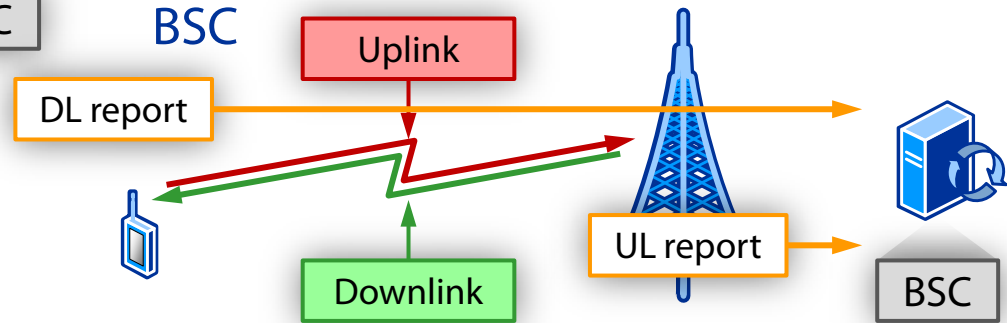
3 TRAU Transcoder and Rate Adaptor Unit

2.2.1. Base Transceiver Station



Key functions

- Ensures **radio coverage** on a given cell
- Performs **signal processing** the MS is performing
- Communication with the **BSC**
- Provides **measurement reports** to the BSC



- Several **emitters/receivers** operating on different **duplex** frequencies, up to 12 (4) duplex frequencies per cell (sector)
- Typically **power** between 35 – 65 W
- Communicates with the MS via the **Um** interface
- Communicates with the BSC via the **Abis** interface

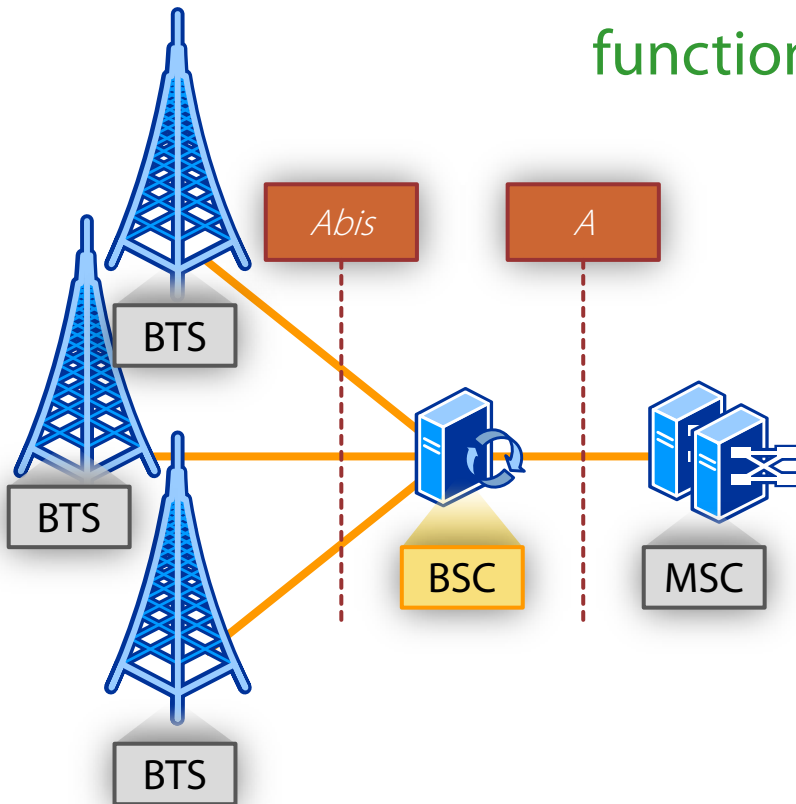
2.2.2. Base Station Controller

BSC

The “intelligent” part of the base station subsystem
Performs radio channels management

Key functions

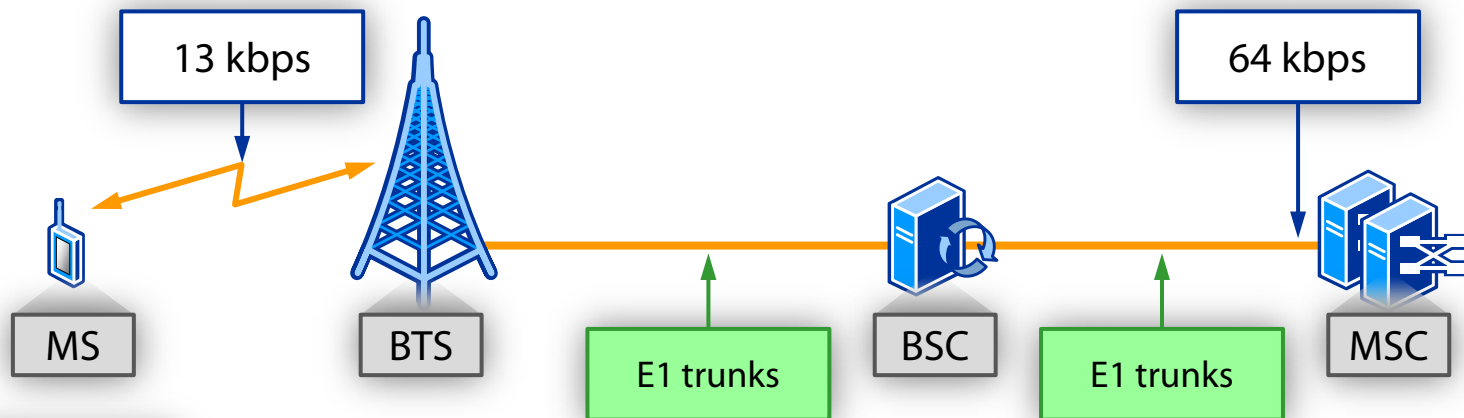
- Allocates the radio channels
- Receives the measurement reports from MS and BTS
- Decides when a handover is necessary
- Acts as a concentrator
 - Consolidates many low utilization channels
 - The BSC can manage several BTSs (up to hundreds)



2.2.3. Transcoder/Rate Adaptor Unit

TRAU Voice transcoding and rate adaptation

- The **radio bandwidth** is an expensive resource
 - Voice over the radio interface (*Um*) is digitized at **13 kbps** (6.5 kbps half-rate)
 - The MSC switches **64 kbps** PCM voice circuits
 - The *Abis* and *A* interfaces are E1/T1 trunks with **64 kbps** channels



Rate
adaptation

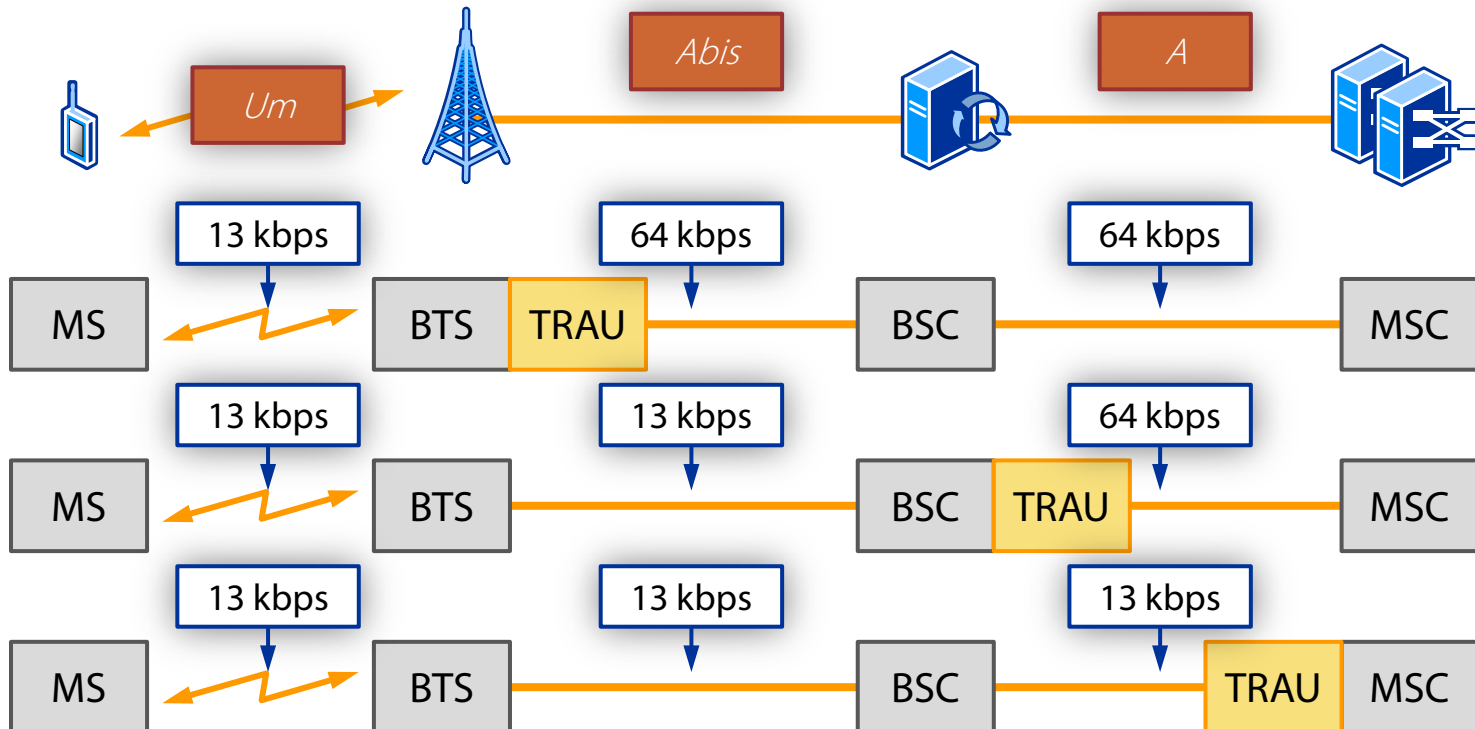
Voice
transcoding

- Transmitting **13 kbps** voice traffic in **64 kbps** channels
- Converting digital voice from **13 kbps** LPC/LTP/RPE to **64 kbps** PCM

2.2.3. Transcoder/Rate Adaptor Unit

TRAU Voice transcoding and rate adaptation

- Where is the **TRAU** located?
 - Left at the **choice** of the manufacturer or mobile operator
 - Must be **before** the MSC



2.3. Network and Switching Subsystem

Key functions

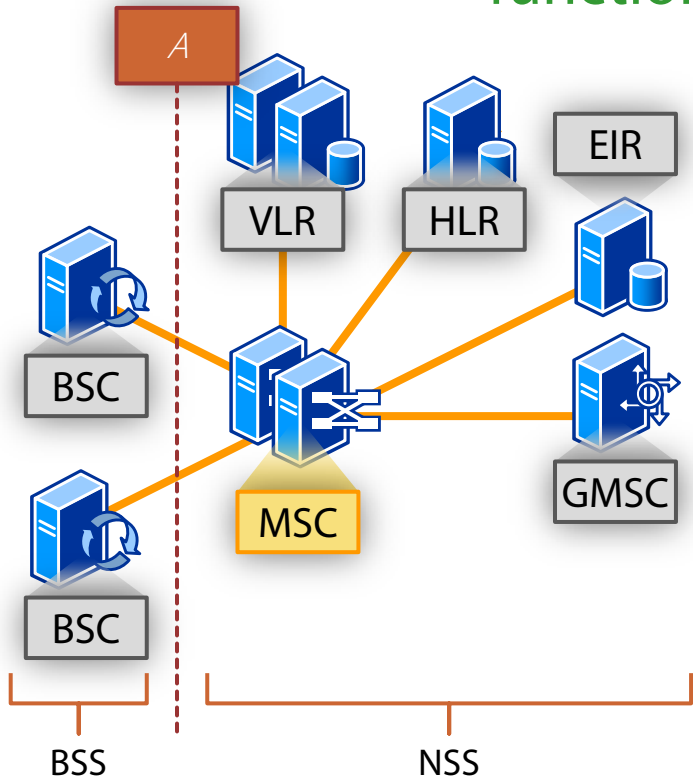
- Performs **switching** functions (MSC/GMSC)
- Handles the **billing**
- Contains **databases for subscriber data and mobility management** (HLR, VLR)
- Contains **databases with MS serial numbers** (EIR)
- Functional units are **connected** through a complete signaling network (SS7)

- 1 MSC Mobile Switching Center
 - 1.1 SMSC Short Message Service Center
 - 1.2 GMSC Gateway Mobile Switching Center
- 2 HLR Home Location Register
- 3 VLR Visitor Location Register
- 4 AuC Authentication Center
- 5 EIR Equipment Identity Register

2.3.1. Mobile Switching Center

MSC

Key
functions



- Switches 64 kbps circuits, like a standard exchange in PSTN
- Handles circuit connections to/from mobile subscribers
- Performs exchange of authentication and location information
- Handles the actualization of databases
- Routes calls to mobile subscribers
- Support for the Short Message Service

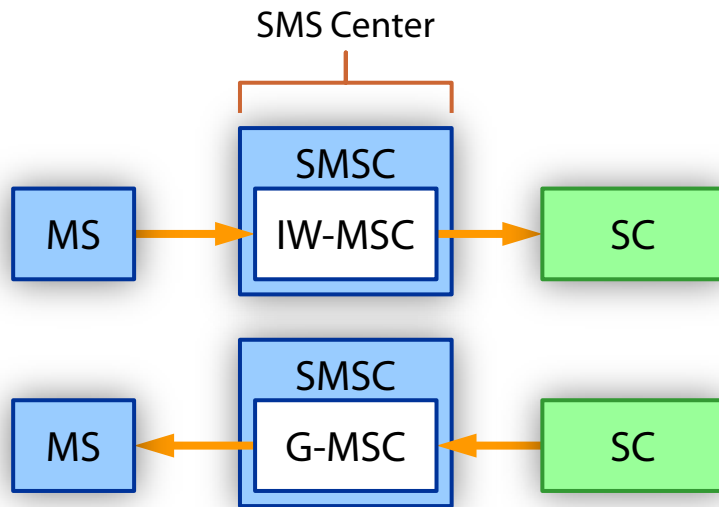
2.3.1.1. Short Message Service Center

SMSC

Key functions

• Support for the Short Message Service

- SMS **Inter Working** MSC for mobile originated SMSs
- SMS **Gateway** MSC for mobile terminated SMSs
- SMSs are exchanged via a **Service Centre**



2.3.1.2. Gateway Mobile Switching Center

SMSC

Key
functions

- Support for the **Short Message Service**
 - SMS **Inter Working** MSC for mobile originated SMSs
 - SMS **Gateway** MSC for mobile terminated SMSs
 - SMSs are exchanged via a **Service Centre**

GMSC

Key
functions

- A special MSC connecting a PLMN with external networks
 - Access points for call **originated** from outside the PLMN
 - May **interrogate** the HLR to retrieve location information
 - It only has **switching** capabilities
 - Not attached to a **BSS**

2.3.2. Home Location Register

HLR

A central database

Contains information about all subscribers of a given PLMN

Static data

- Type of subscription (voice, data, etc.)
- The corresponding IMSI and MSISDN
- The subscriber category (prepaid/contract, billing plan, etc.)

Dynamic data

- The current state of a subscriber: attached/detached
- The current location: address of the MSC/VLR currently serving a mobile subscriber
- Triples (keys) for authentication and encryption (up to 10 for each subscriber)
- The list of subscribed tele/bearer/supplementary services

There is one HLR for a PLMN subscription

2.3.3. Visiting Location Register

VLR

A database similar to the HLR
Maintains temporary copies of HLR data

A VLR is associated with an MSC

Key
functions

- Contains information about **roaming** and **not roaming** subscribers in the coverage area of a MSC (**visiting** subscribers)
- Information stored is **temporary**
- When a subscriber **leaves** the area serviced by a VLR, the information is **deleted**
- When making a call no need to **interrogate** the HLR

VLR data

- Permanent identity numbers: **IMSI, MSISDN**
- Temporary identity numbers: **TMSI, MSRN**
- **Authentication and encryption data**: up to 7 triplets per visiting subscriber
- **More precise location information**: location area identification (LAI)
- **List of subscribed services**

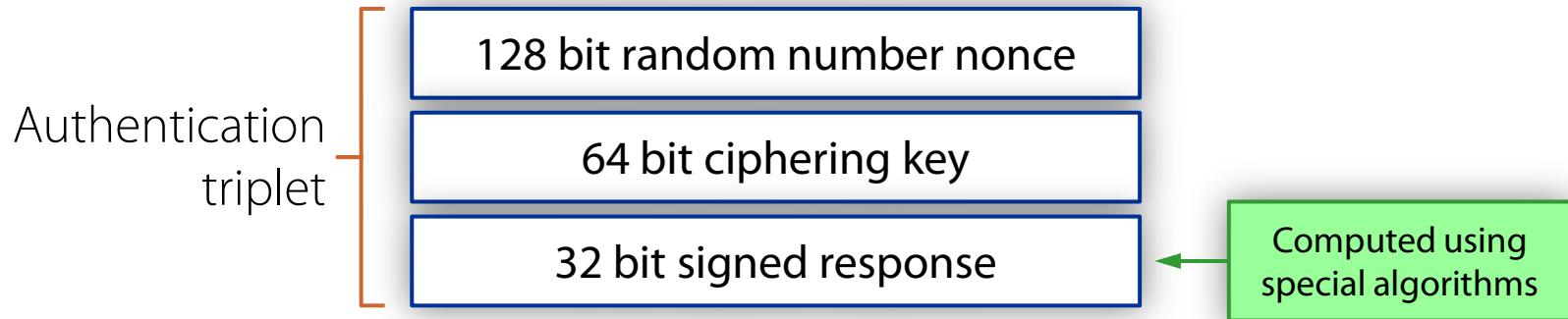
2.3.4. Authentication Center

AuC

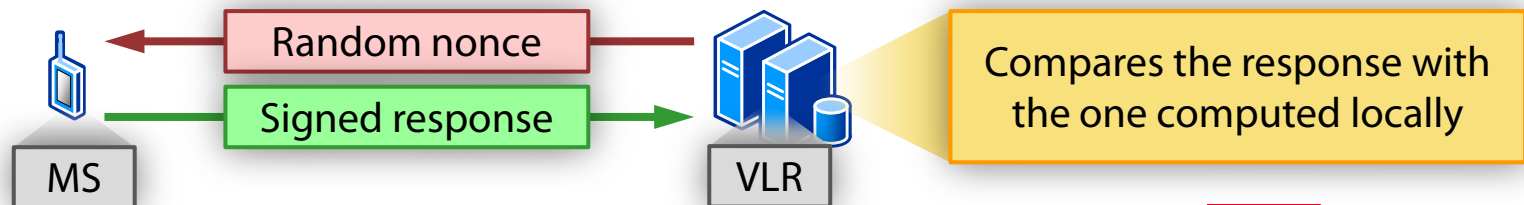
Confirms that a given identity (**IMSI**) transferred by the MS through an **identification** procedure is the one claimed

Authentication takes place on each call

- Generates **authentication triples** for each subscriber



- Forwards** them to the HLR
- The authentication a **challenge – signed response** mechanism



2.3.5. Equipment Identity Register

EIR Its purpose is to **forbid** access of **stolen** mobile equipments

- Associated with a **PLMN** and stores MS serial numbers (**IMEI**)
 - **International Mobile station Equipment Identity**
- Maintains **three** lists:

White list

- Mobile equipments **allowed** to connect without any restriction

Gray list

- Mobile equipments with **potential problems** or status to be clarified

Black list

- **Barred** mobile equipments



CEIR

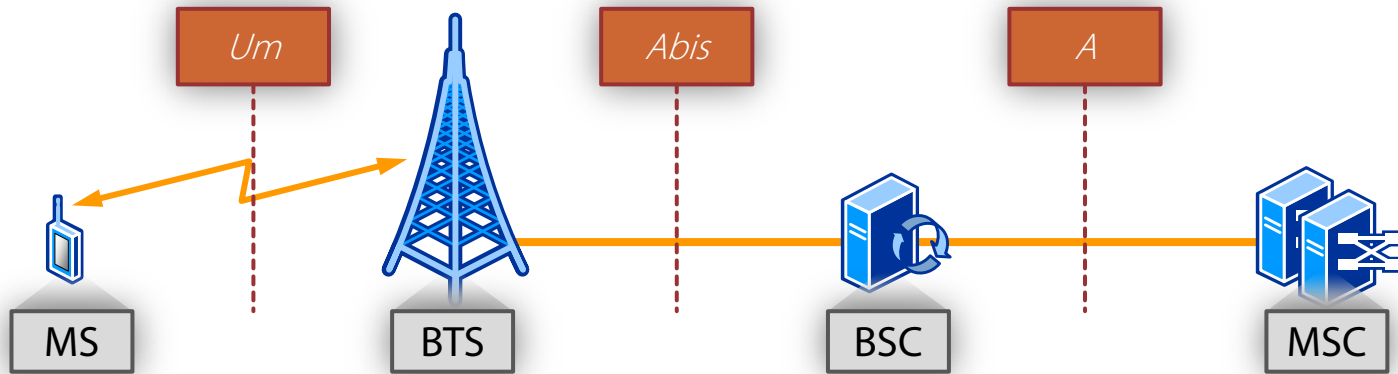
Central EIR with blacklisted MSs for all GSM operators

2.4. Operation and Maintenance Subsystem

OVS Contains the Operations and Management Center
Connected to the BSS and NSS via an X.25 data network

- Key functions**
- Maintains **databases** with the data loaded in BSS and NSS
 - Stores **cell definitions**
 - Deploys **new software**
 - Assists **installation** of new sites
 - Performs performance **measurements** (handovers, traffic, etc.)

2.5. GSM Interfaces



1

Um

- Traffic and signaling channels organized on a TDMA/FDMA scheme
- Frequency carrier spacing 200KHz
- Uses 8 time slots
- Maximum gross data rate: 22.8 kbps per traffic channel

2

Abis

- Inside BSS, between the BTS and the BSC
- Carries voice/data and signaling
- E1 trunks (2 Mbps) land lines or radio links

3

A

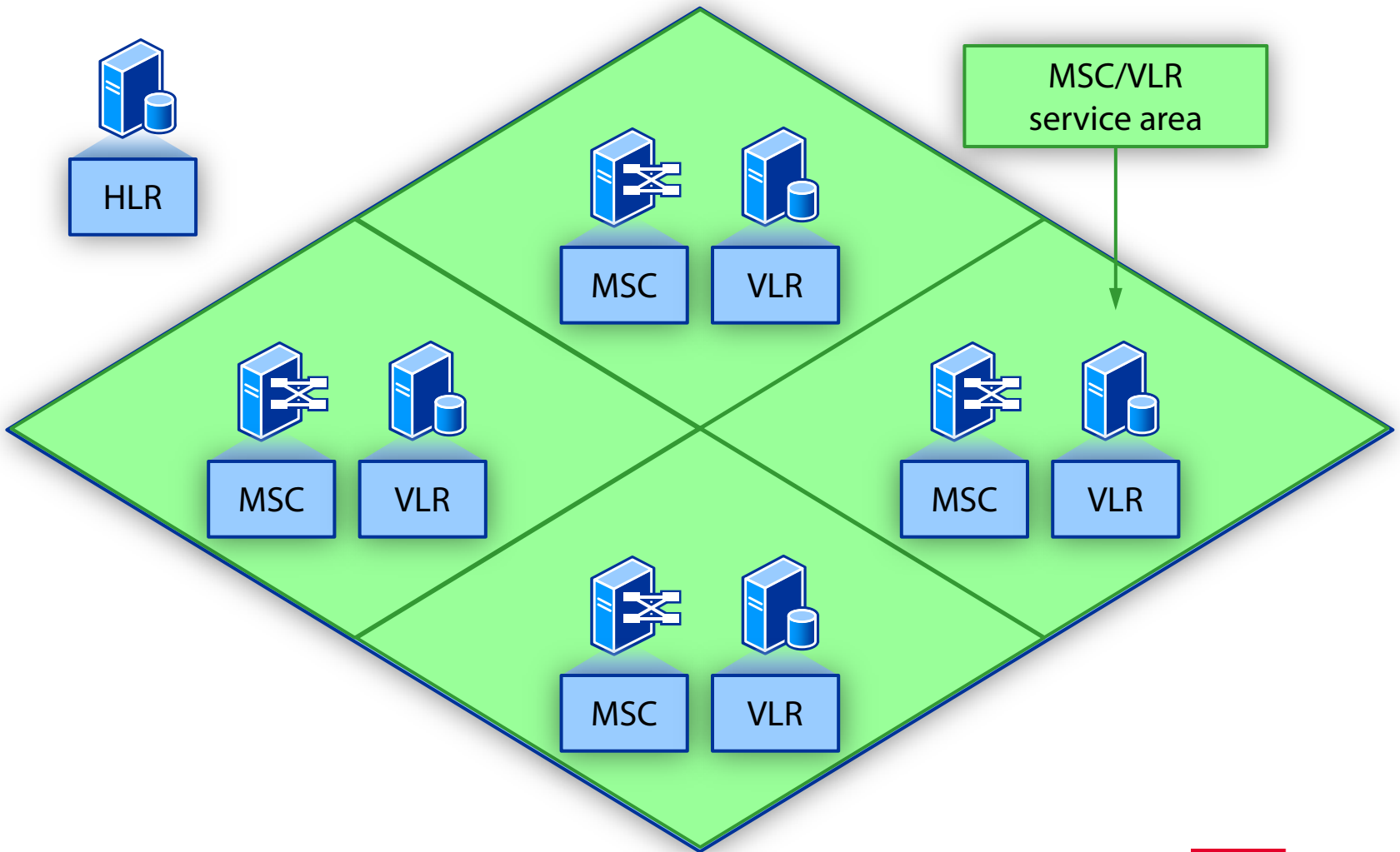
- Between the BSC and the MSC
- Carries voice/data and signaling
- E1 trunks (2 Mbps) land lines

2.6. Geographical Distribution

- 1 GSM Service Area
 - The area covered by **all** GSM operators
- 2 PLMN Service Area
 - The area covered by **a particular** GSM operator
- 3 MSC/VLR Service Area
 - The area covered by **a MSC/VLR**
- 4 Location Area
 - A group of cells which:
 - Share the same **Location Area Identifier (LAI)**
 - A user can **move** within a Location Area without **location updating**
 - Incoming calls are **paged** on all **cells** belonging to the location area
- 5 Cell
 - The area covered by **a BTS**

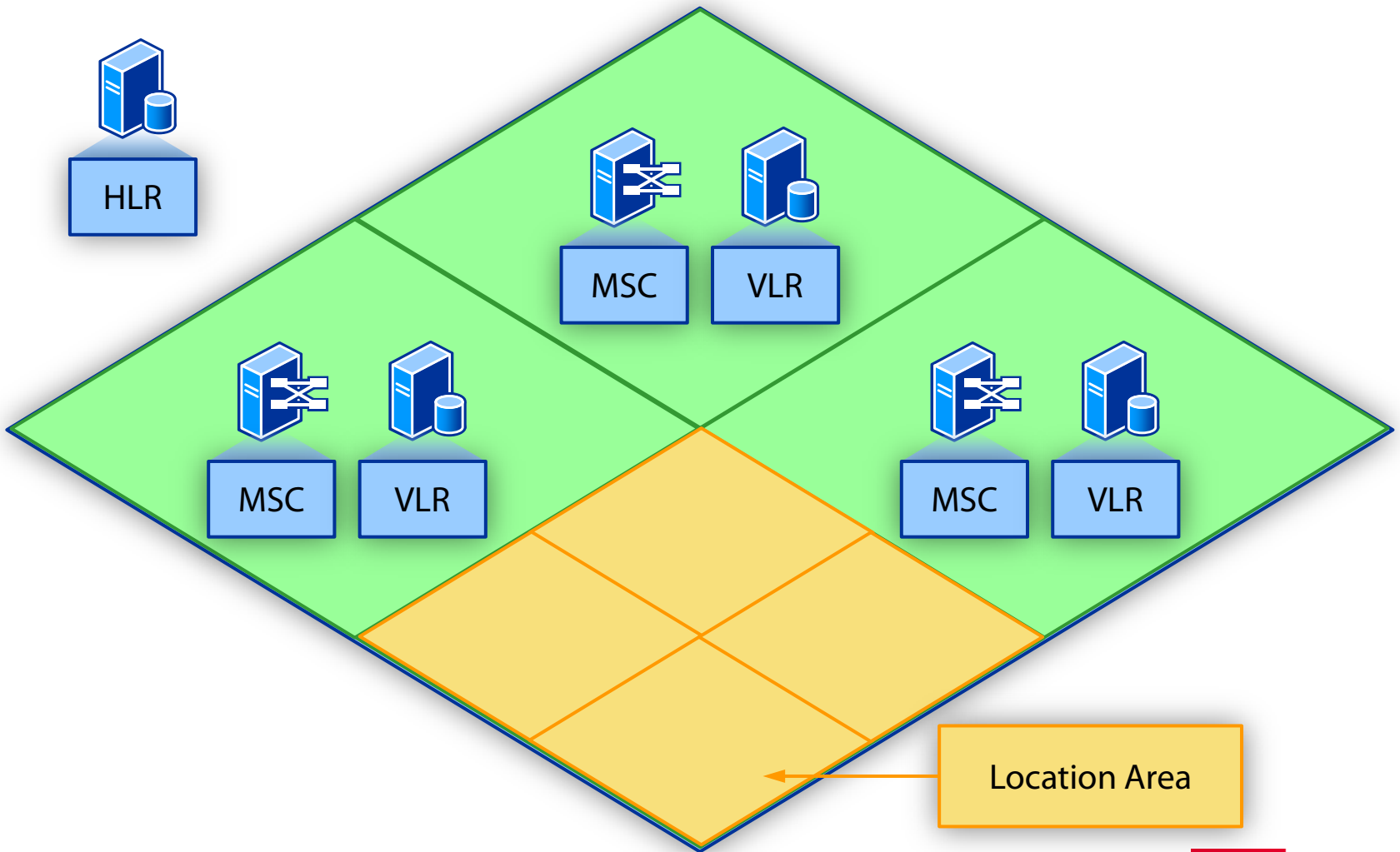
2.6. Geographical Distribution

2 Public Land Mobile Network (PLMN)



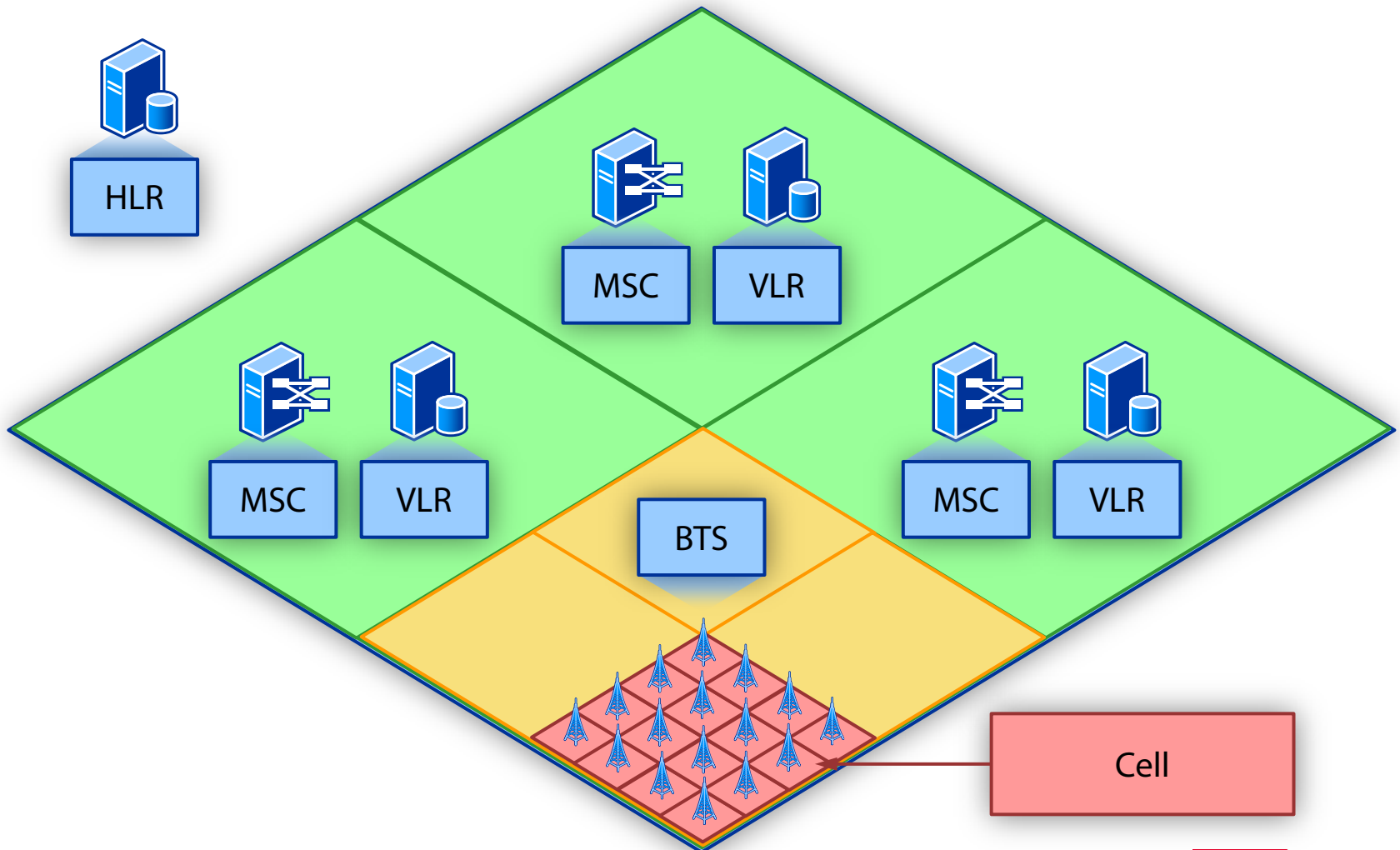
2.6. Geographical Distribution

3 MSC/VLR Service Area



2.6. Geographical Distribution

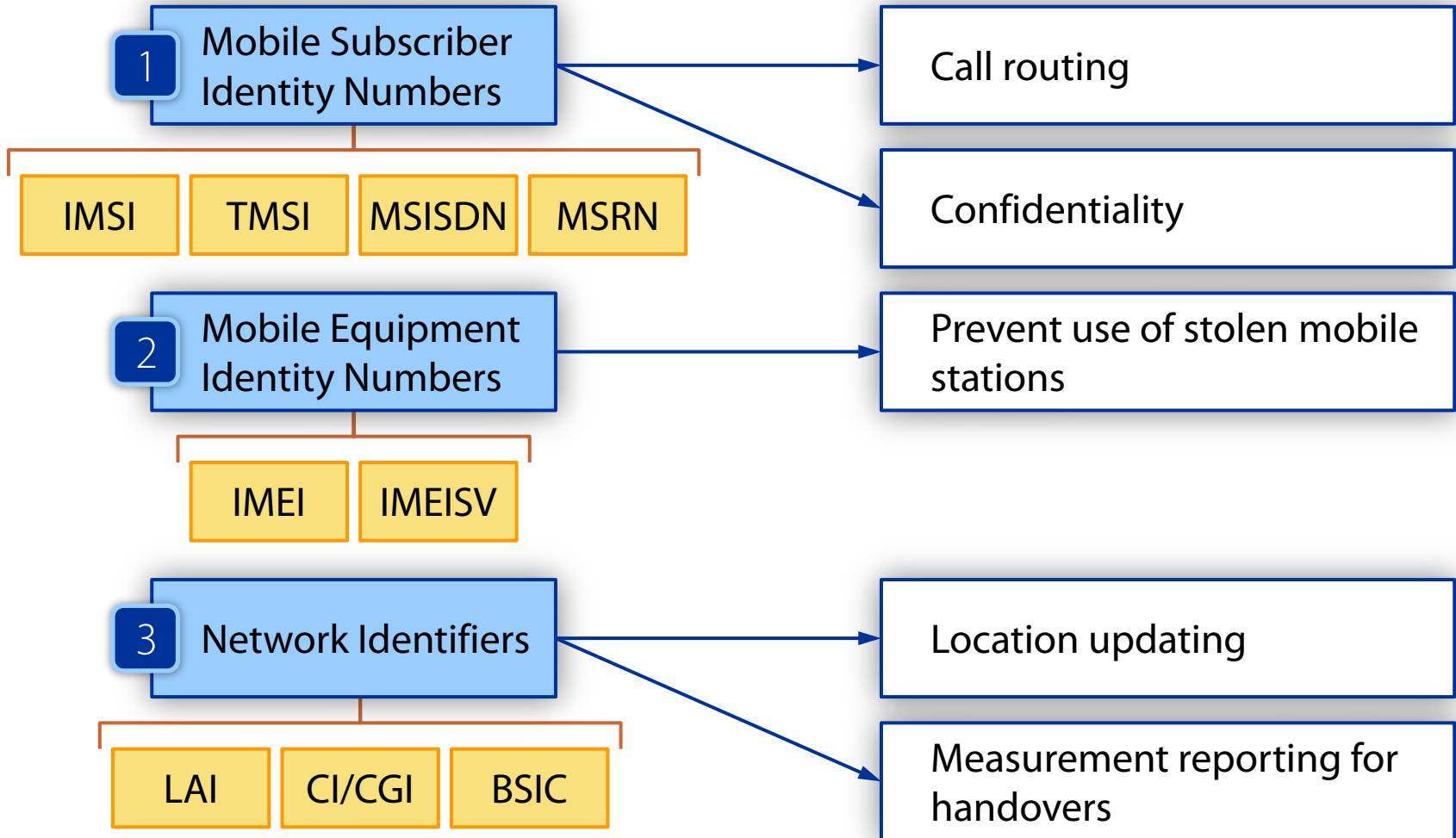
4 Location Area



3. Addresses and Identifiers

Three types

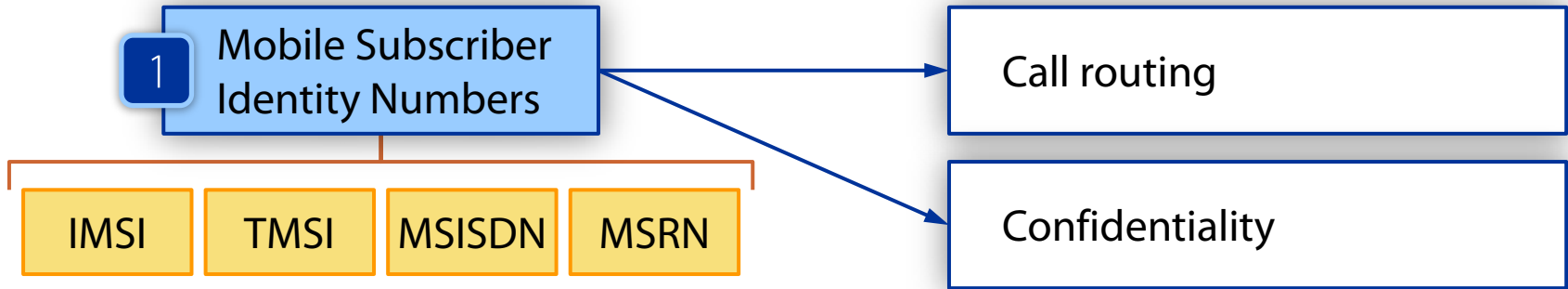
Used for



3.1. Mobile Subscriber Identity Numbers

Three types

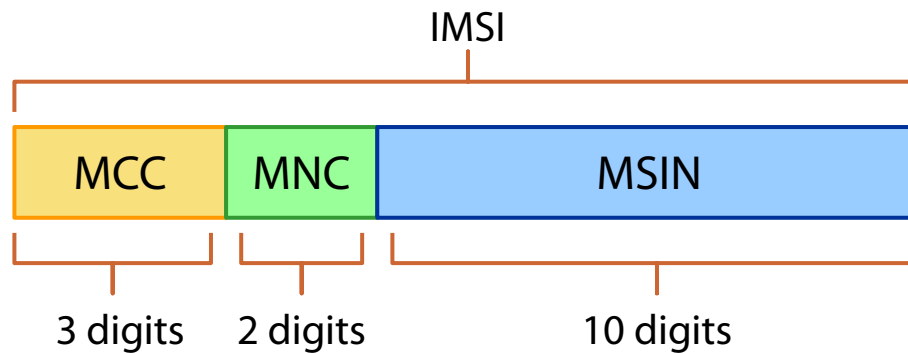
Used for



3.1.1. International Mobile Subscriber Identity

IMSI Uniquely identifies a GSM subscriber in the GSM service area

- Length of 15 digits, only numerical data



Mobile Country Code

- Identifies the **country** where the home PLMN of the mobile subscriber is located (e.g. 214 – Spain)

Mobile Network Code

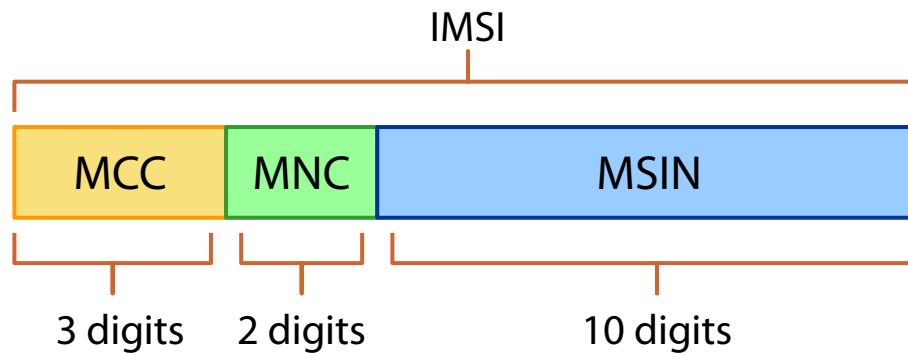
- Identifies the **home PLMN** (e.g. in Spain: 01 – Vodafone, 03 – Orange, 04 – Yoigo, 07 – movistar)

Mobile Subscription Identification Number

- National identity of the **subscriber**, chosen by the PLMN

3.1.1. International Mobile Subscriber Identity

IMSI Uniquely identifies a GSM subscriber in the GSM service area

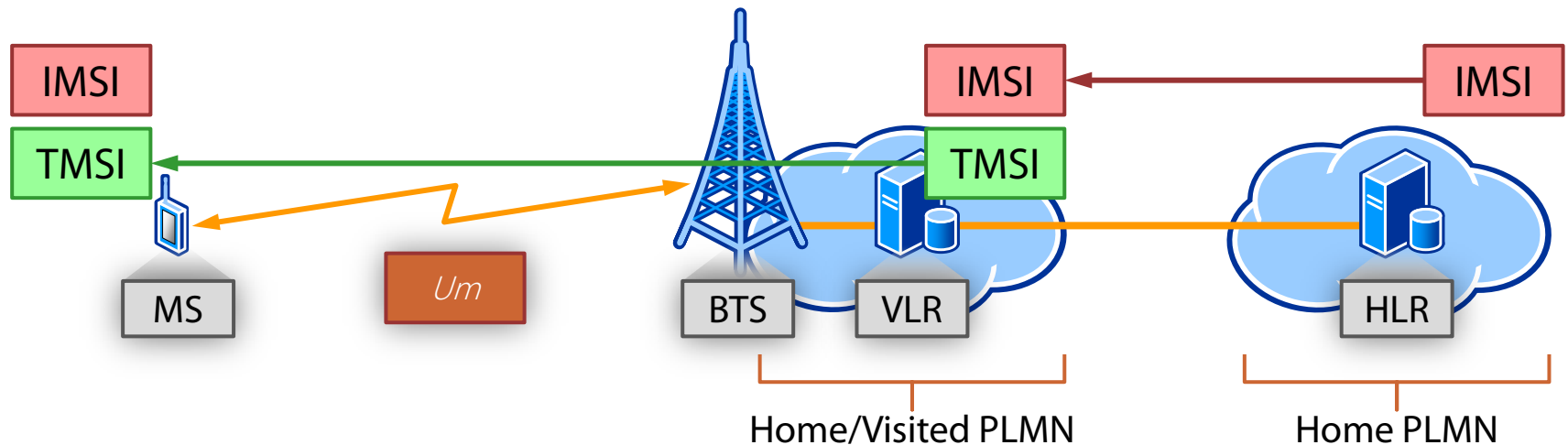


- Inside a GSM PLMN all user data/signaling is connected to IMSI
- Correspondence between the GSM identity (IMSI) and the non-GSM identity (MSISDN) typically is done at subscription inside HLR
- It is stored at the HLR, the VLR and the SIM of the MS

For security reasons the IMSI is never transmitted over the radio interface

3.1.2. Temporary Mobile Subscriber Identity

TMSI Replacement of IMSI on the radio interface

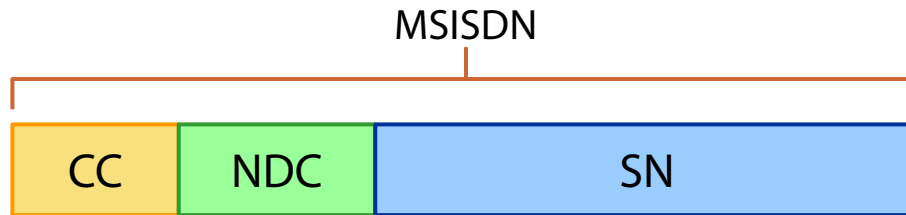


- The MS identified on the *Um* interface by TMSI
- Allocated by the VLR inside a MSC/VLR service area and stored on SIM
- Not known by the HLR
- Correspondence TMSI – IMSI known and stored by the VLR
- The length is 32 bits

3.1.3. Mobile Station PSTN/ISDN Number

MSISDN The number **dialed** for reaching a mobile subscriber

- An unique identity of a mobile subscriber in a PSTN/PLMN
- Structure:



Country Code

- Example: +34 for Spain

National Destination Code

- Specific to the PLMN, but may change due to portability

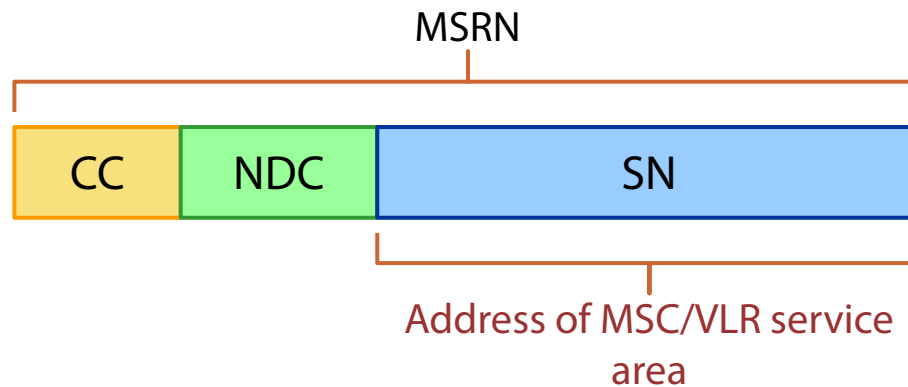
Subscriber Number

- The subscriber number within the PLMN

3.1.4. Mobile Station Roaming Number

MSRN Routing of calls directed to mobile subscribers

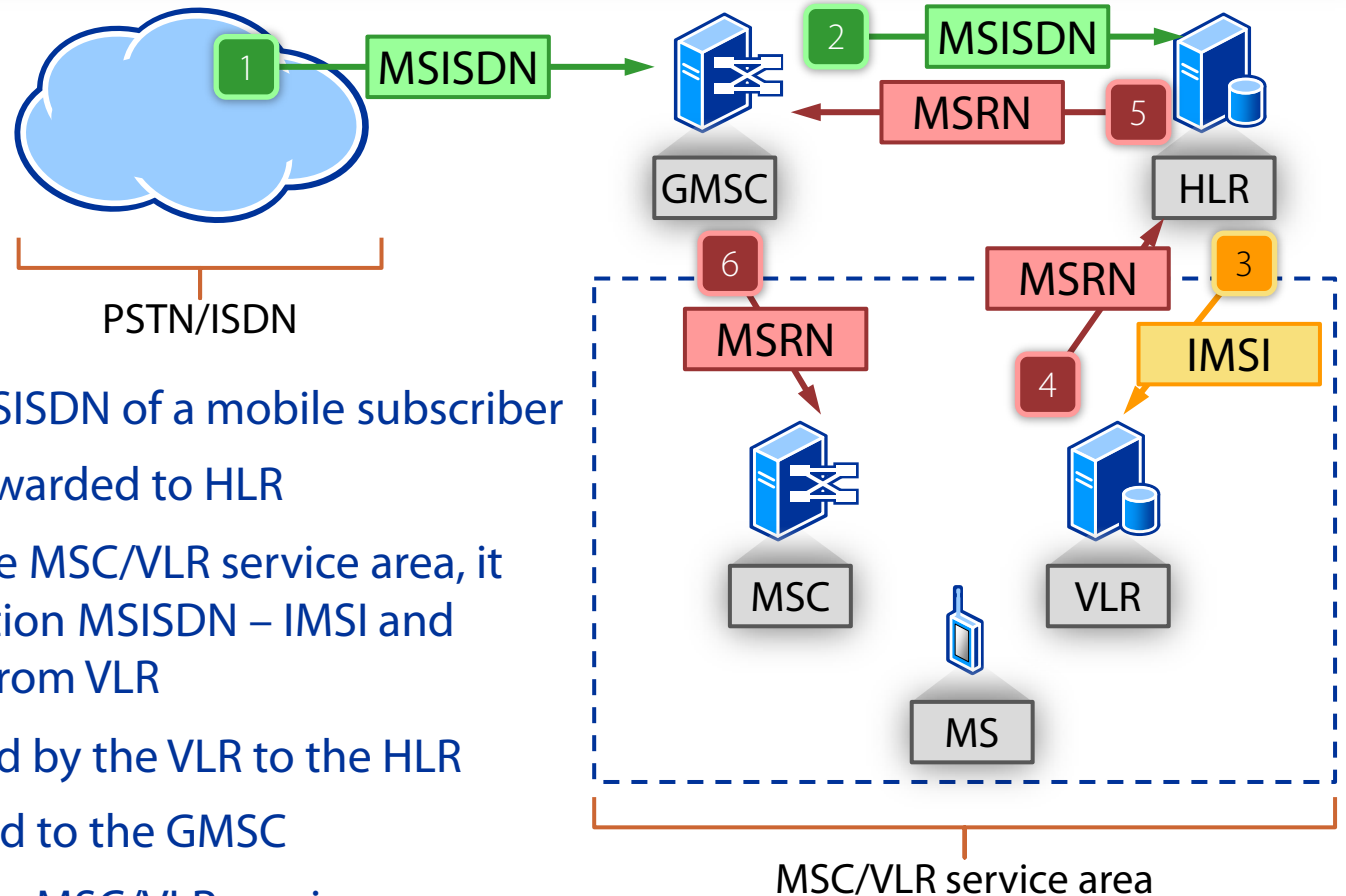
- Structure similar to the MSISDN:



- It is the result of a **HLR** interrogation procedure via the **GMSC/MSC**

3.1.4. Mobile Station Roaming Number

MSRN Routing of calls directed to mobile subscribers

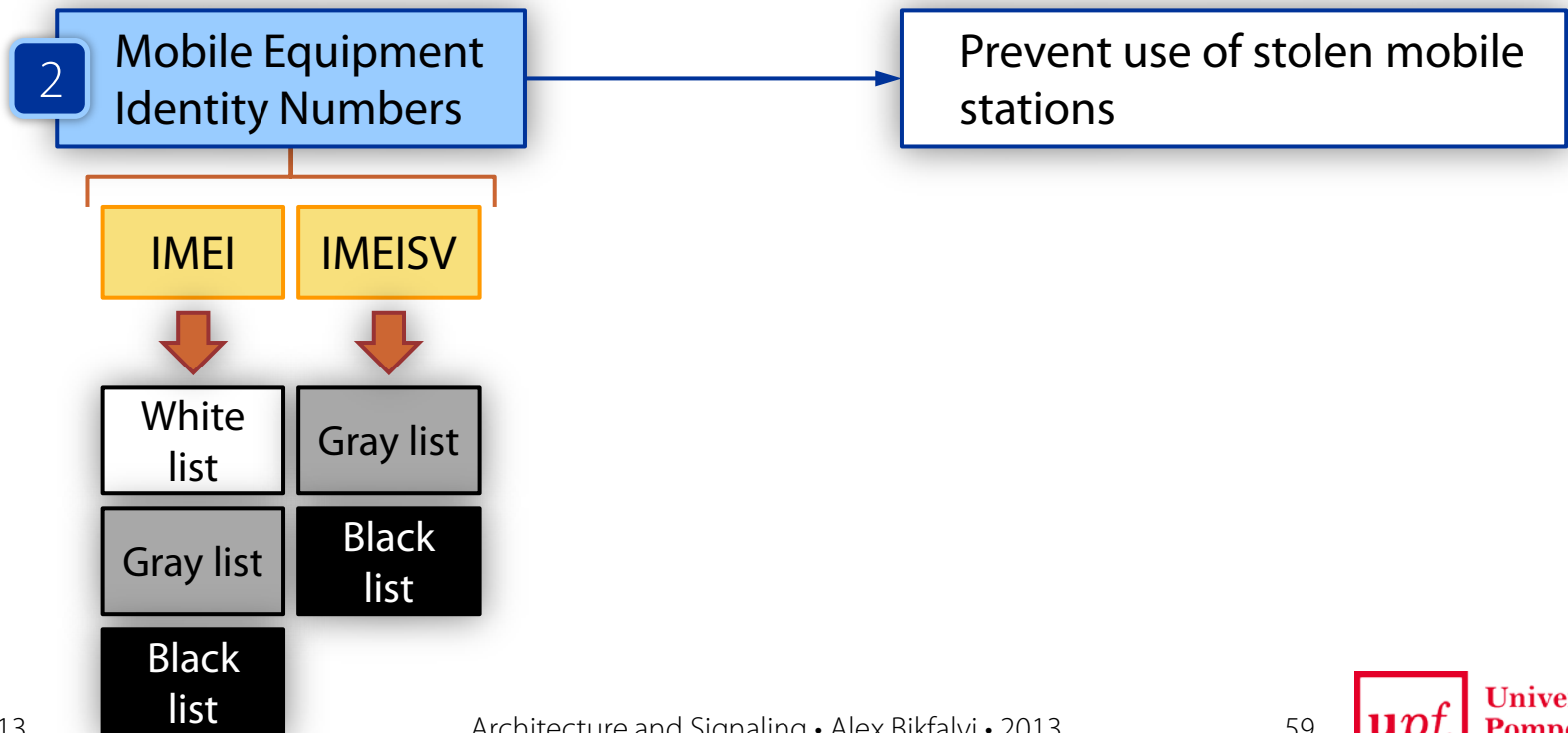


- 1 • A user dials the MSISDN of a mobile subscriber
- 2 • The MSISDN is forwarded to HLR
- 3 • The HLR knows the MSC/VLR service area, it makes the translation MSISDN – IMSI and requests a MSRN from VLR
- 4 • A MSRN is returned by the VLR to the HLR
- 5 • The MSRN returned to the GMSC
- 6 • Call is routed to the MSC/VLR service area

3.2. Mobile Equipment Identity Numbers

Three types

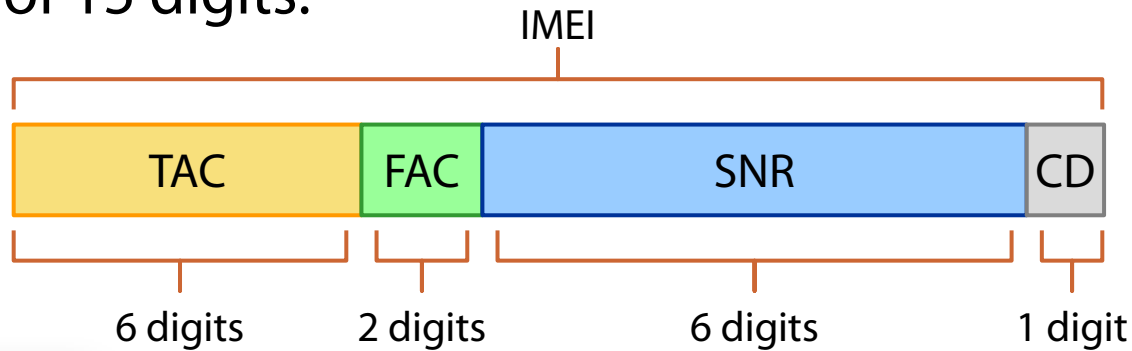
Used for



3.2.1. IMEI

IMEI International Mobile station Equipment Identity number

- Structure of 15 digits:



Type Approval Code

- Country and approval code

Final Assembly Code

- Manufacturer

Serial Number

- Unique for same TAC and FAC

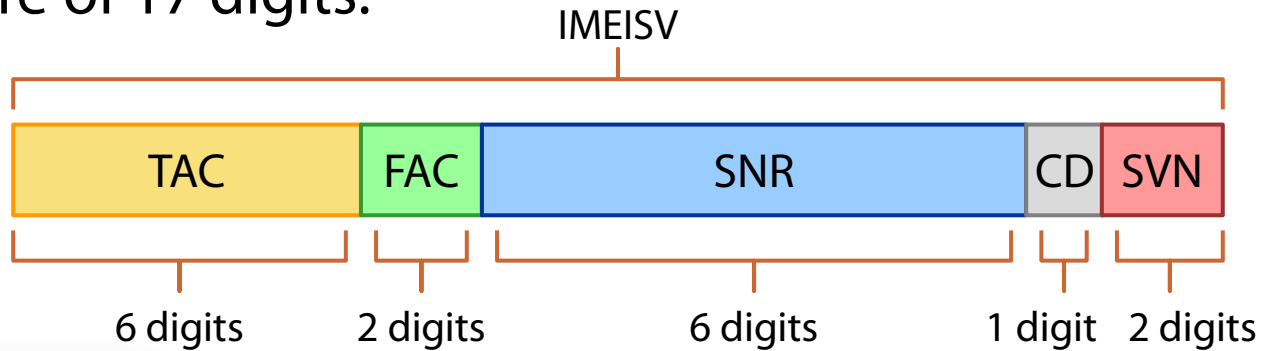
Check Digit

- Verifies transmission errors

3.2.1. IMEI

IMEISV International Mobile station Equipment Identity and Software Version number

- Structure of 17 digits:



Type Approval Code

- Country and approval code

Final Assembly Code

- Manufacturer

Serial Number

- Unique for same TAC and FAC

Check Digit

- Verifies transmission errors

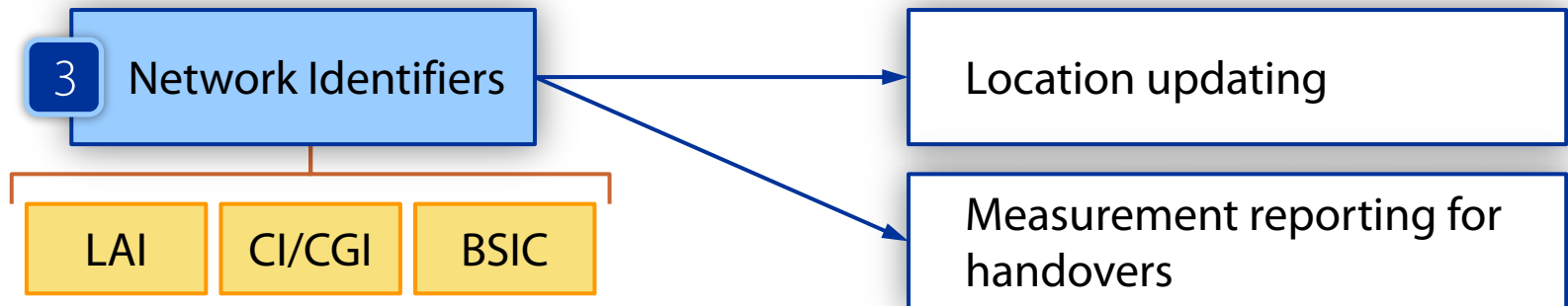
Software Version

IMEI / IMEISV printed on the MS, in software, or by dialing ***#06#**

3.3. Network Identifiers

Three types

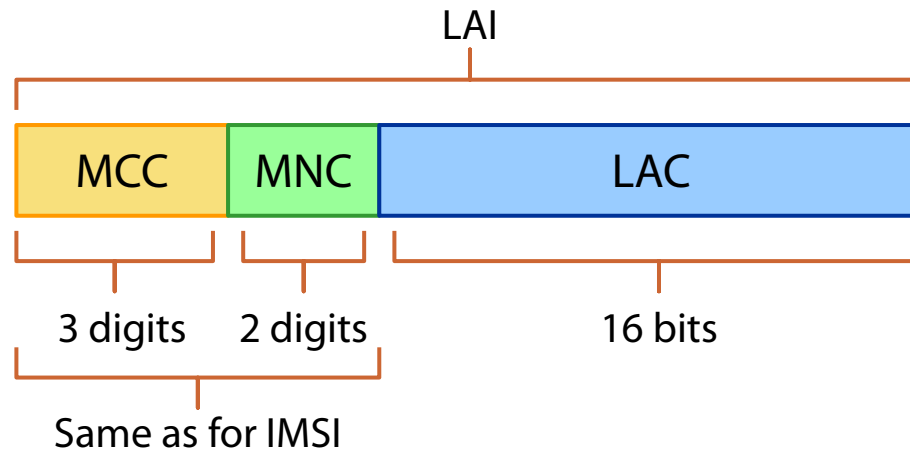
Used for



3.3.1. Location Area Identity

LAI An identifier used for location updating
Indicates the location area of the MS

- The LAI is transmitted by the network
- The LAI of the current location area is stored on SIM



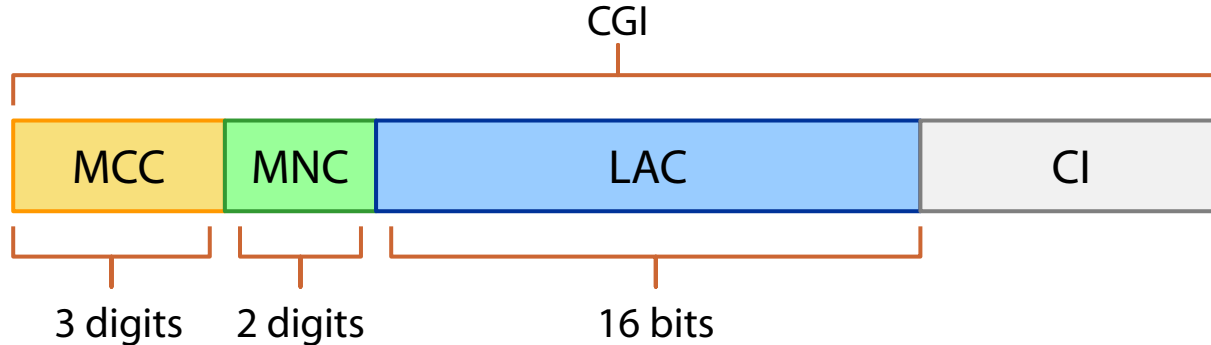
Location Area Code

- It is known by the network (VLR) at each moment
- Up to 65534 location areas

3.3.2. Cell Identity / Cell Global Identity

CI / CGI CI – uniquely identifies a cell within a location area
CGI – uniquely identifies a cell within a GSM PLMN

- Similar to the LAI:



3.3.3. Base Station Identity Code

BSIC Distinguishes between different BTSs using the same beacon frequency

- It is **not** a unique identifier for base stations

Beacon
frequency

A frequency on which a BTS emits **continuously**

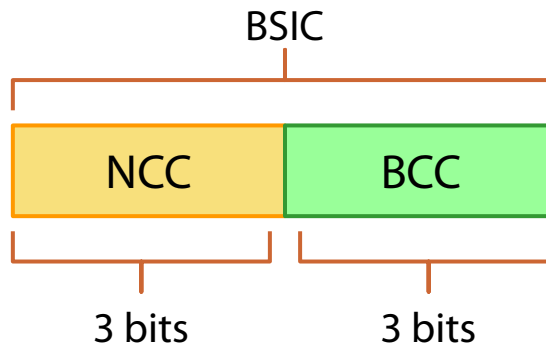
- An MS performs **measurements** on the beacon frequency
- The MS reports only measurements for potentially target cells for **handovers**
- The MS does not handover to cells not part of the PLMN

The BSIC allows the MS to report measurement only from cells belonging to the same PLMN

3.3.3. Base Station Identity Code

BSIC Distinguishes between different BTSs using the same beacon frequency

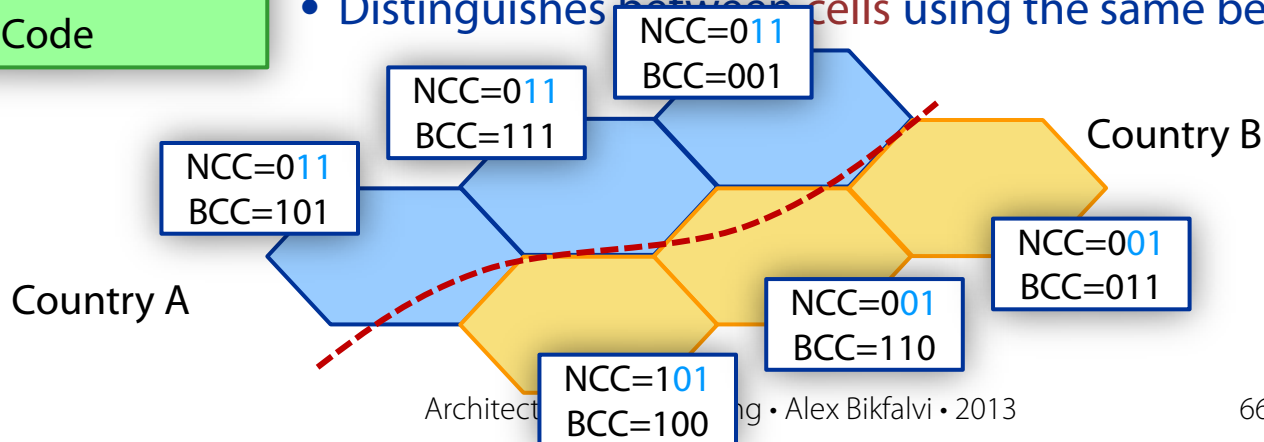
- Structure:



National Color Code

Base Station Color Code

- Has a format xyy , where x the operator and yy the country
- Can distinguish between two operators of the same country
- Distinguishes between cells using the same beacon frequency



4. Call Routing

- Making calls in GSM

1 MT
Mobile Terminating

- The GSM user is the **called** party
- The **calling** party is a PSTN/ISDN user

2 MO
Mobile Originating

- The GSM user is the **calling** party
- The **called** party is a PSTN/ISDN user

3 MO-MT

- Calls **between** GSM users

The routing address for calls directed to GSM subscribers is the **MSRN**

- The **MSRN** is always obtained by interrogating the **HLR**
 - Via the **GMSC** for calls originating in PSTN/ISDN
 - Via the **MSC** for mobile originating calls

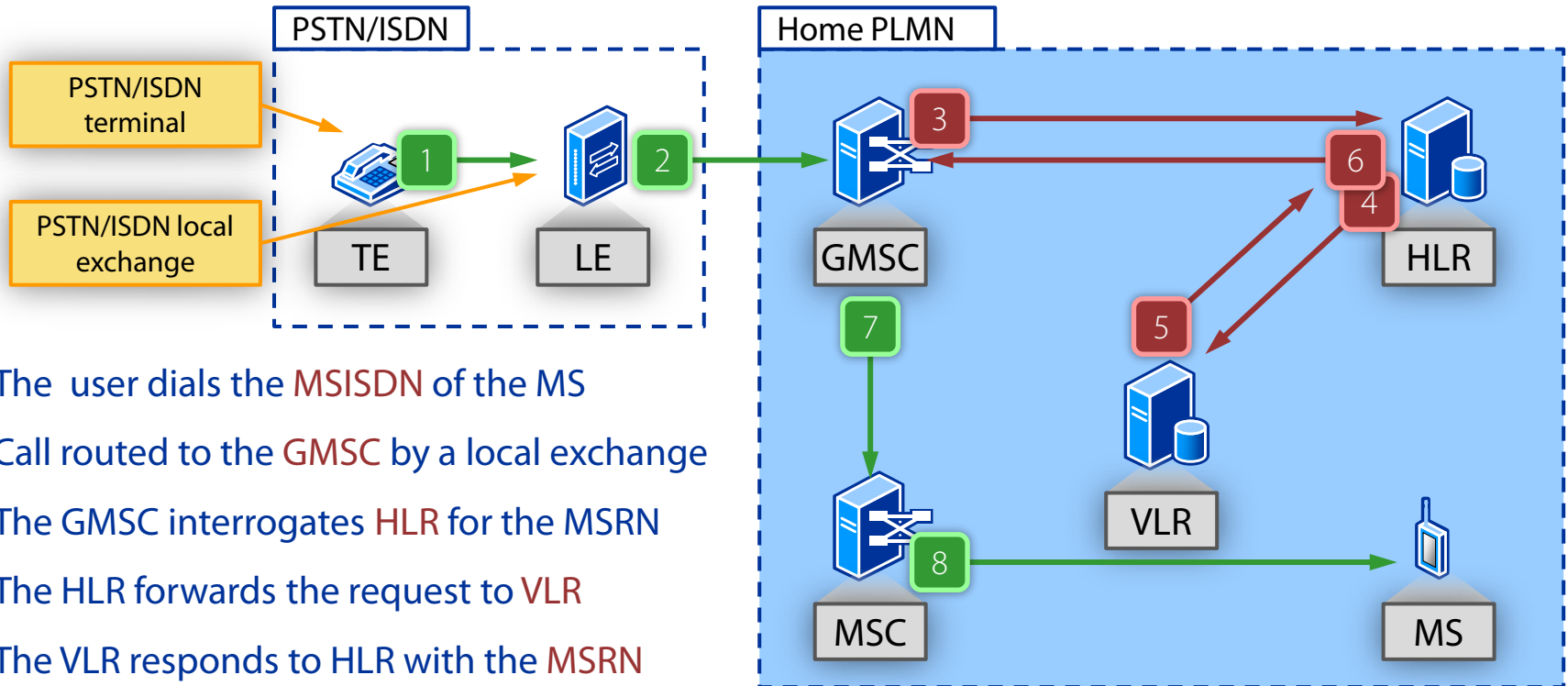
4.1. Mobile Terminating Calls

- General procedure:

- 1 • When a given user wants to call a mobile subscriber it dials its **MSISDN** number
- 2 • The PSTN/ISDN forwards the call based on the **CC** and **NDC** within the MSISDN number
- 3 • The call reaches the **GMSC** of the PLMN
- 4 • The GMSC interrogates the HLR for the **MSRN** (obtained via the VLR)
- 5 • The **SN** part of the MSRN allows the GMSC to route the call to the visited **MSC**

4.1.1. Mobile Terminating Calls

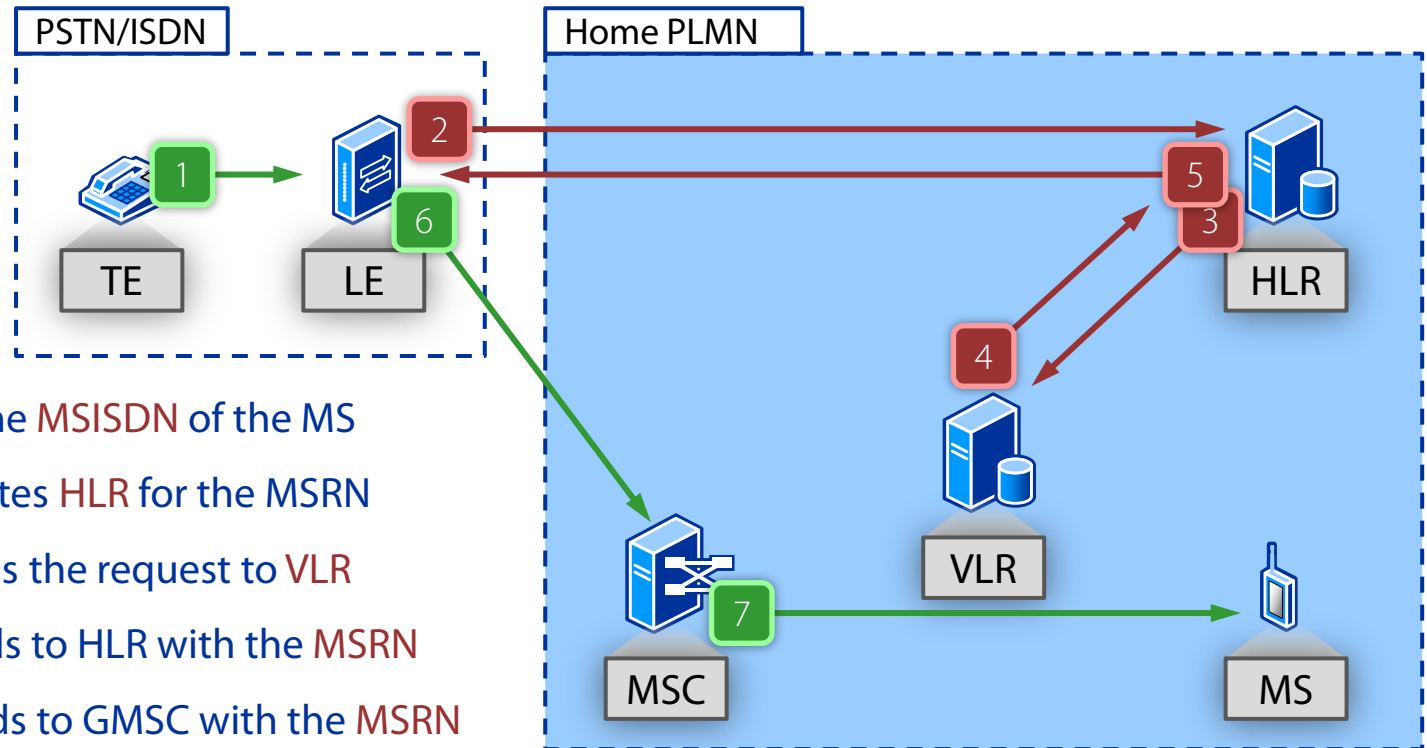
- Call from **PSTN/ISDN** to **MS** in the **home PLMN**
 - Mobile and fixed subscriber in the **same country**



- 1 • The user dials the **MSISDN** of the MS
- 2 • Call routed to the **GMSC** by a local exchange
- 3 • The GMSC interrogates **HLR** for the MSRN
- 4 • The HLR forwards the request to **VLR**
- 5 • The VLR responds to HLR with the **MSRN**
- 6 • The HLR responds to GMSC with the **MSRN**
- 7 • Call routed to the **MSC** by the GMSC
- 8 • Call routed to the **MS** by the MSC

4.1.2. Mobile Terminating Calls

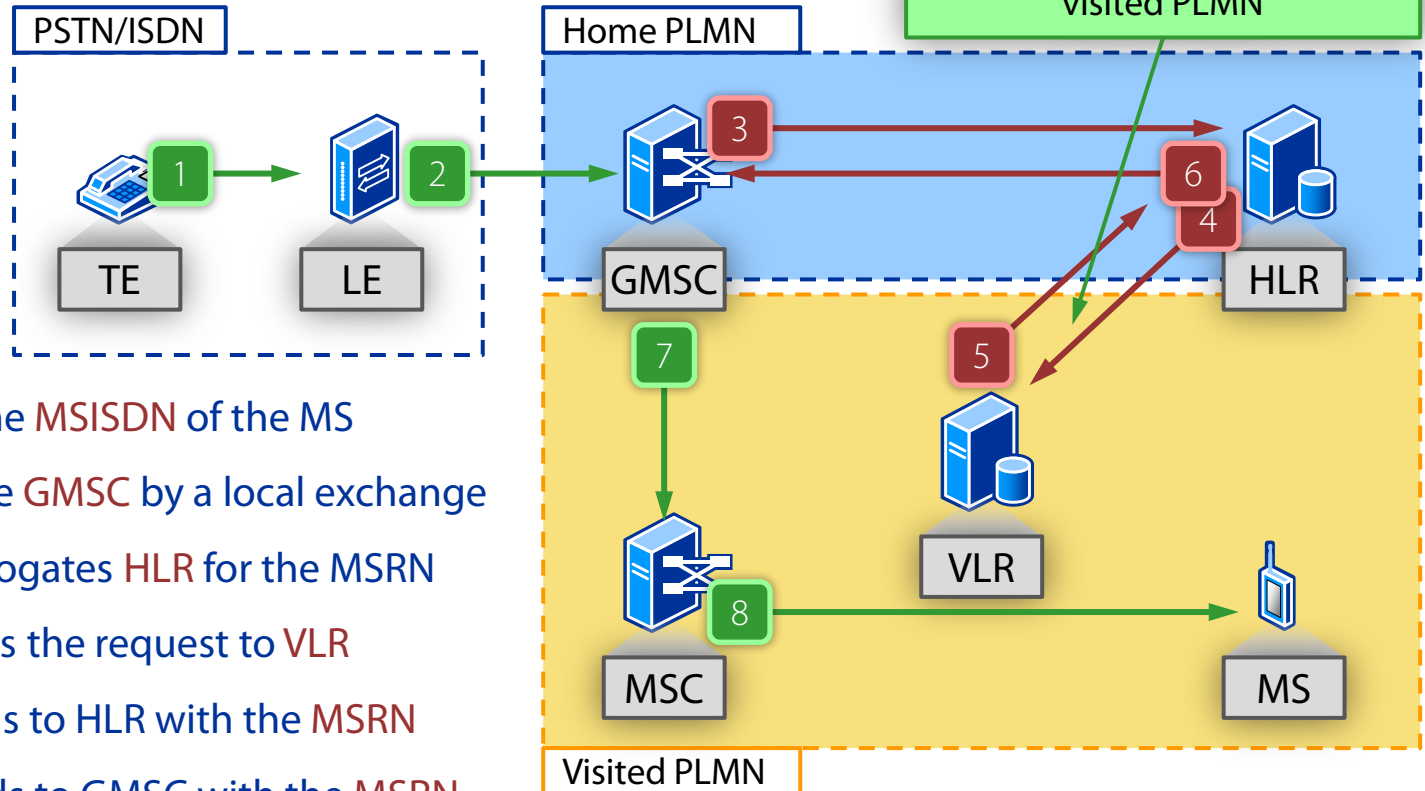
- Call from **PSTN/ISDN** to **MS** in the **home PLMN**
 - Same country and HLR interrogation by the **PSTN/ISDN** local exchange



- 1 • The user dials the **MSISDN** of the MS
- 2 • The LE interrogates **HLR** for the MSRN
- 3 • The HLR forwards the request to **VLR**
- 4 • The VLR responds to HLR with the **MSRN**
- 5 • The HLR responds to GMSC with the **MSRN**
- 6 • Call routed to the **MSC** by the GMSC
- 7 • Call routed to the **MS** by the MSC

4.1.3. Mobile Terminating Calls

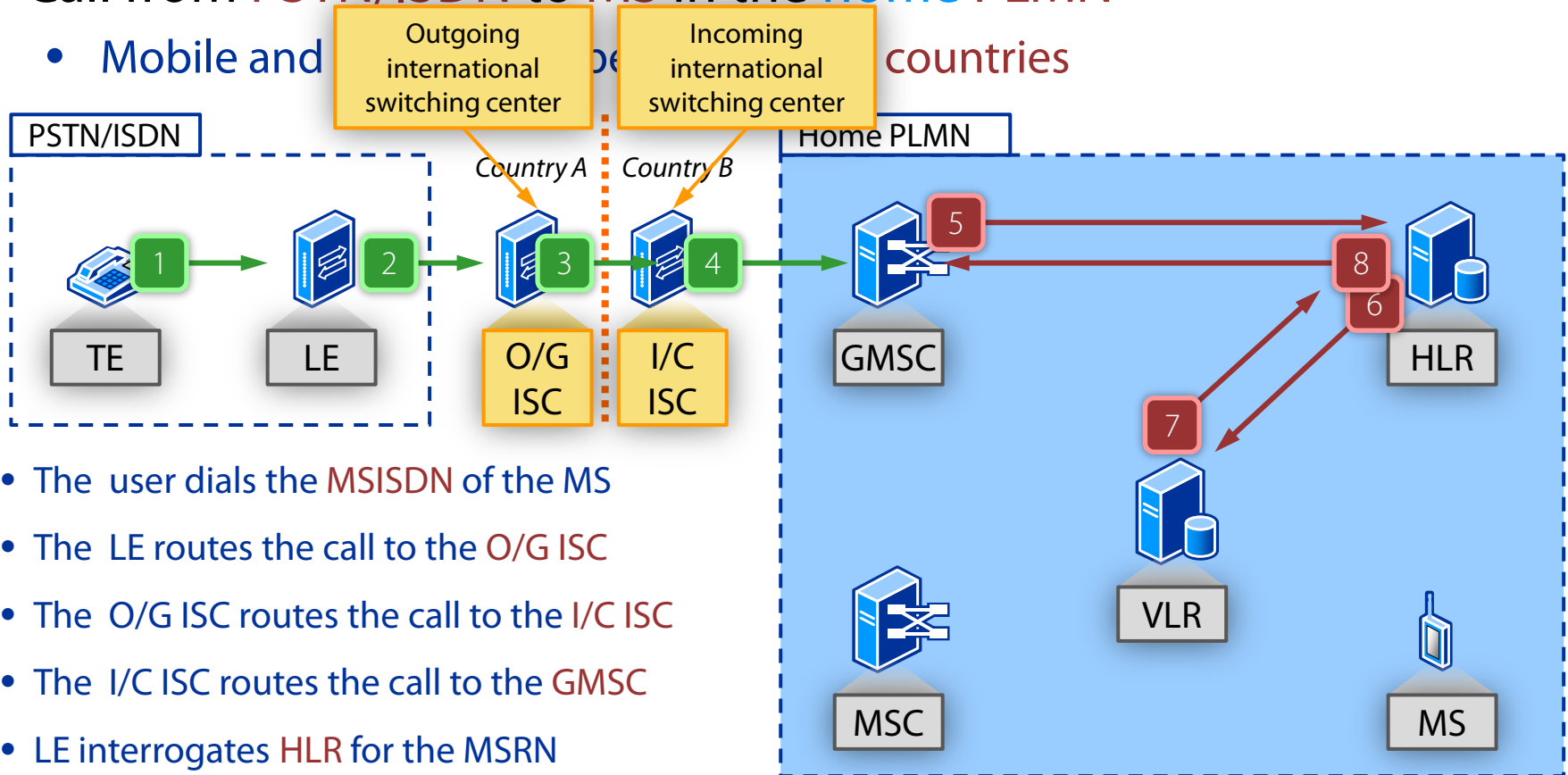
- Call from **PSTN/ISDN** to **MS** in a **visited PLMN**
 - Mobile and fixed subscriber in the **same country**



- 1 • The user dials the **MSISDN** of the MS
- 2 • Call routed to the **GMSC** by a local exchange
- 3 • The GMSC interrogates **HLR** for the **MSRN**
- 4 • The HLR forwards the request to **VLR**
- 5 • The VLR responds to HLR with the **MSRN**
- 6 • The HLR responds to GMSC with the **MSRN**
- 7 • Call routed to the **MSC** by the GMSC
- 8 • Call routed to the **MS** by the MSC

4.1.4. Mobile Terminating Calls

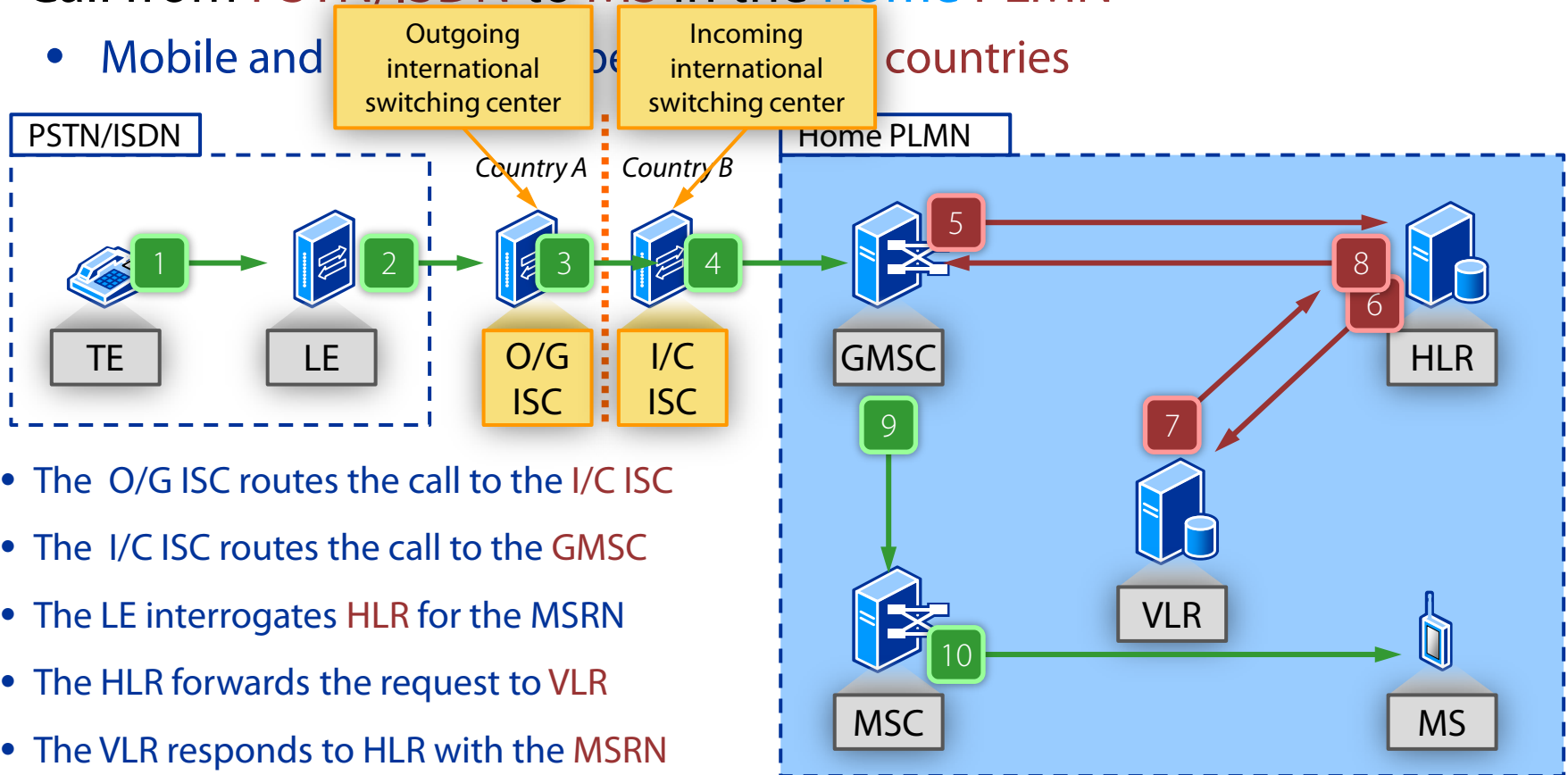
- Call from **PSTN/ISDN** to **MS** in the **home PLMN**
 - Mobile and **countries**



- 1 • The user dials the **MSISDN** of the MS
- 2 • The LE routes the call to the **O/G ISC**
- 3 • The O/G ISC routes the call to the **I/C ISC**
- 4 • The I/C ISC routes the call to the **GMSC**
- 5 • LE interrogates **HLR** for the **MSRN**
- 6 • HLR forwards the request to **VLR**
- 7 • VLR responds to HLR with the **MSRN**
- 8 • HLR responds to GMSC with the **MSRN**

4.1.4. Mobile Terminating Calls

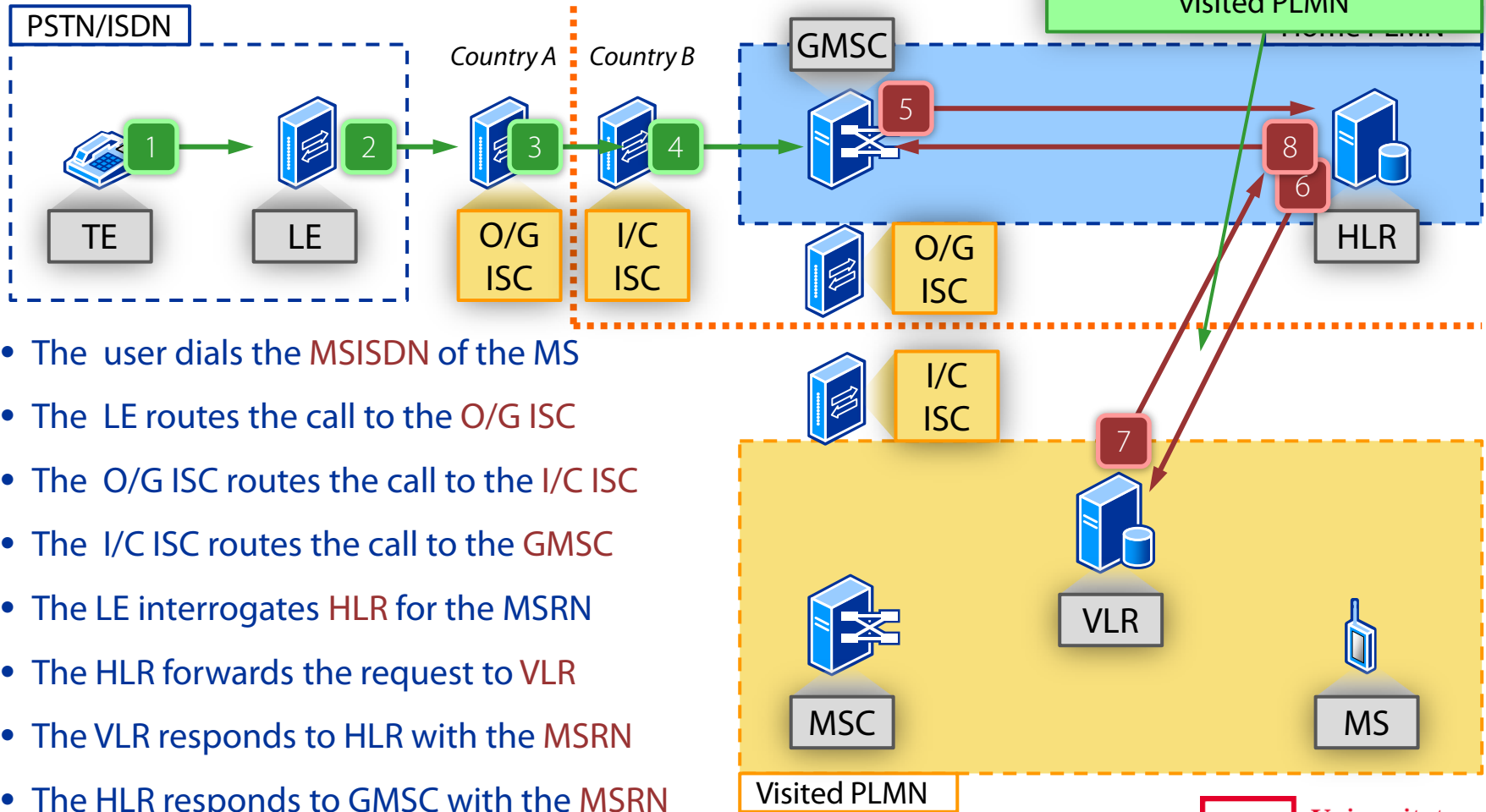
- Call from **PSTN/ISDN** to **MS** in the **home PLMN**
 - Mobile and **countries**



- 3 • The O/G ISC routes the call to the I/C ISC
- 4 • The I/C ISC routes the call to the GMSC
- 5 • The LE interrogates HLR for the MSRN
- 6 • The HLR forwards the request to VLR
- 7 • The VLR responds to HLR with the MSRN
- 8 • The HLR responds to GMSC with the MSRN
- 9 • Call routed to the MSC by the GMSC
- 10 • Call routed to the MS by the MSC

4.1.4. Mobile Terminating Calls

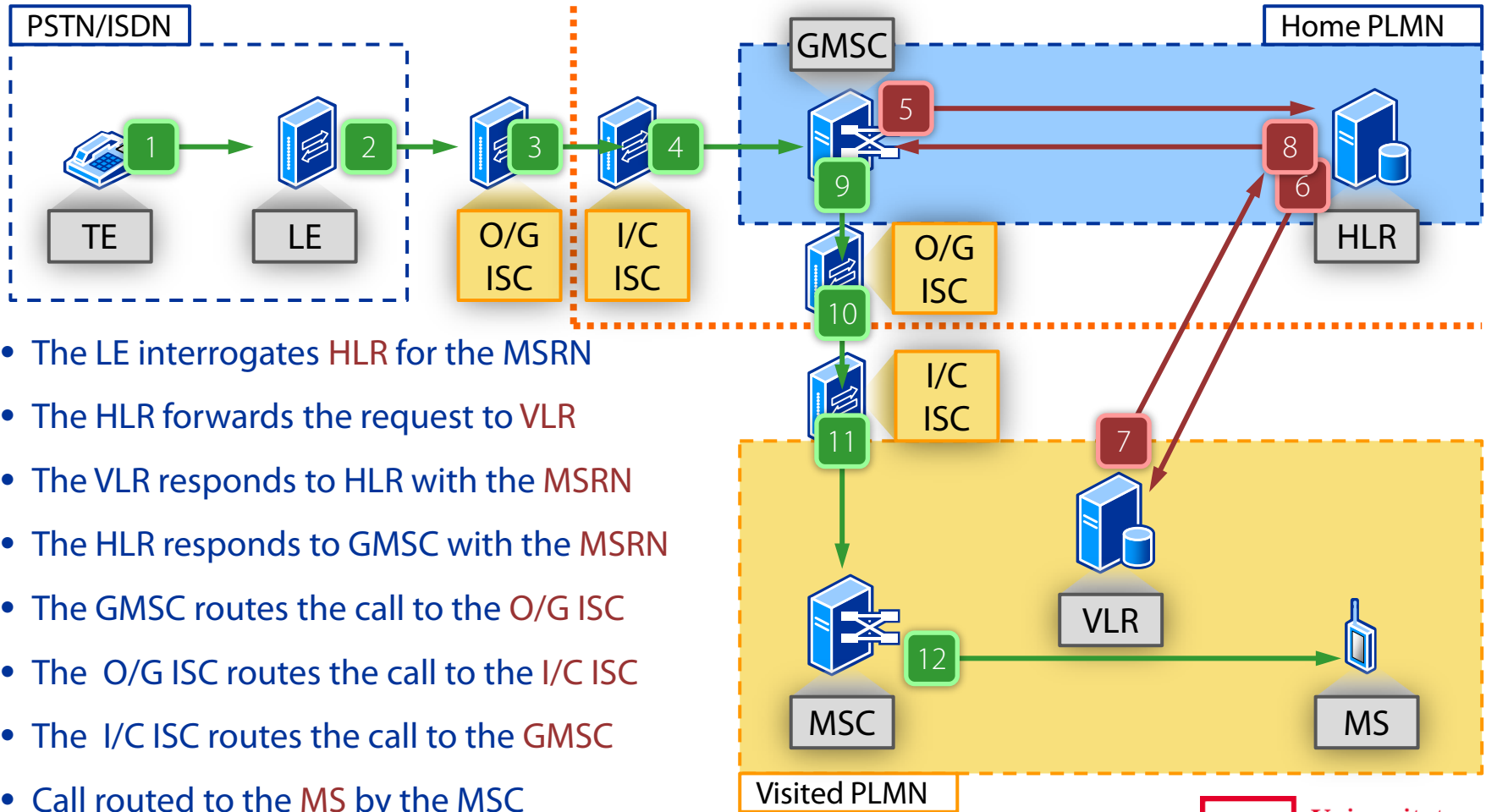
- Call from **PSTN/ISDN** to **MS** in the **visited PLMN**
 - Mobile and fixed subscriber in **different countries**



- 1 • The user dials the **MSISDN** of the MS
- 2 • The LE routes the call to the **O/G ISC**
- 3 • The O/G ISC routes the call to the **I/C ISC**
- 4 • The I/C ISC routes the call to the **GMSC**
- 5 • The LE interrogates **HLR** for the **MSRN**
- 6 • The HLR forwards the request to **VLR**
- 7 • The VLR responds to HLR with the **MSRN**
- 8 • The HLR responds to GMSC with the **MSRN**

4.1.4. Mobile Terminating Calls

- Call from **PSTN/ISDN** to **MS** in the **visited PLMN**
 - Mobile and fixed subscriber in **different countries**

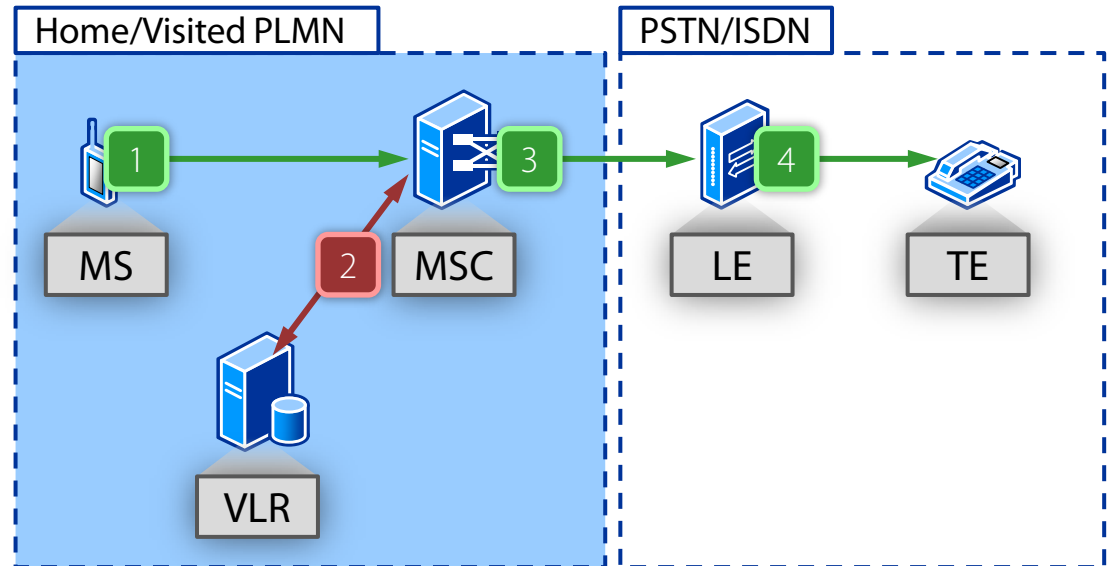


- 5 • The LE interrogates **HLR** for the **MSRN**
- 6 • The HLR forwards the request to **VLR**
- 7 • The VLR responds to HLR with the **MSRN**
- 8 • The HLR responds to GMSC with the **MSRN**
- 9 • The GMSC routes the call to the **O/G ISC**
- 10 • The **O/G ISC** routes the call to the **I/C ISC**
- 11 • The **I/C ISC** routes the call to the **GMSC**
- 12 • Call routed to the **MS** by the **MSC**

4.2. Mobile Originating Calls

- Calls from a **PLMN** to a **PSTN/ISDN** subscriber
 - Does not use the **MSRN**
 - Call routing uses only the **MSISDN**
 - No **HLR interrogation** needed: the **VLR** has all the required information

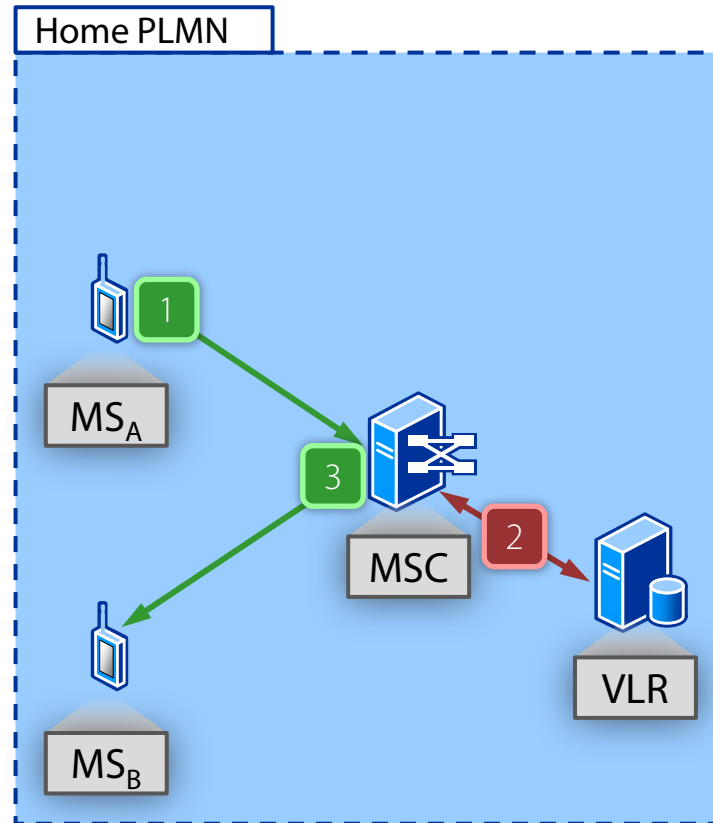
- 1 • The user dials the **MSISDN** of the **TE**, call routed to **MSC**
- 2 • The **MSC** interrogates the **VLR** to authorize the call
- 3 • The **MSC** uses the **MSISDN** to route the call to the **LE**
- 4 • Call forwarded to the **PSTN/ISDN terminal**



4.3.1. Calls Between Mobile Users

- Call to an MS from the **home PLMN / intra-MSC**
 - For intra-MSC calls the **MSRN** points at the current **MSC**

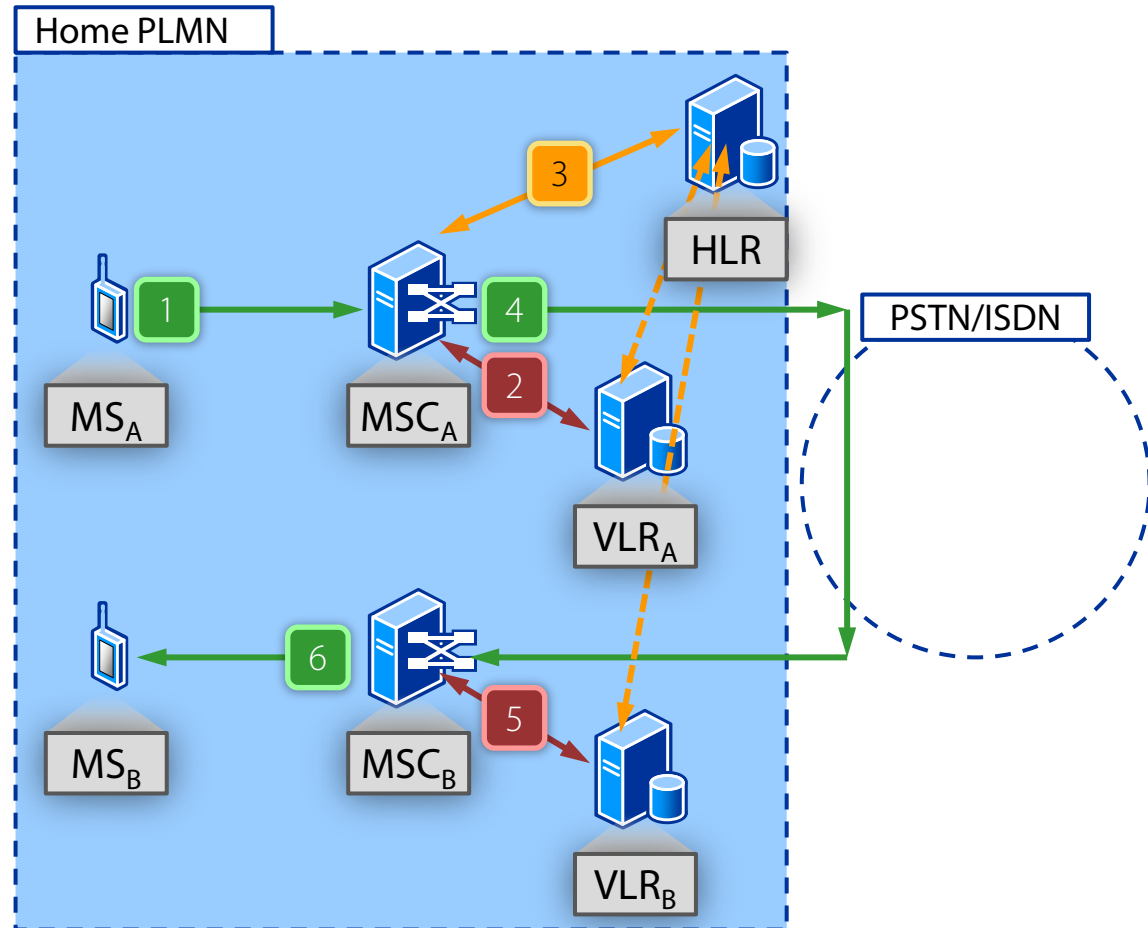
- 1 • The user MS_1 dials the **MSISDN** of the MS_2 , call forwarded to **MSC**
- 2 • The MSC authorizes the call with the **VLR**
- 3 • The MSC forwards the call to the MS_2 (via the BSC and BTS)



4.3.2. Calls Between Mobile Users

- Call to an MS from the **home PLMN** / **inter-MSC**
 - **MSRN** needed for the **called MS** (MS_B)

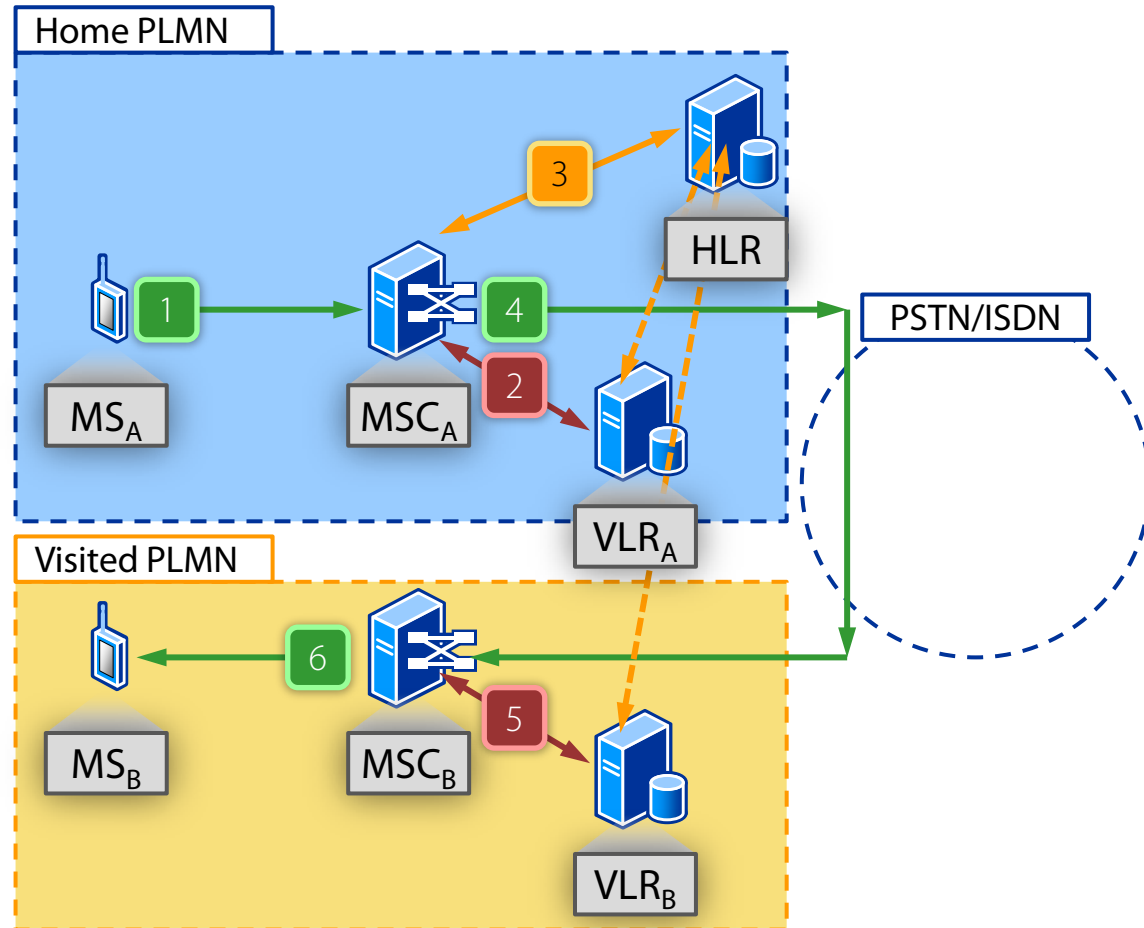
- 1 • The user MS_A dials the **MSISDN** of the MS_B , call forwarded to MSC_A
- 2 • The MSC_A authorizes the call with the **VLR_A**
- 3 • The MSC_A interrogates the **HLR** for the **MSRN** of MS_B
- 4 • The MSC_A forwards the call to MSC_B (via the **PSTN/ISDN**)
- 5 • The MSC_B authorizes the call with the **VLR_B**
- 6 • The MSC_B forwards the call to MS_B (via the **BSC and BTS**)



4.3.3. Calls Between Mobile Users

- Call to an MS from the **home PLMN**
 - Called MS (MS_B) has **roamed** to a network in the same country

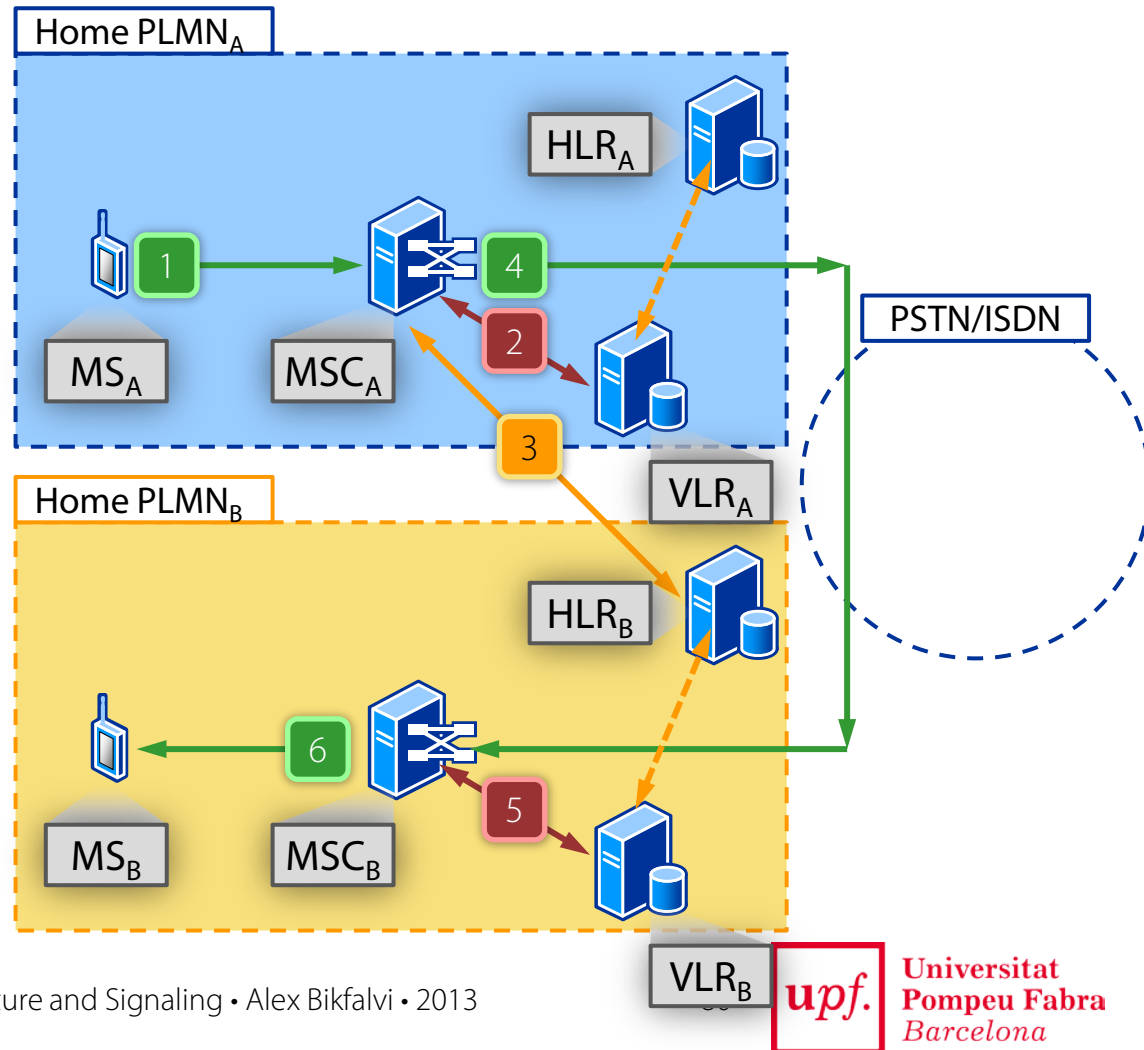
- 1 • The user MS_A dials the **MSISDN** of the MS_B , call forwarded to MSC_A
- 2 • The MSC_A authorizes the call with the **VLR_A**
- 3 • The MSC_A interrogates the **HLR** for the **MSRN** of MS_B
- 4 • The MSC_A forwards the call to MSC_B (via the **PSTN/ISDN**)
- 5 • The MSC_B authorizes the call with the **VLR_B**
- 6 • The MSC_B forwards the call to MS_B (via the **BSC and BTS**)



4.3.4. Calls Between Mobile Users

- Call to an MS from a **different PLMN** (PLMN_B)
 - Both PLMNs are in the **same country**

- 1 • The user MS_A dials the **MSISDN** of the MS_B, call forwarded to **MSC_A**
- 2 • The MSC_A authorizes the call with the **VLR_A**
- 3 • The MSC_A interrogates the **HLR_B** for the **MSRN** of MS_B
- 4 • The MSC_A forwards the call to **MSC_B** (via the PSTN/ISDN)
- 5 • The MSC_B authorizes the call with the **VLR_B**
- 6 • The MSC_B forwards the call to **MS_B** (via the BSC and BTS)



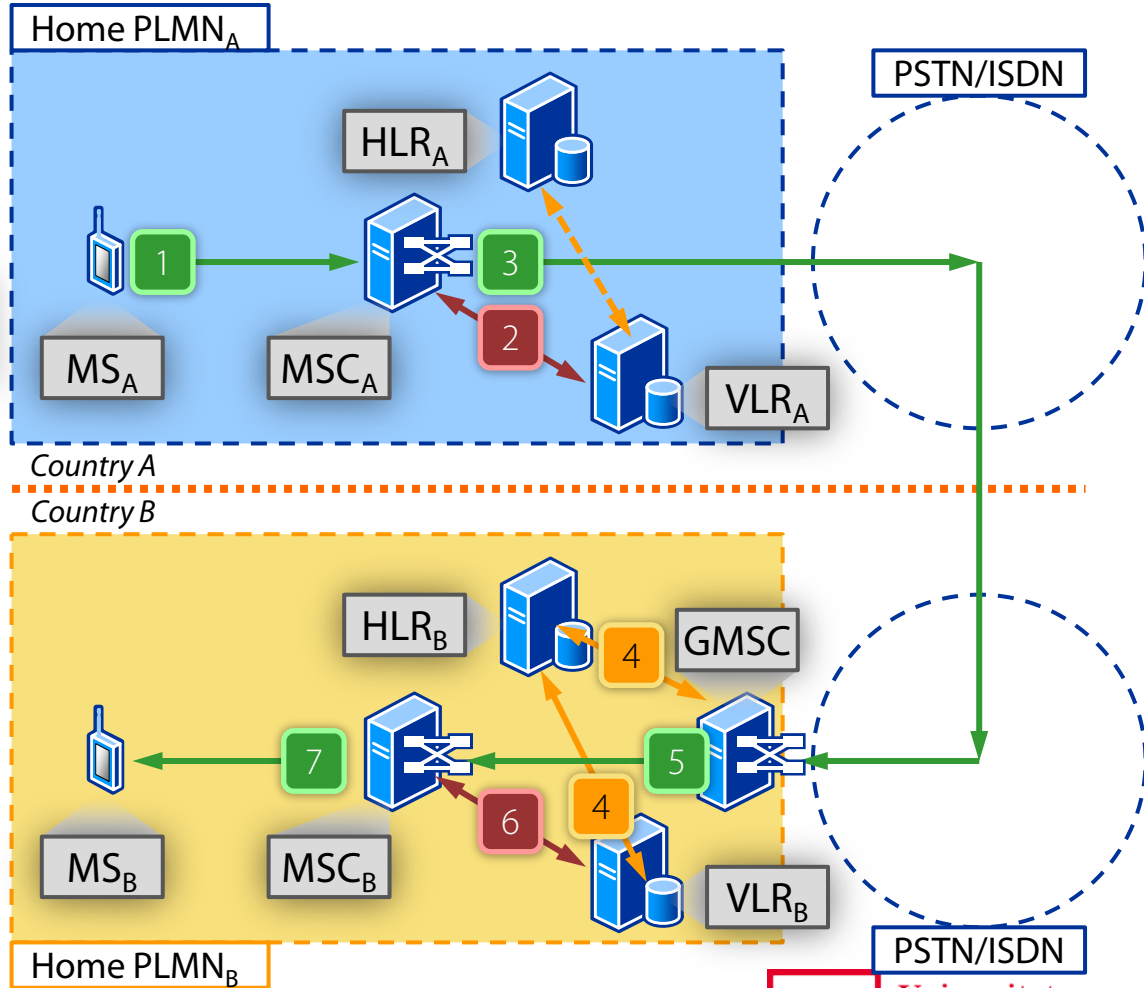
4.3.5. Calls Between Mobile Users

- Call to an MS from a **different PLMN** (PLMN_B)
 - The PLMNs are in the **different countries**

- 1 • The user MS_A dials the **MSISDN** of the MS_B, call forwarded to **MSC_A**
- 2 • The MSC_A authorizes the call with the **VLR_A**

The MSC_A cannot access the HLR of a PLMN in a different country

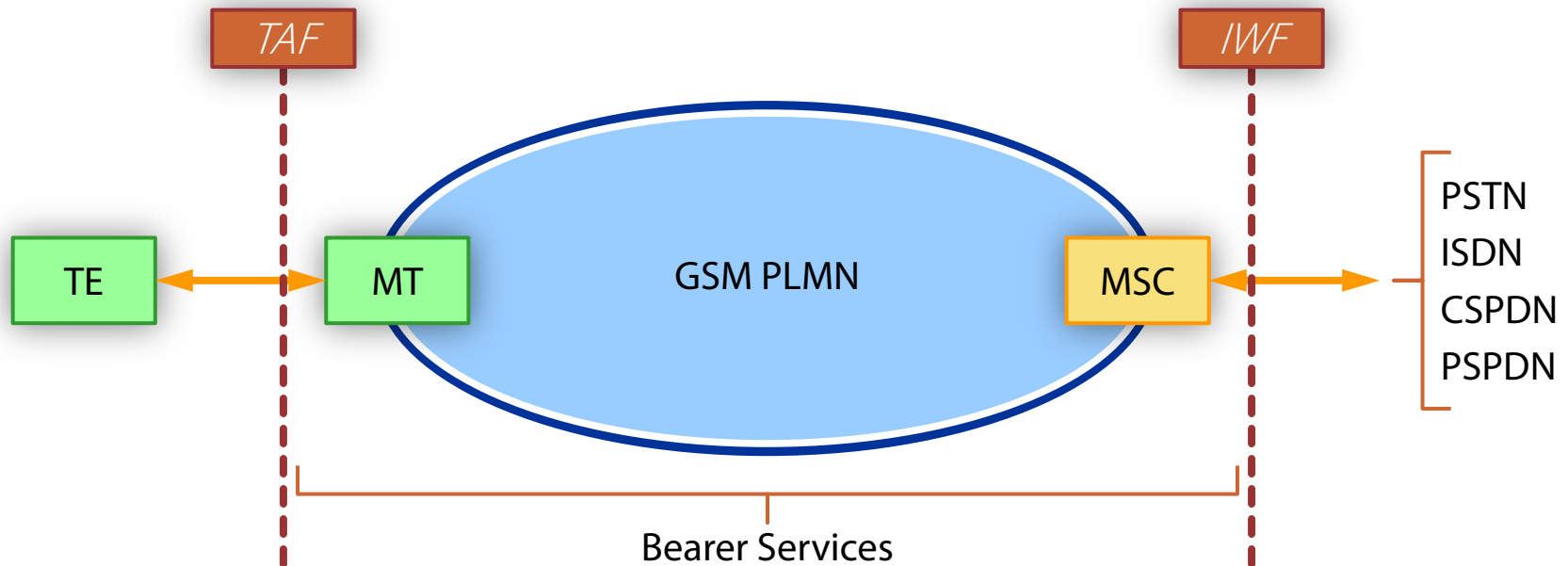
- 3 • The MSC_A forwards the call to the **GMSC_B** (via the PSTN/ISDN)
- 4 • The GMSC_B asks the **VLR_B** for the **MSRN** of MS_B via the **HLR_B**
- 5 • The GMSC_B forwards the call to **MSC_B** using the **MSRN**
- 6 • The MSC_B authorizes the call with the **VLR_B**
- 7 • The MSC_B forwards the call to **MS_B** (via the BSC and BTS)



5. Data Services in GSM

Data services: GSM offers only a **transport** mechanism between **standardized** access points

- They are called **bearer** services
- Do not include **fax** and **SMS**, which are teleservices

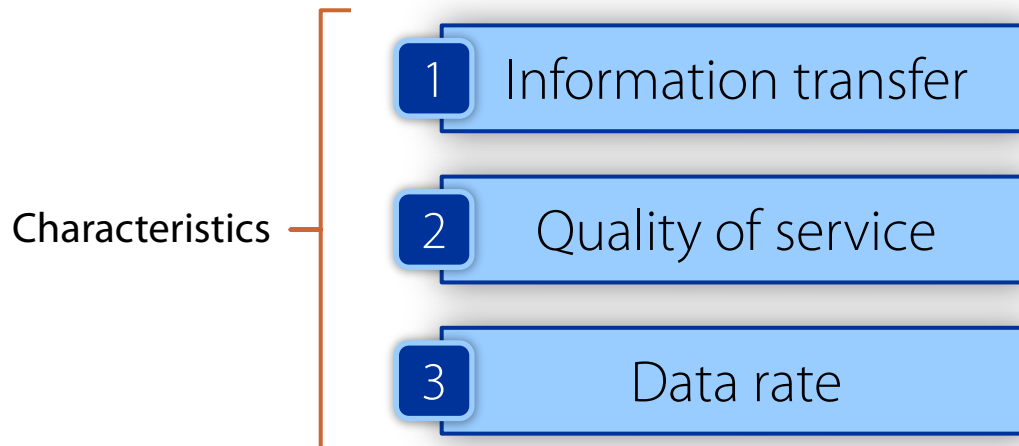


- **TAF** – terminal adaptation function
- **IWF** – interworking function

5. Data Services in GSM

Data services: GSM offers only a **transport** mechanism between **standardized** access points

- They are called **bearer** services
- Do not include **fax** and **SMS**, which are teleservices



5.1. Information Transfer

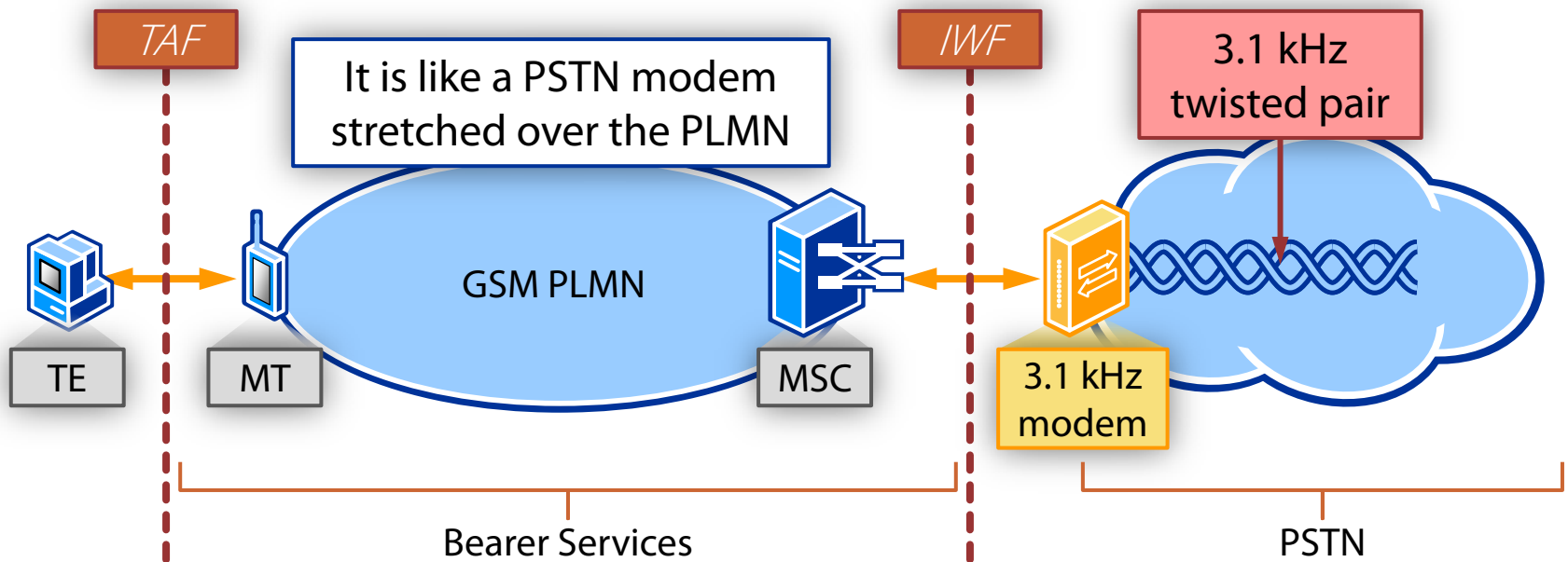
1.1 Mode

- Whether **circuit-switched (CS)** or **packet-switched (PS)**
 - GSM phases 1 and 2 uses **circuit-switched data**
 - **Time-based billing**
 - **Inefficient use of the radio resources**

CSD

1.2 Capability

- **3.1 kHz modem**
 - Dedicated for analog connections to **PSTN**



5.1. Information Transfer

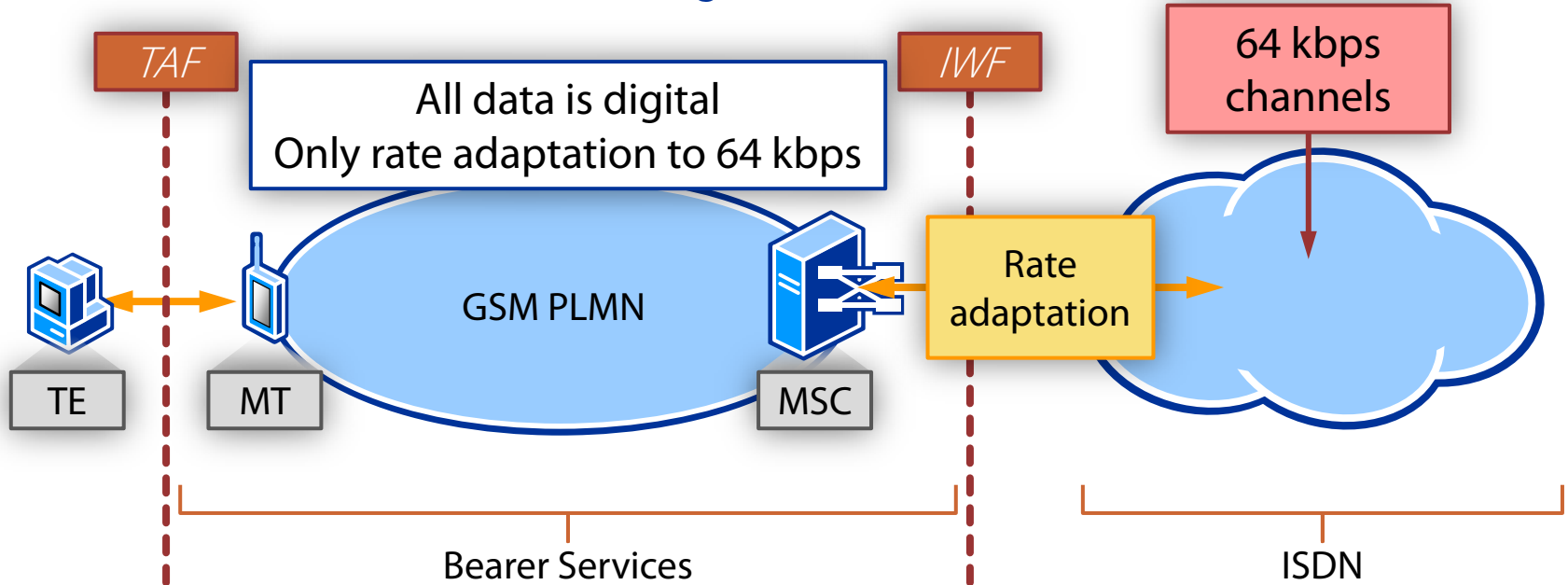
1.1 Mode

- Whether **circuit-switched (CS)** or **packet-switched (PS)**
 - GSM phases 1 and 2 uses **circuit-switched data**
 - **Time-based billing**
 - **Inefficient use of the radio resources**

CSD

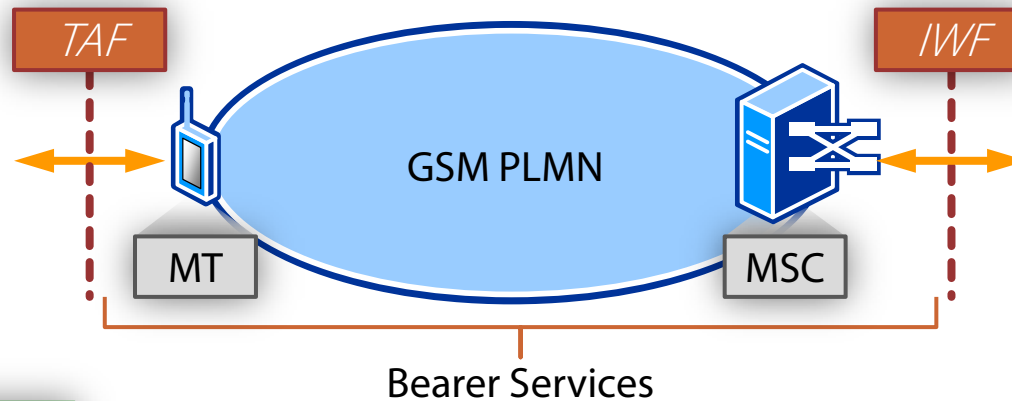
1.2 Capability

- **Unrestricted Digital Information (UDI)**
 - **Dedicated for digital connections to ISDN**



5.2. Quality of Service

Defines **two** different modes for transporting digital information between **TAF** and **IWF**



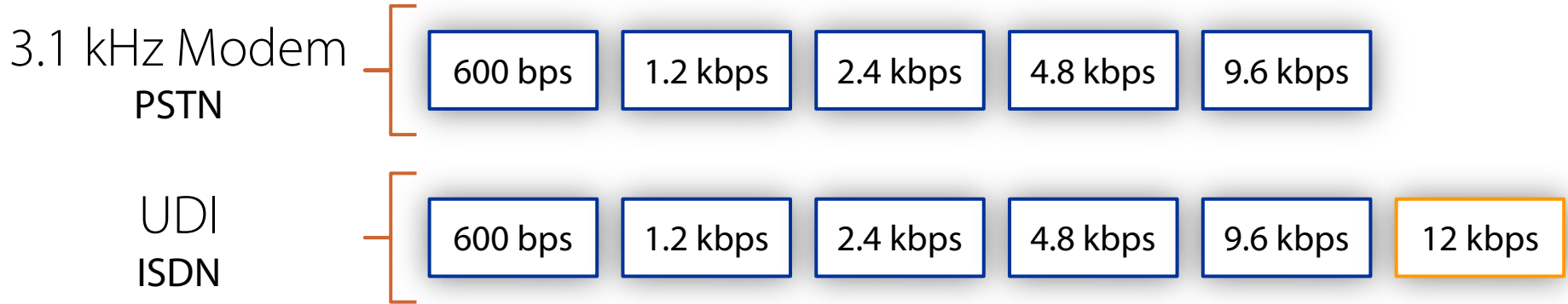
2.1 Transparent

- **Error correction** (FEC) only on the radio interface (*Um*)
- **Constant delays**

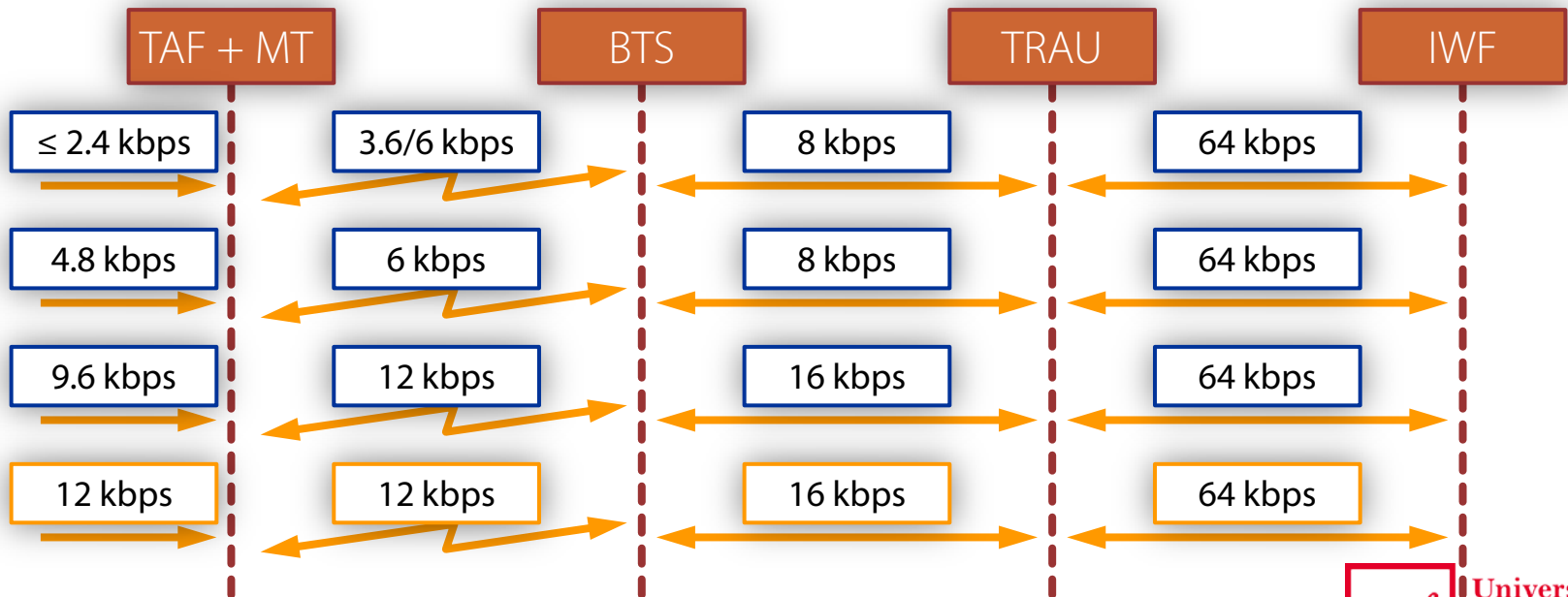
2.2 Non-transparent

- **Error correction** on the radio interface and an ARQ between **TAF** and **IWF**
- Data segmented and transmitted with the **Radio Link Protocol**
- **Variable delays** but **better quality**

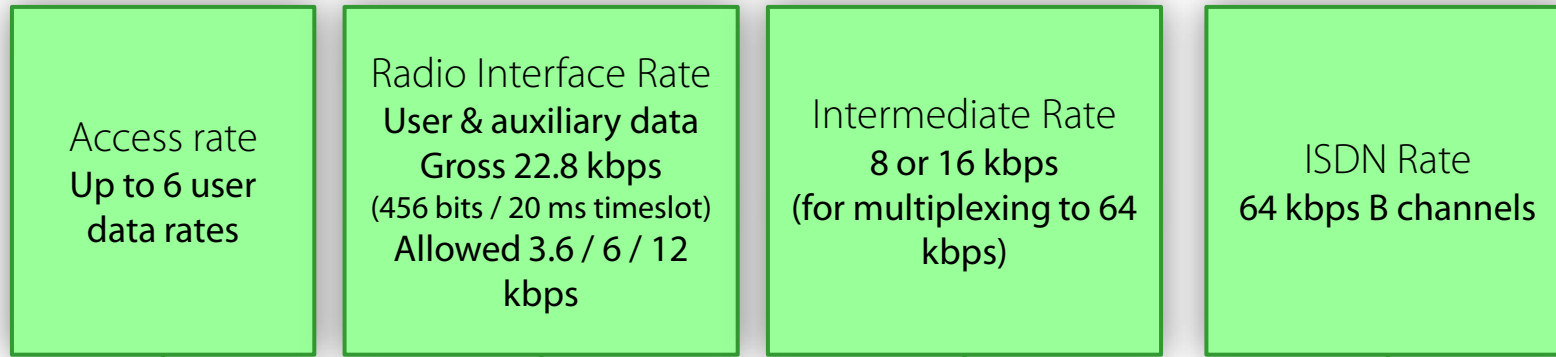
5.3. Data Rate



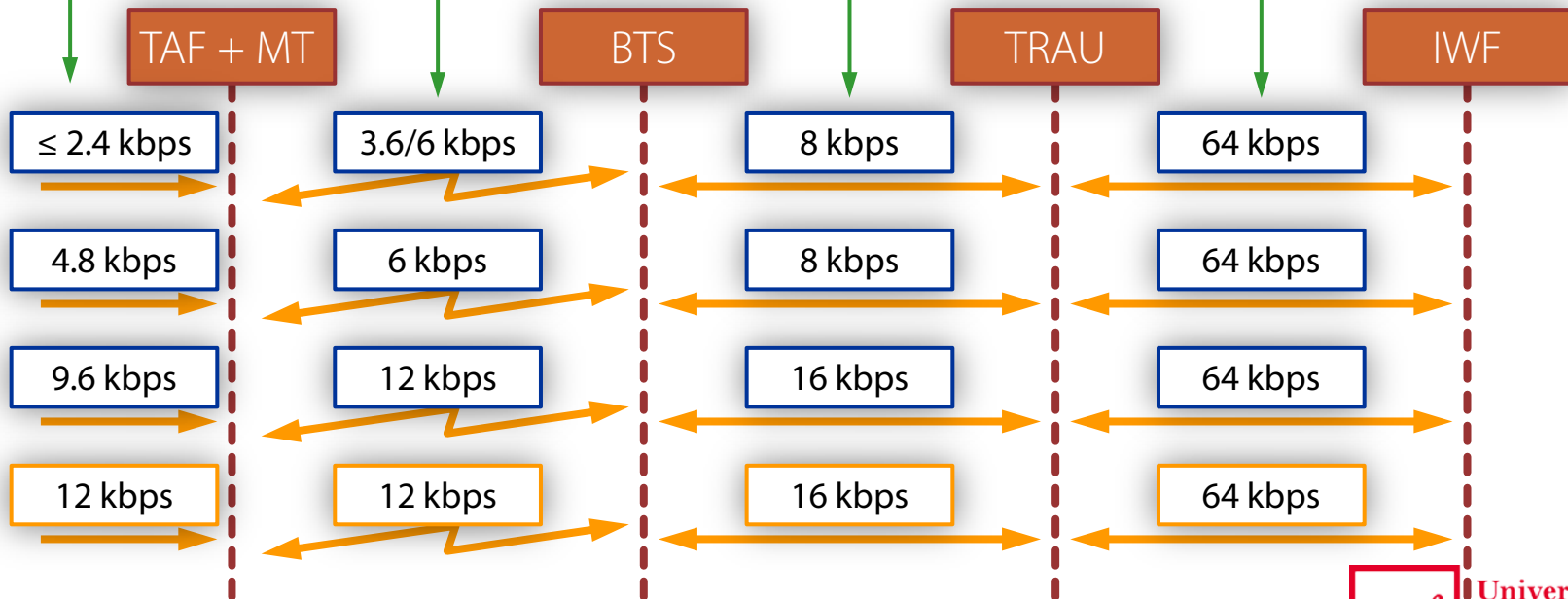
- Rate adaptation



5.3. Data Rate

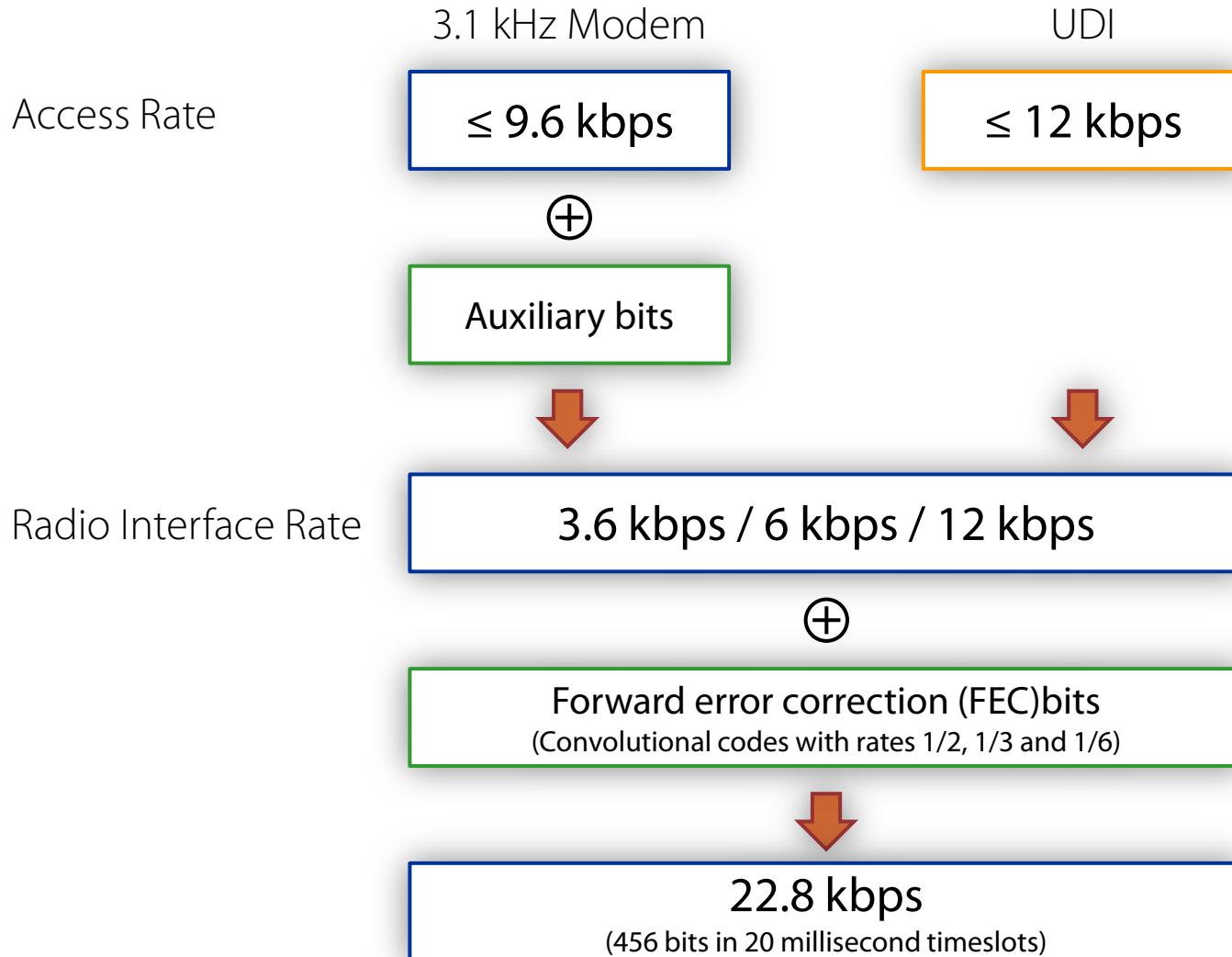


- Rate adaptation



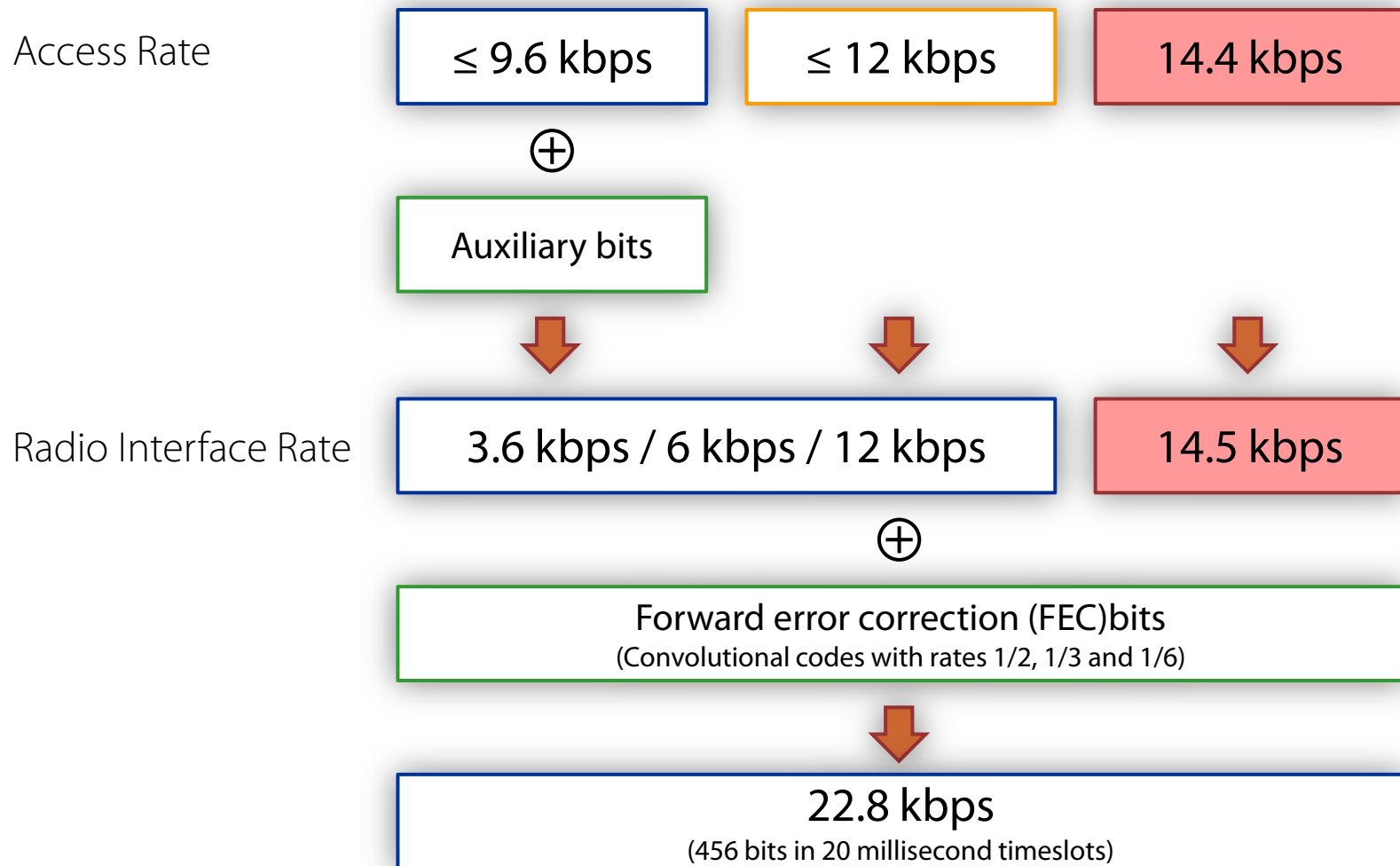
5.3.1. Data rates up to 12 kbps

- User data rate in GSM



5.3.2. Data rate at 14.4 kbps

- An enhanced data rate, by modifying the radio frame structure



5.3.3. High Speed Circuit Switched Data

HSCDS Increased data rates for GSM Phase 2+
It is circuit-switched like CSD

- CSD** [
- Up to 9.6 kbps / 12 kbps in normal GSM frames
 - Up to 14.4 kbps in modified GSM frames

22.8 kbps
(456 bits in 1 time slot)

- HSCSD** [
- Uses multiple slots per transmission
 - All time slots on the same frequency

An MT can use up to 4 TS per direction (UL/DL), but no more than 5 TS in total

Time slots	4.8 kbps	9.6 kbps	14.4 kbps
1	4.8 kbps	9.6 kbps	14.4 kbps
2	9.6 kbps	19.2 kbps	28.8 kbps
3	14.4 kbps	28.8 kbps	43.2 kbps
4	19.2 kbps	38.4 kbps	57.6 kbps

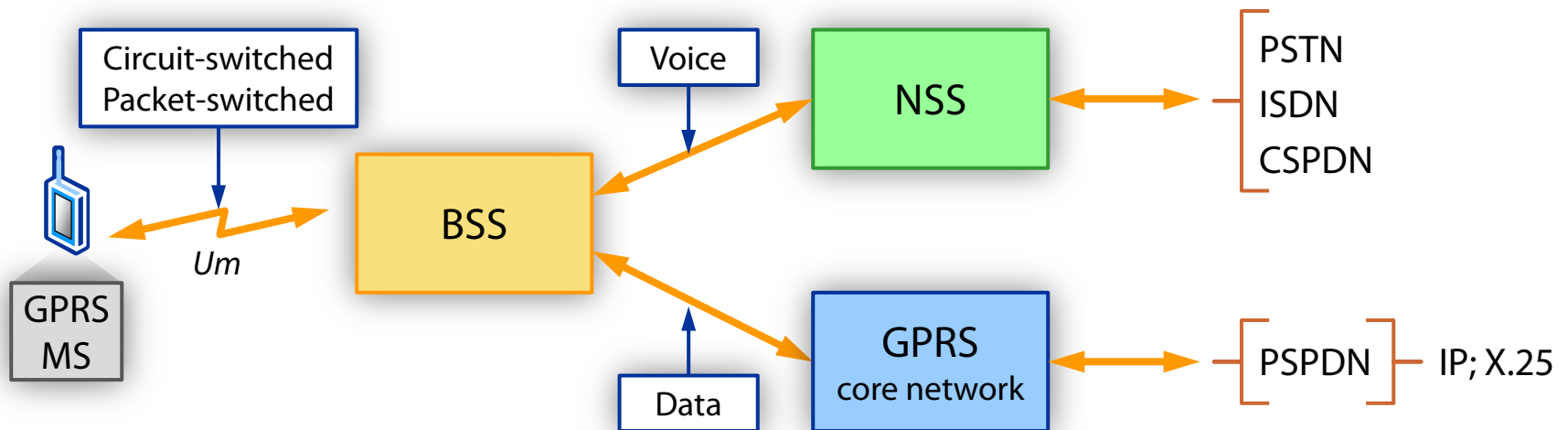
Part III. 2.5G / 2.75 G

General Packet Radio Service

1. Introduction

GPRS Bearer service introduced in GSM Phase 2+
Allows end-to-end transport of packet-switched data

- The GSM core network does not support packet switching

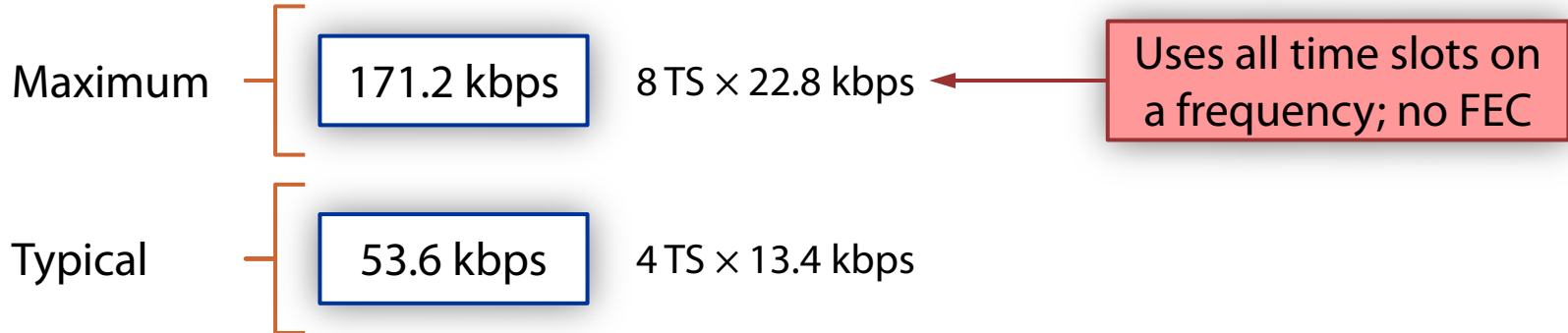


Advantages

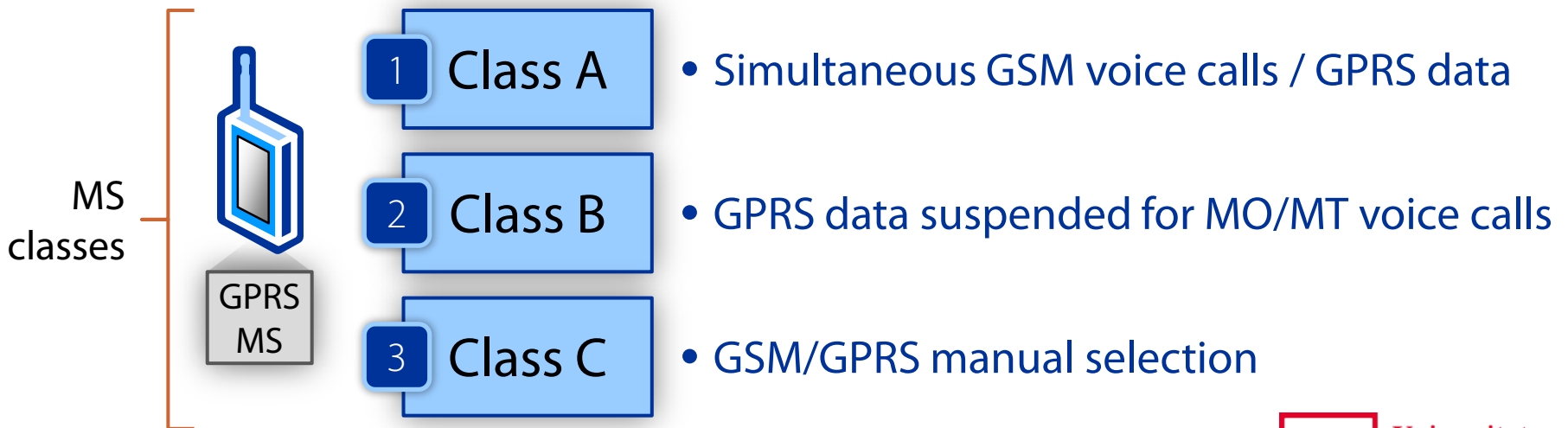
- Radio resources allocated **on demand**
- Same traffic channel (frequency/time-slot) **shared** by several users
- Data volume** billing (instead of time-based billing in CSD)
- Increased data rates**

1. Introduction

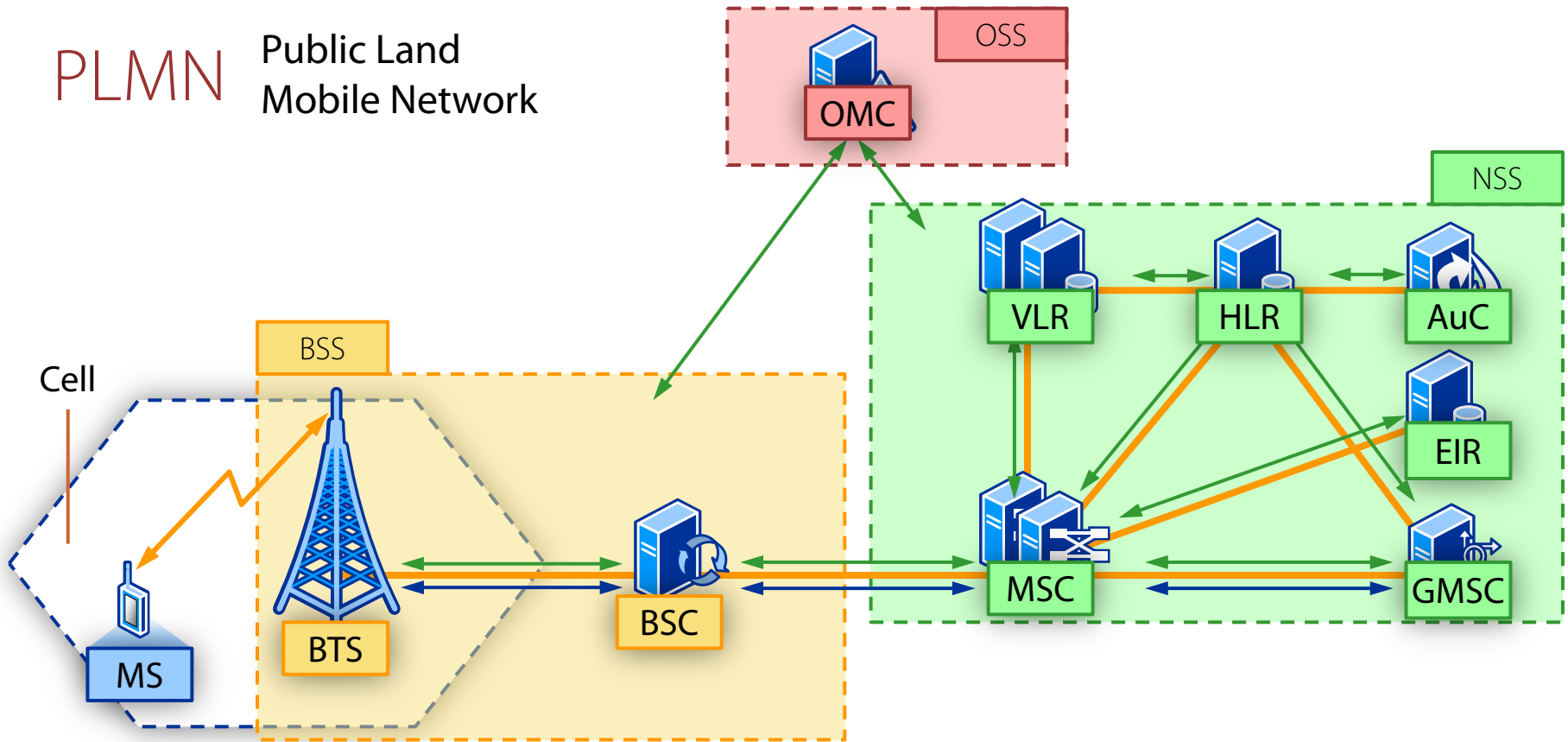
- Like HSCSD, GPRS can use **multiple time-slots** (up to 8)



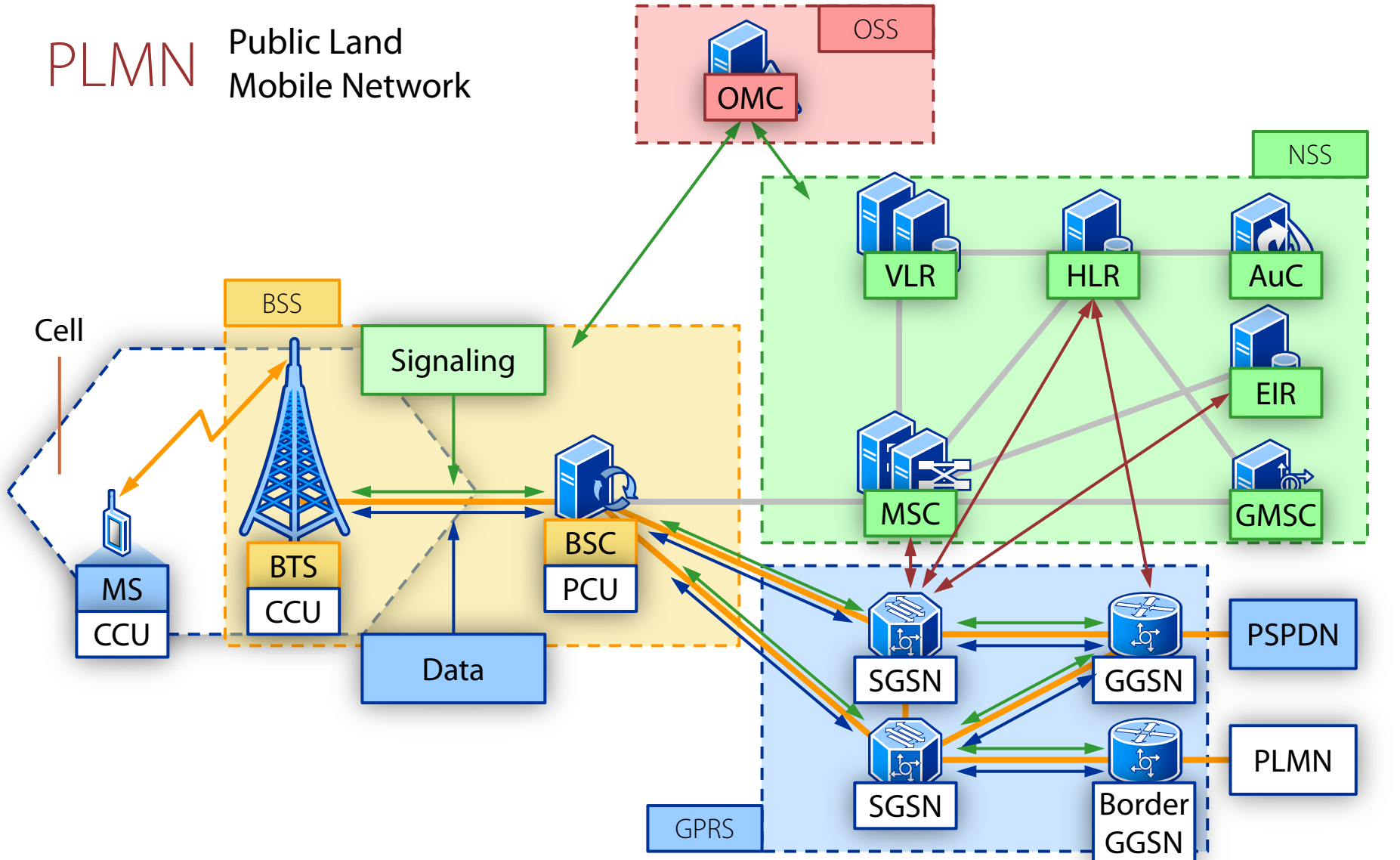
- GPRS Services
- True access to IP networks, **mobile Internet**
 - New transport for **SMS** (no longer limited to 160 characters)



2. GPRS Architecture



2. GPRS Architecture

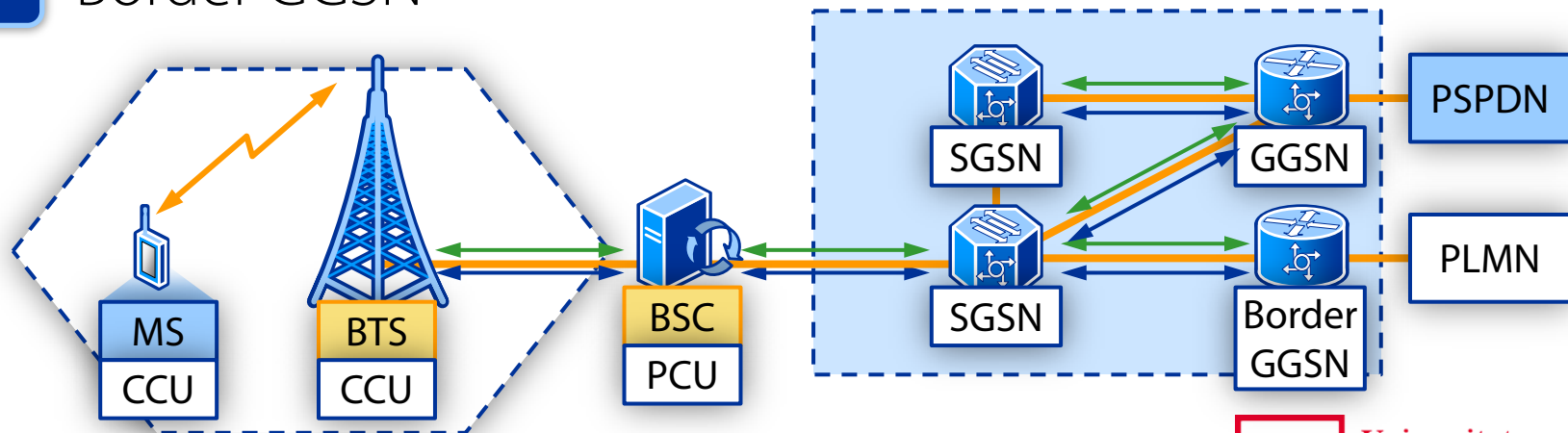


2.1. Functional Entities

- The **GPRS** architecture introduces the following entities

- 1 PCU Packet Control Unit
- 2 CCU Channel Codec Unit
- 3 SGSN Serving GPRS Support Node
- 4 GGSN Gateway GPRS Support Node

4.1 Border GGSN



2.1. Functional Entities

- The **GPRS** architecture introduces the following entities

1 PCU Packet Control Unit

- Manages the **radio resources allocation** for GPRS services
 - Allocation of **multiple TS/user** (up to 8)
 - Sharing of the same TS between **multiple users** (up to 8)
- Selection of the **FEC coding scheme** from 4 available

2 CCU Channel Codec Unit

- Implements **channel coding** for GPRS services
- In charge of **signal strength measurements** for GPRS services
 - Implemented both at GPRS-MS and BTS

2.1. Functional Entities

- The **GPRS** architecture introduces the following entities

3 SGSN Serving GPRS Support Node

- In charge of the GPRS MS **location** in a given PLMN area (typically one or several per BSC)
- **Mobility management** function: GPRS attach/detach, retrieval of mobility data from HLR, authentication, authorization and ciphering, etc
- **IP routing** function: transfer of packets between MS and GGSN

4 GGSN Gateway GPRS Support Node

- The **gateway** to the packet data network (PDN)
- **IP routing** function: IP packets to/from external PDN are routed from/to the SGSN serving the GPRS-MS
- Allocation of **IP addresses** for MS
- Manages the user data sessions (called **PDP sessions**)
- Can **interrogate** the HLR to discover the current SGSN

2.1. Functional Entities

- The **GPRS** architecture introduces the following entities

4.1 Border GGSN

- A special GGSN for connection with the GPRS core network of other operators through private or public IP networks

3. Data Transfer in GPRS

- For accessing GPRS services a MS must **attach** itself to GPRS (to a SGSN)



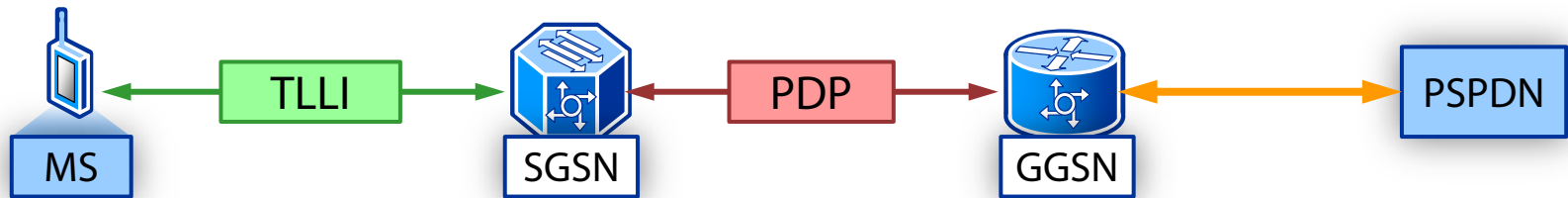
1 TLLI

- MS and SGSN are communicating through a **logical link**
 - It is not a physical link (a TCH allocated for a MS in BTS for GSM only services)
- A GPRS MS is **connected** to the network and the network is aware of the existing link
- The MS can send or receive data at **any moment**
- When not transmitting the radio channel is allocated to **other users**

Temporary Logical Link Identity
Uniquely identifies an MS on the radio interface and issued by SGSN as a result of a **GPRS attach** procedure

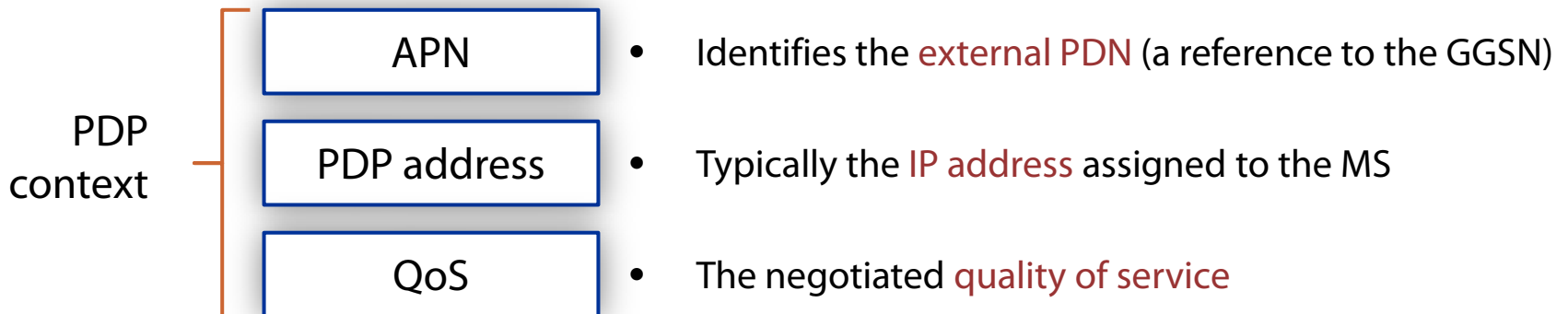
3. Data Transfer in GPRS

- For accessing GPRS services a MS must **attach** itself to GPRS (to a SGSN)



2 PDP

- When initiating data transfer the MS activates a **PDP context**
 - Packet Data Protocol
- It is a connection between the **SGSN** and the **GGSN** of the corresponding PDN
- It is characterized by:



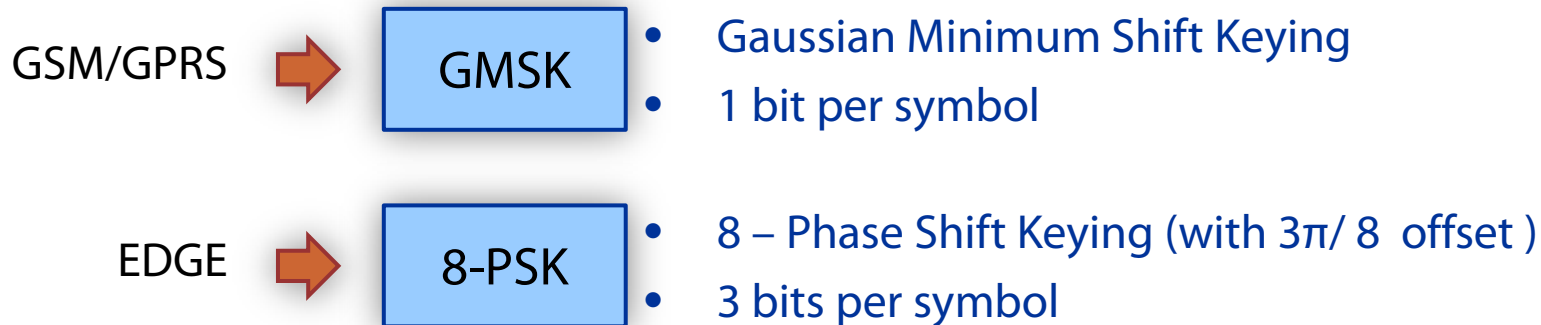
4. EDGE

EDGE Enhanced Data Rates for GSM Evolution
Increased **data rates** on the GSM/GPRS radio interface

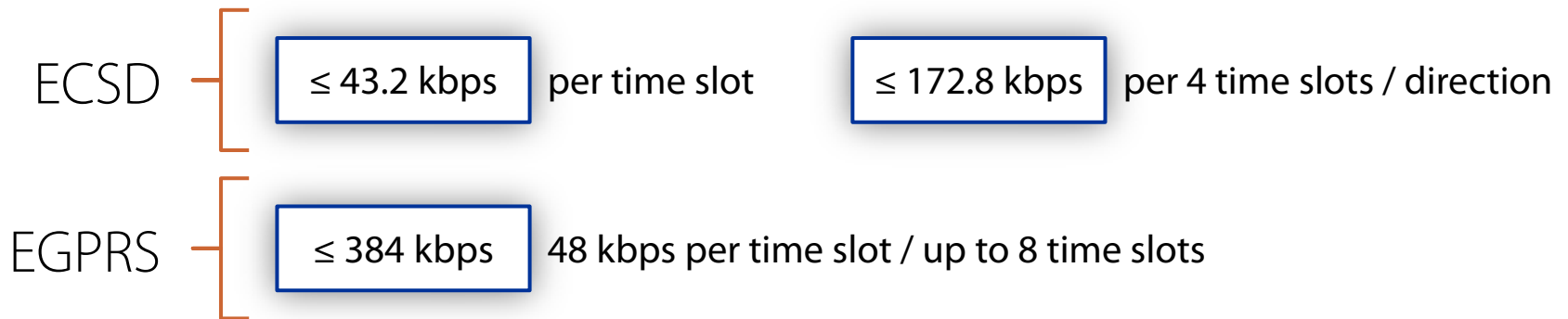
- **Cheap** solution: no additional license needed to operate EDGE
- Supports both CS data (**ECDS** based on HSCSD) and PS data (**EGPRS**)

How does it work?

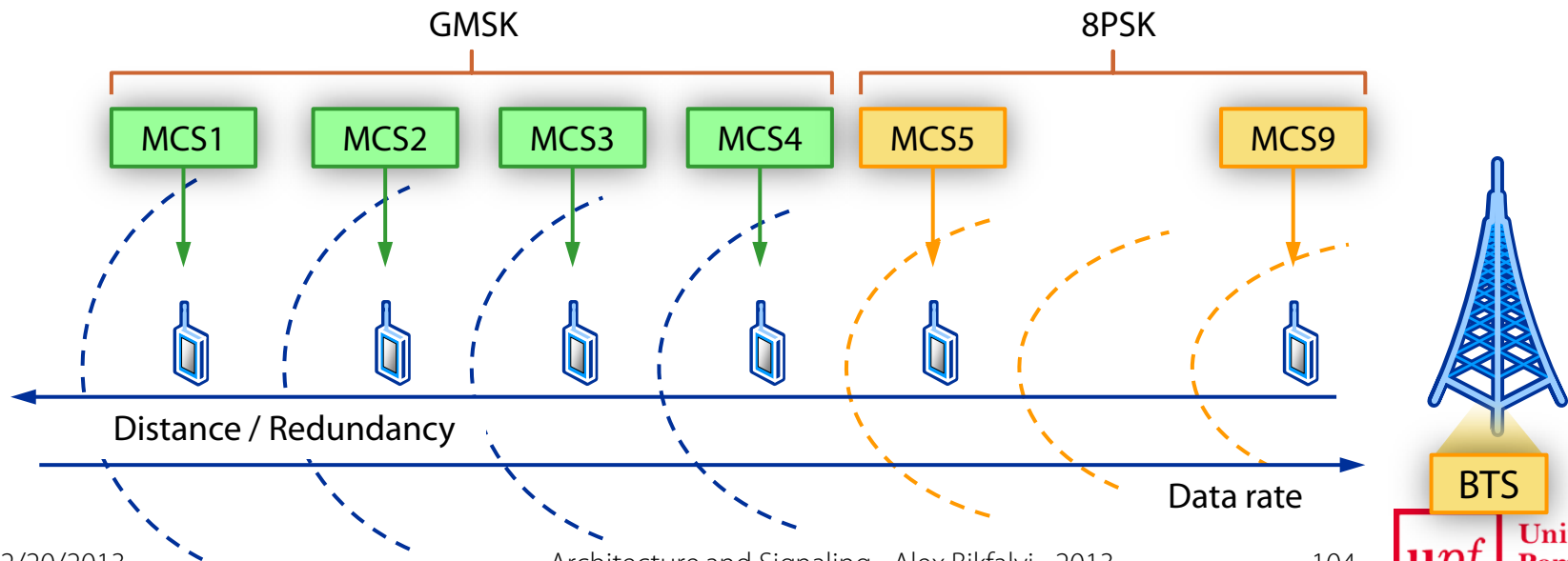
Change the modulation scheme on the radio interface



4.1. Data Rates



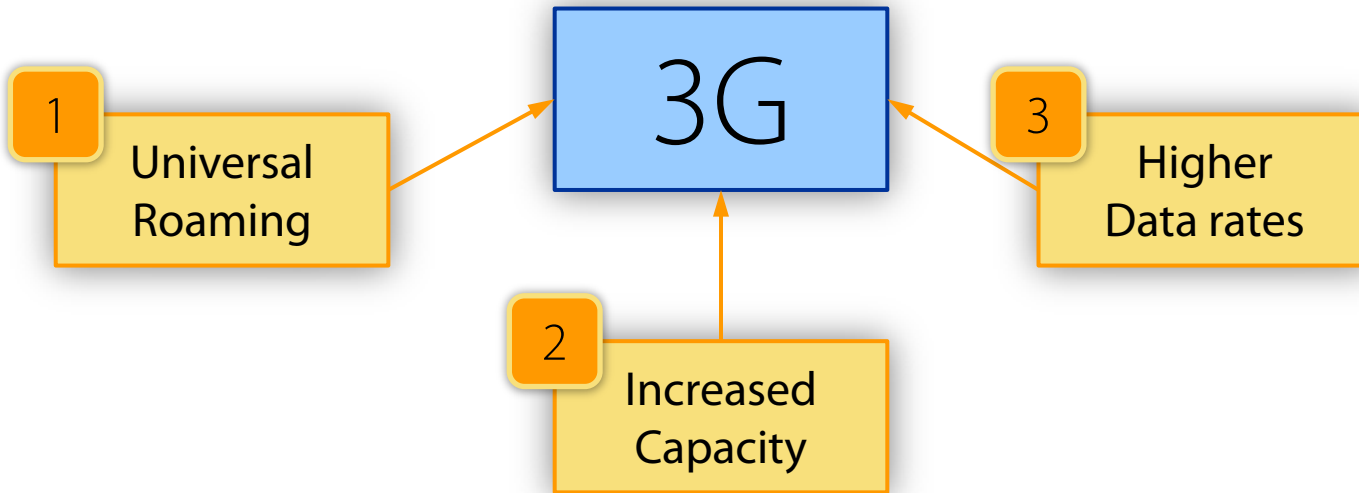
- A MS changes the **modulation and coding scheme** (MSC)
 - Depending on **distance** (signal strength)
 - Determines the maximum **bit rate**



Part V. 3G

Universal Mobile Telecommunications System

1. Introduction

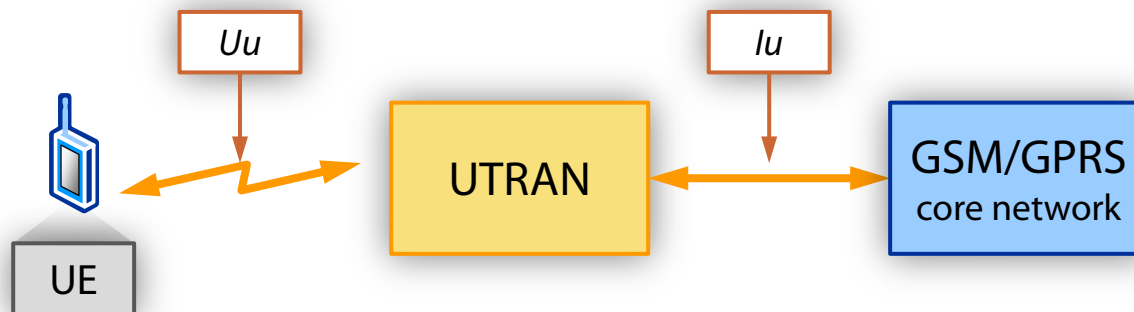


Proposals	UMTS	Evolution of GSM/GPRS/EDGE
	CDMA2000	Evolution of IS-95
	UWC136	Evolution of IS-136

1. Introduction

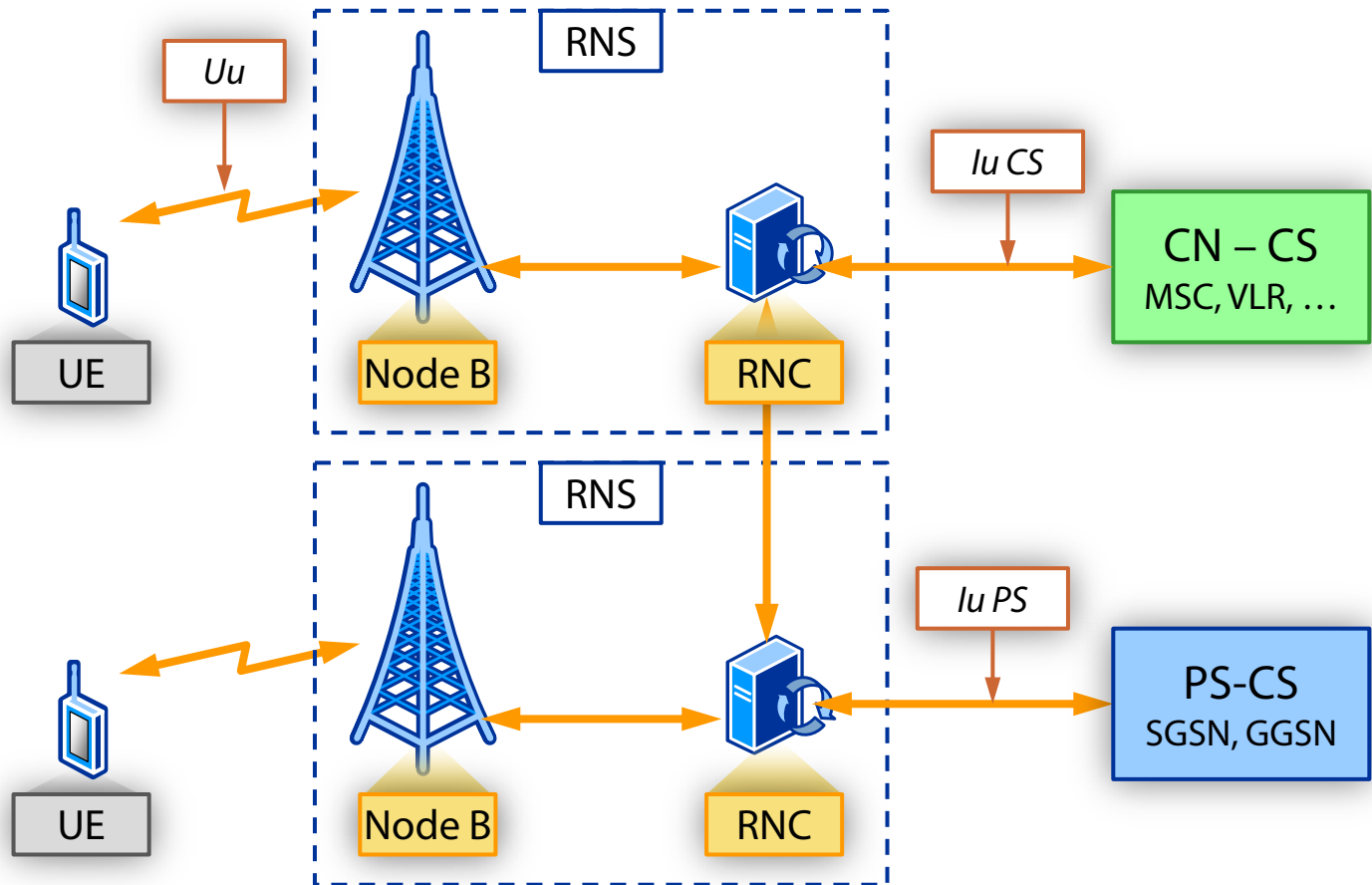
UMTS Introduces a new radio interface called **UTRAN** (Universal Terrestrial Radio Access Network)

- UTRAN uses a new multiple access scheme: **CDMA**
- Connects the **User Equipments** (UE) with the **GSM/GPRS core network**



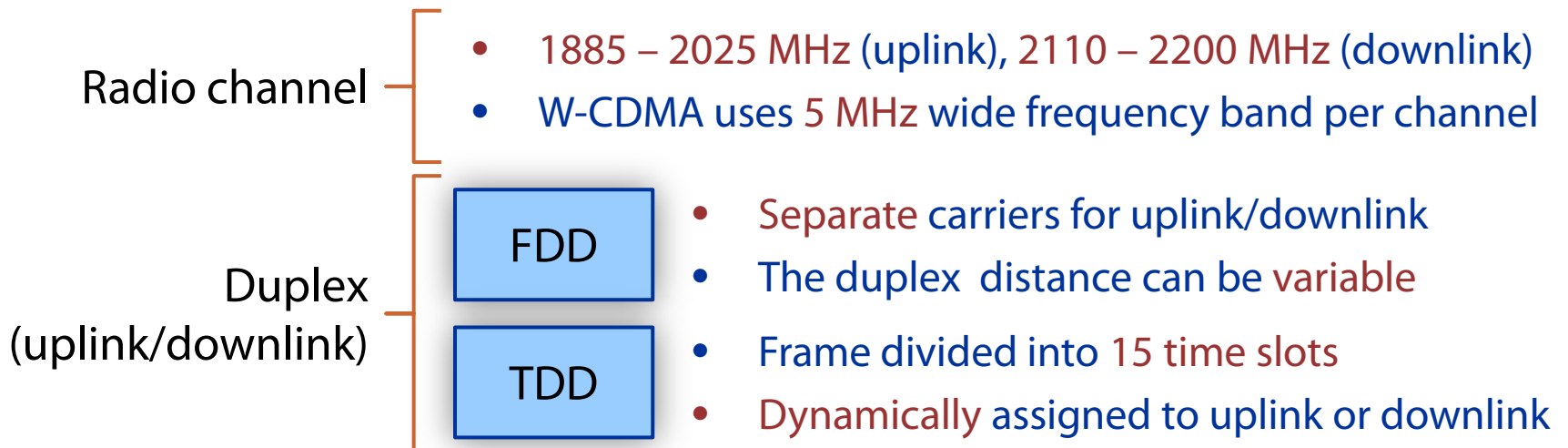
- **User equipment**
- Like the GSM separation between **MS** and a new SIM card **USIM**
- Cell with a single frequency / direction: **frequency division duplex (FDD)**
- Cell with a single frequency: **time division duplex (TDD)**
- GSM NSS for **circuit switched** voice and data
- GPRS core network for **packet switched** data

2. UTRAN Architecture



2. UTRAN Architecture

- 1 NodeB
 - Equivalent of a GSM BTS
- 2 RNC Radio Network Controller
 - The intelligent part of the UTRAN, equivalent of a GSM BSC
- 3 CN-CS Circuit Switched Core Network
 - A GSM NSS
- 4 CN-PS Packet Switched Core Network
 - A GPRS core network



3. Mobility Features

Handovers

- **Soft-handover**
 - For CS traffic a UE can communicate with several Node B
 - RNC multiplies and combines signal received from Node Bs.
- **Hard –handover**: when using multiple carrier frequencies

Location Management

- Handled between the **UTRAN** and the **CN**
 - CN keeps track of the **MS location/routing areas** as in GSM/GPRS networks
 - UTRAN keeps track of the current **cell** and performs the cell update procedures when changing the cell

Hierarchical cell structure: pico/micro/macro cells, resulting in differentiated data rates (144kbps, 384kbps, 2Mbps)

See you next time



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