EPFL

Cours “Mobile Networks”

GPRS & EDGE

« First steps toward Wireless data »

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Network Development Engineering

14/12/2004

GPRS Part 1
Content

From Theory…

1 - INTRODUCTION

2 - SERVICES

3 - ARCHITECTURE

4 - MOBILITY MANAGEMENT

5 - SESSION MANAGEMENT

6 - TRANSMISSION ON BSS NETWORK

7 - RADIO RESOURCE MANAGEMENT

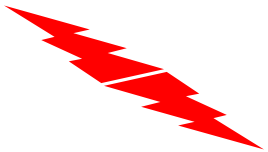
Introduction

General Packet Radio Service:

- a way to extend packet transfer up to the mobile station

GSM

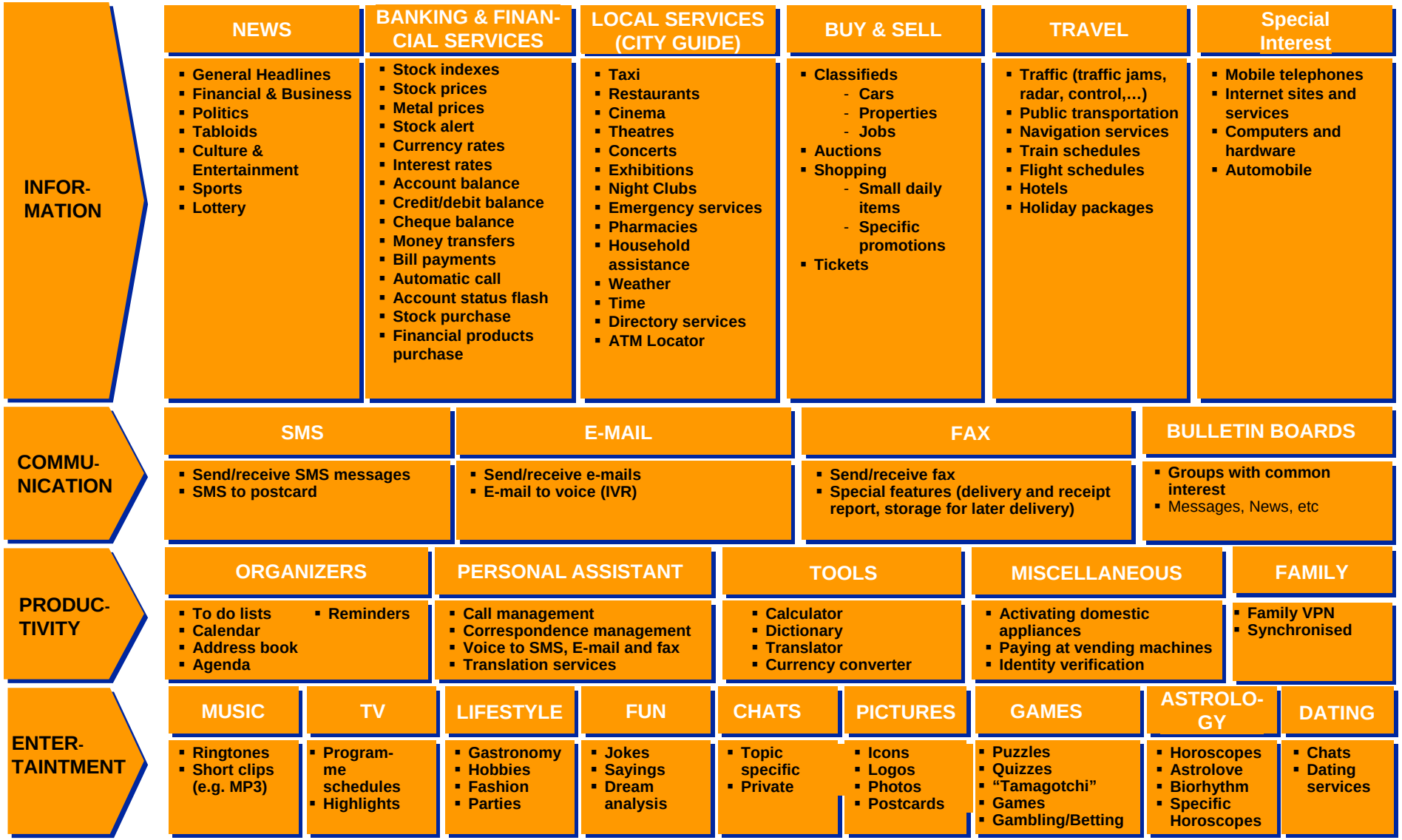
- Circuit Switch architecture
- Indirect access to IP network
- Too sensitive connection for data (today)
- Expensive solution for data network (HSCSD)



GPRS

- Packet Switch architecture
- End to End IP service (mobile = IP host)
- Re-use BSS architecture
- New core architecture
- Max theoretical rates ~170 kbps

Services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Credit/debit balance
Cheque balance
Money transfers
Bill payments
Automatic call
Account status flash
Stock purchase
Financial products purchase
LOCAL SERVICES (CITY GUIDE)
Taxi
Restaurants
Cinema
Theatres
Concerts
Exhibitions
Night Clubs
Emergency services
Pharmacies
Household assistance
Weather
Time
Directory services
ATM Locator
BUY & SELL
Classifieds
- Cars
- Properties
- Jobs
Auctions
Shopping
- Small daily items
- Specific promotions
Tickets
TRAVEL
Traffic (traffic jams, radar, control,…)
Public transportation
Navigation services
Train schedules
Flight schedules
Hotels
Holiday packages
Special Interest
Mobile telephones
Internet sites and services
Computers and hardware
Automobile
COMMU-NICATION
SMS
Send/receive SMS messages
SMS to postcard
E-MAIL
Send/receive e-mails
E-mail to voice (IVR)
FAX
Send/receive fax
Special features (delivery and receipt report, storage for later delivery)
BULLETIN BOARDS
Groups with common interest
Messages, News, etc
PRODUC-TIVITY
ORGANIZERS
To do lists
Calendar
Address book
Agenda
Reminders
PERSONAL ASSISTANT
Call management
Correspondence management
Voice to SMS, E-mail and fax
Translation services
TOOLS
Calculator
Dictionary
Translator
Currency converter
MISCELLANEOUS
Activating domestic appliances
Paying at vending machines
Identity verification
FAMILY
Family VPN
Synchronised
ENTER-TAINTMENT
MUSIC
Ringtones
Short clips (e.g. MP3)
TV
Program-me schedules
Highlights
LIFESTYLE
Gastronomy
Hobbies
Fashion
Parties
FUN
Jokes
Sayings
Dream analysis
CHATS
Topic specific
Private
PICTURES
Icons
Logos
Photos
Postcards
GAMES
Puzzles
Quizzes
“Tamagotchi”
Games
Gambling/Betting
ASTROLO-GY
Horoscopes
Astrolove
Biorhythm
Specific Horoscopes
DATING
Chats
Dating services

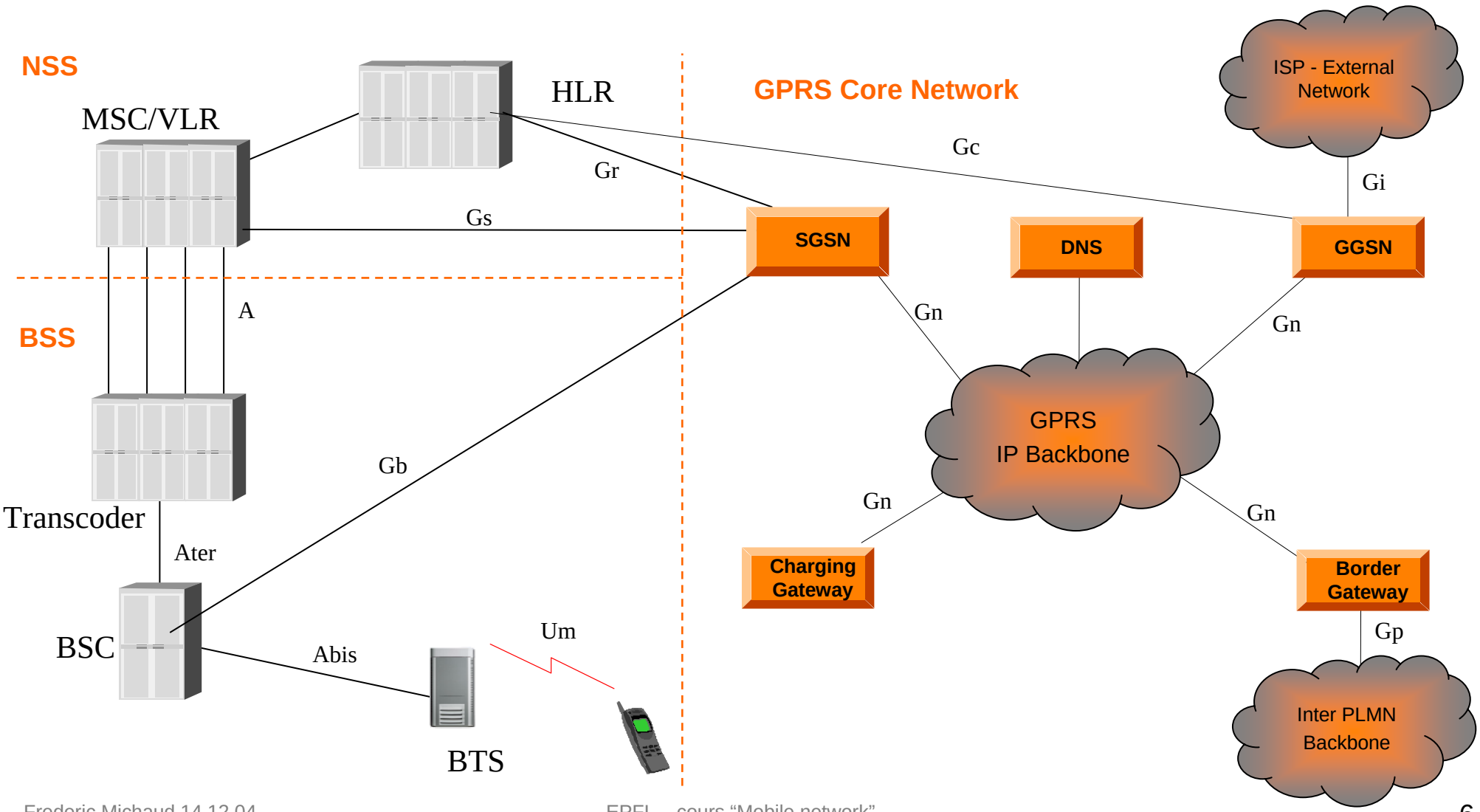
Services
Notion of QoS

- QoS = Quality of Service
- 5 Classes as specified in ETSI
  - Service Precedence / Priority
  - Delay
  - Mean Throughput
  - Peak Througput
  - Reliability

- FTP (NRT):
  - Service: minor
  - Delay: < 7 sec (most likely Best effort)
  - Mean throughput: 4.4 kbps
  - Peak throughput: N/A
  - Reliability: high to medium redundancy

- Video Streaming (RT):
  - Service: medium
  - Delay: < 7 sec (most likely Best effort)
  - Mean throughput: 44 kbps
  - Peak throughput: 64 kbps
  - Reliability: medium to low (UDP protocol)

Architecture
Network Diagram

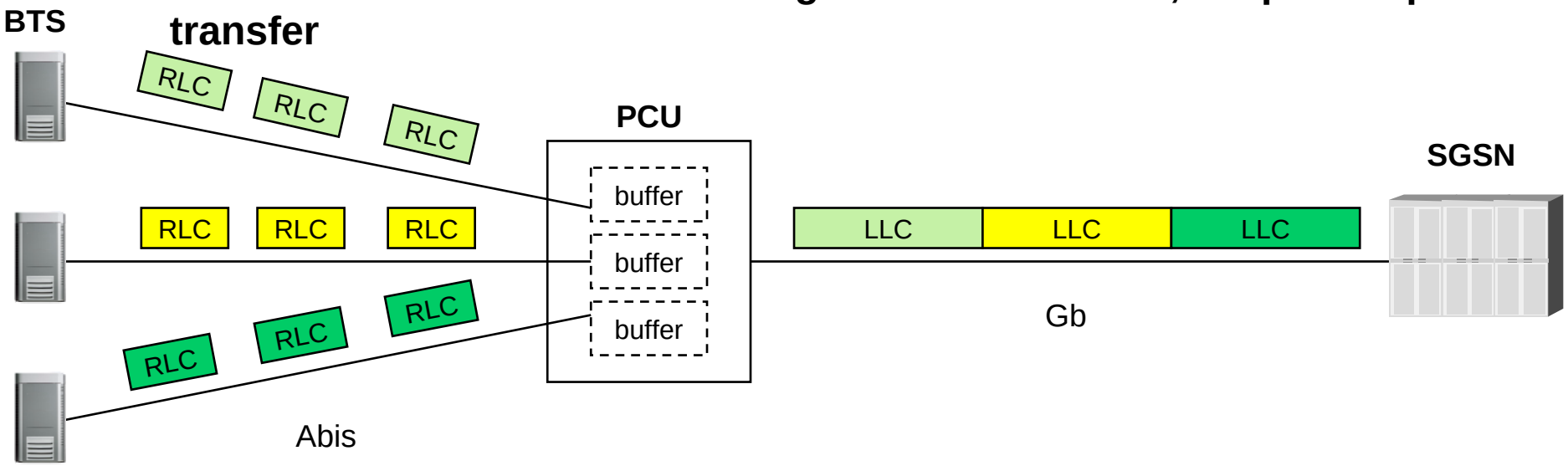


Architecture
New interfaces

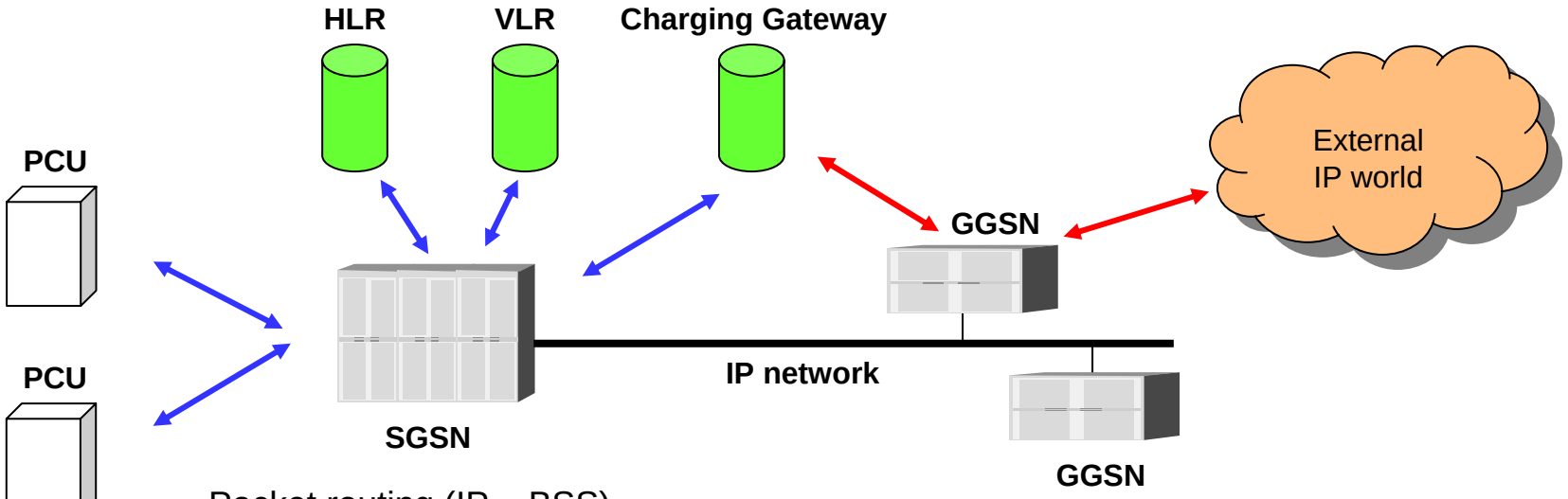
Interface	elements	Main usage	Protocol type
Um	MS – BTS	Radio interface	RLC/MAC
Abis	BTS – BSC	Standard GSM if.	RLC/MAC
Gb	BSC – SGSN	GPRS data	LLC/FR
Gc	GGSN – HLR	HLR queries for PDP context activation	(IP)/SS7
Gd	SGSN – SMS GMSC	Short Messages exchange	SS7
Gf	SGSN – EIR	Terminal identity check	SS7
Gi	GGSN – Data Network	Data transfer	IP
Gn	SGSN – SGSN	Mobility management	IP
	SGSN - GGSN	PDP context activation Data transfer	
Gp	BG – BG	Inter-operator link	IP
Gr	SGSN – HLR	Location management	SS7
Gs	SGSN – MSC/VLR	GSM/GPRS mobility Management	SS7

Architecture
evolution of BSS network

- New hardware in BSS: Packet Controlling Unit (PCU)
  - **can be compared to TRAU function in GSM**
  - **generally located in the BSC**
  - **heart of the packet transmission in BSS network**
  - **allow the dynamic traffic allocation**
  - **Provide the radio resource management mechanism, adapted to packet transfer**



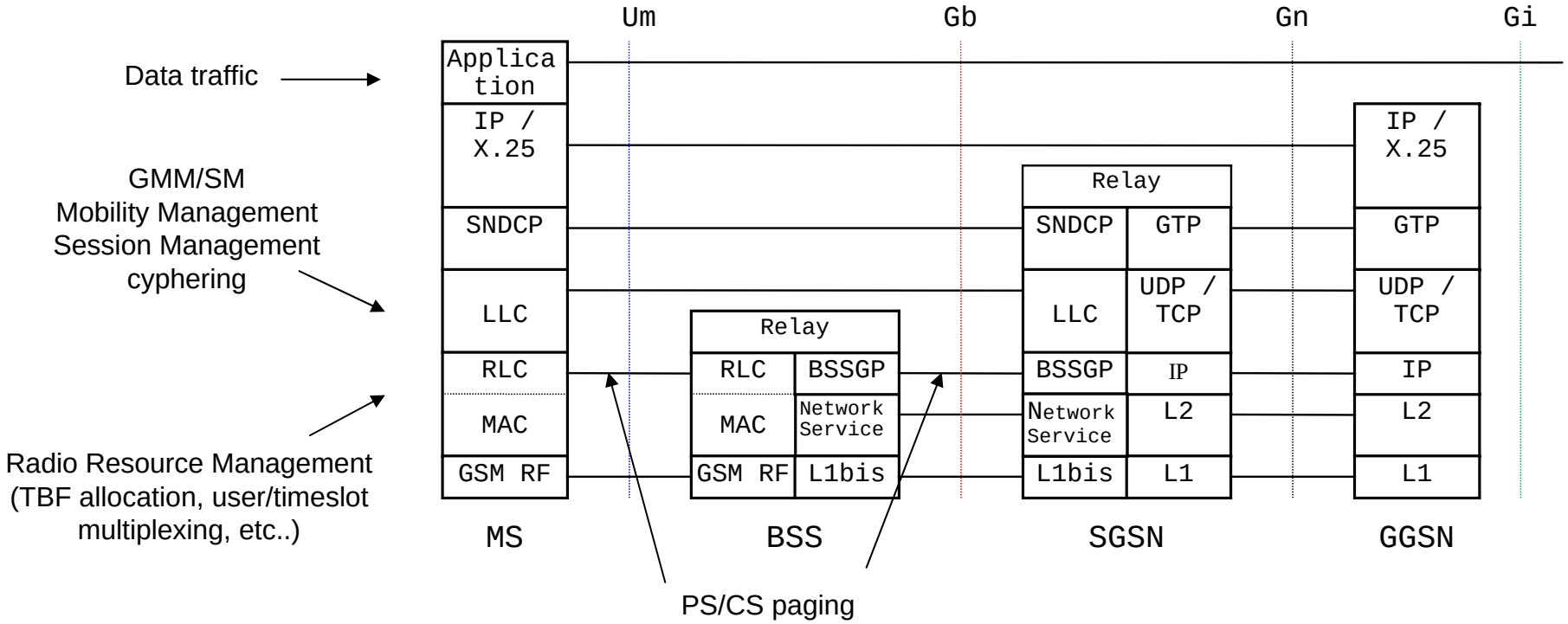
Architecture
New core equipments



- **Other equipment:**
  - Border Gateway, Charging Gateway, DNS, Firewalls

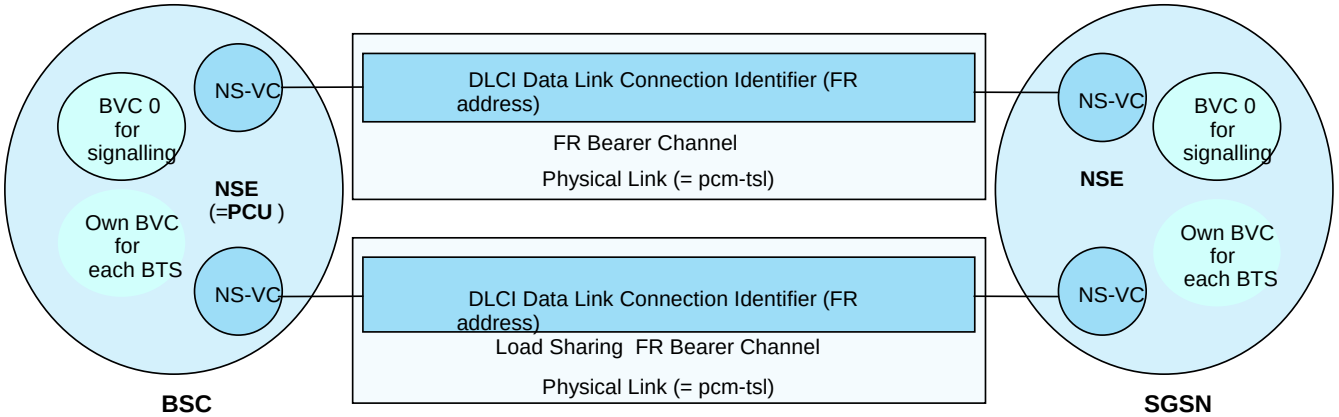
Architecture
GPRS Protocol stacks

- BSS elements manage everything related to radio resource, mobility and session management



Architecture
Gb interface

- Open interface between the BSC and the SGSN. Consist of three layers:
  - Frame Relay**: link layer access between peer entities via a** Bearer Channel**.**
  - Network Service**: set of** virtual connections **responsible for data transmission, congestion control, load sharing between Network Service Entities.**
  - BSSGP**:** Virtual Connection management**, paging support, flow control support.**



BVC = BSSGP Virtual Connection
BSSGP = Base Station Subsystem GPRS Protocol
NSE = Network Service Entity
NS-VC = Network Service Virtual Connection
FR = Frame Relay

→ Gb interface will move on IP protocol

Mobile equipment

Three types of Mobile Classes

- CLASS A: « Rolls Royce »

Simultaneous CS/PS Paging
Simultaneous CS/PS data transfer

CS Core Network (GSM)

PS Core Network (GPRS)

- CLASS B: « Standard »

Simultaneous CS/PS Paging
CS call or PS data transfer

CS Core Network (GSM)

PS Core Network (GPRS)

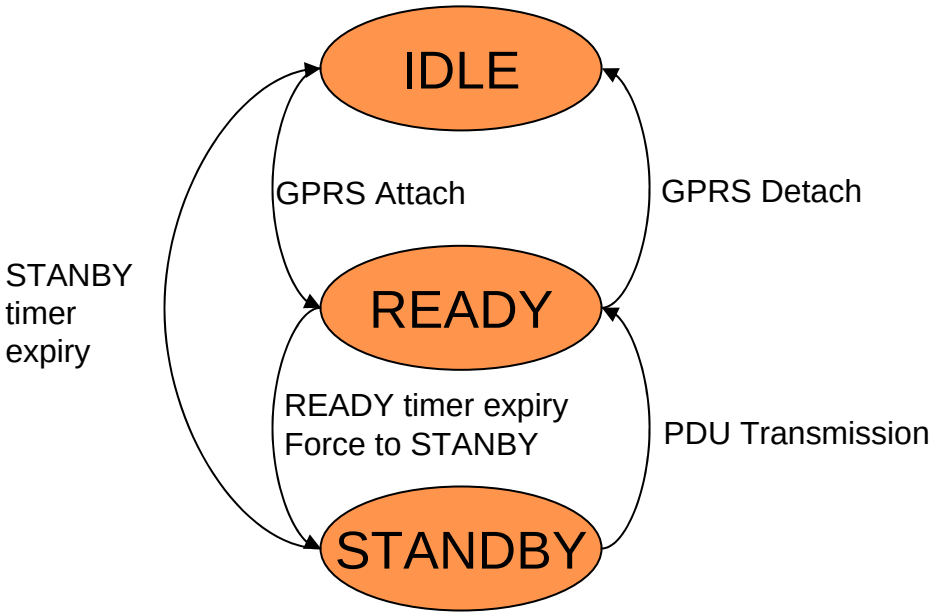
- CLASS C: « Cheap »

CS mode (GSM only) or PS mode (GPRS only)

CS Core Network (GSM)

PS Core Network (GPRS)

Mobility Management
Mobile States



- IDLE
  - **not attached to GPRS**
  - **MS is not reachable**
- READY
  - **MS known down to Cell by SGSN**
  - **May receive/transmit packets**
  - **No Packet paging required**
  - **MS remains in READY state until "READY Timer" expires or GPRS Detach**
- STANDBY
  - **MS known down to Routing Area by SGSN**
  - **MS attached to GPRS**
  - **May receive Packet paging**
  - **No data reception or transmission**

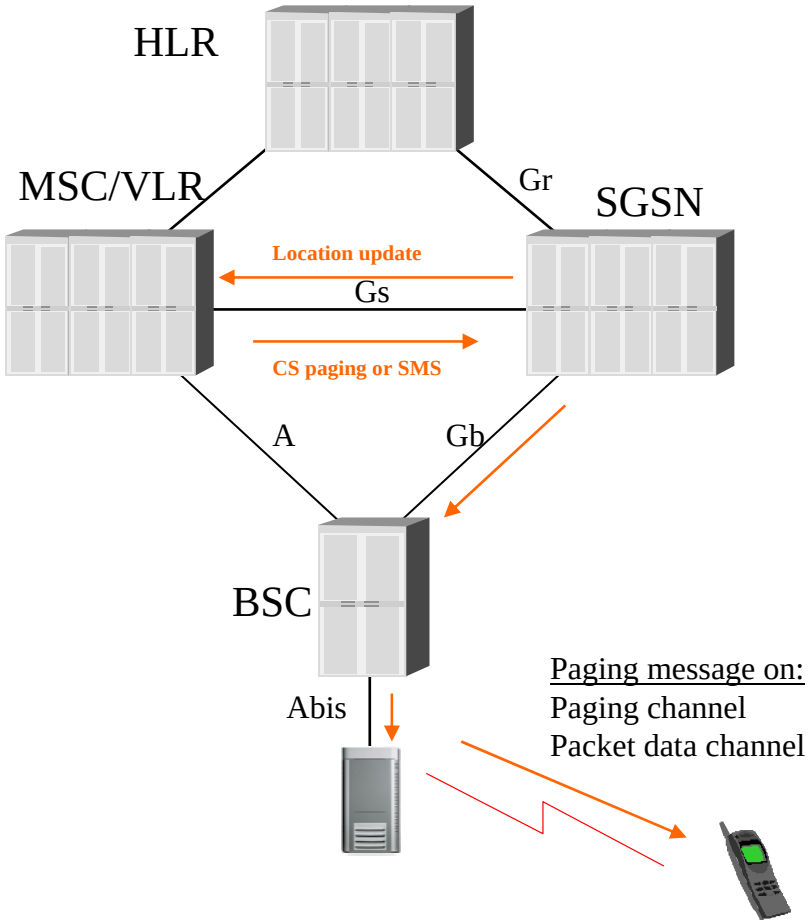
Mobility Management
Temporary identity

- Notion of P-TMSI (Packet Temporary Mobile Subs Identifier)
  - **Temporary identifier to differentiate a mobile in a SGSN**
  - **associated to a ciphered signature**
  - **P-TMSI+ signature transferred at each location update**
- **Notion of TLLI (Temporary Logical Link Identifier)**
  - used between MS and SGSN before attachment
  - randomly selected by MS when uplink request (risk of collision)
  - after attach : TLLI=P-TMSI
  - used to identify MS on the air interface

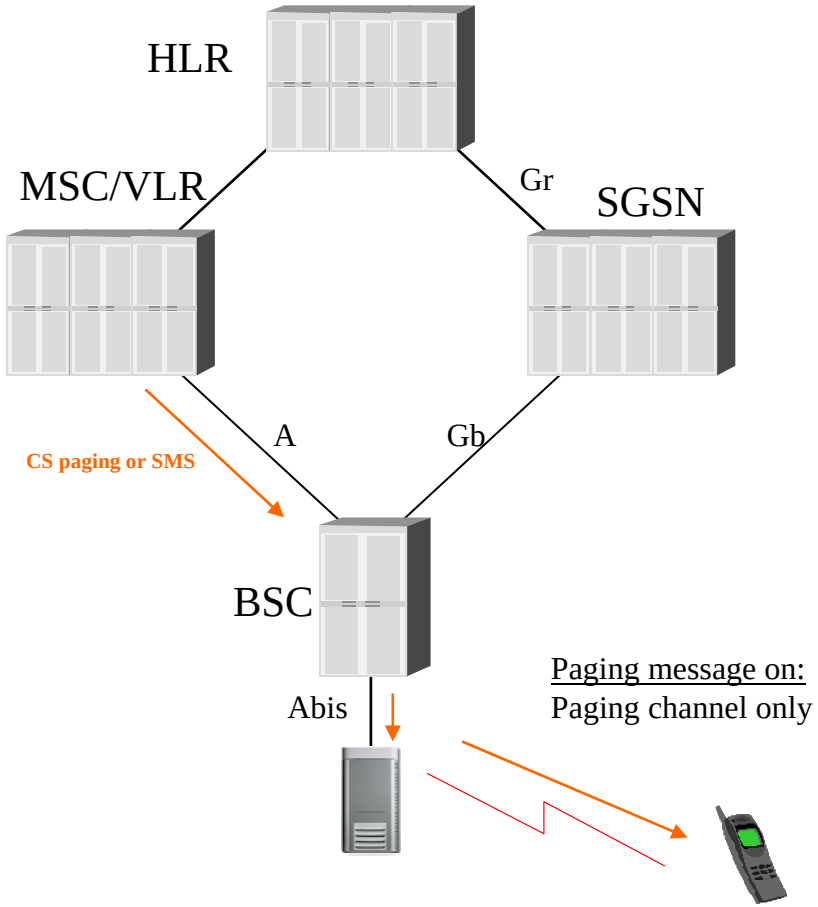
➢ **IMSI is never transferred**

Mobility Management
Paging enhancement with GPRS

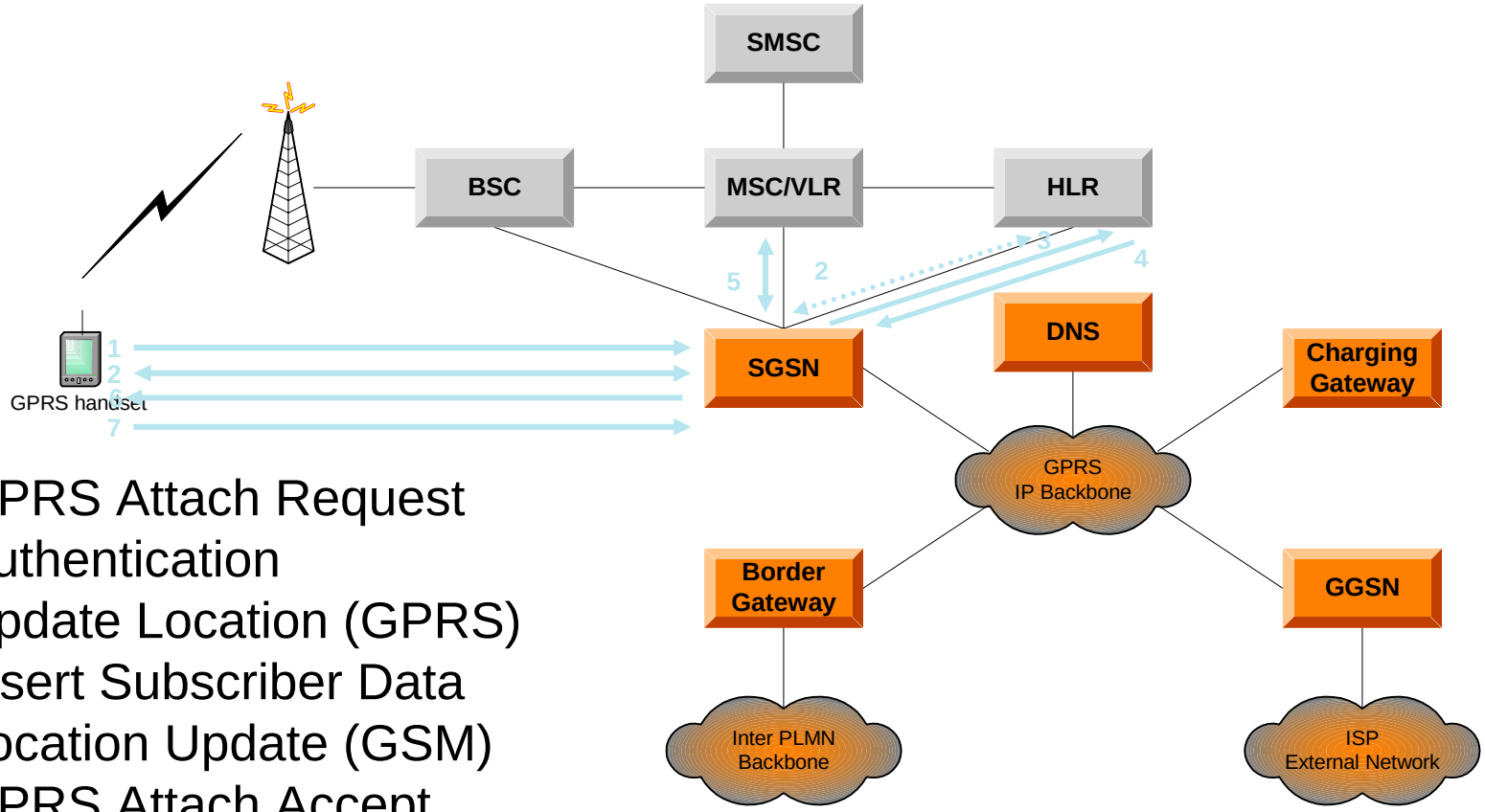
Network Mode I



Network Mode II

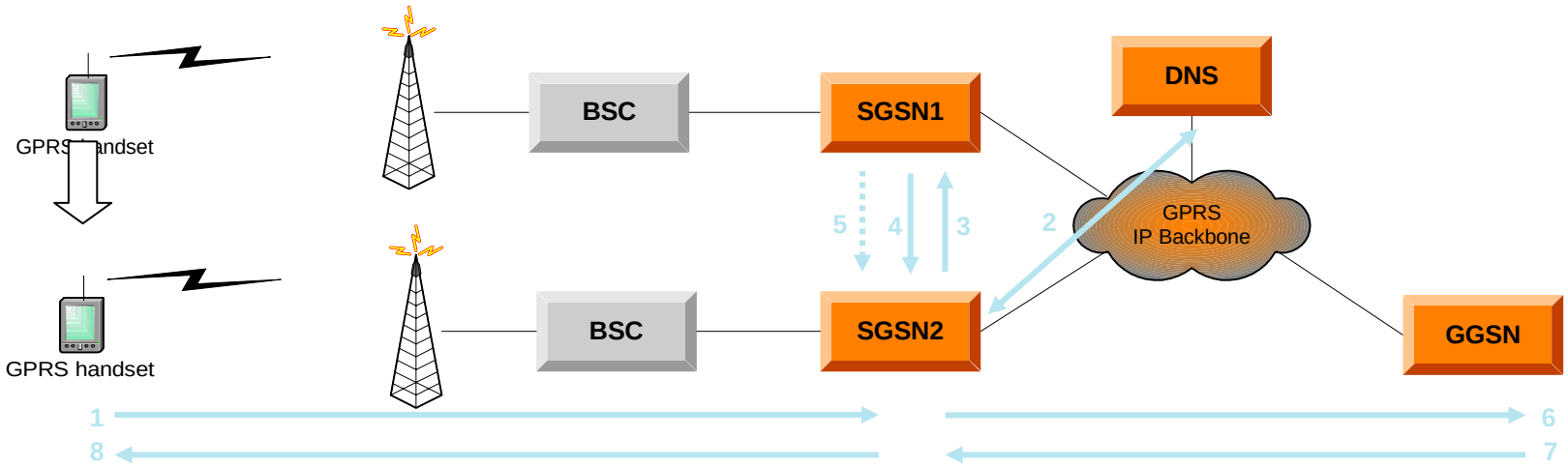


Mobility Management
GPRS Attach



1. GPRS Attach Request
2. Authentication
3. Update Location (GPRS)
4. Insert Subscriber Data
5. Location Update (GSM)
6. GPRS Attach Accept
7. Attach complete

Mobility Management
Routing Area Update



1. RA Update Request (old RAI)
2. DNS Query: IP @ for old RAI
3. SGSN Context Request
4. SGSN Context Response
5. Forward Packets
6. Update PDP Context Request: IP @ of new RAI
7. Update PDP Context Response
8. RA Update Accept

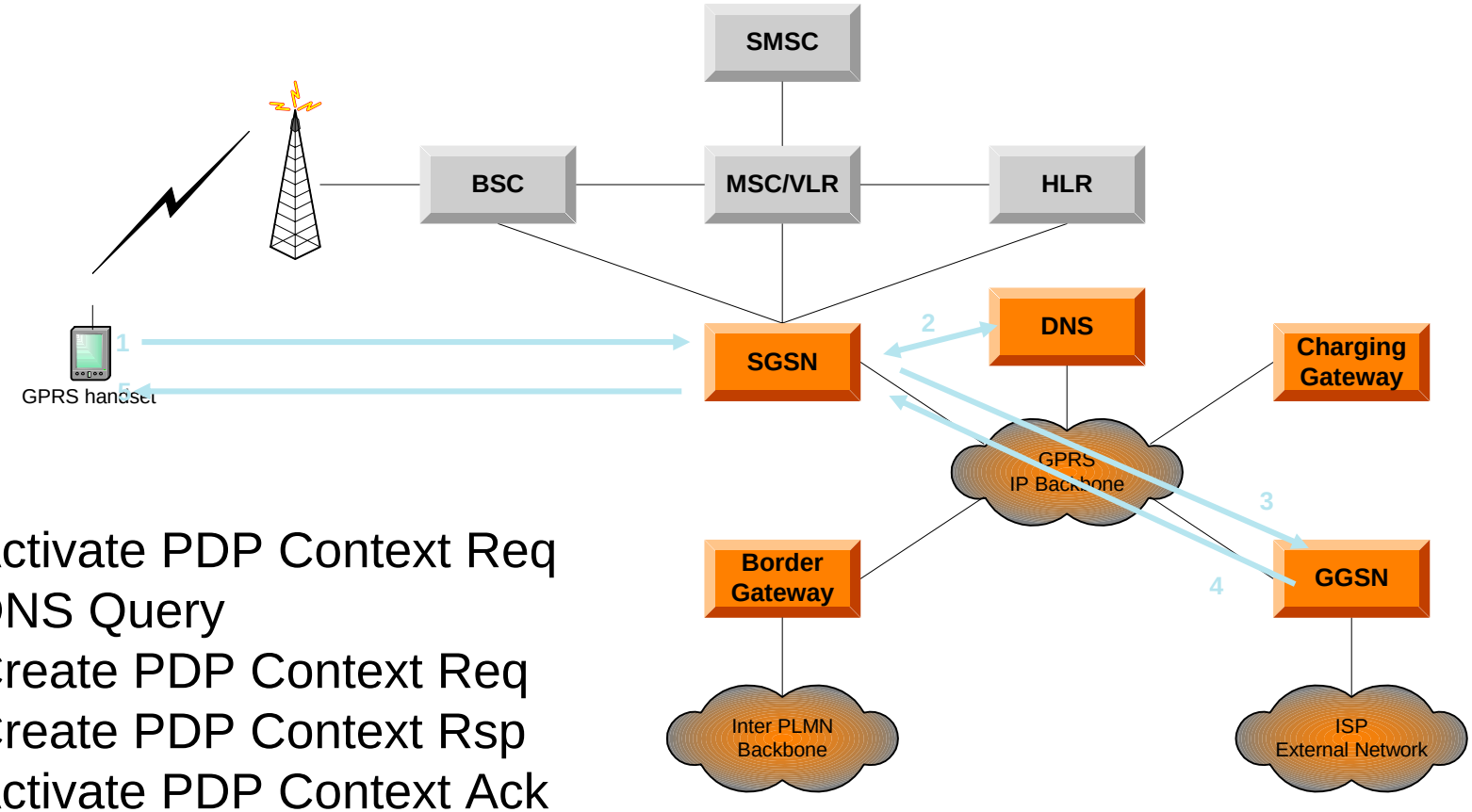
Session Management
Notion of PDP context

- Packet Data Protocol context:
  - **set of information stored in mobile, SGSN and GGSN**
  - **allow packet data transfer between a certain type of network and the mobile**

- PDP context contains:

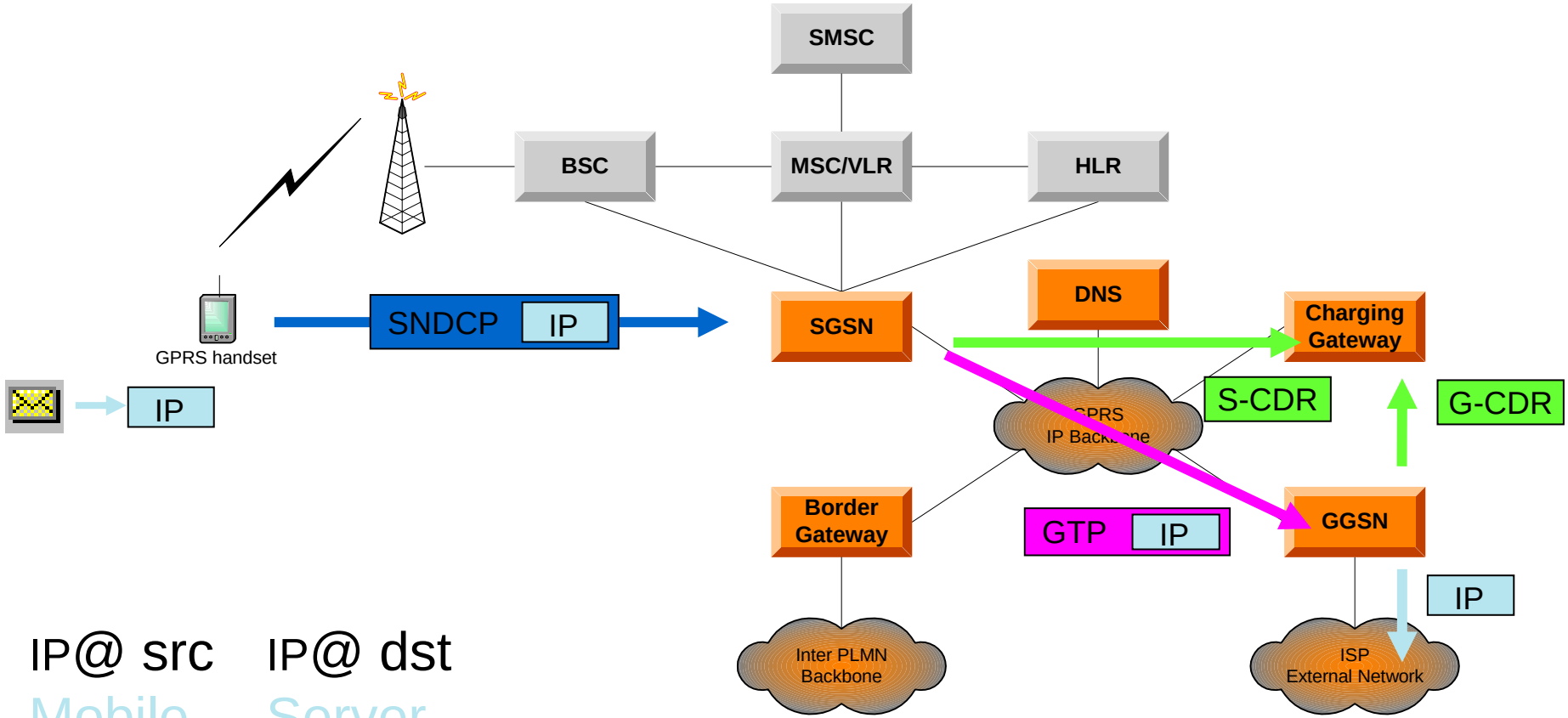
Main Field	Description
type of PDP network	**IP, X25 ….**
Mobile address	**IP address or X.121 address for X25 network**
SGSN address	**IP address of the serving SGSN**
NSAPI	**Network Service Access Point**
QoS Profile	**Quality of service negociated for this PDP context**
Access Point Name	**APN (service) requested by the mobile (ie WAP, internet…)**

Session Management
PDP Context Activation



1. Activate PDP Context Req
2. DNS Query
3. Create PDP Context Req
4. Create PDP Context Rsp
5. Activate PDP Context Ack

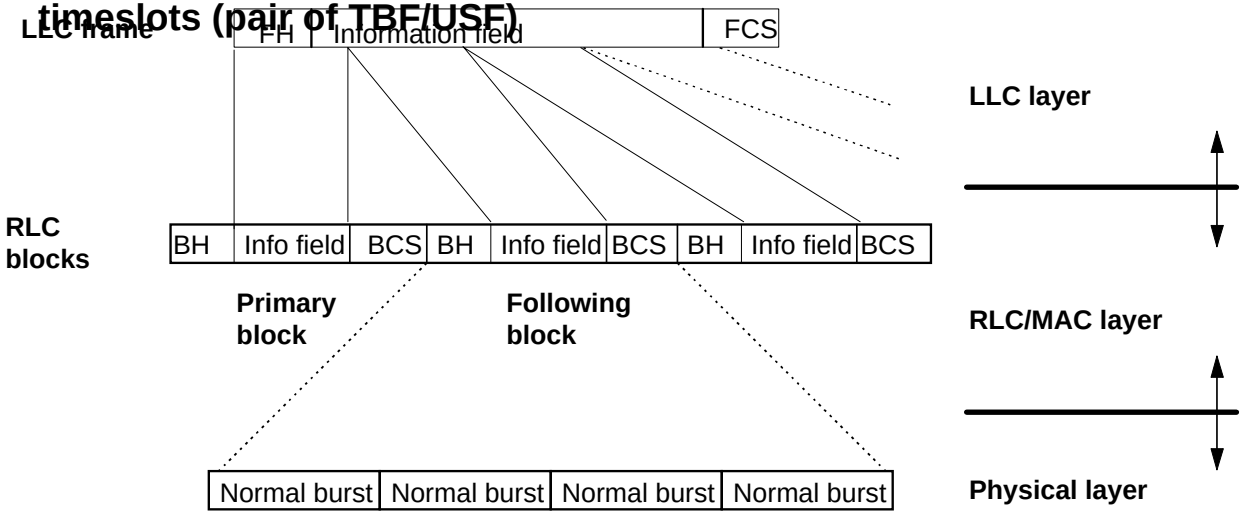
Session Management
Data Transfer



IP@ src IP@ dst
Mobile Server
SGSN GGSN

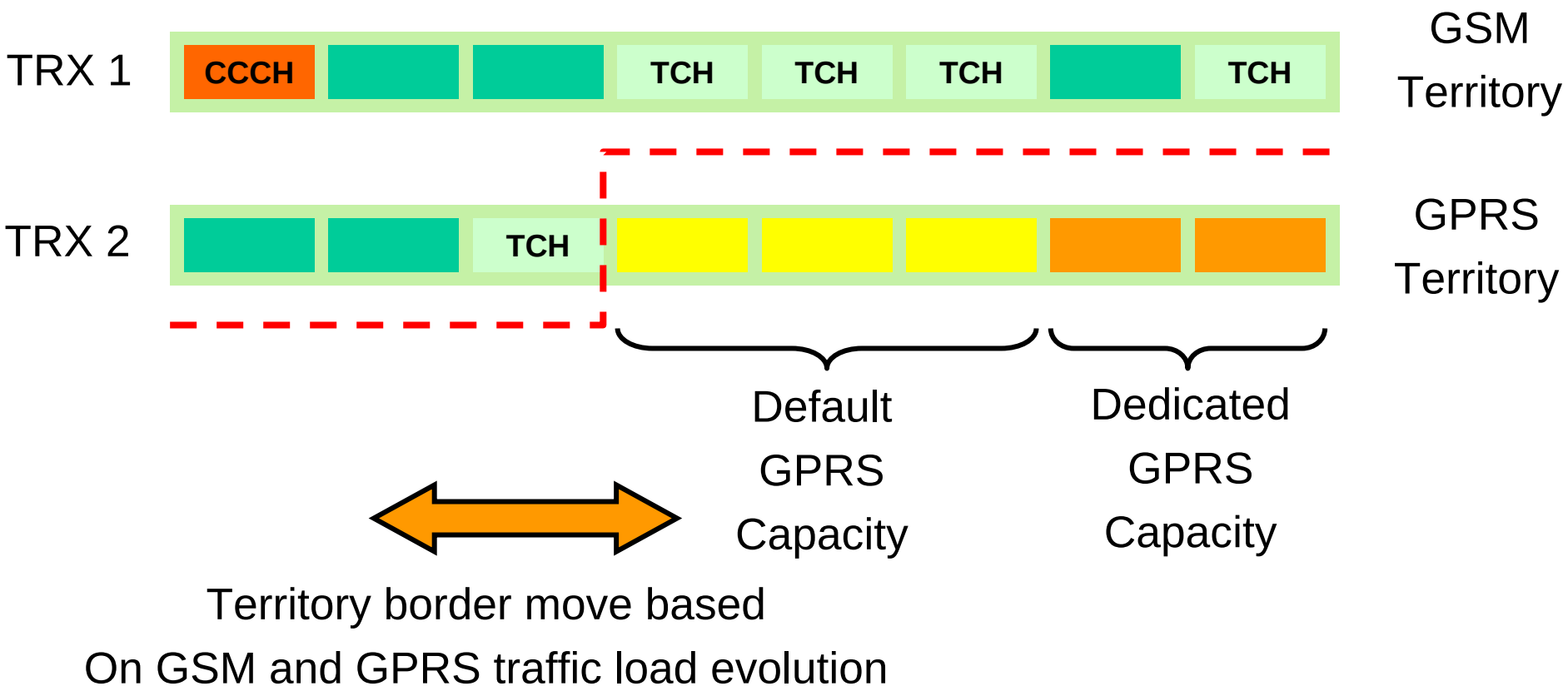
Radio Resource Management
RLC/MAC layer

- RLC/MAC is the most important layer for communication between MS and BSC:
  - **RLC/MAC controls the data flow over the air interface and Abis interface.**
  - **BSS performance are based on RLC block transmissions / retransmission**
    - RLC**: Provide controlling function (ack/unack mode)**
    - MAC**: Medium Access mode: allows to have dynamic allocation of Mobiles over radio timeslots (pair of TBF/USF)**

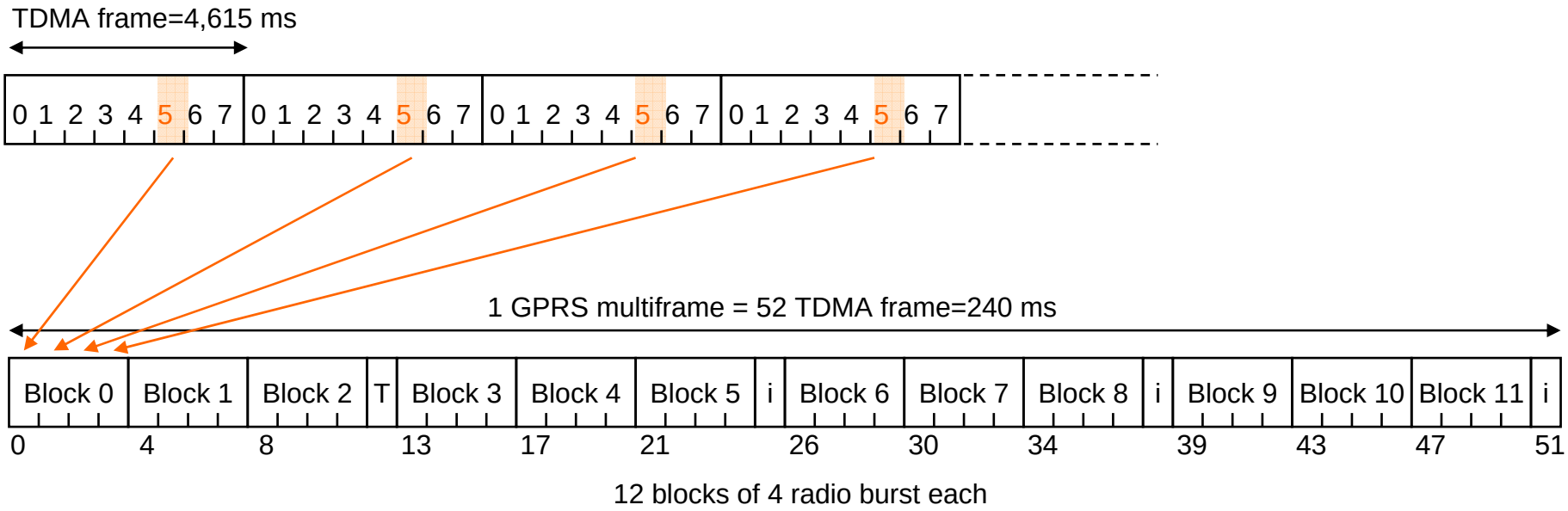


FH = Frame Header
FCS = Frame Check Sequence
BH = Block Header
BCS = Block Check Sequence
(When SDCCH coding is used, BCS corresponds to the Fire code)

Radio Resource Management
Notion of GPRS territory

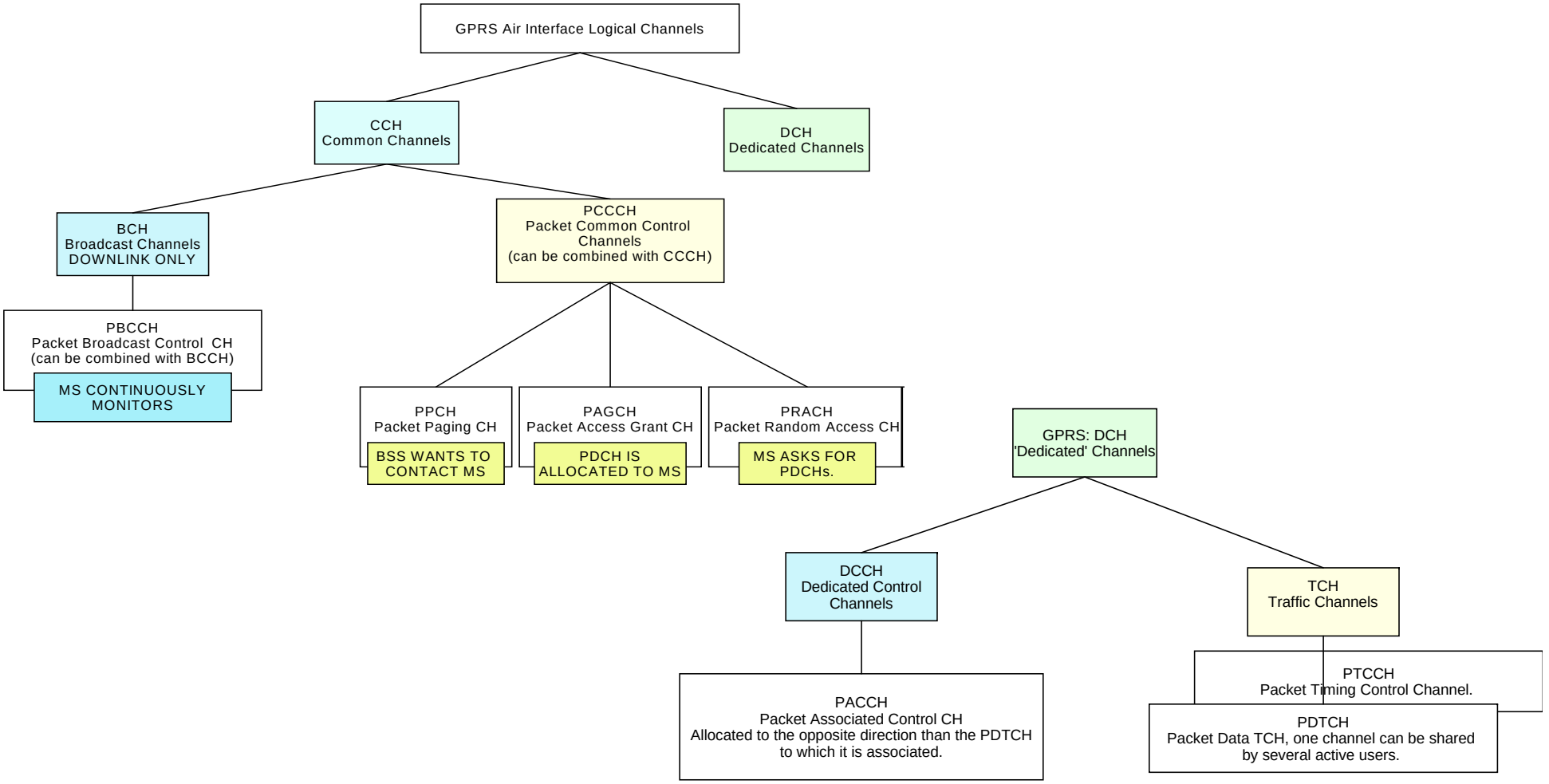


Radio Resource Management
Physical Layer



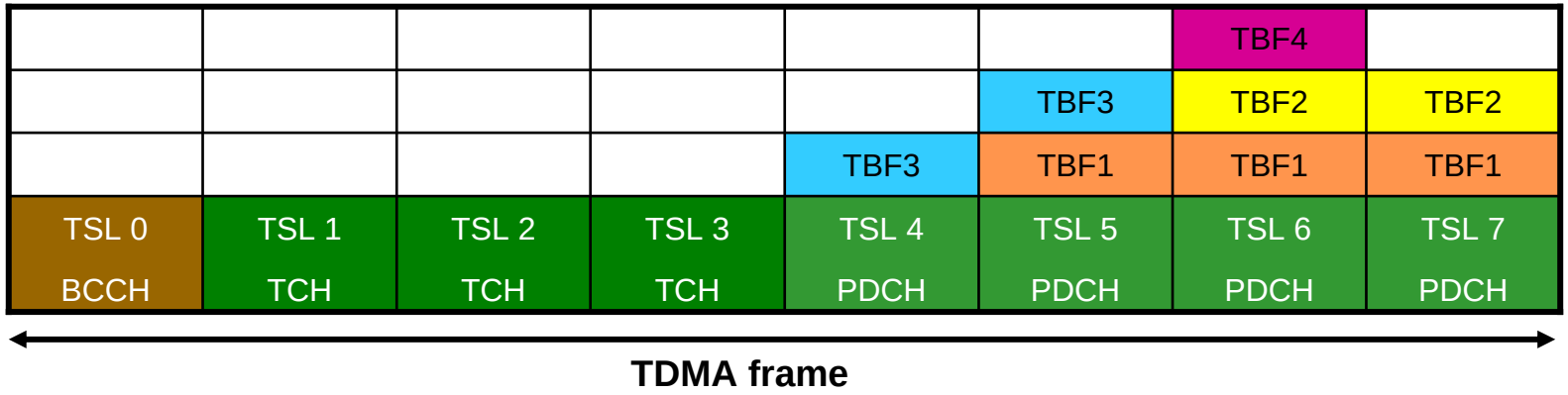
Each block can transfer one GPRS logical channel information

Radio Resource Management
Logical Signalling for GPRS



Radio Resource Management
Timeslot sharing

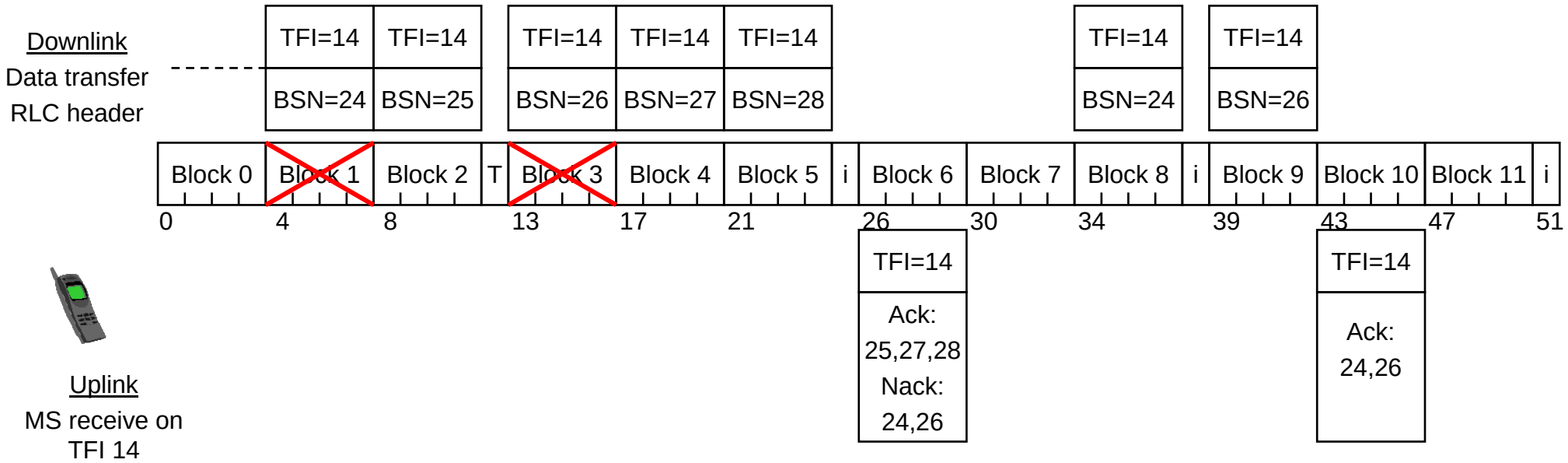
- GPRS data transfer = discontinuous series of Temporary Block Flows.
  - 1 TBF = 1 user (with a given TFI, TLLI, USF)
  - 1 TBF can be transferred onto several radio timeslots



- Data transfer = Uplink / Downlink TBF (Temporary Block Flow) Assignment
  - **Timeslots allocation GSM CCCH channels (RACH - AGCH - PCH) (GPRS - phase 1)**
  - **GPRS phase 2: dedicated common control channels (PBCCH/PCCCH)**

Radio Resource Management
Notion of Data flow

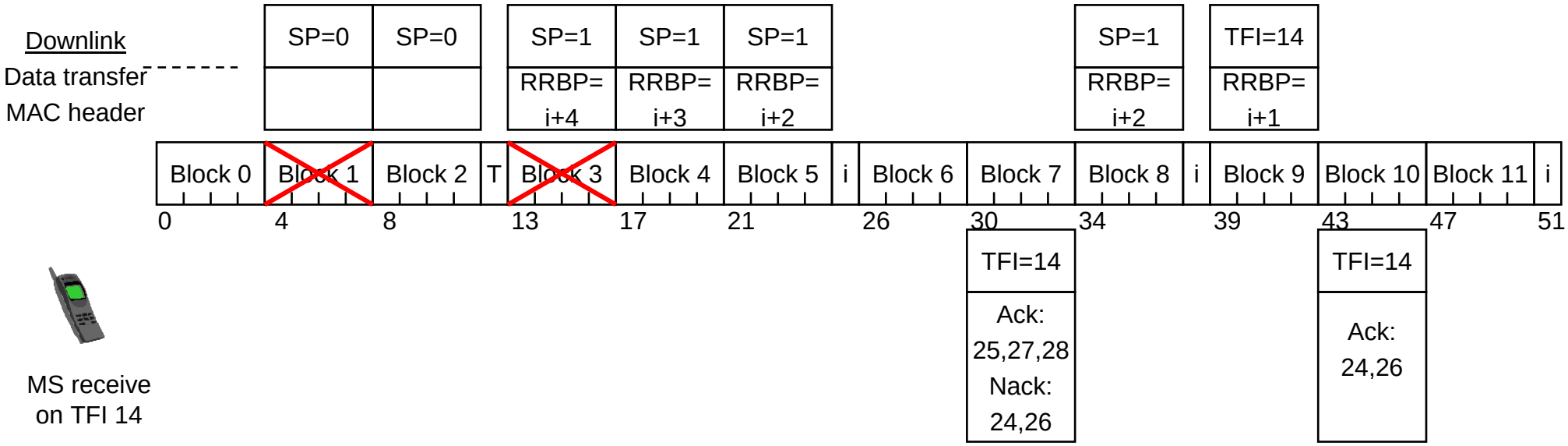
- **RLC layer** create a **Temporary Block Flow**, each time data needs to be sent



- TBF dynamically managed by the network
- To avoid collisions, network identify each user with **TFI** and **TLLI**
- Number of retransmission linked to C/I ratio
- Retransmissions will decrease real user data throughput

Radio Resource Management
Multi user radio sharing

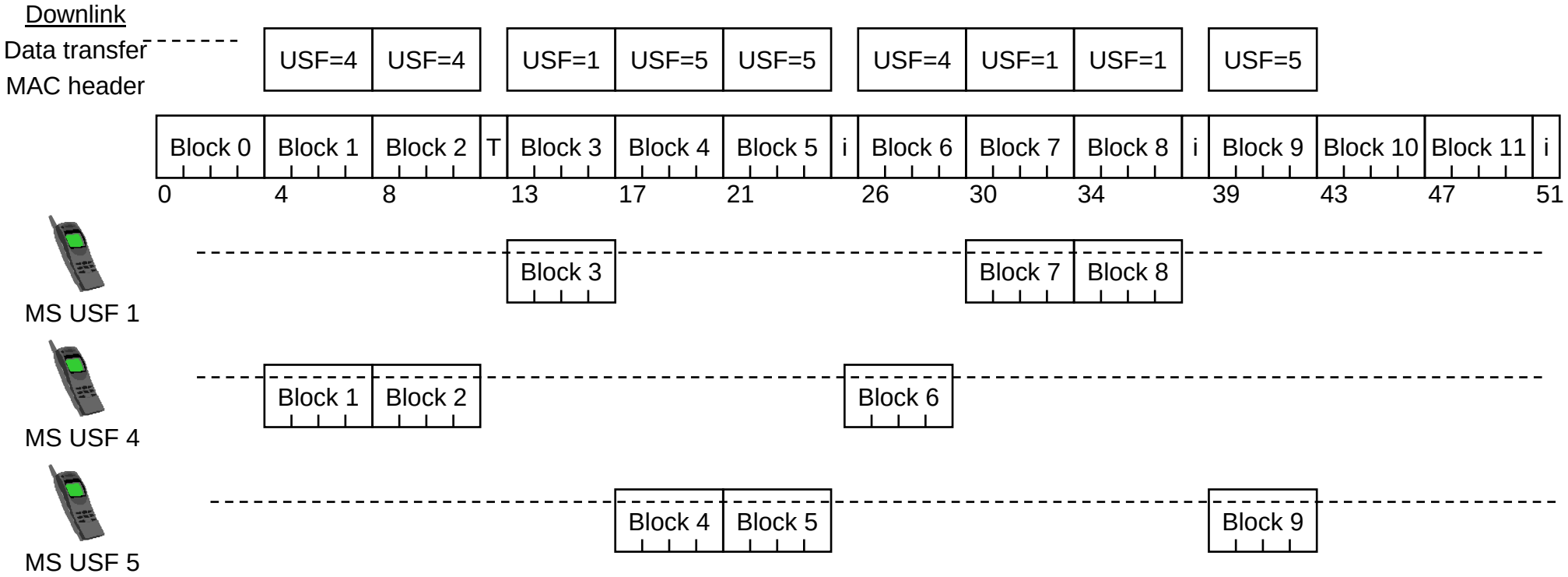
- MAC layer handle resource sharing between mobiles



- Mobile knows on which block to ack/nack received PDU
- Mobile use these control blocks to transfer other information (measurement reports, uplink resource request, etc…)

Radio Resource Management
Dynamic uplink sharing

- Several mobiles can share the same radio timeslot
- MAC layer indicates each mobile which block it can use for uplink transfer



- **U**plink **S**tate **F**lag definition only local to a physical channel (i.e. 1 radio timeslot in the TDMA frame)

GPRS Part 2
Content

… to practice

IMPLEMENTATION CONSTRAINTS

NETWORK DIMENSIONING & PLANNING

NETWORK PERFORMANCE

ANALYSIS AND OPTIMISATION

TOOLS FOR GPRS

Implementation Constraints
Upgrade of GSM network

- New Core Network
  - GPRS backbone is an IP network
    - **New approach in Mobile Telecommunication**
    - **First interaction between IT and mobile telecom network dept.**

- Multi-supplier solution
  - Interoperability problems
    - **Interface Gb, Gs, Gr are standardised by ETSI but multi-vendor solution always leads to complexity.**
    - **Mobile and network compatibility over the air interface is another source of problems**
      - **Different mobiles = different performances**

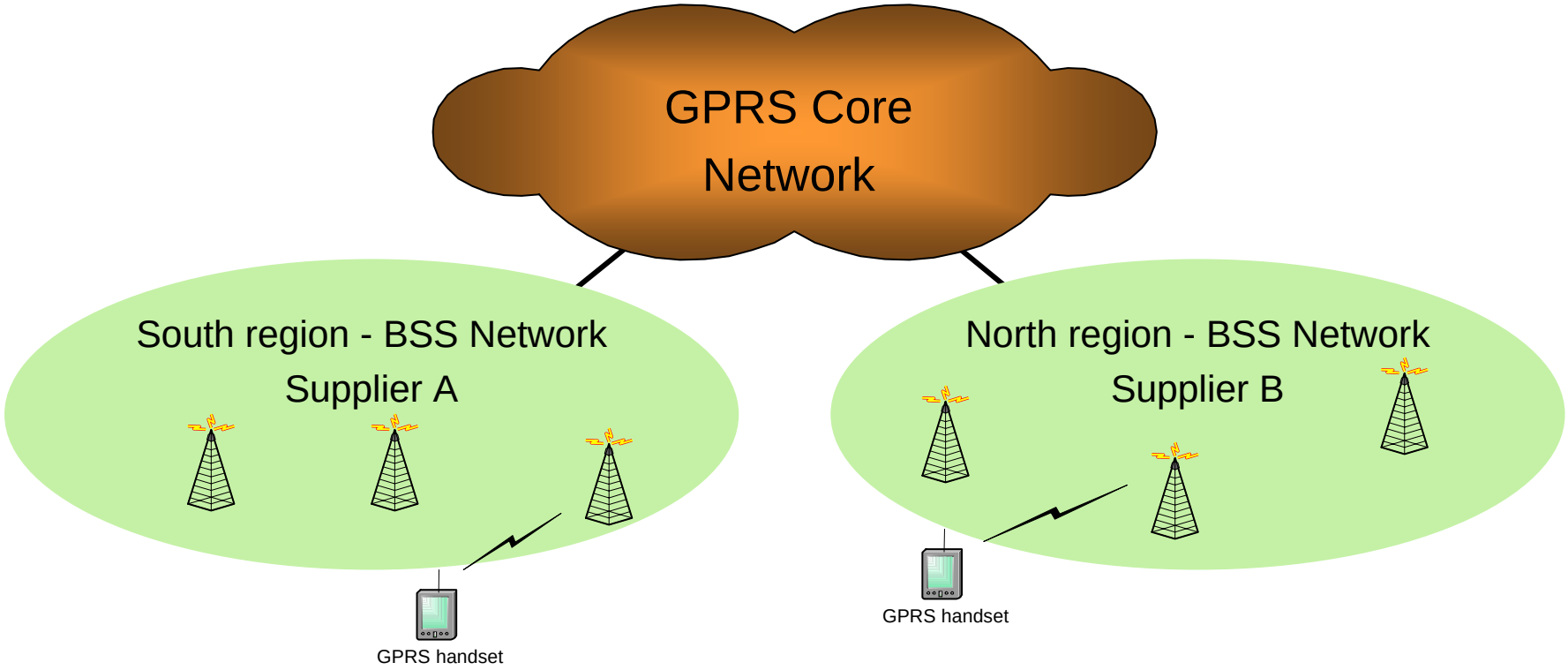
Implementation Constraints
Hardware & Software Releases

- HW & SW Release management
  - **Network is often heterogeneous**
    - **Different generation of base stations, BSC and MSC**
  - **Software Releases are delivered at different times**

- Incomplete GPRS features
  - **QoS not fully implemented**
  - **Radio enhancement (PBCCH) not fully implemented**

- immature ETSI specifications
  - **Suppliers follow different versions**

Implementation Constraints
Heterogeneous BSS Network



- **Problem of uniform** Quality of Service **(different SW/HW, different problems)**
- **Complex** network evolution **(i.e. new feature cannot be implemented country wide)**

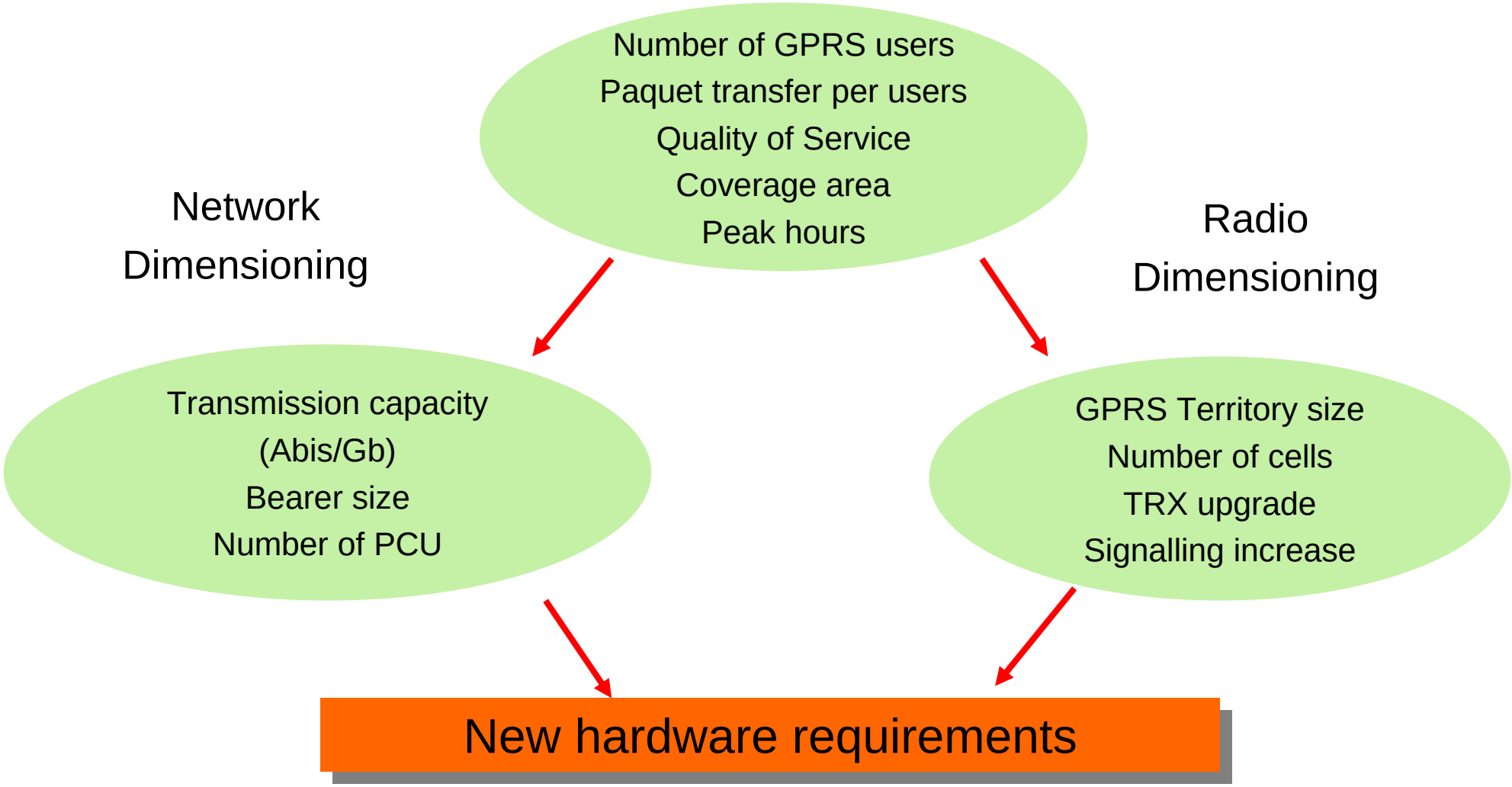
Implementation Constraints
Handsets & Services

- Limitation in mutlislot & coding scheme capability:
  - **First handsets: 2+1 (i.e. 2 TSL DL / 1 TSL UL)**
    - **24 kbps DL / 12 kbps UL**
  - **Current handsets: 4+1**
    - **48 kbps DL / 12 kbps UL**

- ETSI specifications problems
  - **Lots of change request**
  - **PBCCH not supported by network and first GPRS mobiles**

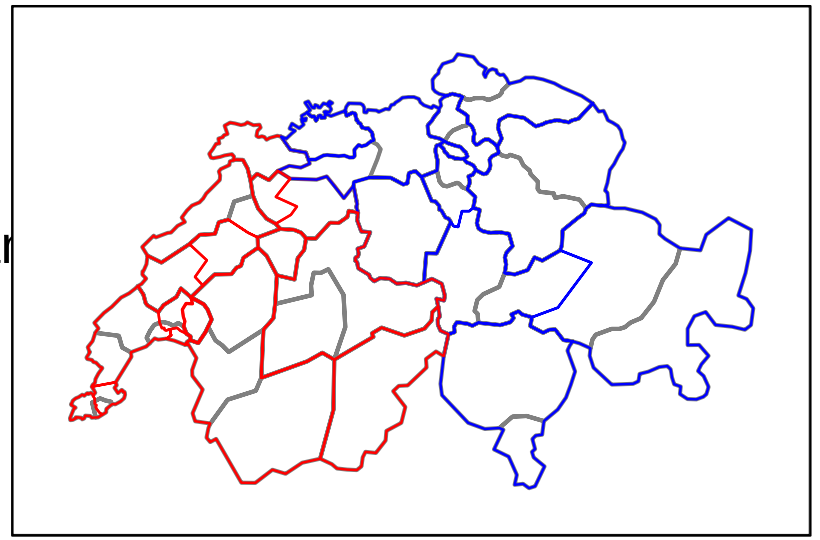
- Poor content for GPRS Services
  - **Lack of «adapted» phones**
  - **Lack of «killer» applications**

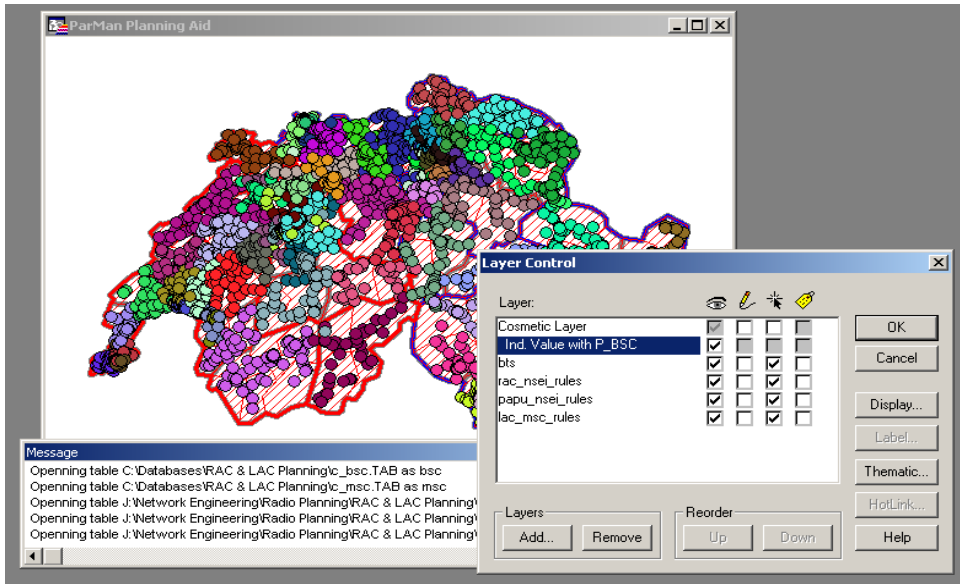
GPRS Dimensioning

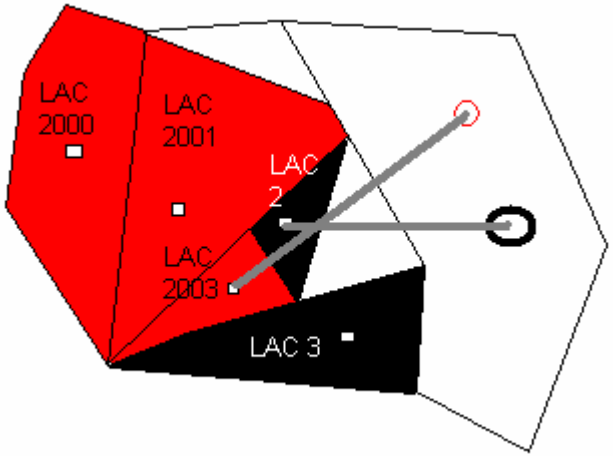


Network Planning

- Reuse existing GSM coverage
- Reuse of GSM signalling and traffic plan
- New core network planning
- New Routing Area Planning







Network Performance
Radio constraints

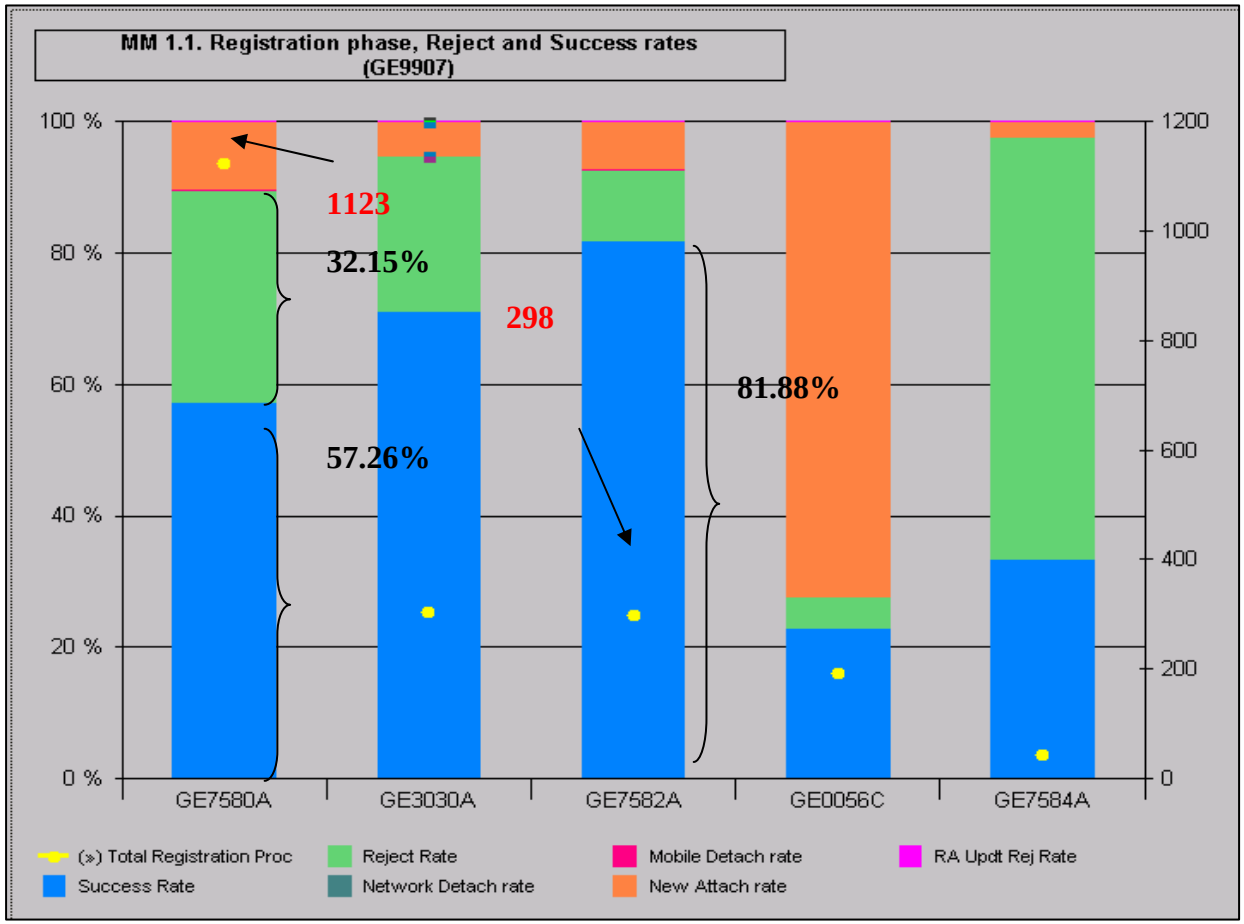
- Cell reselections
  - **GPRS phase 1:**
    - **Network doesn't control cell re-selection process**
    - **Based on GSM cell re-selection of MS in idle mode**
  - **Risk of ping-pong effect**
  - **Critical decrease of user data throughput**

- C/I (carrier/interference) criteria
  - **GPRS is very sensible to interferences**
  - **Data throughput drops quickly with interferences**

- Capacity
  - **GSM traffic has priority over GPRS**
  - **« Best effort » mode**
  - **Low throughput in peak hours**

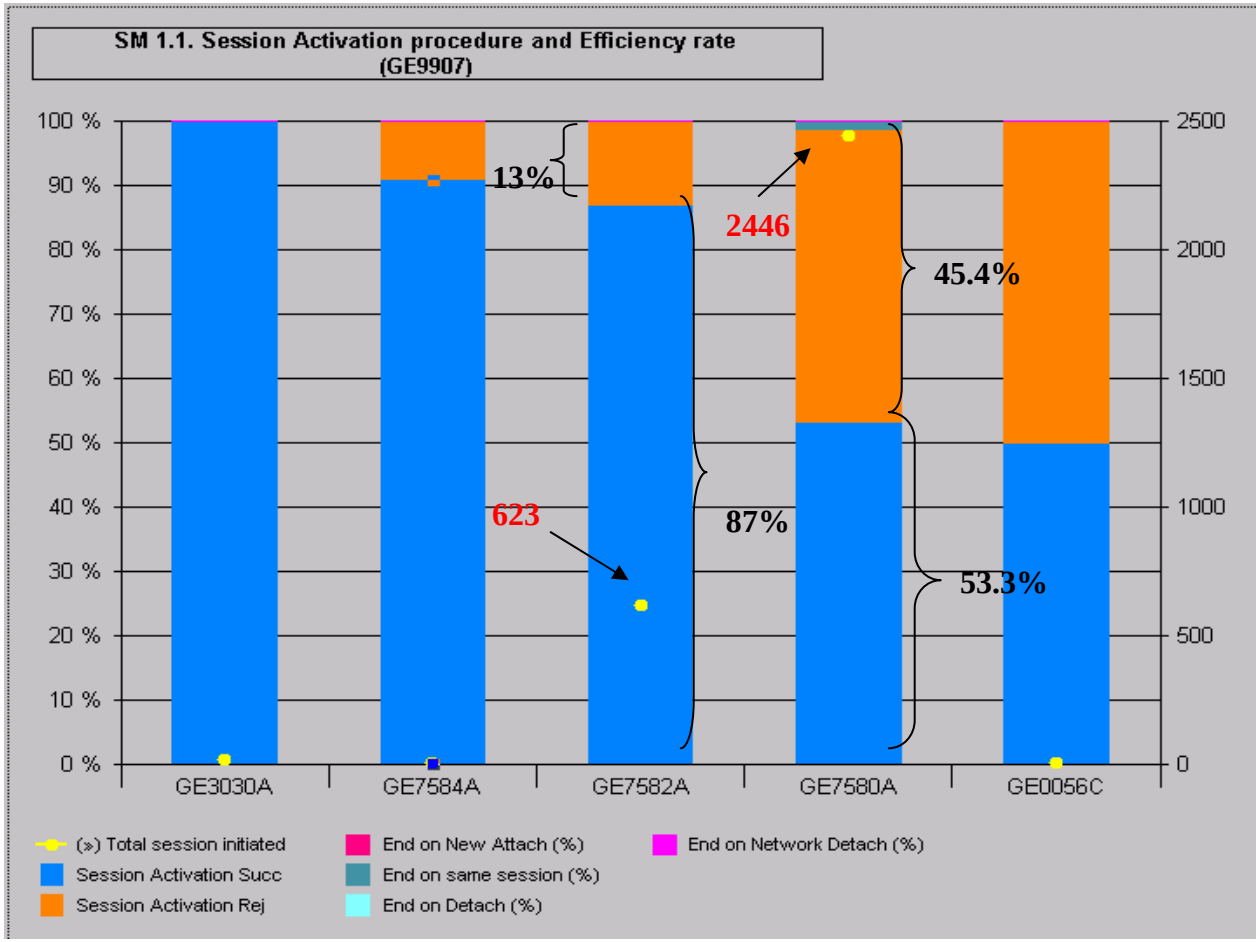
Analysis and optimisation

- Performance Analysis – Access to Network resource



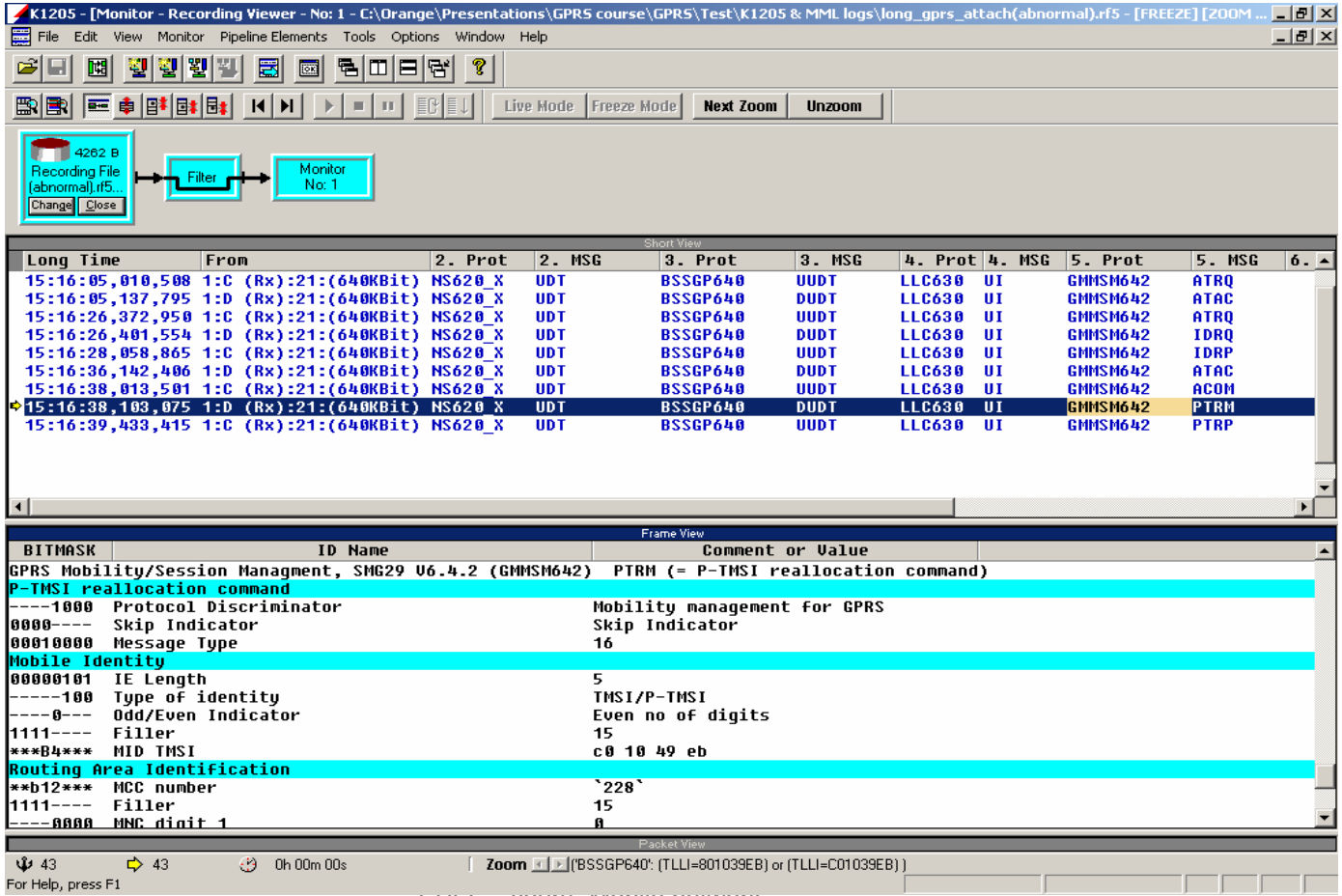
Analysis and optimisation

- Performance Analysis – Session success



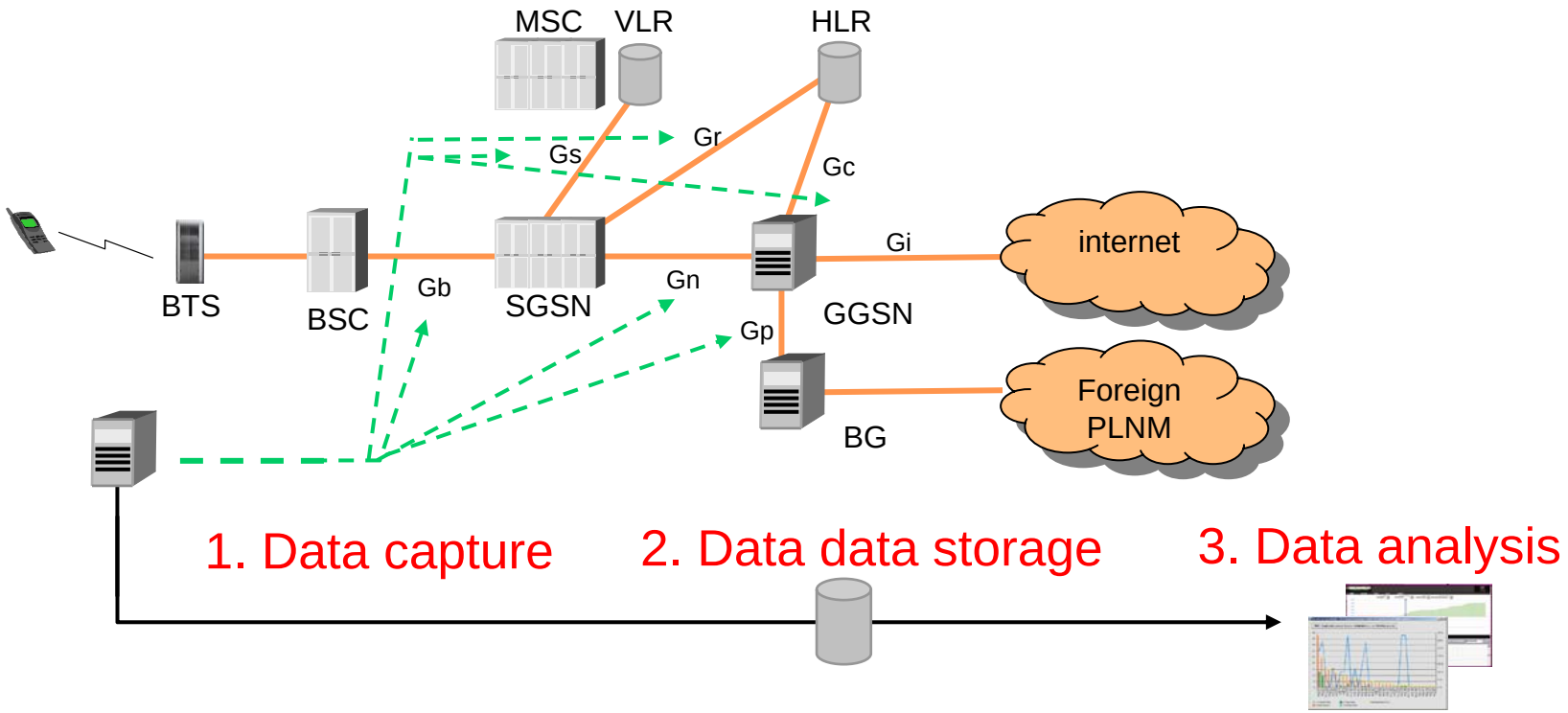
Analysis and optimisation
Tools for GPRS

- Protocol analyser
  - » In depth signalling study



Analysis and optimisation
Tools for GPRS

- Probe System
  - » Data capture across all GPRS network interfaces



Analysis and optimisation
Benefit of Gb analysis

- Full network supervision
- Access to QoS information
- Information that can be shared accross mainy actors:
  - Radio optimisation team
  - Maintenance team
  - Quality team
  - Traffic team
- High level of detail
  - Info per session
  - Info per user
  - Info per cell/PCU
  - Info per network area

Documentation

- Réseaux GSM **(ISBN 2-7462-0153-4)**
  - **Xavier Lagrange, Philippe Godlewski, Sami Tabbane**
- Ingénierie des réseaux cellulaires **(ISBN 2-7462-0550-5)**
  - **Sami Tabbane**
- The GSM Evolution - Mobile Packet Data Services **(ISBN 0-470-84855-3)**
  - **Peter Stuckmann**
- GPRS Signalling & Protocol Analysis – Vol. 1
  - **Gunnar Heine**

Evolution towards EDGE
Content

DEFINITION

NETWORK PERFORMANCE

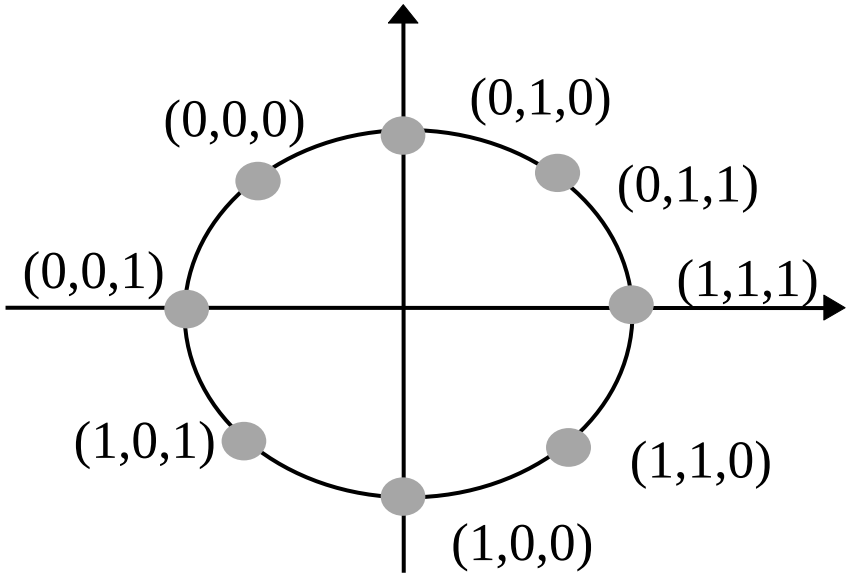
EDGE IMPLEMENTATION

EDGE DIMENSIONING

APPLICATIONS FOR EDGE

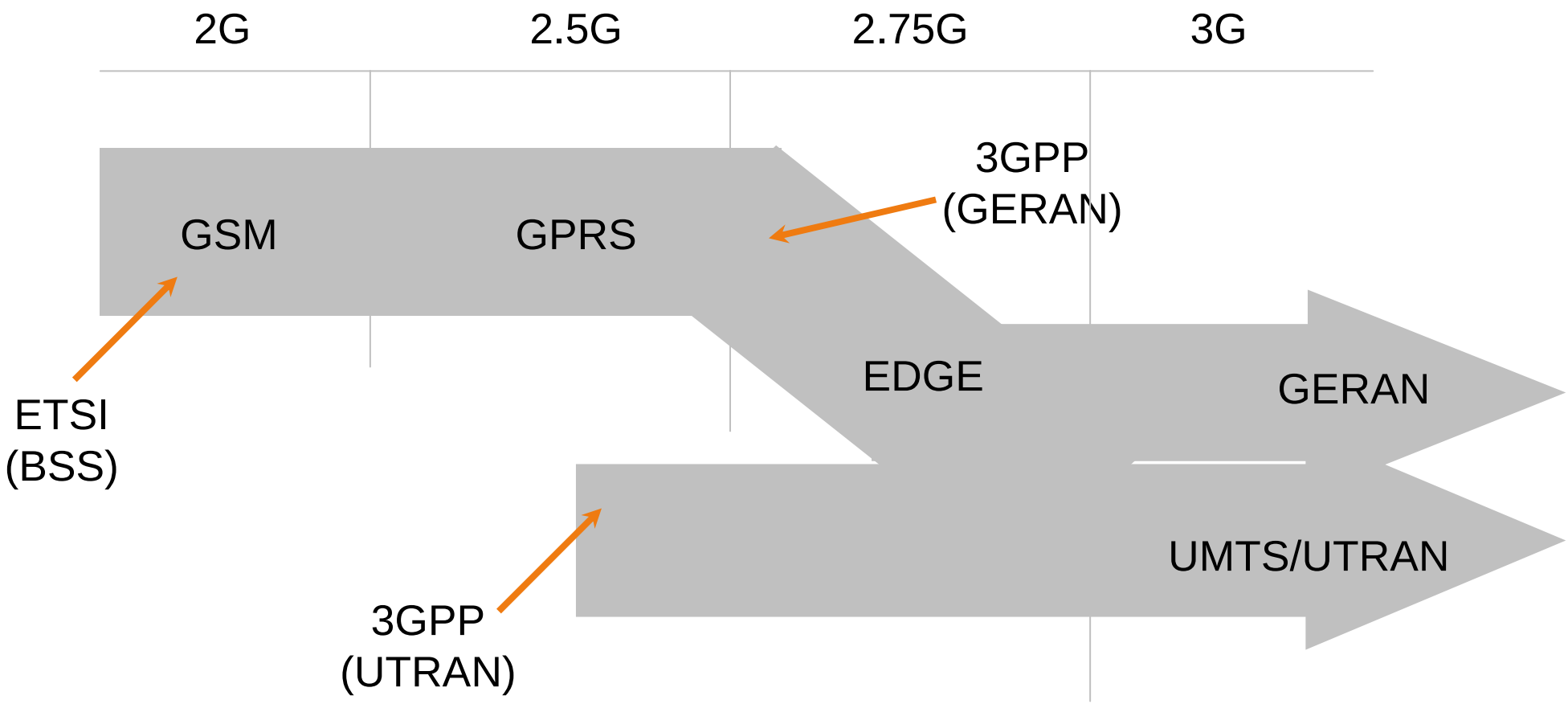
EDGE – evolution of GSM air interface

8PSK modulation to replace GMSK



	EDGE	*GSM*
Modulation	8-PSK, 3bit/sym	GMSK, 1 bit/sym
Symbol rate	270.833 ksps	270.833 ksps
Payload/burst	346 bits	114 bits
Gross rate/time slot	69.2 kbps	22.8 kbps

From GSM to GERAN
evolution of specifications



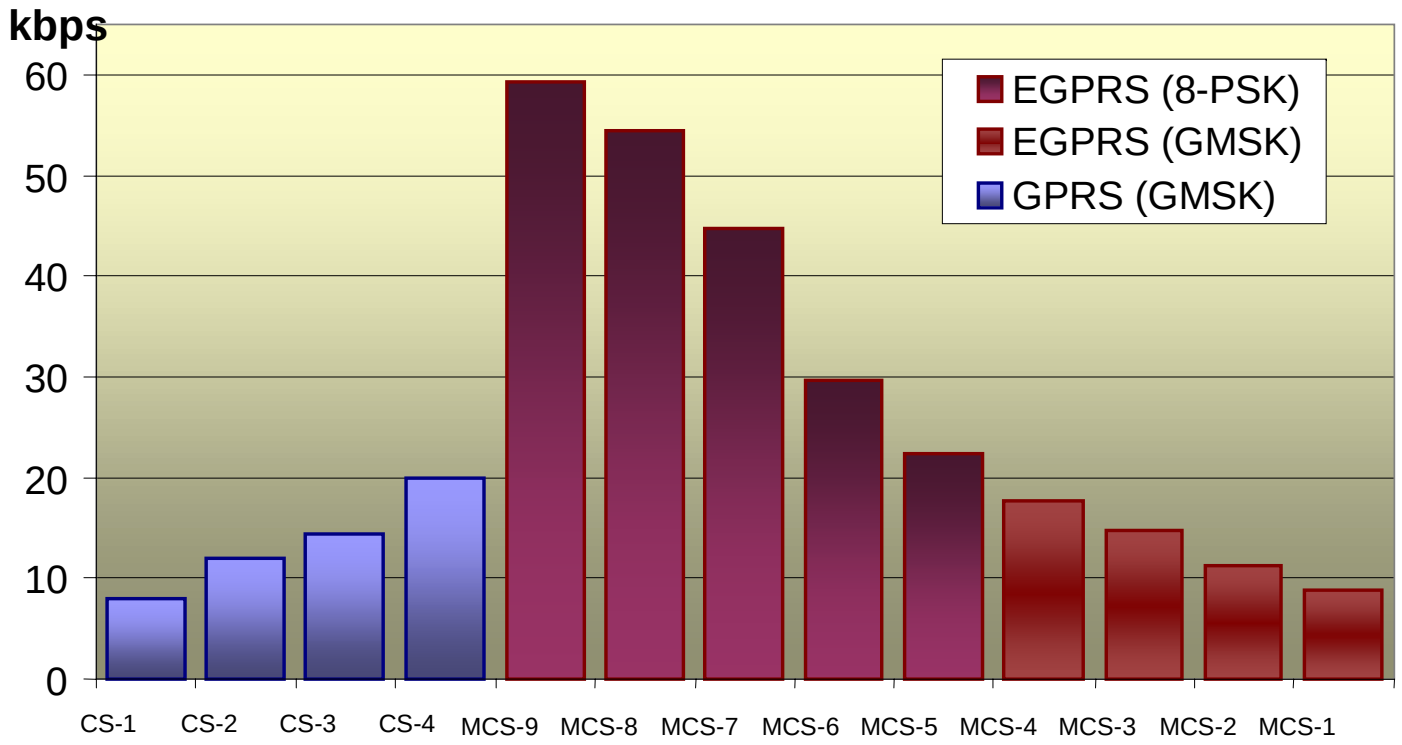
EDGE as a GERAN feature

Enhanced Data rates for Global Evolution, from Release 99

Technical aspects	Performances
▪ EDGE is a **mature** product (all vendors NEs & features are ready since mid'2004) ▪ **EGPRS** only (ECSD not implemented by suppliers) ▪ Available for all bands (850/900/1800/1900) ▪ Ensure the **backward compatibility** with GPRS mobiles	▪ 2 to 4 times higher data throughput than GPRS ▪ Interactive and Background classes*, Rel 99: **Now** ➢ Web browsing, mail attachment, chat, e-commerce, file transfer,… at high data rate ▪ Streaming with mobility QoS*, Rel 4: **2005** ➢ Audio & Video streaming ➢ Video on-demand. **2006/2007** ▪ Conversational for data services*, Rel 5 & Rel 6: ➢ Videotelephony (*) EDGE has been standardised to enhance the data rate but not to enhance QoS service (still best effort service) other features of GERAN will do it

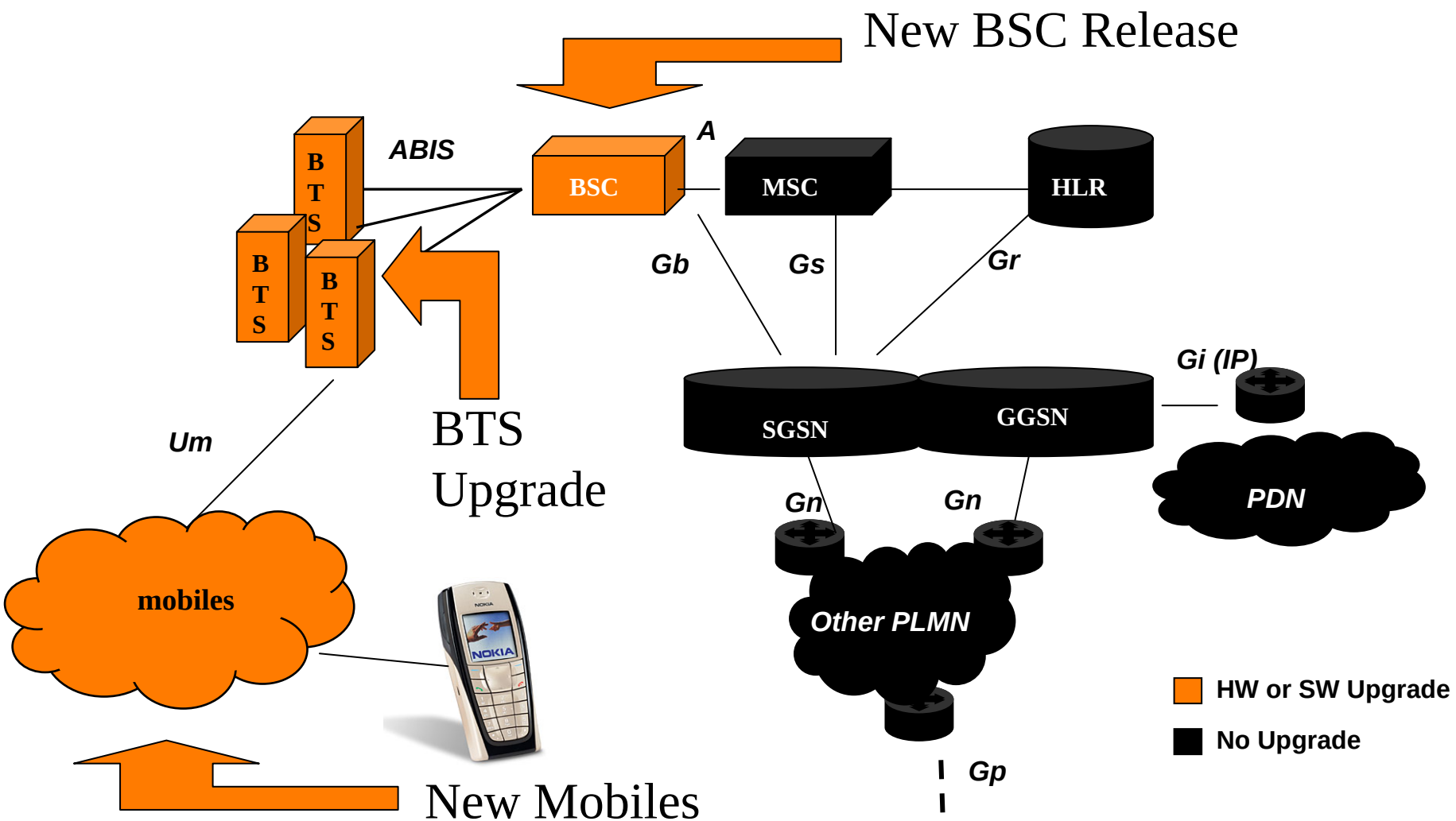
Objective: a higher data throughput thanks to a better spectral efficiency.

Theoretical performance of EDGE



EDGE can provide data services with maximum radio throughput of **235kbps** using 4 TS.

Network impact of EDGE implementation

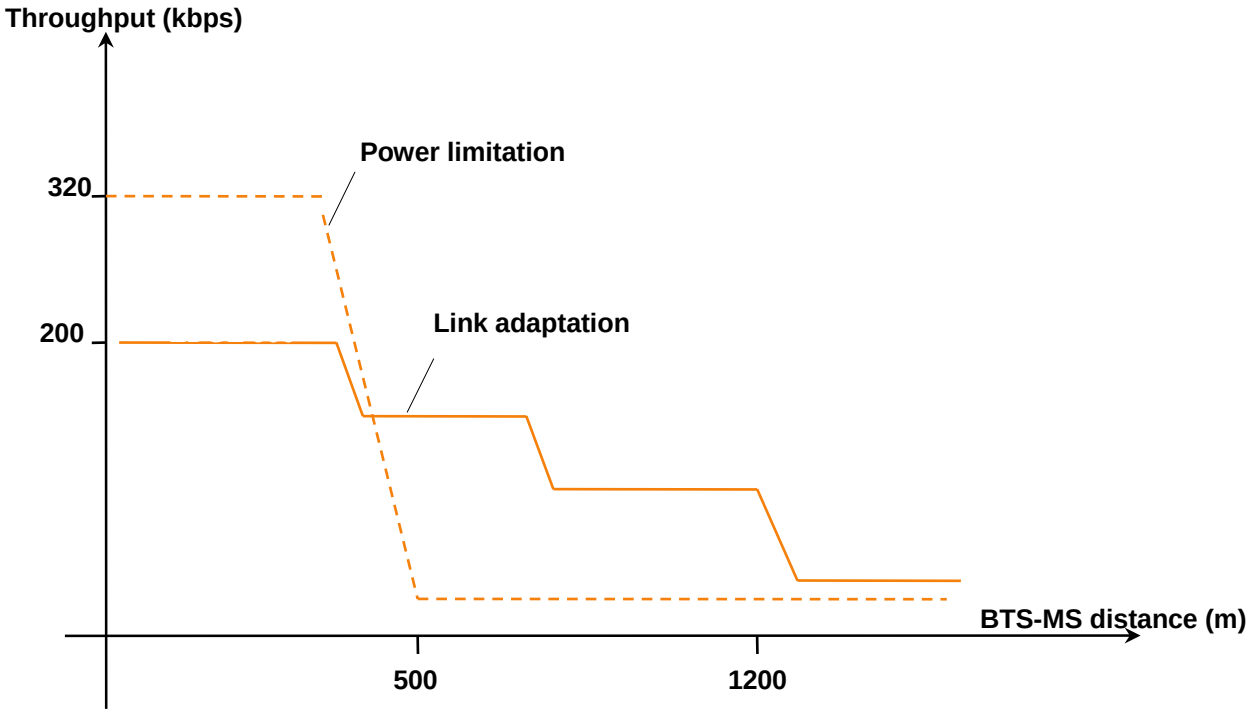


Radio performances impact of EDGE implementation

- EDGE is main influence on GSM is on the radio interface.
- Upgrade of GSM network with EDGE will influence the radio conditions
- There is a need for carefull radio optimisation
- EDGE throughput is highly dependent on interferences (C/I), especially at the cells' border

EDGE vs UMTS for indoor coverage

- **Robustness of Edge** :
  - Compensation of radio propagation fluctuation thanks to Link Adaptation
- **Instability of UMTS** :
  - Throughput Drop due to building penetration and the mobile « Power rise » phenomenon.



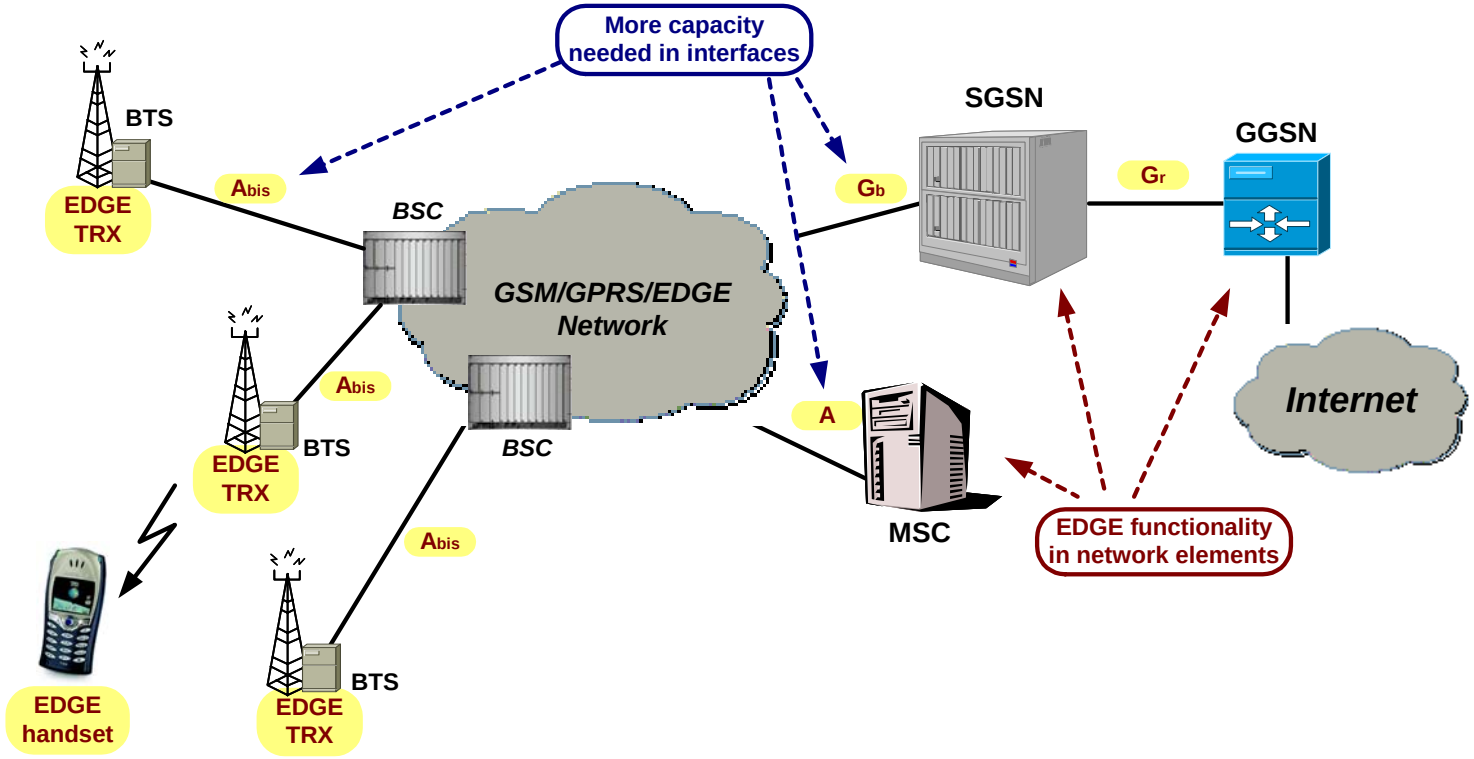
Dimensioning principles: radio

Deploy EDGE on BCCH TRX (beacon channel) or not?

Preferred configuration	C/I mostly > 15dB	For all values of C/I
Small PS traffic (1 to 5 TS)	**BCCH**	**Choose the TRX** that have the **best C/I distribution** If BCCH and non BCCH TRX have same C/I distribution ➔ try to optimize the network to increase the C/I. If BCCH and non BCCH TRX have always slightly the same C/I distribution ➔ put **EDGE on non BCCH with synthesized SFH** (EDGE performances could not reach expected values, i.e. average of 30kbps/TS)
Important PS traffic (more than 5 TS)	**non BCCH**	Try to optimize the network to increase the C/I of non BCCH TRX. If non BCCH TRX have always slightly the same C/I distribution, put **EDGE on non BCCH with synthesized SFH** ➔ EDGE performances could not reach expected values (i.e. average of 30kbps/TS)

Dimensioning principles: transmission

Objective: a **higher data throughput** thanks to a better spectral efficiency.



- EDGE capable TRX need to be added, old BTS might have to be changed, BSC/PCU shall support EDGE capability.
- Re-dimensioning of the interface according to the traffic growth.

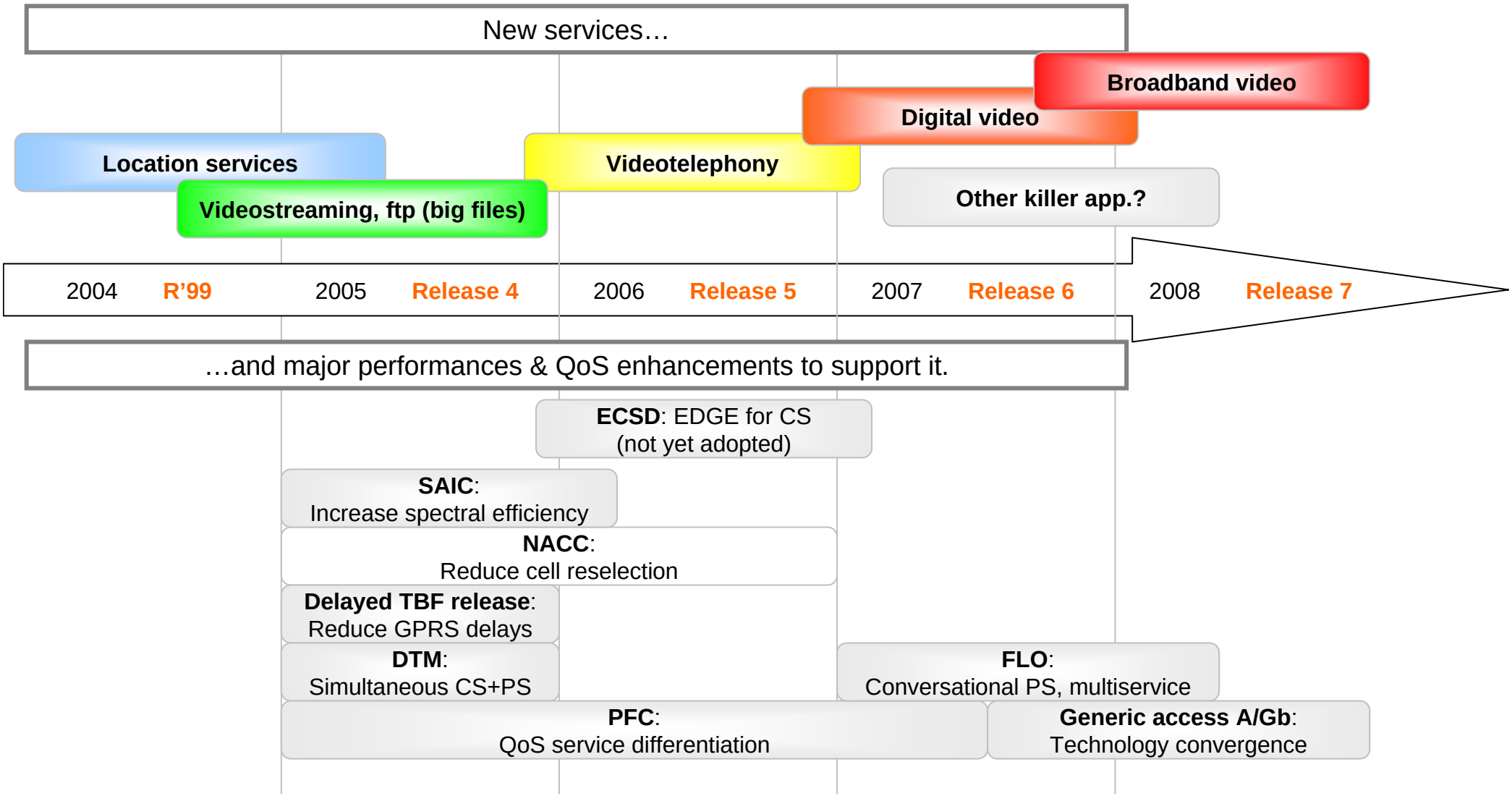
Dynamic Abis principle

PCM transmission frames = permanent time slots for the CS traffic and signalling
+ Dynamic Abis Pool for the data (DAP)

Dynamic Abis Pool common for multiple GSM/EDGE TRXs located under the same BTS.

	MCS-1	MCS-2	MCS-3	MCS-4	MCS-5	MCS-6	MCS-7	MCS-8	MCS-9
no-Slaves	X								
1 Slave		X	X	X	X				
2 Slaves						X			
3 Slaves							X		
4 Slaves								X	X

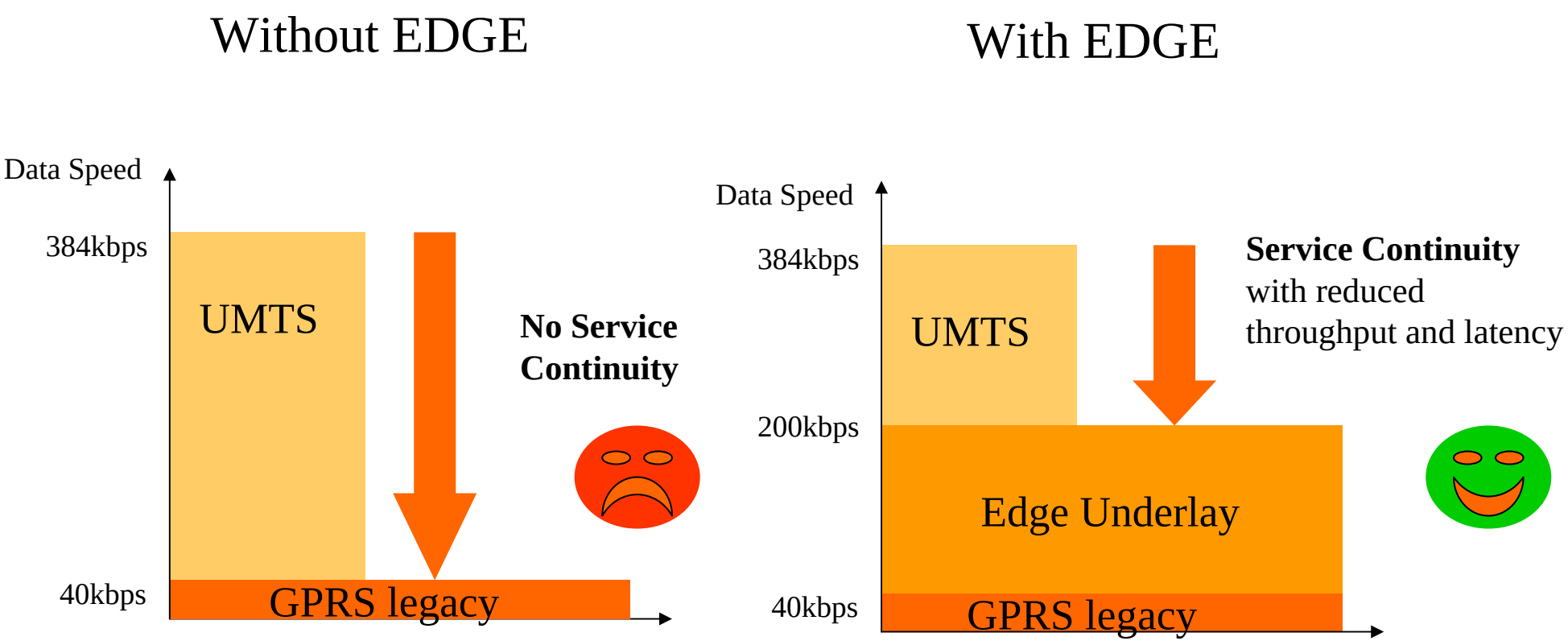
… and services evolution



EDGE Status Worldwide

- Edge is a GSM - BSS feature to enable highest data throughput (proven technology)
- 38 devices are currently Edge compatible
- GSM Wireless Industry entirely committed to Edge
- 111 networks deploying Edge currently
- 35 commercially available Edge networks

Continuity of Service



Edge Introduction -> Bridging the Broadband Services gap

EDGE Service Portfolio

	FTP (kbps)	RTT (sec)	GPRS	EDGE	UMTS
• MMS	Best Effort	N/A	◇	◆	◆
• Orange World	>16	1-5	◁	◇	◆
• Audio/Video Streaming	>128	<1	—	◇	◆
• Video Messaging	>64	N/A	—	◇	◆
• File Downloads	64-384	N/A	—	◇	◆
• Video Telephony	>64	<0.2	—	—	◇

— Not possible

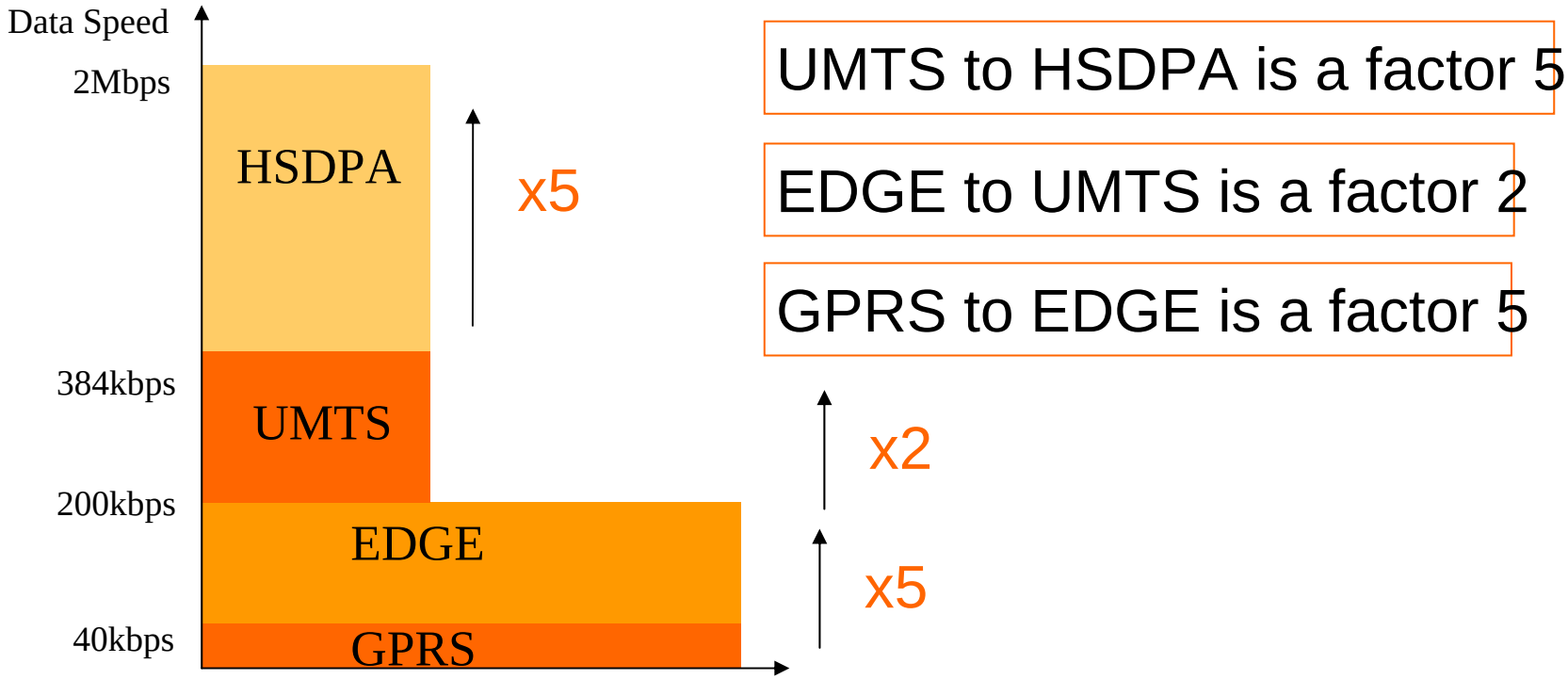
◇ Best Fitted technology

◁ Enabler technology

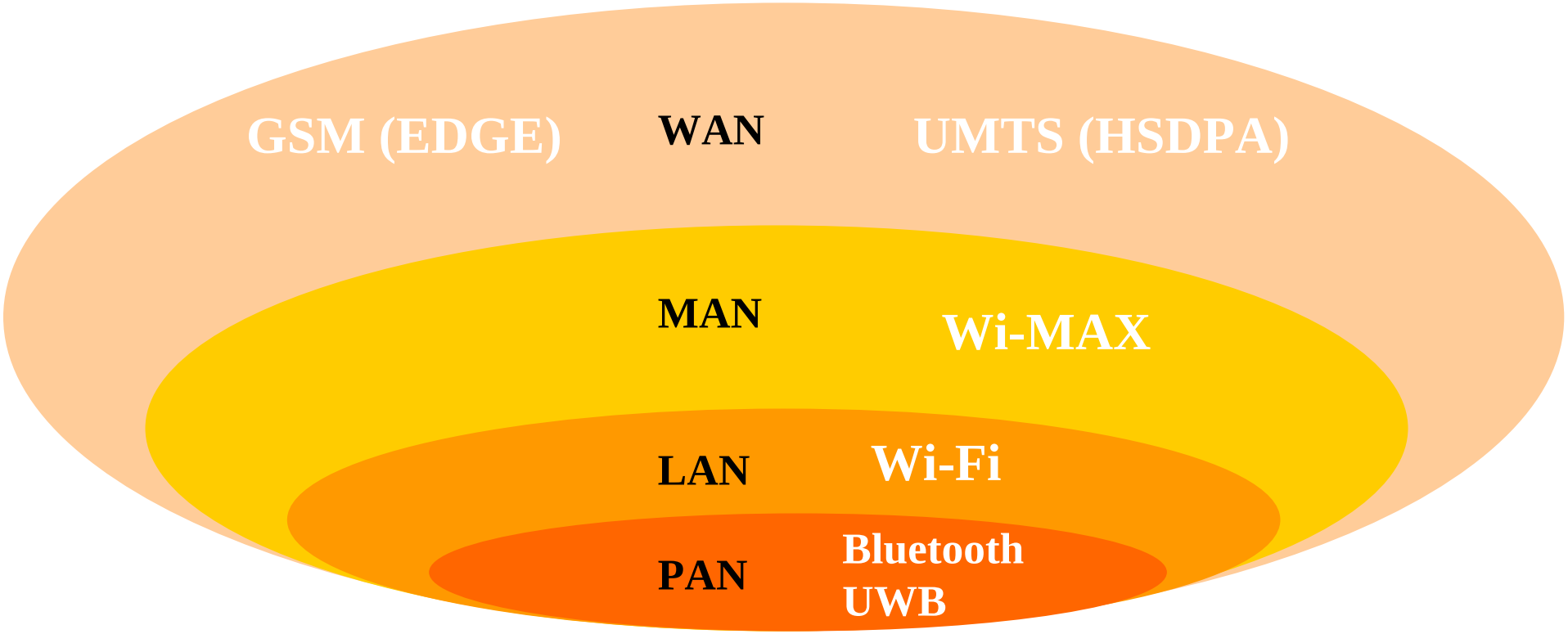
◆ Premium technology

HSDPA as the next evolution after EDGE

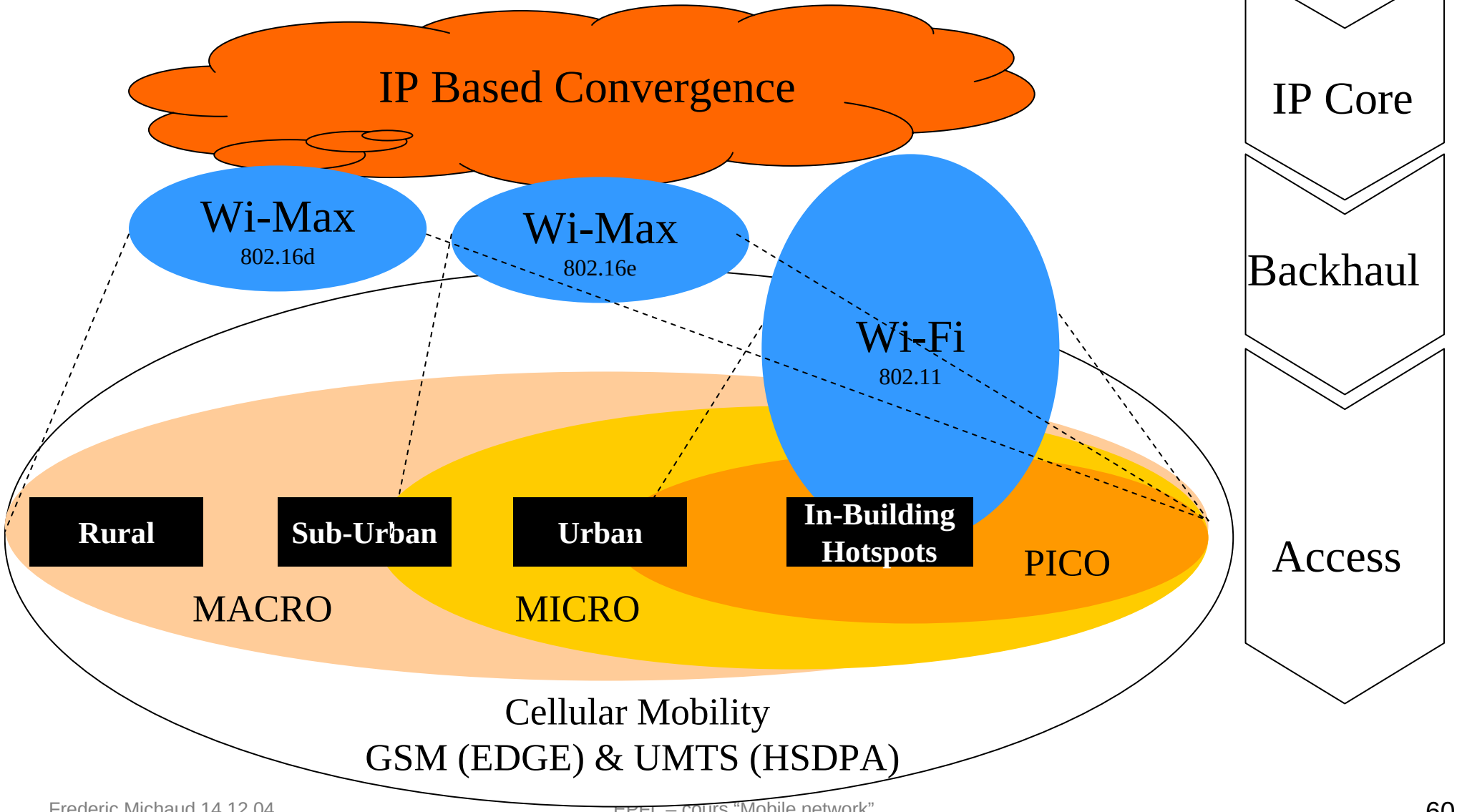
- **HSDPA is to UMTS what EDGE is to GPRS**
  - New radio modulation offering higher bandwidth



Access Network Logical Layers



Mobile Broadband Technology map



Conclusion

- EDGE deemed as a mature/stable/robust technology-
  - Edge as a key technology for in building coverage
  - Edge terminals are cheaper and more robust than UMTS (batteries…)
  - Complementary to UMTS in rural and suburban areas
  - International roaming with American/Asian operators that will transit to EDGE in Europe
- For usual radio conditions:
  - RLC throughputs around 40 kbps may be expected per timeslot (x4 for class 10 MS)
  - FTP throughputs around 35 kbps may be expected per timeslot (x4 for class 10 MS)
- This performance greatly depends on
  - The link adaptation algorithm of the manufacturer and parameter settings
  - The engineering solution chosen for EGPRS implementation