Cellular Networks

Mobile cellular networks

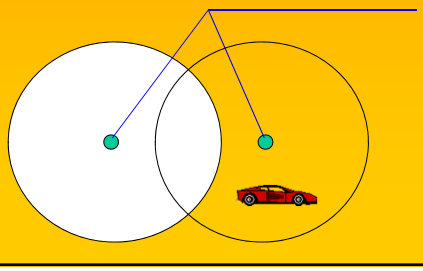
GSM to 5G

Wireless cellular network

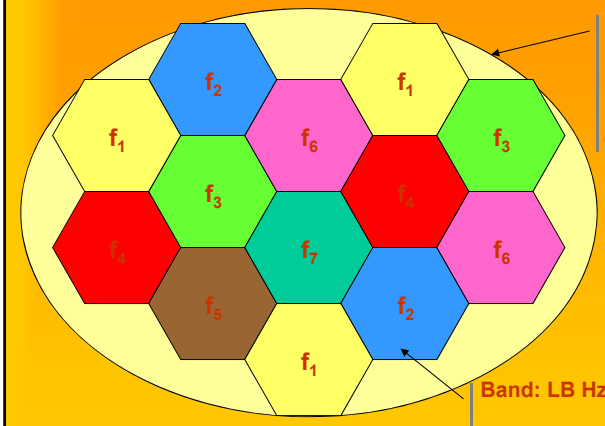
Single hop widespread wireless connectivity to the wired world

- **Usually space divided into cells, and MTs assigned to a cell**
- **A base station is responsible for communicating with MTs in its cell – typical communication: a voice call.**
- **Handoff occurs when a MT starts communicating via a new base station, while busy on a call**
- **Battery drain low.**

Cell size:
-Highly variable
-Technology dependent
-Varies with number of users



Cells and spectrum efficiency

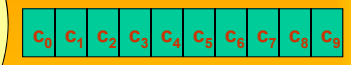


Band: LB Hz

LB → k sub-bands (f_1, …, f_k)

1 sub-band → n channels (TDMA)

Capacity = k×n channels
(7×10 =70 channels)



Band: LB Hz (the same)

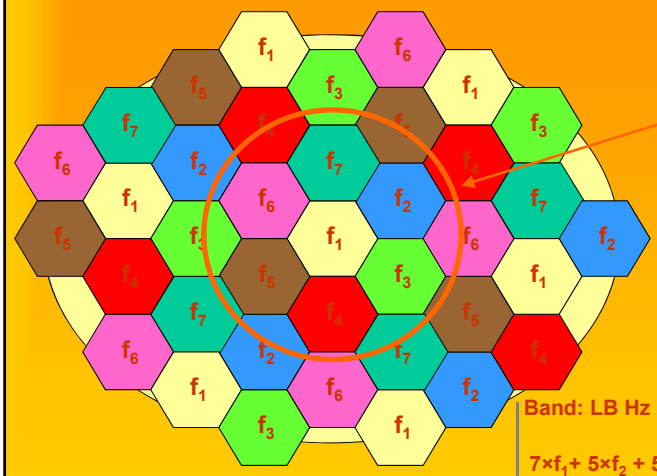
sub-bands:

$3\times f_1 + 2\times f_2 + 2\times f_3 + 2\times f_4 + 1\times f_5 + 2\times f_6 + 1\times f_7$

=13 sub-bands

Capacity = 13×10 = 130 channels!

Cells and spectrum efficiency



Smaller cells = higher network capacity

Cluster

Re-use factor: 7

Band: LB Hz (still the same)

sub-bands:

$7\times f_1 + 5\times f_2 + 5\times f_3 + 5\times f_4 + 5\times f_5 + 6\times f_6 + 5\times f_7$

=38 sub-bands

Capacity = 38×10 = 380 channels

5

Cell: Pros/Cons

Advantages:

- > capacity
- > # users
- < power
- > Reliability (distributed system)

Disadvantages

- Needs interconnection network between cells
- Needs to support Handovers!
- Needs to handle inter-cell interference!

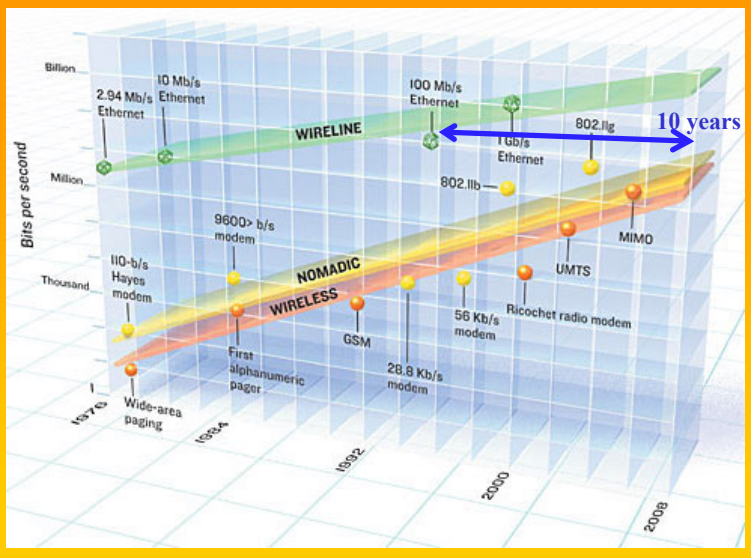
Fundamental:

Each cell handles interferences, coverage areas, etc… *locally*

- Cell planning
- Cell size
- Frequency/code usage
- Channels (logical/physical) reservation

6

Edholm's Law



Shannon, Isenberg & Cooper

Shannon's Law

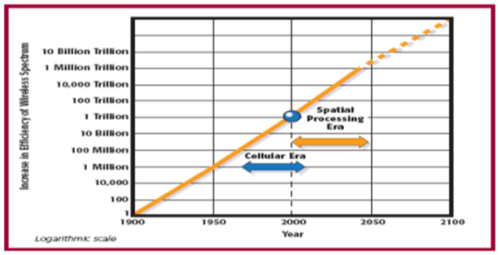
- There *is* a limit to capacity
- … and we are getting close to it
- Best way to increase capacity is shrink cells
  - Shorter range, improves C/I
  - Improves capacity & quality

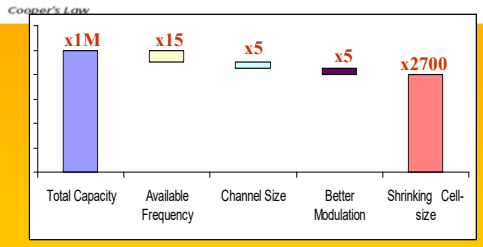
Isenberg

- "The rise of the stupid network"
- Push intelligence out to the edge

Cooper's Law

- Capacity of wireless has doubled every 30 months for the past 105 years.
- The gains come from a range of sources, but most significant is the reuse of frequencies in smaller and smaller cells.





"Since 1950 wireless capacity has increased 1 million fold; the primary factor in this is the move to many, smaller, cells"

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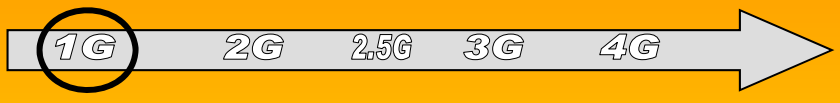
Evolution of Mobile Wireless

Advance Mobile Phone Service (AMPS)
- FDMA
- 824-849 MHz (UL), 869-894 MHz (DL)
- U.S. (1983), So. America, Australia, China



European Total Access Communication System (E-TACS)
- FDMA
- 872-905 MHz (UL), 917-950 MHz (DL)
- Deployed throughout Europe

1st Mobile services
Frequency shift keying; FDMA for spectrum sharing

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Evolution of Mobile Wireless

Global System for Mobile communications (GSM)

- TDMA
- Different frequency bands for cellular and PCS
- Developed in 1990, expected >1B subscriber by end of 2003

IS-95

- CDMA
- 800/1900 MHz – Cellular/PCS
- U.S., Europe, Asia

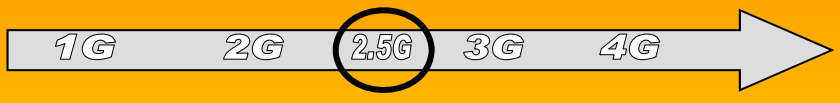
TDMA/CDMA for spectrum sharing; Circuit switching, primary voice
<56kbps data rates

11

Evolution of Mobile Wireless

General Packet Radio Services (GPRS)

- Introduces packet switched data services for GSM
- Transmission rate up to 170 kbps
- Some support for QoS



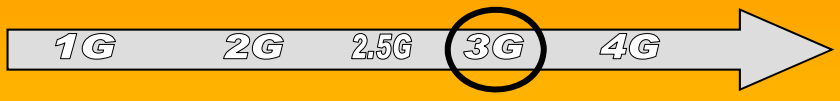
Enhanced Data rates for GSM Evolution (EDGE)

- Circuit-switched voice (at up to 43.5 kbps/slot)
- Packet-switched data (at up to 59.2 kbps/slot)
- Can achieve on the order of 475 kbps on the downlink, by combining multiple slots

Digital: GSM to GPRS; Analog: AMPS to CDPD
Higher data rates (<192kbps), bridge to 3G

Evolution of Mobile Wireless

Universal Mobile Telecommunication Systems (UMTS)
- Wideband DS-CDMA
- Bandwidth-on-demand, up to 2 Mbps
- Supports handoff from GSM/GPRS



IS2000
- CDMA2000: Multicarrier DS-CDMA
- Bandwidth on demand (different flavors, up to a few Mbps)
- Supports handoff from/to IS-95

High speed, seamless integration of voice and data (Internet) services
< 7 Mbps data rates, packet switching

First-Generation Analog

- **Advanced Mobile Phone Service (AMPS)**
  - **In North America, two 25-MHz bands allocated to AMPS**
    - One for transmission from base to mobile unit
    - One for transmission from mobile unit to base
  - **Each band split in two to encourage competition**
  - **Frequency reuse exploited**
- **AMPS Operation**
  - **Subscriber initiates call by keying in phone number and presses send key**
  - **Network verifies number and authorizes user**
  - **Network issues message to user's cell phone indicating send and receive traffic channels**
  - **Network sends ringing signal to called party**
  - **Party answers; network establishes circuit and initiates billing information**
  - **Either party hangs up; network releases circuit, frees channels, completes billing**

Differences Between First and Second Generation Systems

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

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2nd Generation: GSM

- **Defined by CEPT/ETSI**
- **Requirements in terms of:**
  - **Services** — **Portability, =PSTN**
  - **QoS** — **= PSTN**
  - **Security** — **Low cost cipher**
  - **RF Usage** — **Efficiency**
  - **Network** — **Numbering ITU-T, SS-7**
  - **Cost** — **Low**

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Basic Architecture

- Defines cells
- Defines a Mobile Terminal

  MobileEquipment+ SubscriberIdentityModule

  (etc…; e.g. International Mobile Station Equipment Identity (IMEI))
- Uses a Network Subsystem

  MSC; HLR, VLR
- Uses a Radio Subsystem

  BSS; BTransceiverS, BSController
- Defines a Operation Support Subsystem

  (security)

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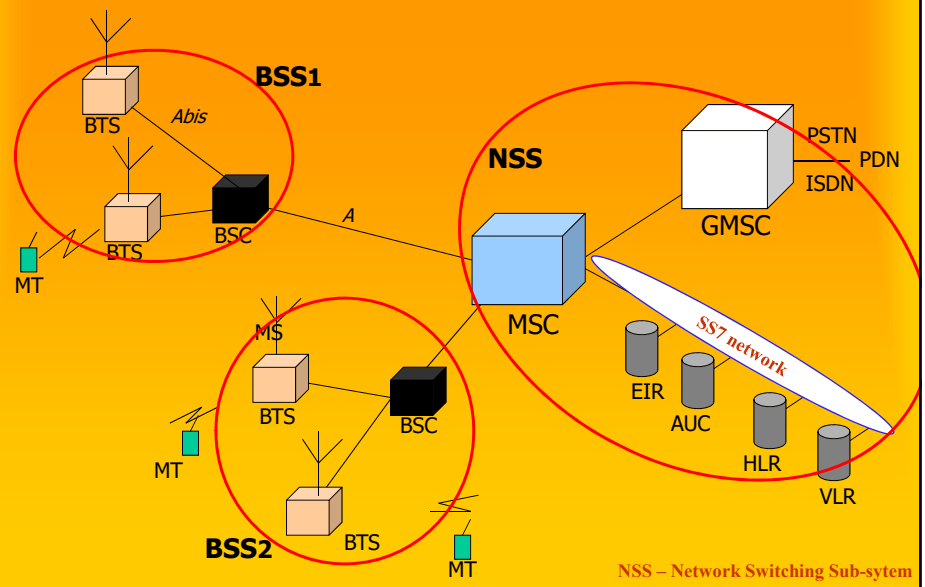
Basic Architecture

- Each cell is controlled by a base station (BS)
- The Base Station Subsystem (BSS) is structure as base station controllers (BSC) + base transceiver station (BTS)
- BSCs are connected to the mobile switching center (MSC) through physical lines
- MSCs are interconnected to each other
- There are MSCs connected to the public network (PSTN), the gateway mobile switching center (GMSC).

GSM Architecture



NSS – Network Switching Sub-sytem
BSS – Base Station Sub-system

Mobile Switching Center

- **MSC = local switching center**
  Contains:
  - Home Location Register (HLR)
  - Visitor Location Register (VLR)
  - Autentication Center (Au)
  - Equipment Identity Registry (EIR)
- **Connects the BSS (base station subsystem)**
  (Master of the cell, define channels and access to them...)
- **Contains the registers for "their" mobile terminals**
- **Specific signalling channels**
  - **MT-BS (MSC): location, call setup, received call answer**
  - **BS (MSC)-MT: cell identification, location update, received call setup**

Network Subsystem DBs

- **HLR - Home Location Register**
  - **maintains permanent information about the subscribers of a GSM network (subscriber record)**
    - Subscription data: IMSI, MSISDN, subscription type (restrictions, supplementary services, ...)
  - **tracks the location and state of the mobile terminal within the network**
    - Location information: mobile VLR number.
- **VLR - Visitor Location Register**
  - **maintains temporary information about the subscribers registered on a GSM network (including subscribers in roaming)**
    - Data: IMSI, MSISDN, TMSI, MSRN, subscription type, location area, ...
  - **keeps up-to-date information about the location of the user within the network**

Network Subsystem DBs

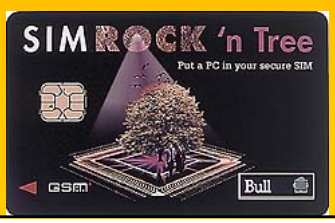
- **AuC – Authentication Center**
  - **service responsible for the authentication of the subscribers**
  - **maintains the encryption algorithms**
  - **maintains the secret key (k_i) for each subscriber**
  - **generates the session keys**
- **EiR – Equipment Identity Register**
  - **provides security mechanisms for the mobile equipments**
  - **keeps lists of mobile equipments**
    - white list (authorized)
    - gray list (under "observation")
    - black list (blocked)

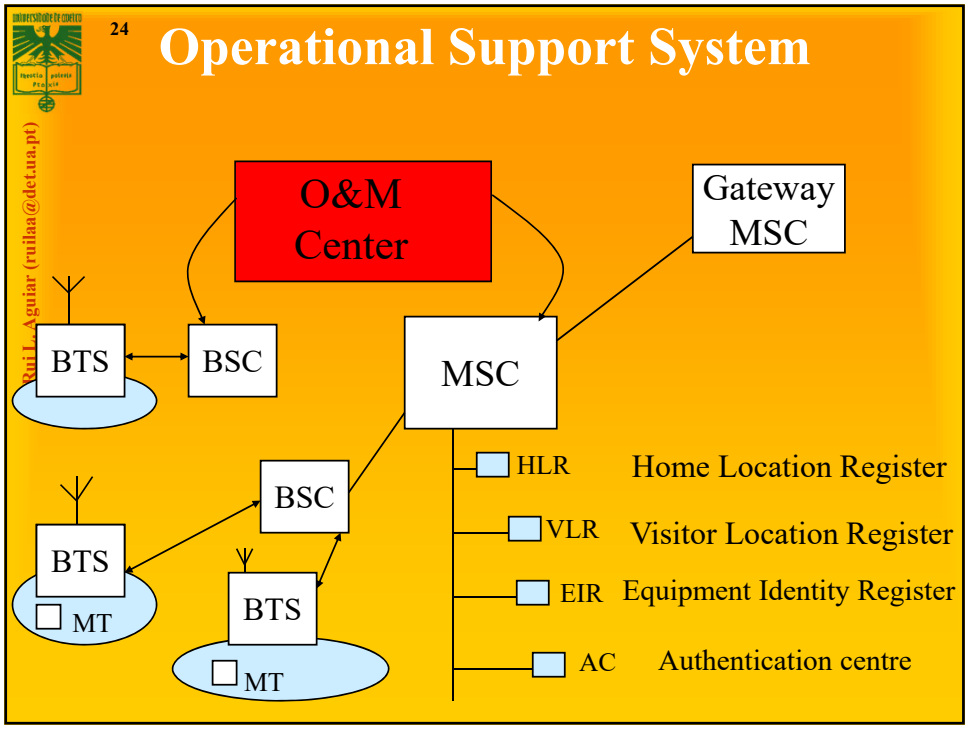
Mobile Station

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

SIM: Suscriber Identity Module

- *Informations*:
  - **subscriber identity, password (PIN), subscription information (authorized networks, call restrictions, …), security algorithms, short numbers, last received/dialed numbers, last visited location area, ...**
- **SIM card + GSM terminal = access to GSM services.**




24
Operational Support System
O&M Center
Gateway MSC
BTS
BSC
MSC
BSC
BTS
MT
BTS
MT
HLR
Home Location Register
VLR
Visitor Location Register
EIR
Equipment Identity Register
AC
Authentication centre
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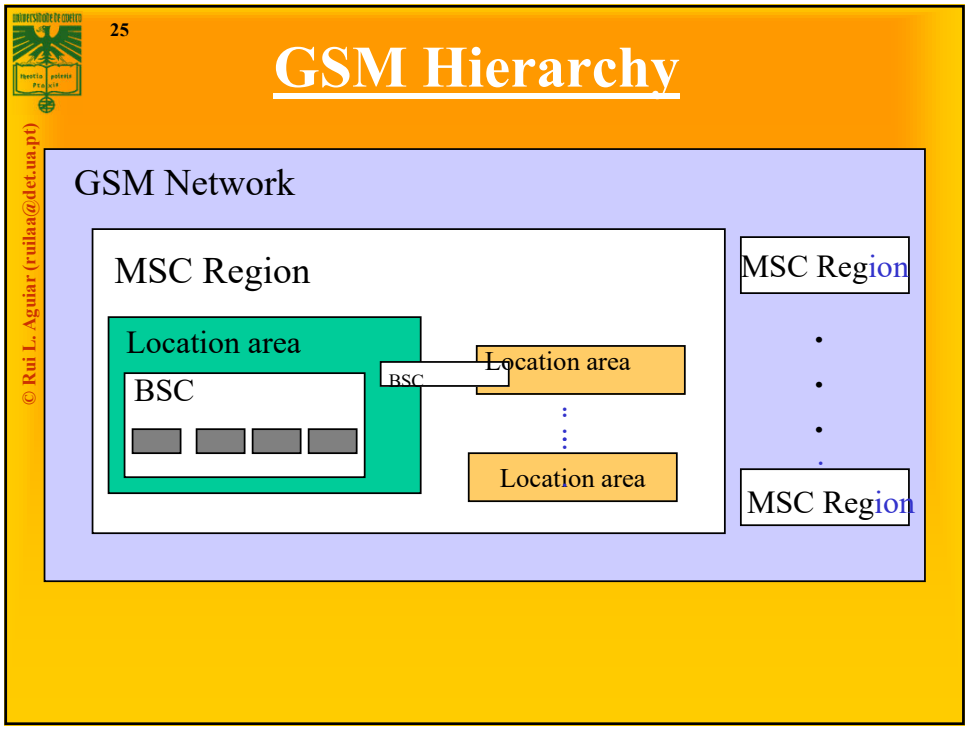
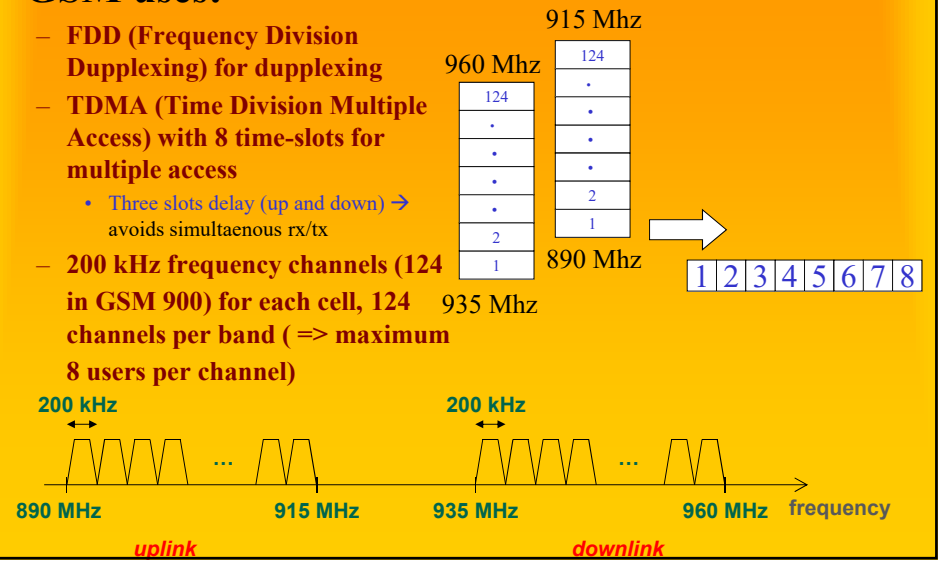

25
GSM Hierarchy
GSM Network
MSC Region
Location area
BSC
BSC
Location area
Location area
MSC Region
MSC Region
© Rui L. Aguiar (ruilaa@det.ua.pt)

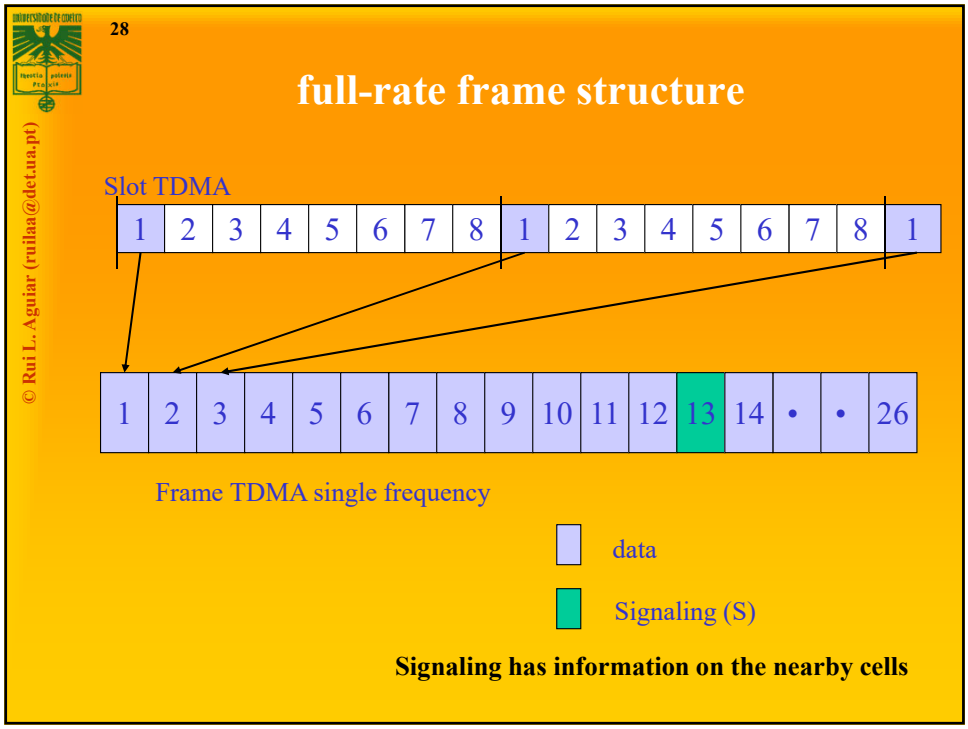
Air interface (Um) – channel allocation

- **GSM uses:**
  - **FDD (Frequency Division Dupplexing) for dupplexing**
  - **TDMA (Time Division Multiple Access) with 8 time-slots for multiple access**
    - Three slots delay (up and down) → avoids simultaenous rx/tx
  - **200 kHz frequency channels (124 in GSM 900) for each cell, 124 channels per band (=> maximum 8 users per channel)**



Logical channels

- **Logical channels are mapped in physical channels**
- **Physical channel is a timeslot, in a given frequency.**
- **Data channels:**
  - **TCH/FS - *full-rate speech* (13 kbps)**
  - **TCH/HS - *half-rate speech* (6,5 kbps)**
  - **TCH/F9.6 - *9.6 kbps full rate data***
  - **TCH/F4.8 – *4.8 kbps full rate data***
- **Signaling channels**
  - **BCH – Broadcast channels**
  - **CCH – common control channels**
  - **DCCH/ACCH – dedicated/associated control channels**


28
full-rate frame structure
Slot TDMA
1 2 3 4 5 6 7 8 1 2 3 4 5 6 7 8 1
1 2 3 4 5 6 7 8 9 10 11 12 13 14 • • 26
Frame TDMA single frequency
data
Signaling (S)
Signaling has information on the nearby cells
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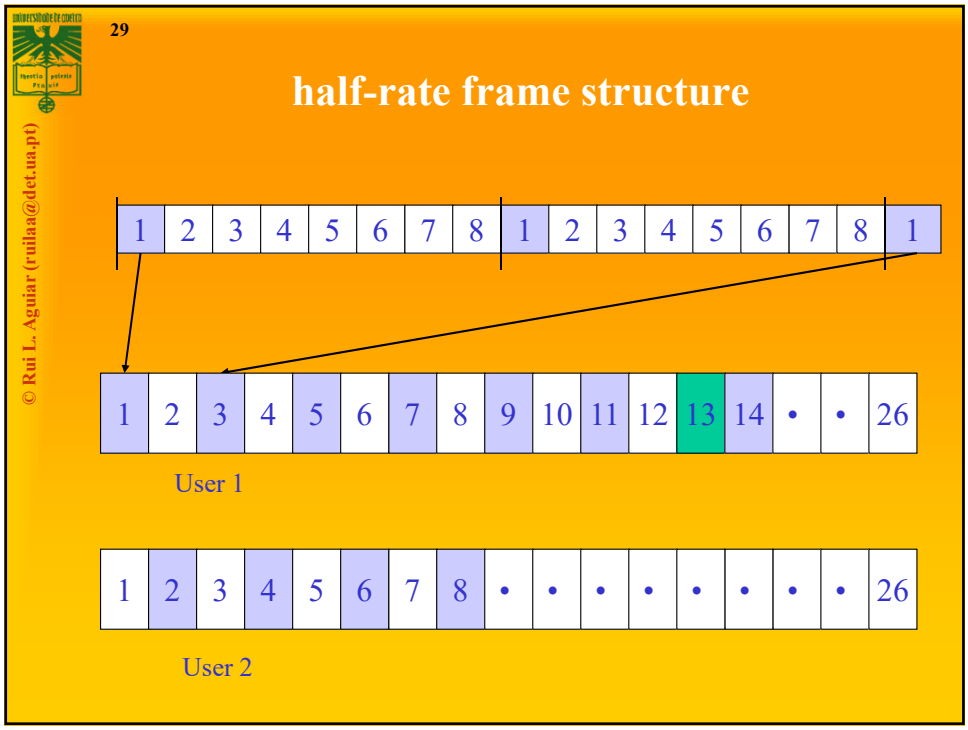
29
half-rate frame structure
1 2 3 4 5 6 7 8 1 2 3 4 5 6 7 8 1
1 2 3 4 5 6 7 8 9 10 11 12 13 14 • • 26
User 1
1 2 3 4 5 6 7 8 • • • • • • • • 26
User 2
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Control channels

Used for:

- **Synchronizing MT with the cell**
- **Informing the MT about**
  - Cell parameters
  - Nearby cells
  - Channel information
- **Support paging**
  - Search for the MT when in low power mode
- **Allows the MT to access the network**
  - Shared (contention) access
  - Essential for the MT to request connections

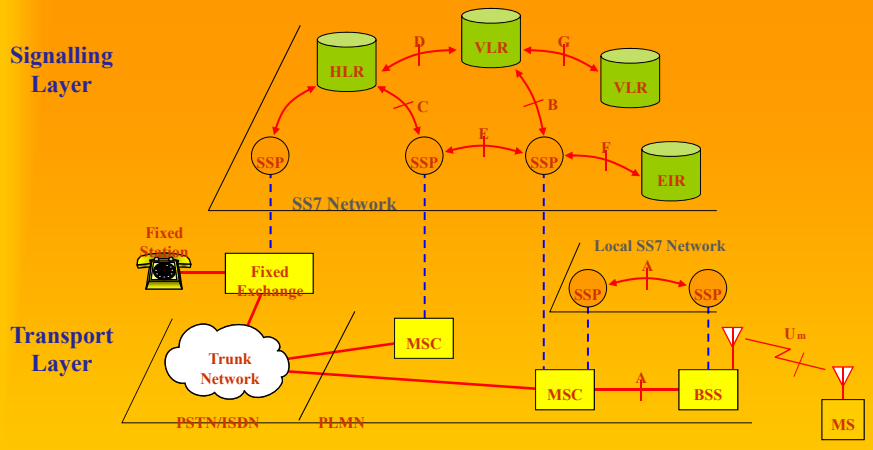
Signalling Channels

BCH :
- Broadcast Control Channel (BCCH)
- Frequency Correction Channel (FCCH)
- Synchronization Channel (SCH)

CCH :
- Random Access Channel (RACH)
- Paging Channel (PCH)

D/ACCH
- Stand-alone Dedicated Control Channel (SDCCH)
- Slow Associated Control Channel (SACCH)

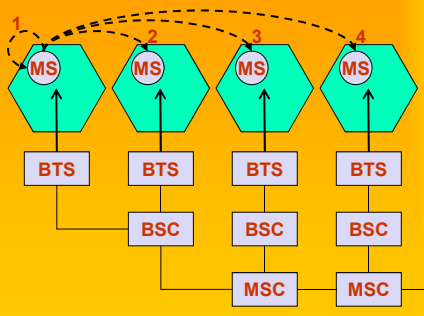
GSM Signalling and Transport Layers



MSC - Mobile Services Switching Centre
BSS - Base Station System
HLR - Home Location Register
VLR - Visitor Location Register
EIR - Equipment Identity Register
MS - Mobile Station
SSP - Service Signalling Point in SS7 Network

Types of handover (GSM)

1. **Intra-cell: from a channel to another within the same cell**
2. **Inter-cell, Intra-BSC: from a channel in one cell to a channel in another cell, both controlled by the same BSC**
3. **Inter-BSC, Intra-MSC: from a channel in one cell to a channel in another cell, controlled by different BSCs, under the same MSC control**
4. **Inter-MSC: from a channel in one cell to a channel in another cell connected to different MSCs**



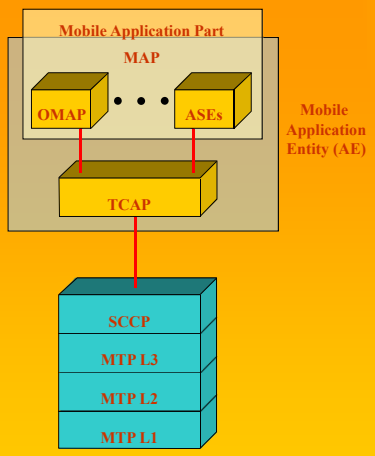
Functions Provided by Higher Protocols

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

Mobile Application Part (MAP)

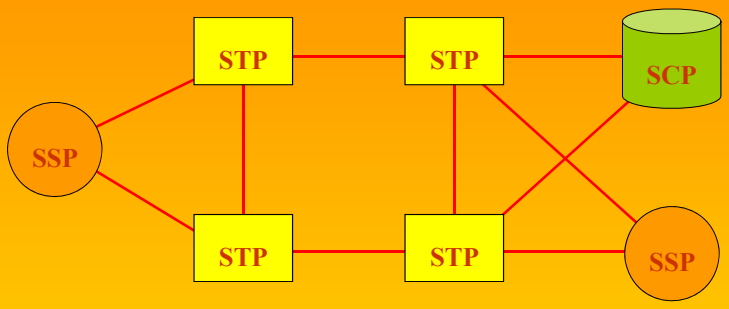
Information transfer between GSM PLMN entities uses the Mobile Application Part (MAP) of SS7.

- **Location registration and cancellation**
- **Handover procedures**
- **Handling of supplementary services**
- **Retrieval of subscriber parameters during call set-up**
- **Authentication procedures**
- **OA&M**



Signalling System 7 (SS7)

SSP - Service Signalling Point
STP - Signal Transfer Point
SCP - Service Control Point



SS7 is a set of protocols governing mainly the transfer of call control information over a signalling network.
This signalling network is a packet switching network.

The SS7 Architecture

OMAP - Operations Maintenance and Administration Part

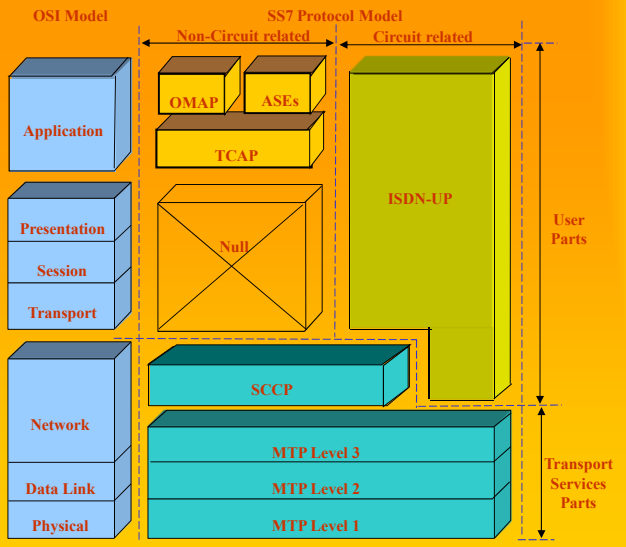
ASE - Application Service Element

TCAP - Transaction Capabilities Application Part

ISDN-UP - ISDN User Part

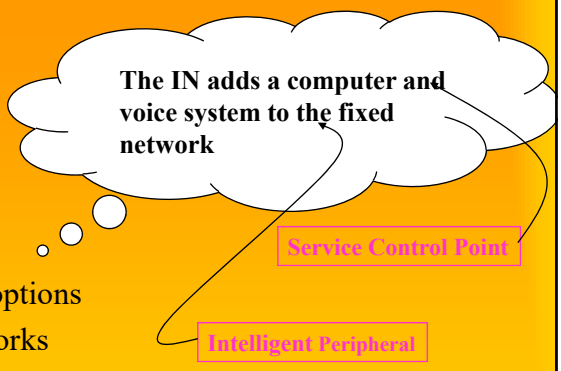
SCCP - Signalling Connection Control Part

MTP - Message Transfer Part

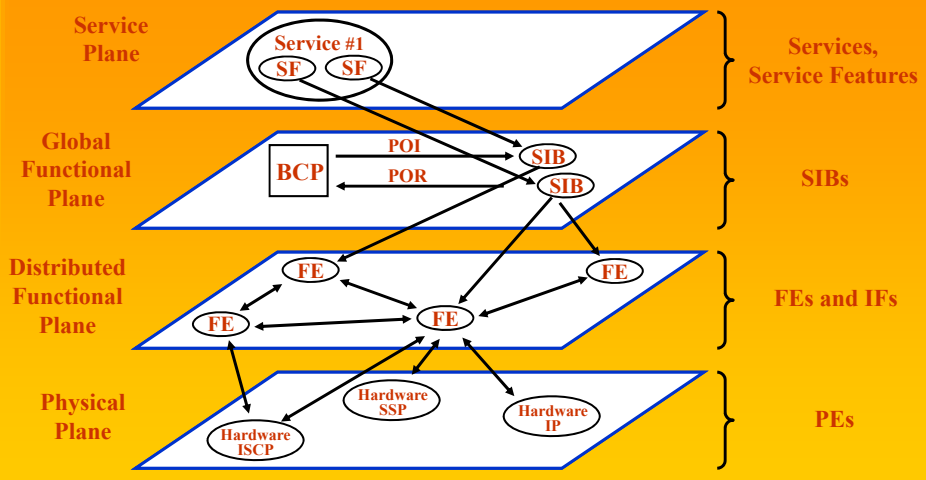


The Intelligent Network

- **Charging options**
  - **Freephone**
  - **Local rates**
  - **Premium rates**
- **Routing options**
  - **Group calls**
    - Network call centre options
    - Virtual Private Networks
  - **Personal calls**
    - one number
    - configurable routing



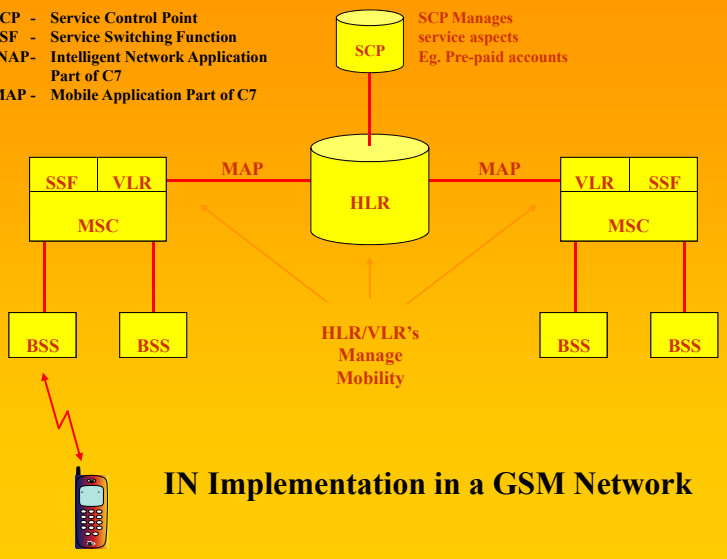
Intelligent Network Conceptual Model



PoI - Point of initiation
PoR – Point of Return
SIB Service Independent Block
BCP – Basic Call Processing

Intelligent Networks - CAMEL

SCP - Service Control Point
SSF - Service Switching Function
INAP- Intelligent Network Application Part of C7
MAP - Mobile Application Part of C7



IN Implementation in a GSM Network

Short Message Service - SMS

- **supports the transmission of messages up to 160[1] characters, between mobile terminals**
- **messages are transmitted through the signaling channels**
- **is used for a variety of applications:**
  - **text messages between users (very popular)**
  - **broadcast of information by the network operator (e.g. promotions)**
  - **broadcast of location-dependent information (e.g. local restaurants)**
  - **access to computing applications (e.g. home banking and e-mail)**
  - **configuration of mobile terminals over the air**

1 – When using (7 bits/charater); only 70 caracteres wehn using other codes (8 bits).

SIM Toolkit

Principle: **The SIM card can initiate actions on the terminal.**

Objectives: **Allow exchanges between the network and the SIM through SMSs (without displaying them)**

➲ **Value-added services provision.**

Examples:

- *Reservation* in a restaurant (send a menu by the network, manages user choices and the SIM card sends back the reservation in an SMS).

- *Menus management* (kiosk services).

GPRS

- **Packet-oriented transport service, for data network connections (Internet). GPRS features:**
  - **Better transmission bit rates(max 150kbps).**
  - **Allows burst communications ("immediate": connections in <1s)**
  - **New network applications**
  - **New billing mechanisms (user-oriented: by traffic, p.ex.)**

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GPRS Architecture

- New entities are defined
  - SGSN – serving GPRS support node
  - GGSN – gateway GPRS support node
  - Interfaces between entities GPRS, GSM, core, e PSTN
- Transmission plane
  - Data packets are transmitted by a tunnel mechanisms
- Control plane
  - GTP: a protocol for tunnel management (create, remove, etc..)
- Radio interface
  - Changed the logical channels and how they are managed
  - Remains the concept of "master-slave"

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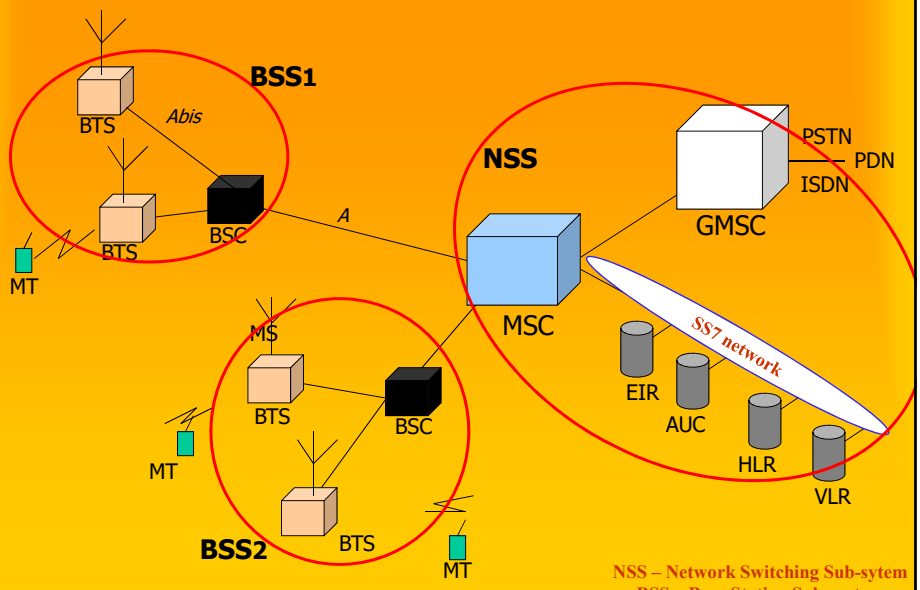
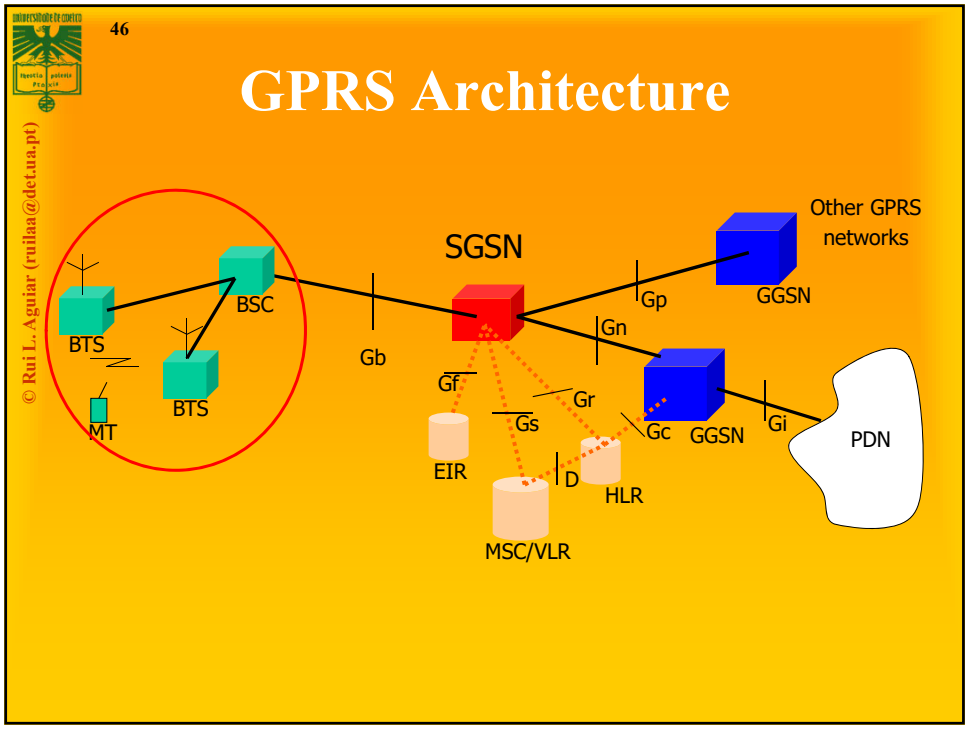
GSM Architecture



NSS – Network Switching Sub-sytem
BSS – Base Station Sub-system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GPRS Architecture
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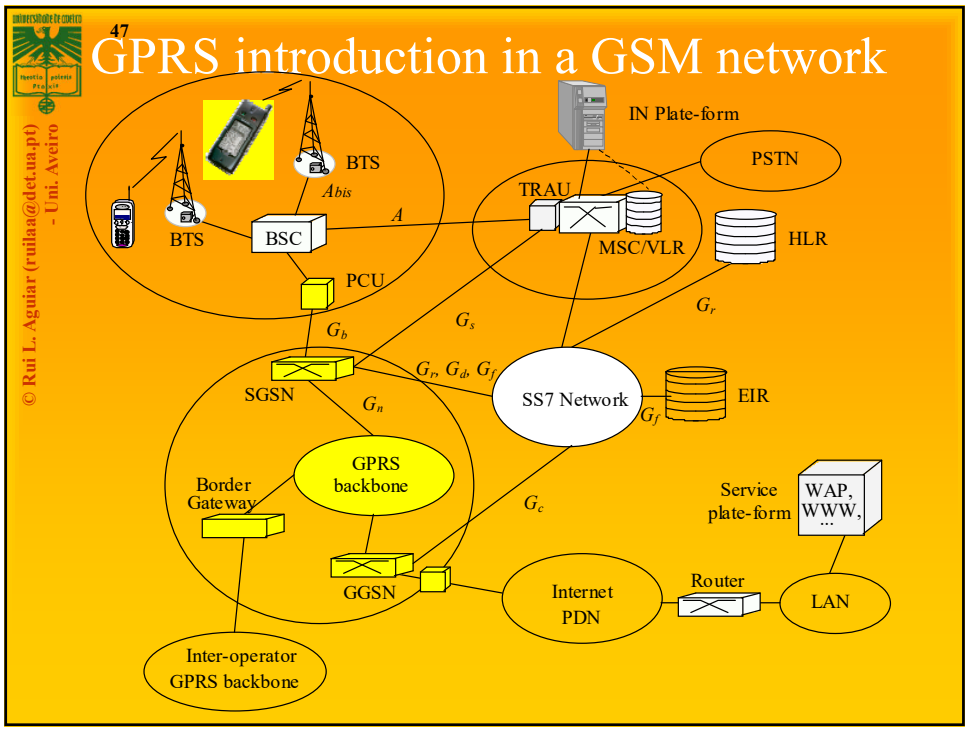
BTS
BSC
BTS
MT
Gb
SGSN
Gf
Gr
Gs
EIR
D
HLR
MSC/VLR
Gp
Gn
GGSN
Other GPRS networks
Gc
GGSN
Gi
PDN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GPRS introduction in a GSM network
© Rui L. Aguiar (ruilaa@det.ua.pt) - Uni. Aveiro
BTS
Abis
BTS
BSC
A
PCU
IN Plate-form
PSTN
TRAU
MSC/VLR
HLR
Gb
Gs
Gr
SGSN
Gn
Gp, Gd, Gf
SS7 Network
EIR
Gf
GPRS backbone
Border Gateway
Gc
Service plate-form
WAP, WWW, ...
GGSN
Internet PDN
Router
LAN
Inter-operator GPRS backbone

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GGSN (*Gateway GPRS Support Node*) Functions

- ***Gateway:***
  - **Allows the connection to other IP or GPRS networks.**
- ***Routing*:**
  - **IP router which supports dynamic or static routing,**
- ***Mobility management:***
  - **Use of *routing areas*.**
  - **Handover management between the BSCs and other SGSNs.**
  - **Allows the routing of the packets towards the users SGSNs, according to their mobility.**
- ***Sessions management:***
  - **At each session, the SGSN activates a PDP (*Packet Data Protocol*) context, and allocates an IP address to the MT.**

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GGSN (*Gateway GPRS Support Node*) Functions

- ***Security:***
  - **Ciphers the communications towards or from the mobiles.**
  - **Includes firewalls for filtering the packets coming from external IP networks.**
- ***Authentication:***
  - **At *Attach* and inter-SGSN RA updates.**
- ***Billing:***
  - **Production of the CDRs according to the quantity of information and the session duration (attachment, duration of active PDP context).**
- ***SMS:***
  - **Supports the Gd interface for the communications with the SMS-GMSC and the SMS-IWMSC.**

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Connection management

After attach: receive a packet with a PDP identifier

- **Acts as an address**

PDP identifier: per session.

- static: allocated by the MT home networks
- Dinamic: allocated by the GGSN

PDP profile:

- **Type**
- **PDP identifier**
- **Requested QoS**
- **correspondent GGSN address**

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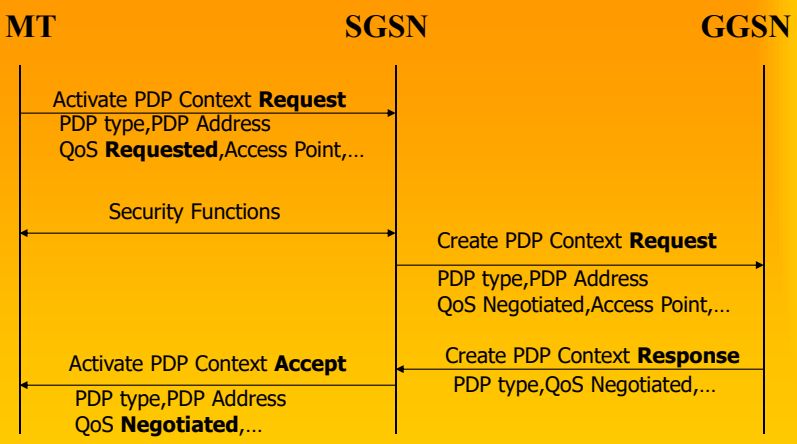
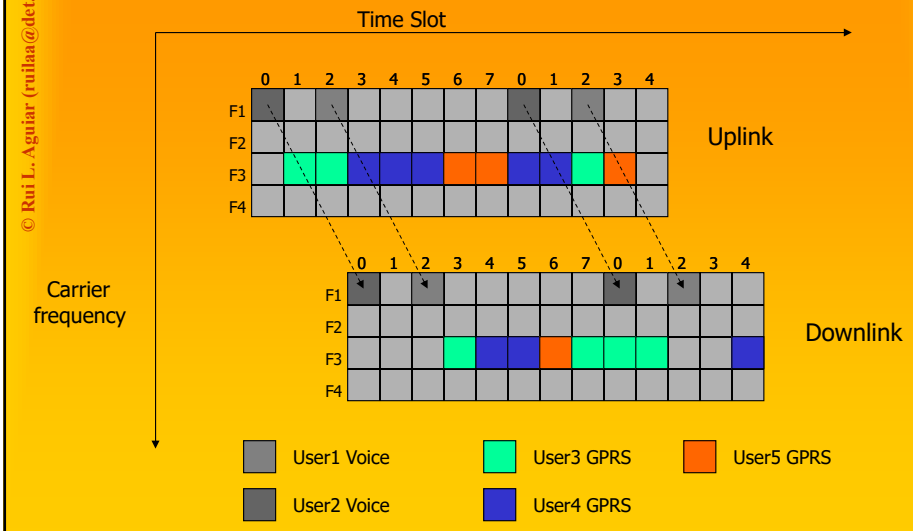
PDP context activation

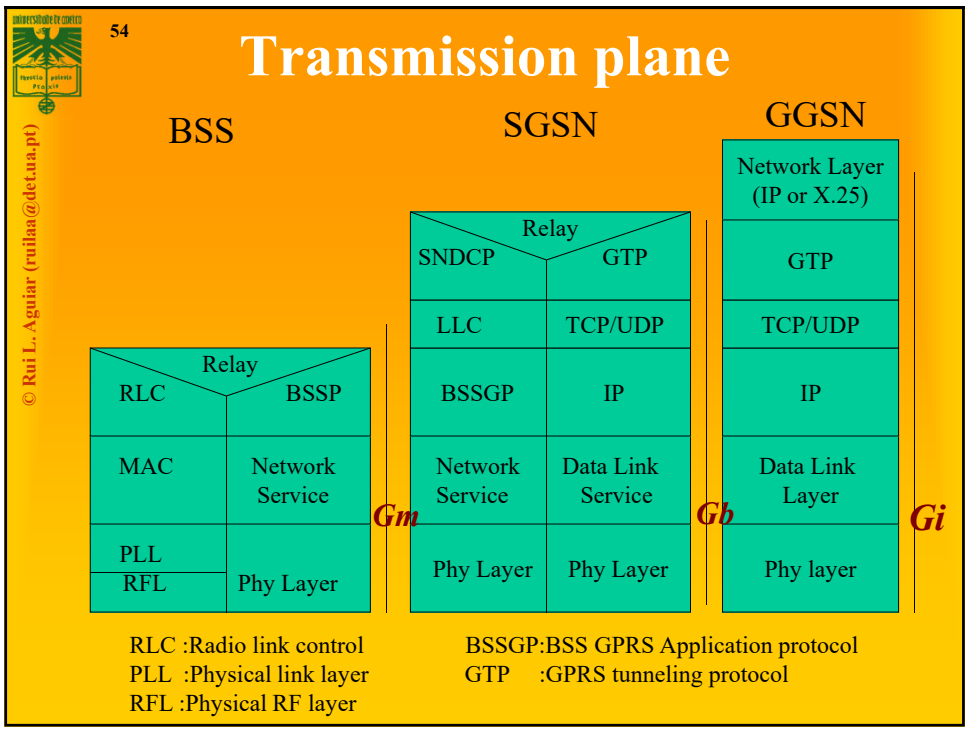


GPRS Radio Interface



GPRS: logical channels

Group	Channel	Function	Direction
Packet data Traffic channel	PDTCH	Data Traffic	MS ↔ BSS
Packet broadcast control channel	PBCCH	Broadcast Control	MS ← BSS
Packet common Control Channel (PCCCH)	PRACH	Random Access	MS → BSS
	PAGCH	Access Grant	MS ← BSS
	PPCH	Paging	MS ← BSS
	PNCH	Notification	MS ← BSS
Packet Dedicated Control Channels	PACCH	Associated Control	MS ↔ BSS
	PTCCH	Timing Advance Control	MS ↔ BSS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Transmission plane
BSS
SGSN
GGSN
Relay
RLC
BSSP
MAC
Network Service
PLL
RFL
Phy Layer
Gm
Relay
SNDCP
GTP
LLC
TCP/UDP
BSSGP
IP
Network Service
Data Link Service
Phy Layer
Phy Layer
Gb
Network Layer (IP or X.25)
GTP
TCP/UDP
IP
Data Link Layer
Phy layer
Gi
RLC :Radio link control
PLL :Physical link layer
RFL :Physical RF layer
BSSGP:BSS GPRS Application protocol
GTP :GPRS tunneling protocol
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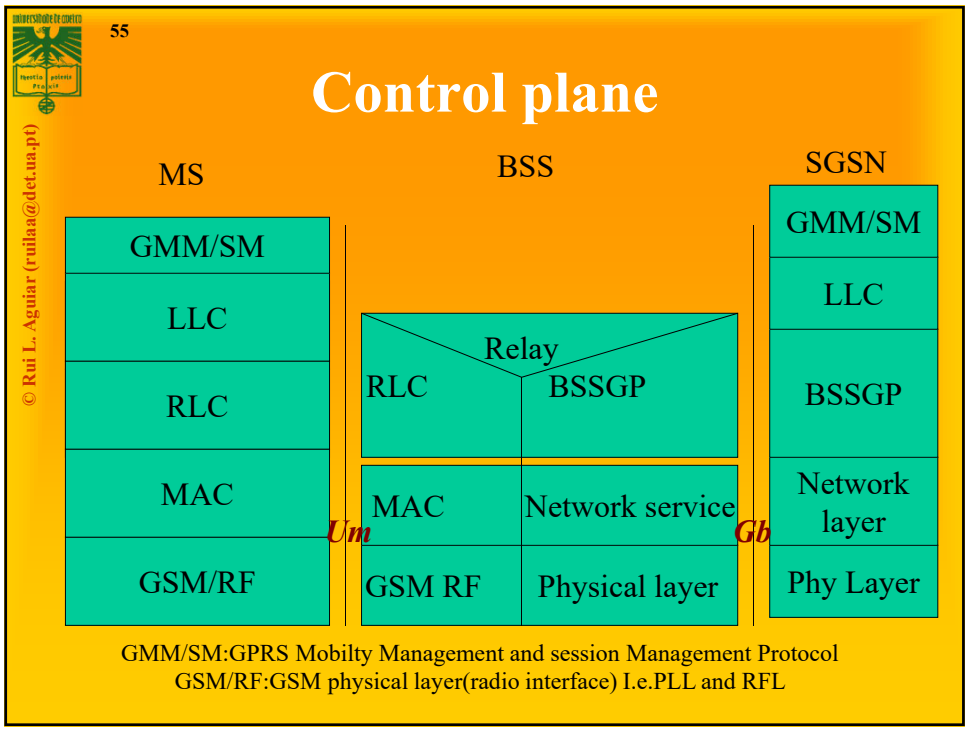
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Control plane
MS
BSS
SGSN
GMM/SM
LLC
RLC
MAC
GSM/RF
Um
Relay
RLC
BSSGP
MAC
Network service
GSM RF
Physical layer
Gb
GMM/SM
LLC
BSSGP
Network layer
Phy Layer
GMM/SM:GPRS Mobilty Management and session Management Protocol
GSM/RF:GSM physical layer(radio interface) I.e.PLL and RFL
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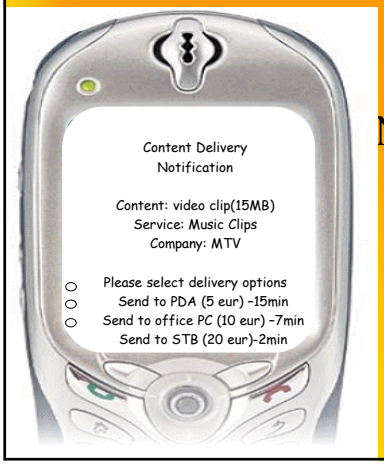
UMTS



New idea for new technology

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UMTS Abbreviations

AAL2 ATM adaptation layer 2
ANSI American National Standards Institute
ARIB Association of radio industries and businesses
ASN.1 Abstract Syntax Notation One
ATM Asynchronous transfer mode
BER Bit error rate
BS Base station
BSAP Base Station application part
BSC Base station controller
BSSGP Base Station Sub-System GPRS Protocol
CC Call control
cdma code division multiple access
CDPD Cellular Digital Packet Data
CN Core network
CS Circuit switched
CSCF Call services control function
EDGE Enhanced data rates for GSM evolution
ETSI European Telecommunication standardisation institute
FDD Frequencey division duplex
GERAN Global system for mobile communications enhanced data rates for GSM evolution radio access network
GGSN Gateway GPRS support node
GMM GPRS MM
GMSC Gateway MSC
GPRS General packet access
GSM Global system for mobile communication
GTP GPRS tunneling protocol
HLR Home location register
HSCSD High speed circuit switched data
HSS Home subscriber server
IETF Internet engineering task force
IM Internet multimedia
IP Internet protocol
ISDN Integrated services digital network
ITU International telecommunications union
LLC Link layer control
MAC Medium access control
MAP Mobile application part
MM Mobility management
MGCF Media gateway control function
MGW Media gateway
MSC Mobile services switching center
MMS Multimedia messaging
OSA Open services architecture
P-CSCF Proxy-CSCF
PDC Personal digital communication
PDCP Packet data convergence protocol
PDP Packet data protocol
PHB Per hop behaviour
PLMN Public land mobile network
PS Packet switched
PSTN Public switched telephony network
RAN Radio access network
RANAP RAN application part
RF Radio frequency
RLC Radio link control
RNC Radio network controller
RRC Radio resource control
RSVP Resource reservation protocol
SCP Services control point
SA Services and System Aspects
SDL Specification and description language
SDU Serving data unit
SGSN Serving GPRS support node
SGW Signalling gateway
SM Session managament
SMG Special mobile group
SNDCP Sub-network dependent convergence protocol
T Terminal
TD-CDMA Time division-CDMA
TDD Time division duplex
TDMA Time division multiple access
TFT Traffic flow template
TIA Telecommunications industry association
UMTS Universal mobile telecommunication system
UWCC Universal wireless communications consortium
UTRAN UMTS terrestrial RAN
VHE Virtual home environment
VLR Visitor location register
VoIP Voice over IP
WAP Wireless application protocol
WLAN Wireless local area network
WCDMA Wideband CDMA
3GPP 3rd generation partnership project
3GPP2 3rd generation partnership project 2

What is 3GPP?

3rd Generation Partnership Project - partnership of regional SDOs

SDOs take 3GPP specifications and transpose them to regional standards. Addresses:

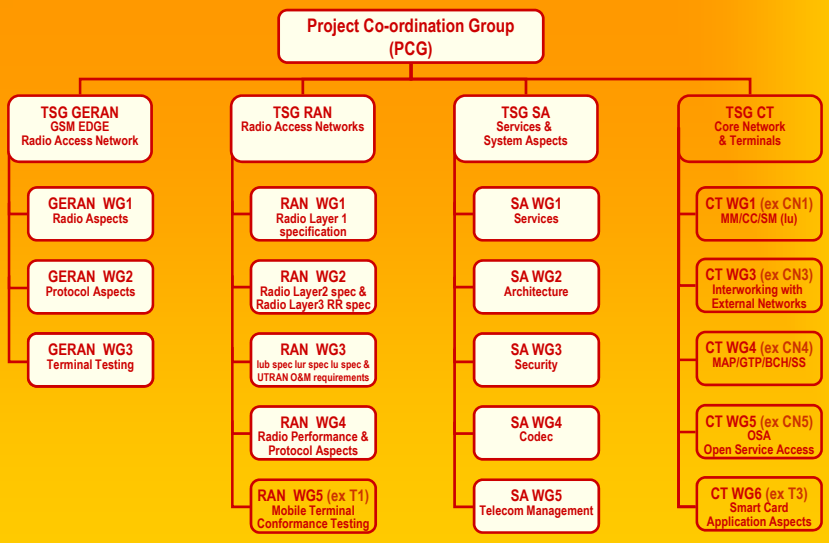
3G (IMT-2000) systems based on the evolved GSM core network and the Universal Terrestrial Radio Access (UTRA), in FDD and TDD modes;

GSM, including GSM evolved radio access technologies (GPRS/EDGE/GERAN)

ITU references the regional standards

GSM
GPRS
EDGE
W-CDMA – FDD (Frequency Division Duplex)
TD-CDMA – TDD (Time Division Duplex)

Structure of 3GPP



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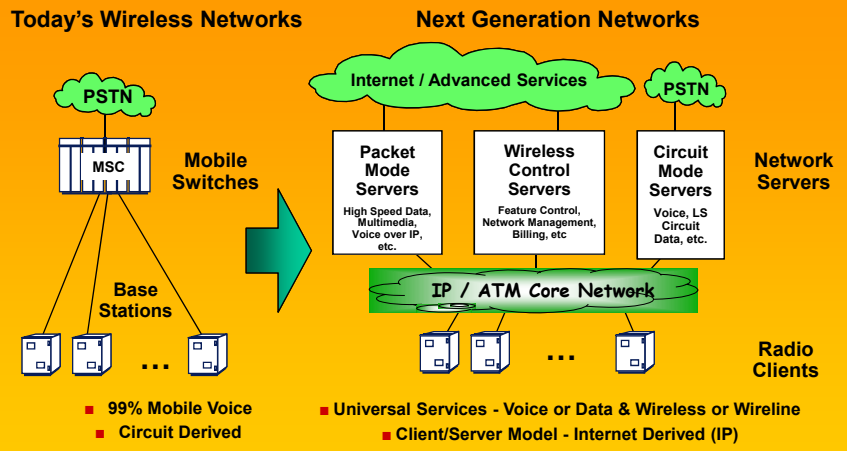
Transition to Next Generation Networks



- 99% Mobile Voice
- Circuit Derived
- Universal Services - Voice or Data & Wireless or Wireline
- Client/Server Model - Internet Derived (IP)

The next generation architecture uses Internet based client-server platforms to enable universal services and reduce network cost structure.

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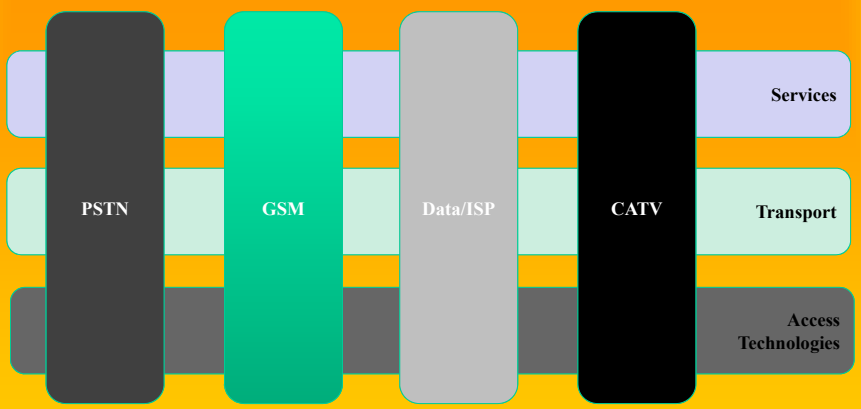
Legacy Telecom Model



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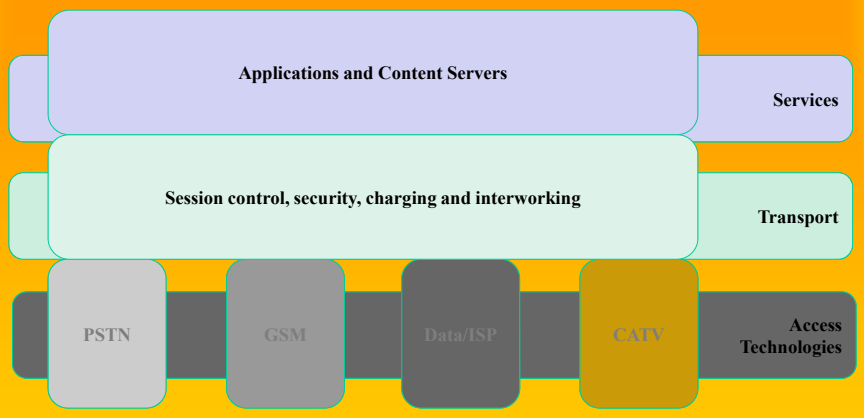
3GPP/TI-SPAN Telecom Model



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3GPP and service provision

- 3GPP is much more than radio
- It contains a full service exploitation context
  - Under consideration and evolution for telecom operators
  - Future integrated networks following from these trends
- Service support trends are not new
  - 2G systems also had their architectures (CAMEL)
  - Web brought some changes to this (hey, java, hey)
- Business models are paramount here
  - Walled garden concepts

3G: Universal Mobile Telecommunication System

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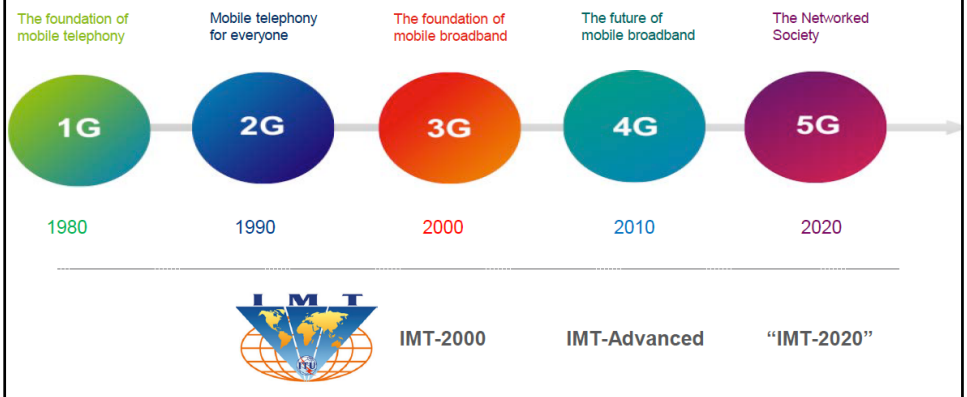
wireless access generations

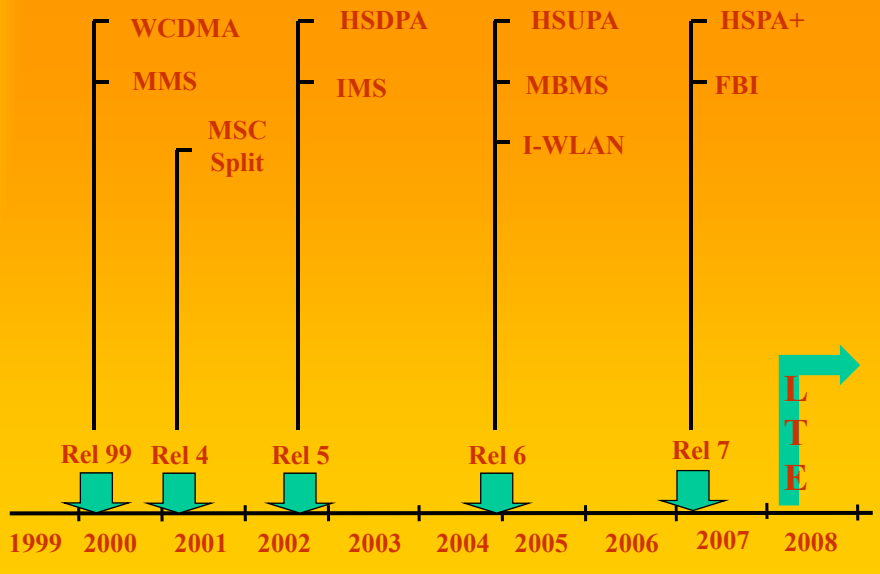
Non-limiting access to information and sharing of data anywhere and anytime for anyone and anything



UMTS

- UMTS – Universal Mobile Telecommunication System –3G system
- Oriented towards generalized service diffusion, and future user trends: combines “cellular, “wireless”, “internet”, etc…
- “multimedia everywhere”
- Developed in order to have na evolutionary path from 2.5G systems; progressive evolution (GPRS-EDGE-UMTS)

3GPP Release initial timeline: UMTS is phased



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Implications

- **Any Device**
- **Any Access Technology**
- **Any Where**

ALWAYS BEST CONNECTED

- **One Network, multiple access technologies**
- **Common Session Control**
- **Generic Application Servers**
- **Single set of services that apply network wide**
- **Consistent user experience**
- **Operational efficiency**
- **New services/applications**

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UMTS (Universal Mobile Transport Service)

Specification

- Flexible
  - **Handles multiple multimedia flows in a single connection.**
- Support to packet transport
- Flexible coding mechanisms (FDD/TDD WCDMA)
- Variable transmission rates
  - Max. 384 Kbps for global coverage (initially)
  - Max. 2Mbps for local coverage (initially)

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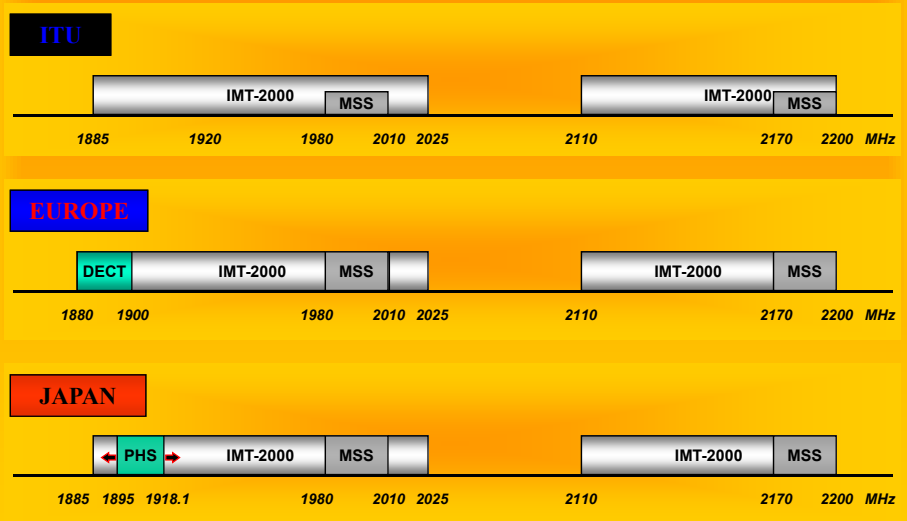
W-CDMA (Wide Band CDMA)

- **Larger capacity and coverage, keeping compatibility with 2G**
- **Supports the flexibility required, with multiple parallel connections**
- **Efficient packet access**
- **Advantages for the operator:**
  - **Interaction between asynchronous base stations (FDD)**
  - **Hierarchical cell structure**
  - **Adaptive antennas**
  - **TDD mode for asymmetric environments, and without coordination**

Spectrum usage



Multiplexing modes

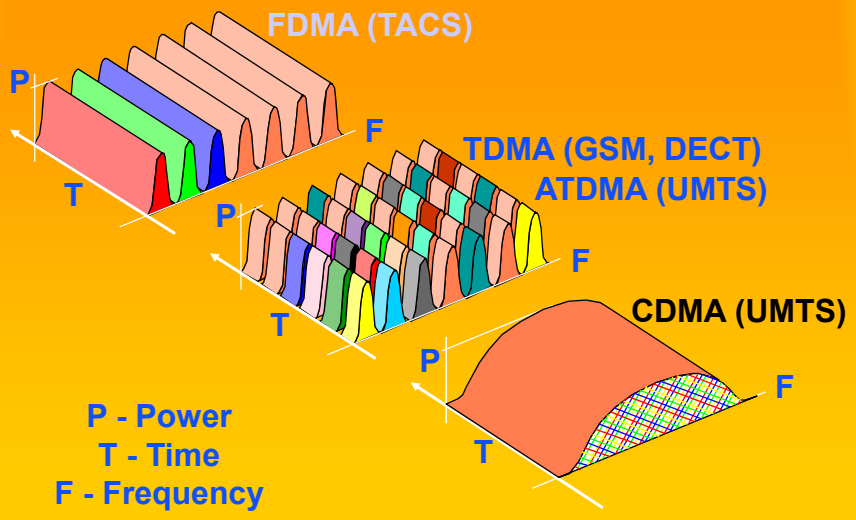
- **FDD – spectrum sharing based in the usage of different frequencies; good for symmetric services in large areas**
- **TDD – spectrum sharing based in timeslots; good for asymmetric services; require timing synchronism.**

- **Different modes licensed in different countries**
- **Different frequencies licensed for each mode**

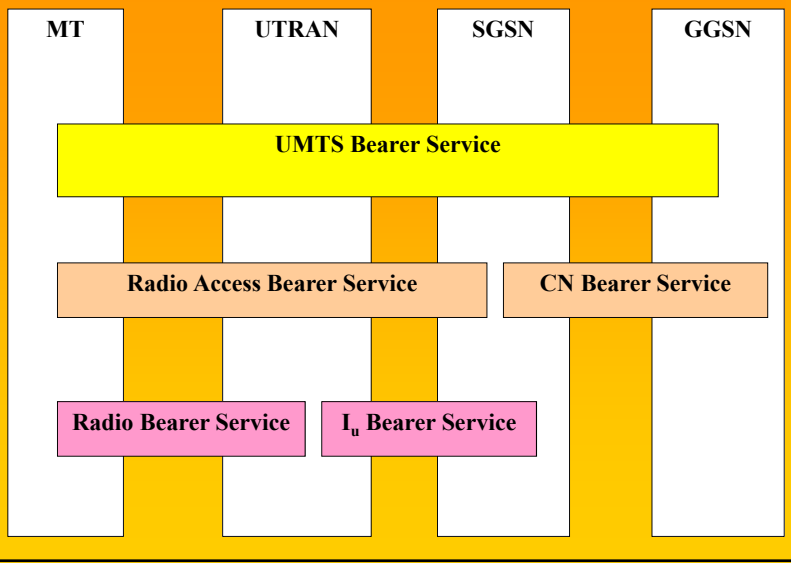
UMTS – air interface

- **UTRA-FDD:**
  - ***uplink*: 1920 – 1980 MHz (60 MHz)**
  - ***downlink*: 2110 – 2170 MHz (60 MHz)**
- **UTRA-TDD:**
  - **1900 – 1920 MHz (20 MHz)**
  - **2010 – 2025 MHz (15 MHz)**
- **In Portugal:**
  - **2x15 MHZ for UTRA-FDD**
  - **1x5 MHz for UTRA-TDD**

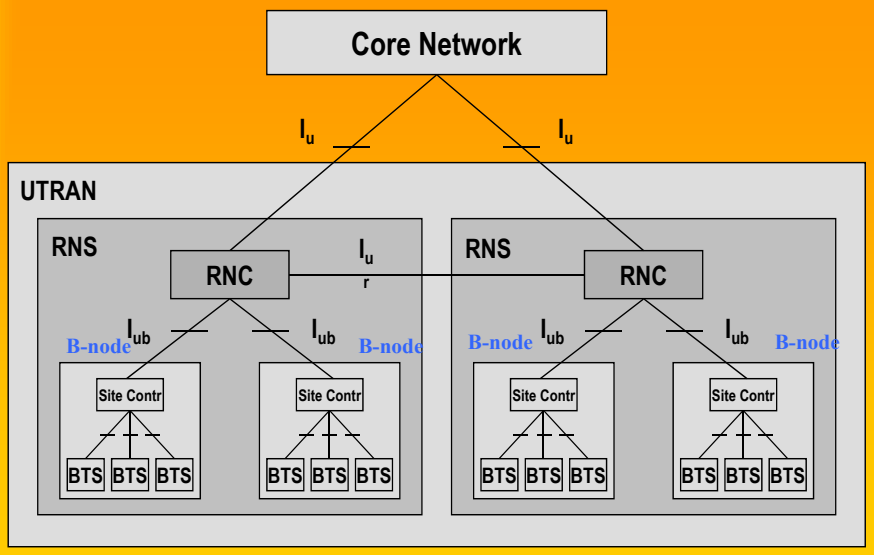
Multiplexing mechanisms



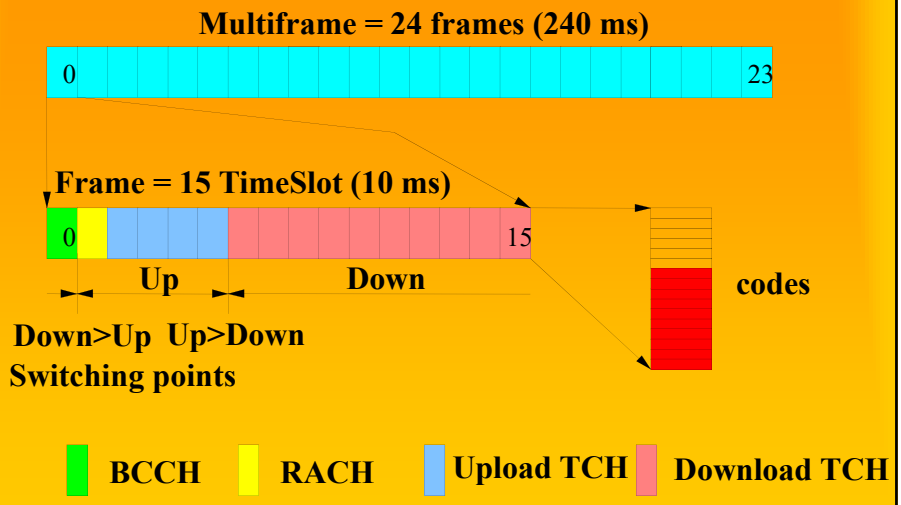
UMTS global architecture



UTRAN (UMTS Terrestrial Radio Access Net)



TDD: Frame structure



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Transport channels

- Dedicated Channel (DCH): fast bit rate changes (10ms)
  fast power control
  inherent MS addressing
- Random Access Channel (RACH) - up link: colisions
  open loop power control
  explicit MS addressing
- Broadcast Control Channel (BCH) - down link
- Forward Access Channel (FACH) - down link: slow power control
  explicit MS addressing
- Paging Channel (PCH) - down link: power saving modes

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Data transport

Data transport can be made using three different channels:

- **RACH (Random Access Channel):**
  - Used for small data quantity
  - Low latency (no reserved used)
    - no power control, collisions may happen
- **Dedicated channel requested (≈ VC setup):**
  - o MS send a reservation request (in RACH), with a traffic spec; network returns a ReqAll + CapAll (with proper traffic formats) in FACH, if possible; CapAll may be delayed if network load is high; MS only transmit after CapAll.
- **Using an existing dedicated channel (before expire):**
  - If a DCH already exists, trnasmit the new packet in that channel; if the timer is expiring, transmit only the CapAll

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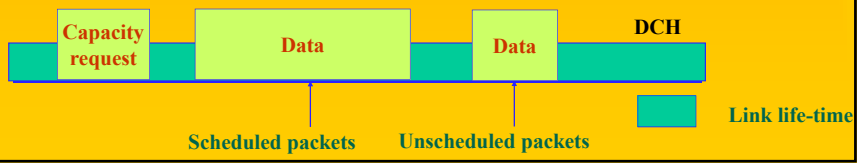
Real-time services

- MS does a Res_Req in RACH
  - (or in an existing active DCH)
- Network transmits a Res All (with TF parameters)
- MS starts transmission immediately (without waiting by Cap_All)
- Network may change/reduce/restore TF according with load



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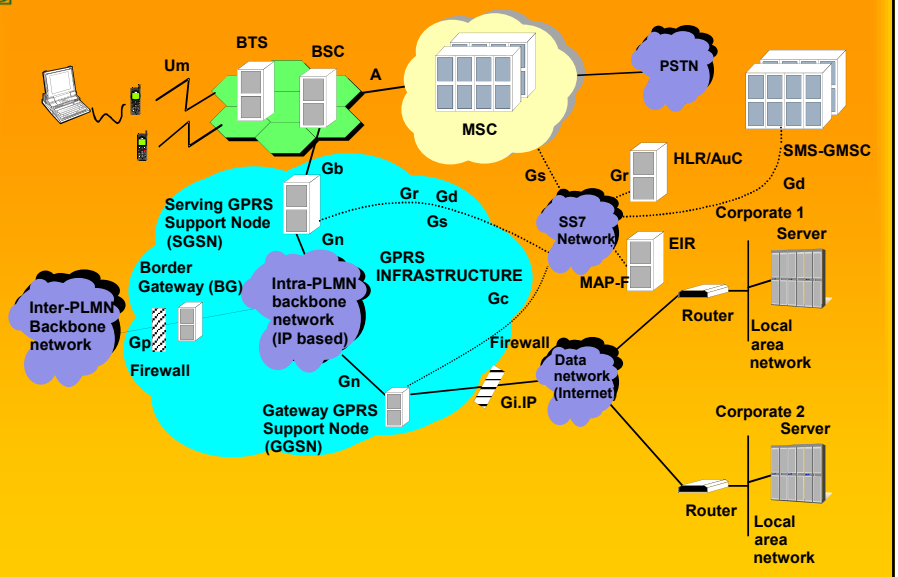
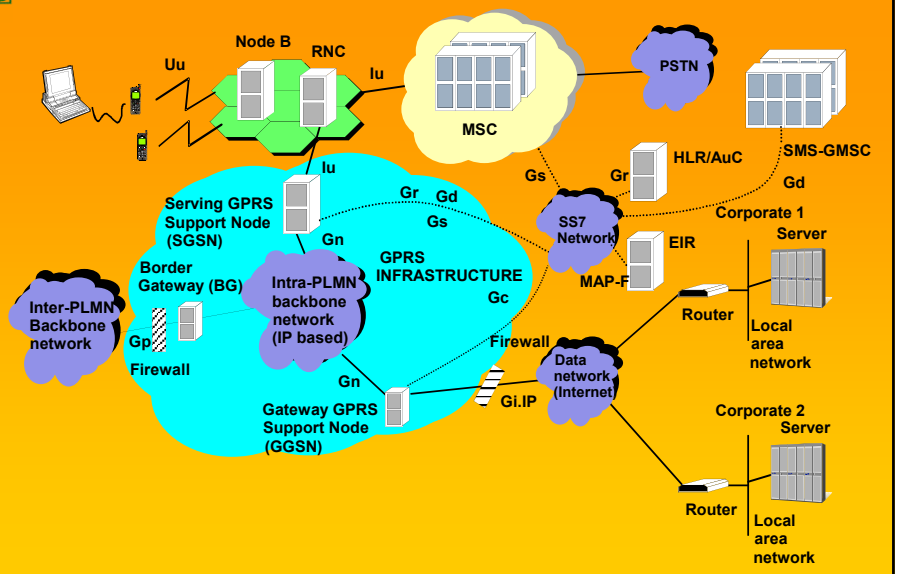
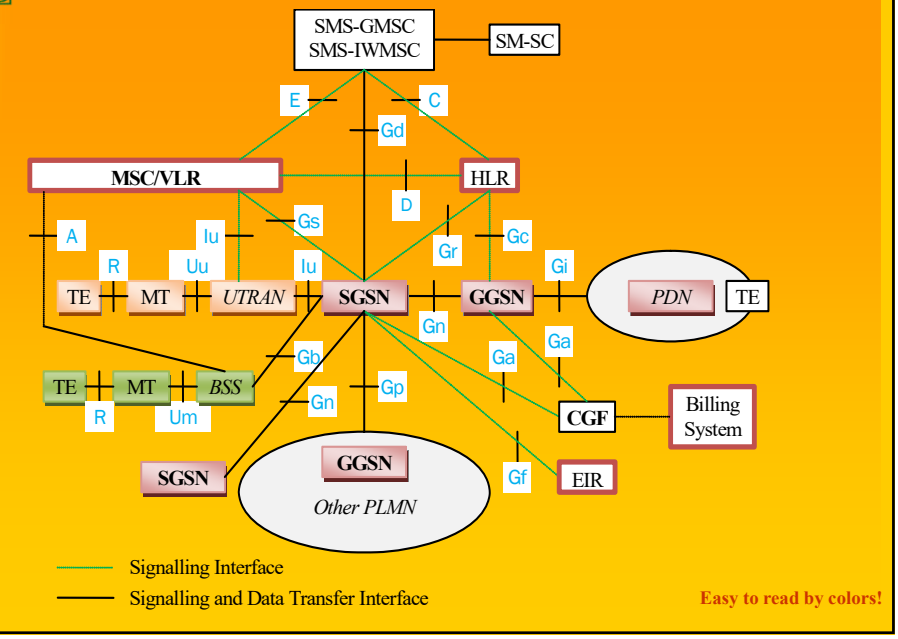
GSM Architecture / GSM Radio



UMTS Architecture / WCDMA (R'99)



GPRS/UMTS R 99 Architecture



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Entities

- The Serving GPRS Support Node (SGSN)
  - Mobility Management
  - Authentication
  - Gathers Charging Information
- Gateway GPRS Support Node (GGSN)
  - Gateway between UMTS Core Network and external networks
  - Address allocation for MS
  - Gathers Charging Information
  - Filtering
- Base Station Subsystem (BSS) / Radio Network Subsystem (RNS)
  - BSS
    - BSC
    - BTS
  - RNS
    - RNC
    - Node-B

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Interworking with Backbone Networks: UMTS service levels

Allocation/retention priority
Traffic handling priority
Transfer delay
Residual BER
SDU error ratio
Maximum bitrate
Guaranteed bitrate
Maximum SDU size
Delivery order
SDU format information
Delivery of erroneous SDUs

mapping

DiffServ PHB
- Expedited forwarding
- Assured forwarding (some codepoints)
- Best effort

UMTS
Conversational
Streaming
Interactive
Background

mapping

ATM service classes
MPLS (DiffServ & other QOS schemes)

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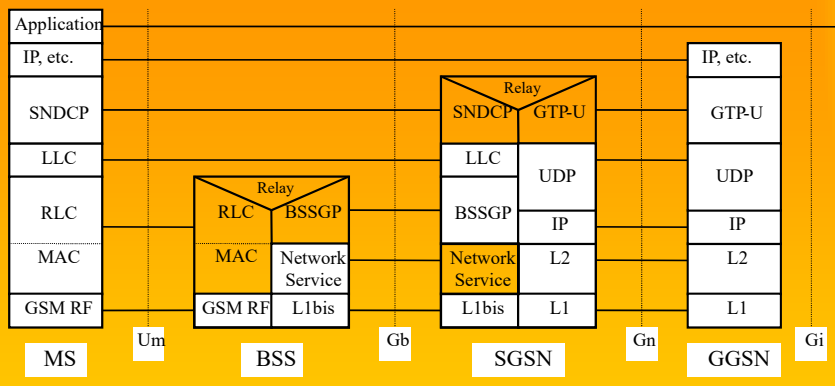
R99 Interfaces and Protocols GSM User Plane



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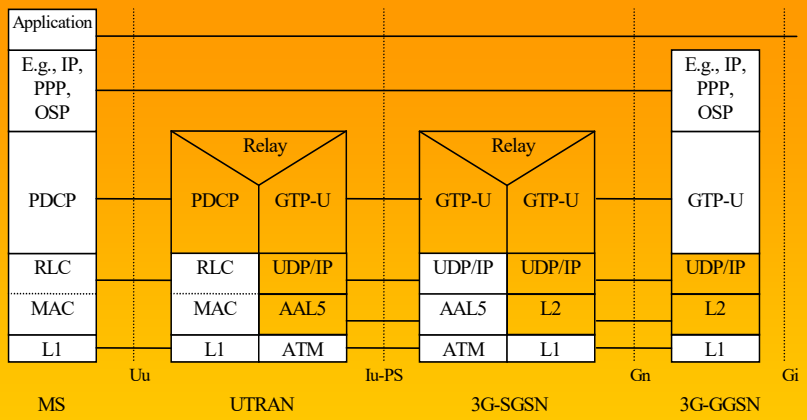
R99 Interfaces and Protocols UMTS User Plane



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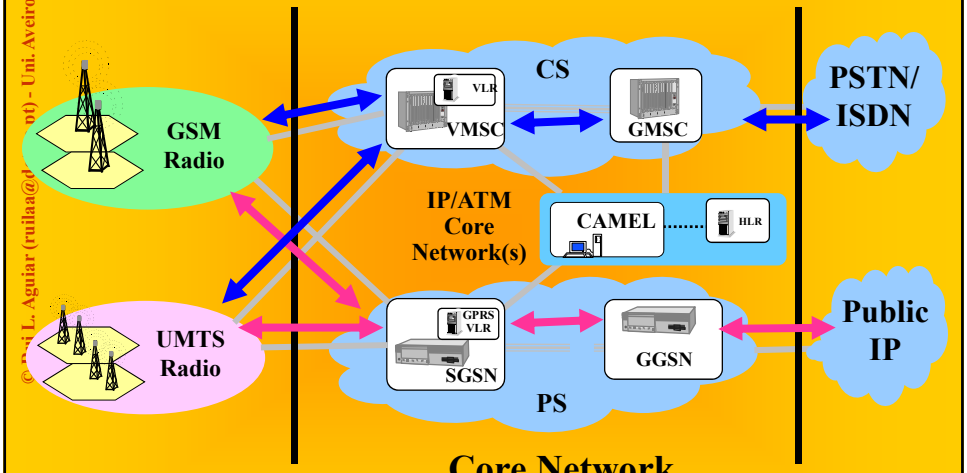
UMTS R99/R4 and GSM/GPRS



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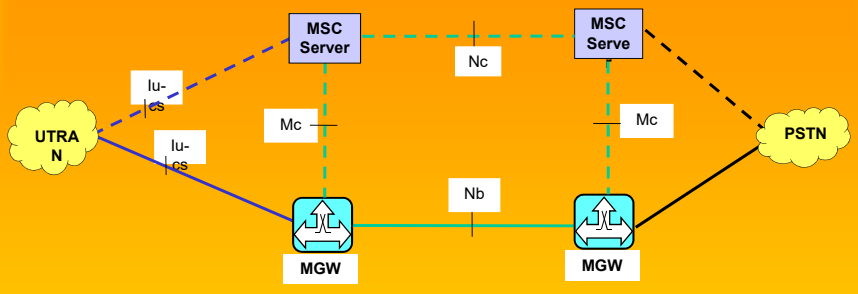
CS Domain: Signaling & User Plane



This bearer independent architecture makes possible the use of IP-based transport

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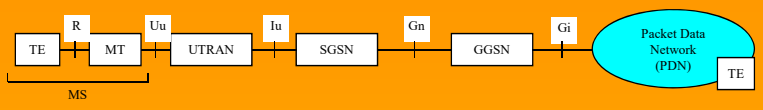
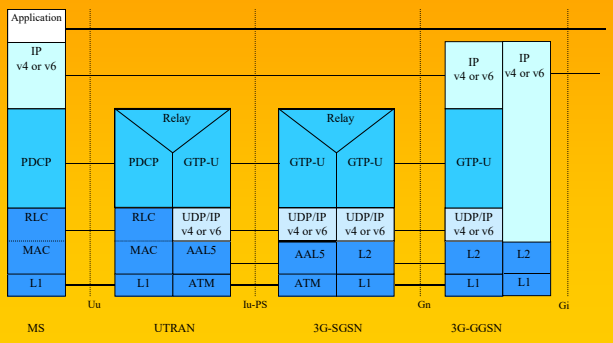
Simplified PS Domain Architecture



PS Domain User Plane protocol stack



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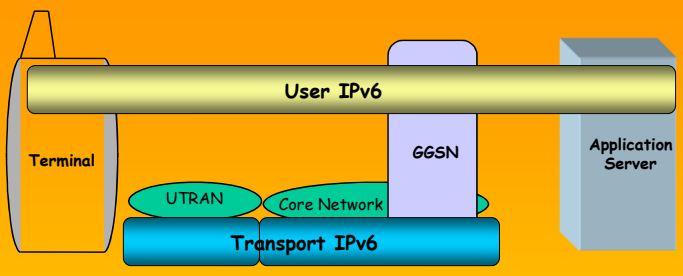
User plane vs transport plane



- User and transport planes are completely independent, i.e. the transport plane can run on a different IP version than the user plane
- UTRAN and Core Network transport can also run on different IP versions

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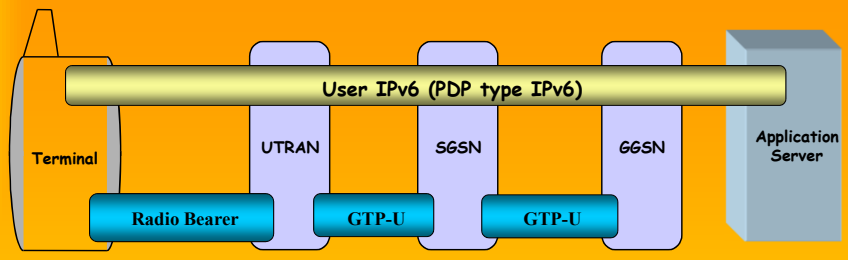
Transport of user IP packets in UMTS



IP packets to/from the terminal are tunneled through the UMTS network, they are not routed directly at the IP level.

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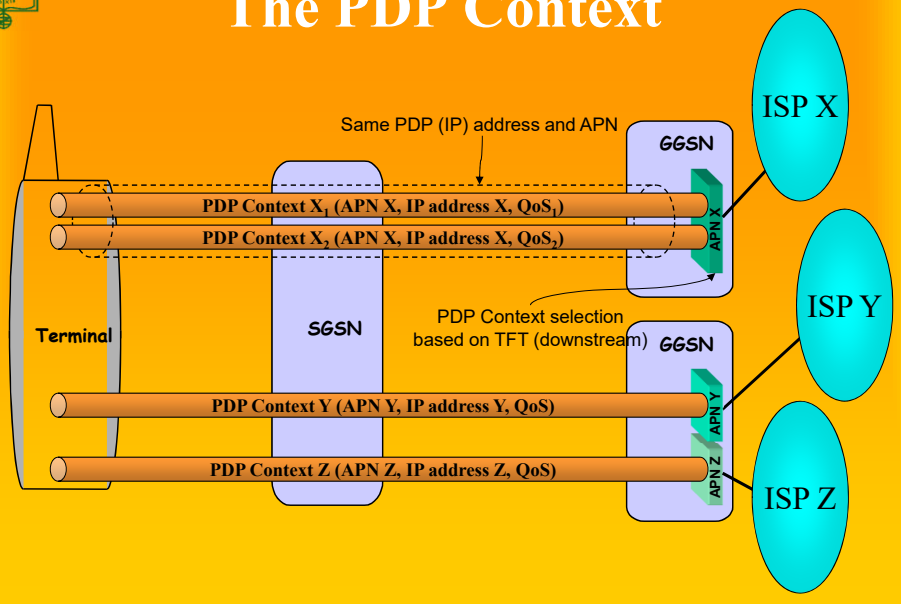
The PDP Context



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GTP and PDP Context

- GTP
  - GPRS Tunneling Protocol is a simple tunneling protocol based on UDP/IP - used both in GSM/GPRS and UMTS.
  - Identified by a Tunnel Endpoint Identifier (TEID)
  - For every MS:
    - one GTP-C tunnel is established for signalling
    - Multiple GTP-U tunnels, one per PDP context (i.e. session), are established for user traffic.
- PDP Context
  - When an MS attaches to the Network:
    - SGSN creates a Mobility Management context with information about mobility and security for the MS.
    - At PDP Context Activation (PDP - Packet Data Protocol), both SGSN and GGSN create a PDP context, with information about the session (e.g. IP address, QoS, routing information , etc.),

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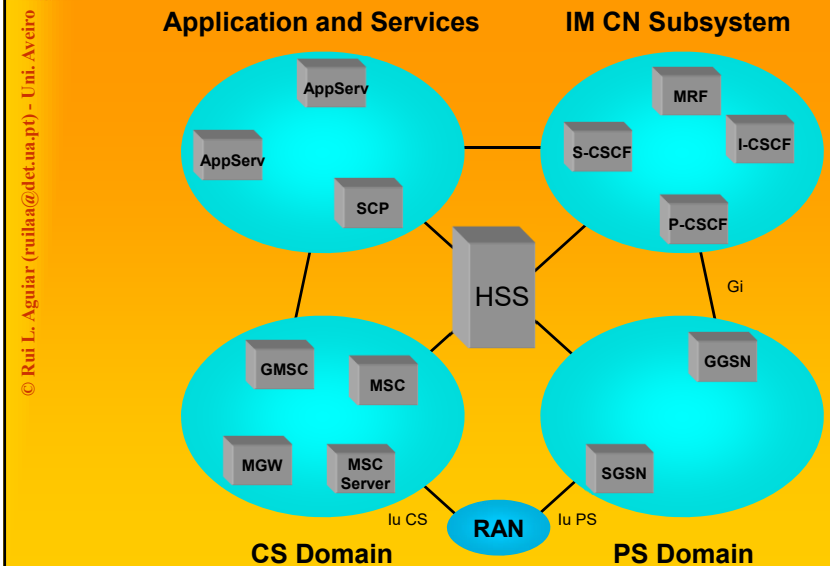
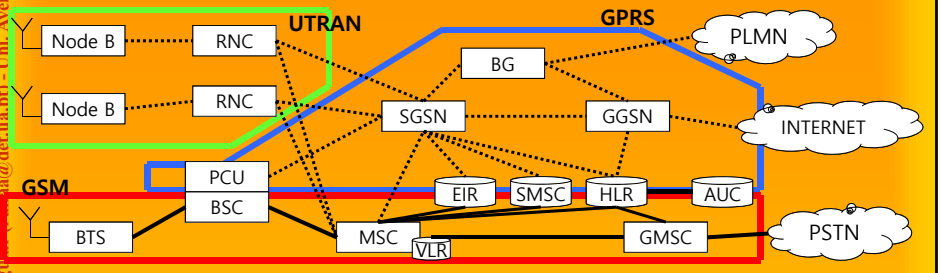
PDP Context

- **Packet Data Protocol (PDP) Context**
  - **Session**
  - **Logical Tunnel between MS and GGSN**
  - **Anchored GGSN for Session**
  - **Multiple PDP Contexts**
    - Per Mobile
    - Per PDP Address
- **PDP Context Activities**
  - **Activation**
  - **Modification**
  - **Deactivation**

Release 4/5 Architecture



Access Networks simplified



RNC: Radio network Controller

BG: Border Gateway

SGSN: Serving GPRS Support Node

GGSN: Gateway GPRS Support Node

PCU: Protocol Control Unit

BTS: Base Transceiver Station

PLMN: Public Land Mobile Network

BSC: Base Station Controller

MSC: Mobile Switching Center

GMSC: Gateway Mobile Services Switching Center

EIR: Equipment Identity Register

SMSC: Standard Modular System Card

H/VLR: Home/Visitor Location Register

PSTN: Public Switched Telephone Network

UMTS features and sub-systems for service provision

Introduction of IP	**IMS** *IP Multimedia Service*	Development of multimedia IP services with hardware and software componants integration
Customization	**VHE** *Virtual Home Environment*	User framework portability
Provision by third parties	**OSA** *Open Service Access*	Services development by external applications and contents providers
Terminal related	***MeXE*** ***Mobile eXecution Environment***	Adaptation of the service to the user terminal according to its characteristics, task sharing with the network

VHE - *Virtual Home Environment*

Principles

- **PSE** (*Personal Service Environment*) **portability between networks and terminals**: user – services interaction modes, multiple subscriptions management (pro/perso), multiple terminals and preferences according to the location.
- **Same features always available to the user**: interface and services customization, whatever the network and the terminal.
- **Independancy relatively to the network** (roaming) **and the terminal**

Applications

VAB Virtual Address Book	*Customer Care service*	*Calender multiparty application*	*Multimedia Delivery service*
Use of many types of terminals to access and update user data	Support to the users: interactive tutorials, problems detection and solutions proposal, on-line assistance, …	Coordinated calendar management among remote users: answers collection, meeting dates determination, …	Adaptation of the video to the user terminal

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OSA - *Open Service Access*

Principles

- Introduction of *SCF* (*Service Capability Features*) to provide **applications with service features**: call control, user location,…
- **Access to network features** which application developpers will use to develop or improve services

Applications

VPN, teleconferencing, LBS Applications implemented in one or many application servers

Advantages

- **Introduction of services by third parties** through standardized interfaces and applications
- **Easier introduction of application and service providers**

Drawbacks

- **Supervision of the services and contents** by the operator
- **QoS management by external providers** for offered services

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MExE - Mobile Execution Environment

Principles

- **Standardised execution environment** for the mobiles
- Negociation of the features between UE and MExE server during service initiation or dynamically
- Execution of service applications inside the UE or in the MExE server
- MExE defines the classmarks to support various terminals (Classmark 1: WAP environment, Classmark 2: PersonalJava, Classmark 3: J2ME CLDC MIDP environment)

Advantages

- **Adaptation of the services to user terminals**

Drawbacks

- **Définition, standardisation and implementation** of these terminal classes

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USIM characteristics

Capacities	▪ 64K, 128K, eventually 1Mo
Profile management	▪ Operator and user profiles management through radio interface (OTA, *Over The Air*): VAS real-time implementation, with updates and applets downloading, file management, …
Security	▪ Point-to-point messages exchange security provision in OTA
SIM Application Toolkit (STK)	▪ Pro-active SIM card for execution of features; management of UE by USIM and thus by the operator
Operations	▪ OTA based on SMS transport, then via other bearers (CSD, GPRS, UMTS)

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IMS - IP Multimedia Service

Principles

- **QoS characteristics differentiation** for voice or video associated with a multimedia session (streaming, IM, etc.)
- **Separation of the planes** IP data and session control (SIP)
- **Independant** from the access network

R5

IMS for mobile networks GPRS, EDGE, UMTS & CDMA2000
Non real time services
IP multimedia applications plate-form
IETF specifications based

R6

IMS extended to wideband fixed networks (xDSL, WLAN, cable, …)
Supports **services convergence** on fixed and mobile networks (conversion CS voice traffic in IP)

Advantages

- **Introduction of multimedia services** with **QoS** management
- **Integration** with other networks (WLANs, fixed, CDMA2000, …)
- **Flexible billing**: billing / service, connectivity, QoS, time, destination

Drawbacks

- **Implementation of many equipments, softwares, interfaces, protocols**, which may cause integration, interworking and optimisation problems
  - –Ex.: S-**CSCF** (*Call Status Control Function*); SIP AS (*SIP Application Server*); OSA SCS (*Service Capability Server*); IM-SSF (*Inter-working Module*); CSE (*Camel Service Environment*); **HSS** *(Home Subscriber Server)*
- **Security and QoS** with Internet interconnection

IMS – Key Architectural Principals

- **Border Functions**
  - Access and Network Border Security
  - QoS and Admission Control
  - Media and Signaling Adaptation
- **Core Functions**
  - Subscriber Management – Registration
  - Session Switching – Set-up and tear-down of session legs, Session state maintenance, Application Server invocation
  - Session Routing – Breakout to external networks
  - Centralized Provisioning – Subscriber and Routing data
- **Application Functions**
  - Access to legacy applications
  - Native SIP Applications
  - Service Brokering

SIP Protocol

- **Defined in IETF RFC 3261**
  - "… an application-layer control (signaling) protocol for creating, modifying, and terminating sessions with one or more participants. These sessions include Internet telephone calls, multimedia distribution, and multimedia conferences."
- **SIP is to the Internet what SS#7 is to telephony**
- **In IMS, SIP is extended to include extra functionality**
  - E.g. 3GPP TS 23.228
- **At the core of IMS there are several SIP proxies:**
  - I-CSCF, S-CSCF, P-CSCF
  - The Call Session Control function (CSCF) is the heart of the IMS architecture
  - The main functions of the CSCF:
    - provide session control for terminals and applications using the IMS network
    - secure routing of the SIP messages,
    - subsequent monitoring of the SIP sessions and communicating with the policy architecture to support media authorization.
    - responsibility for interacting with the HSS.

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Services in IMS

- IMS is an advanced infrastructure enabling services. But the services are in the end points or peers (calls, etc.), not in the IMS
- Application Servers (AS) are the key part to endow IMS with services
  - AS are not owned by the network operator
    - (therefore not part of IMS)
  - AS offered services enjoy all IMS advantages
  - AS interact – using SIP - with the S-CSCF (which controls user's SIP session)
  - AS can behave as another SIP proxy or as a SIP UA (terminal)
    - in this case they also receive and send media!

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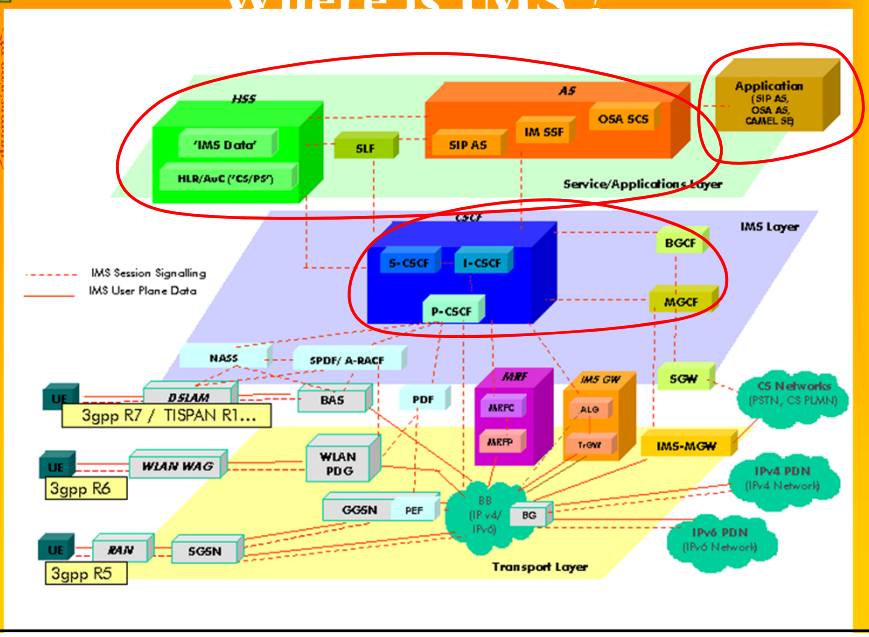
Where is IMS ?



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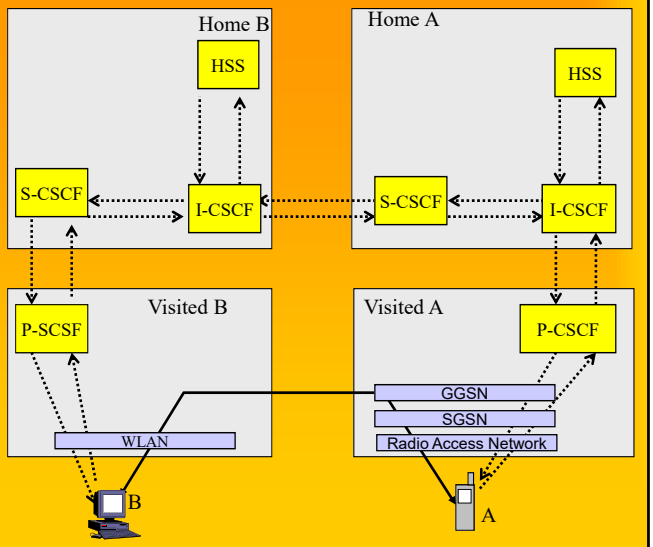
UMTS IMS: basic call flow

Non-GPRS access Networks (e.g. WLAN) comes in release 6



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S-CSCF

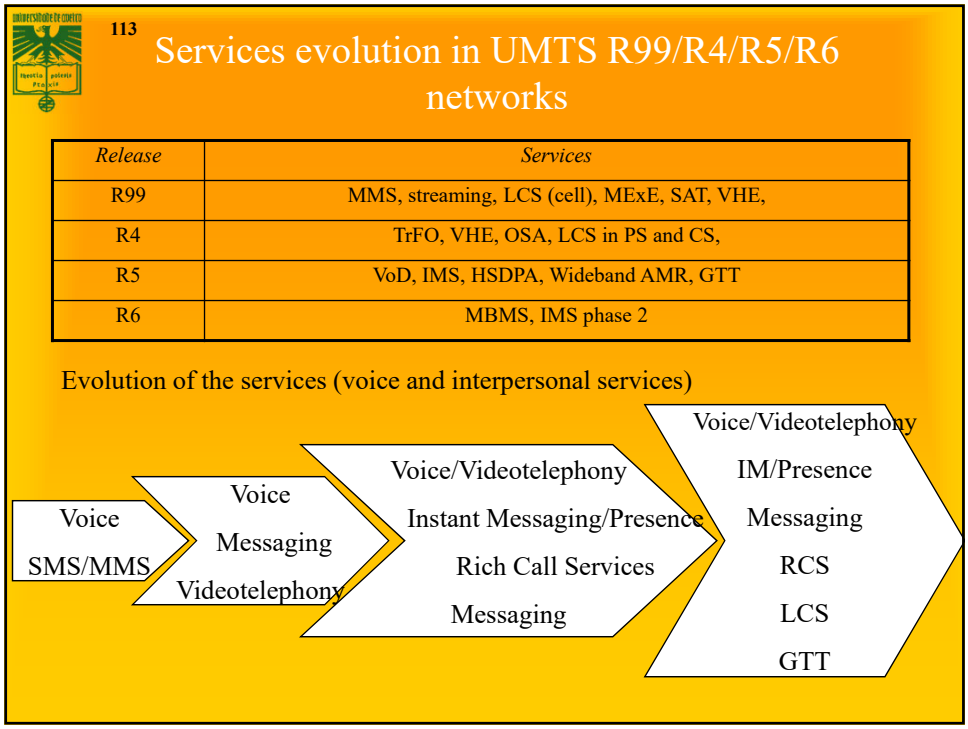
- **Serving - CSCF**
  - **Controls the user's SIP Session**
  - **very few per domain**
  - **Located in the home domain**
  - **Is a SIP registrar (and proxy)**

P-CSCF

- IMS contact point for the user's SIP signaling
- Several in a domain
- Located in the visited domain
- Terminals must know this proxy (e.g. DHCP used)
- Compresses and decompresses SIP messages
- Secures SIP messages
- Assures correctness of SIP messages

I-CSCF

- domain's contact point for inter-domain SIP signaling
- one or more per domain
- In case there are more than one S-CSCFs in the domain, locates which S-CSCF is serving a user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Services evolution in UMTS R99/R4/R5/R6 networks
Release
Services
R99
MMS, streaming, LCS (cell), MExE, SAT, VHE,
R4
TrFO, VHE, OSA, LCS in PS and CS,
R5
VoD, IMS, HSDPA, Wideband AMR, GTT
R6
MBMS, IMS phase 2
Evolution of the services (voice and interpersonal services)
Voice
SMS/MMS
Voice
Messaging
Videotelephony
Voice/Videotelephony
Instant Messaging/Presence
Rich Call Services
Messaging
Voice/Videotelephony
IM/Presence
Messaging
RCS
LCS
GTT