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UMTS
Architettura e Sistema di Accesso

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Agenda

- **UMTS Architettura e Sistema di accesso**
  - **- La struttura del sistema GSM ed il GPRS**
  - **- La struttura del sistema UMTS**
  - **- L'accesso radio CDMA e TDMA**
  - **- Le caratteristiche della nuova/e banda/e**
  - **- La copertura a livelli ed in funzione della mobilità**
  - **- Le prestazioni della nuova copertura**
  - **- References (www.3gpp.org)**

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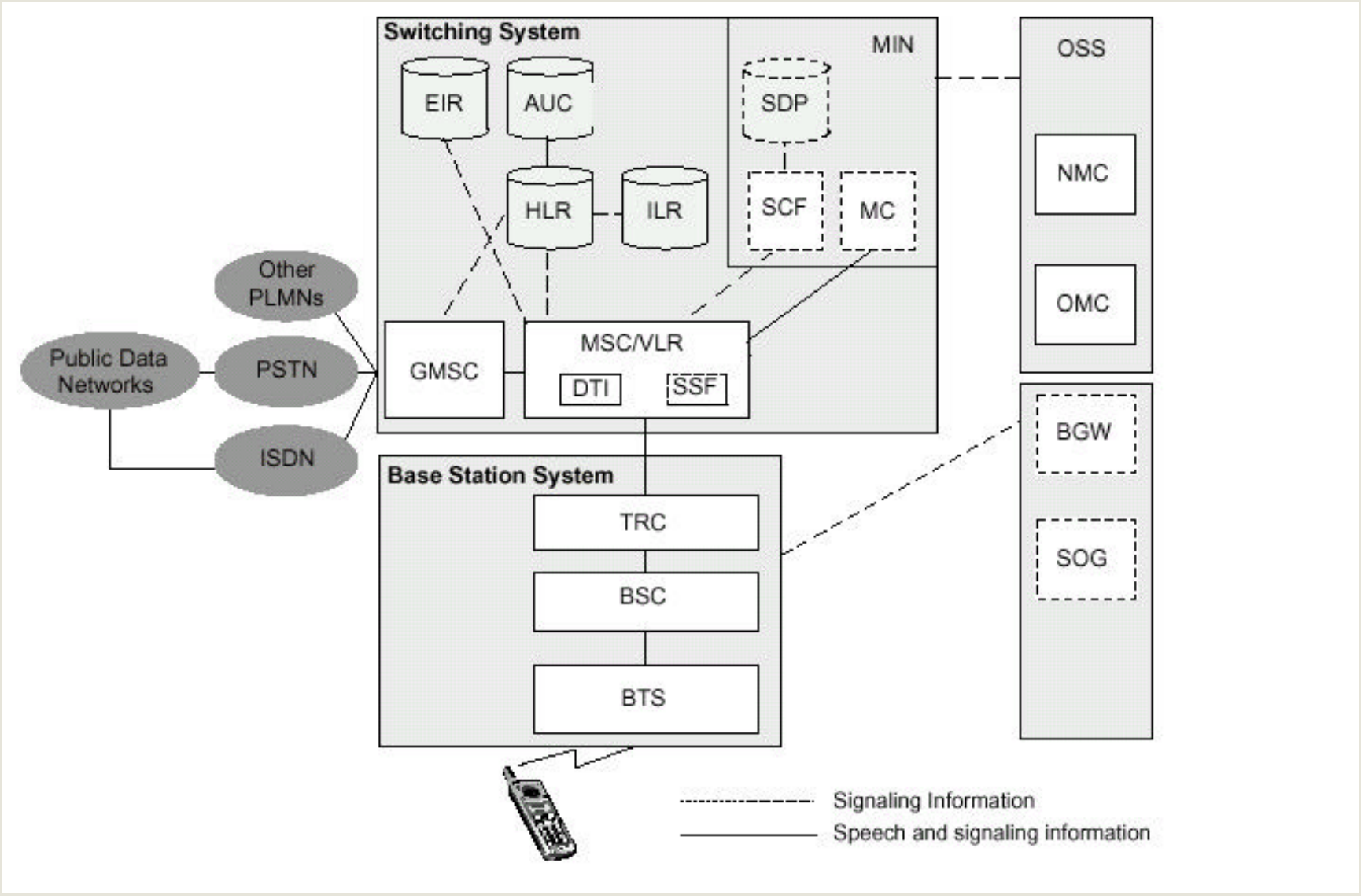
Sistema GSM - Struttura



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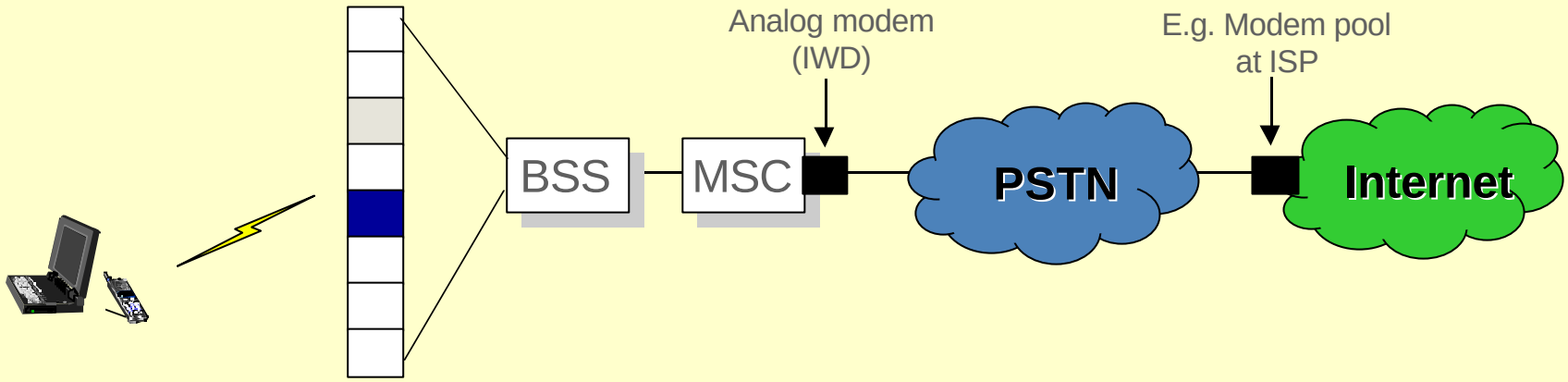
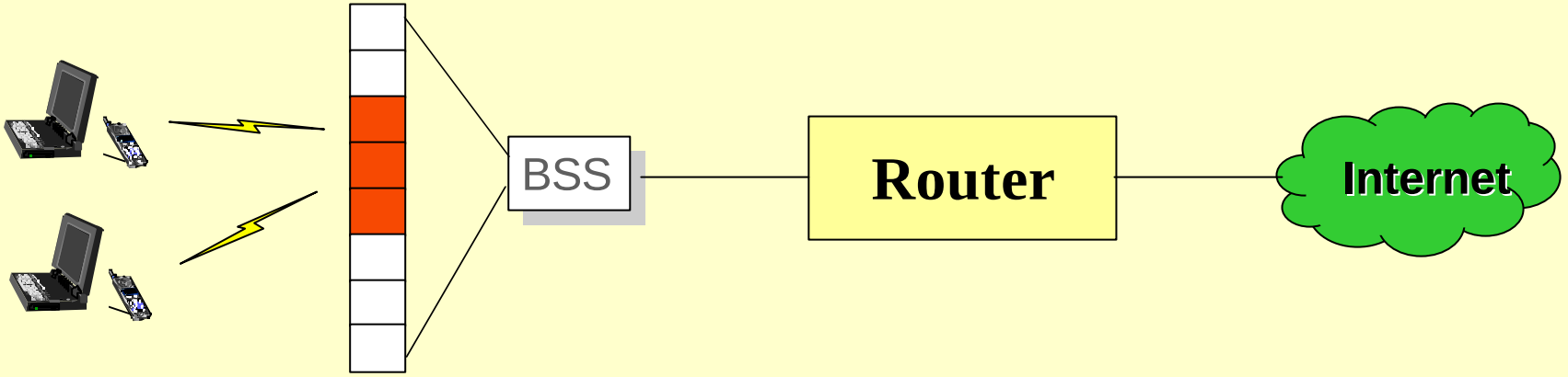
Data access in GSM before GPRS



- **Circuit switched dial-up data connection**
- **Long setup time**
- **Typical 9.6 kbit/s (Multi Slot is allowed)**

Data access in GSM with GPRS (simple model)



- Packet switched data connection
- Always connected, always online

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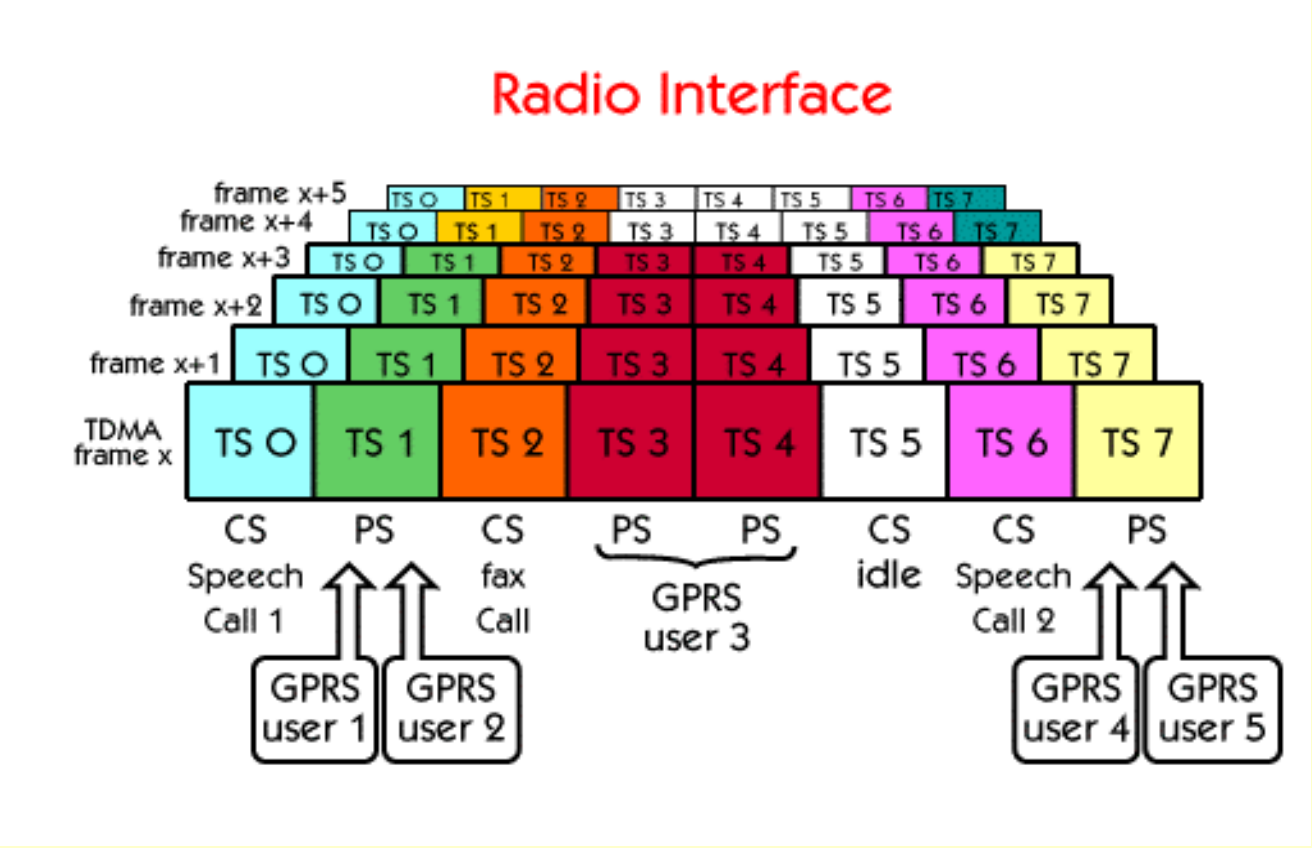
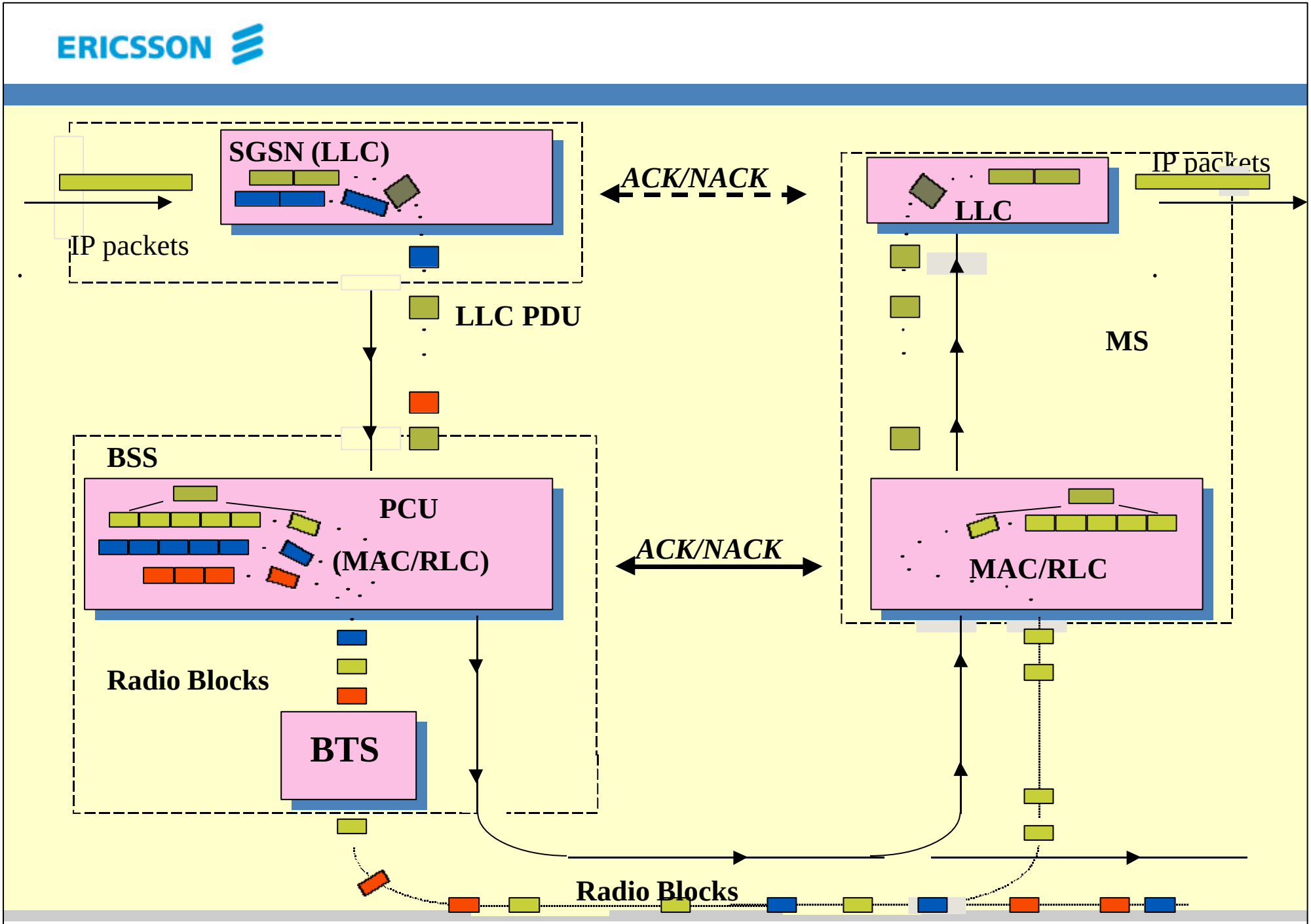
Channel Sharing in GPRS

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SGSN (LLC)
IP packets
ACK/NACK
LLC
IP packets
LLC PDU
MS
BSS
PCU
(MAC/RLC)
ACK/NACK
MAC/RLC
Radio Blocks
BTS
Radio Blocks

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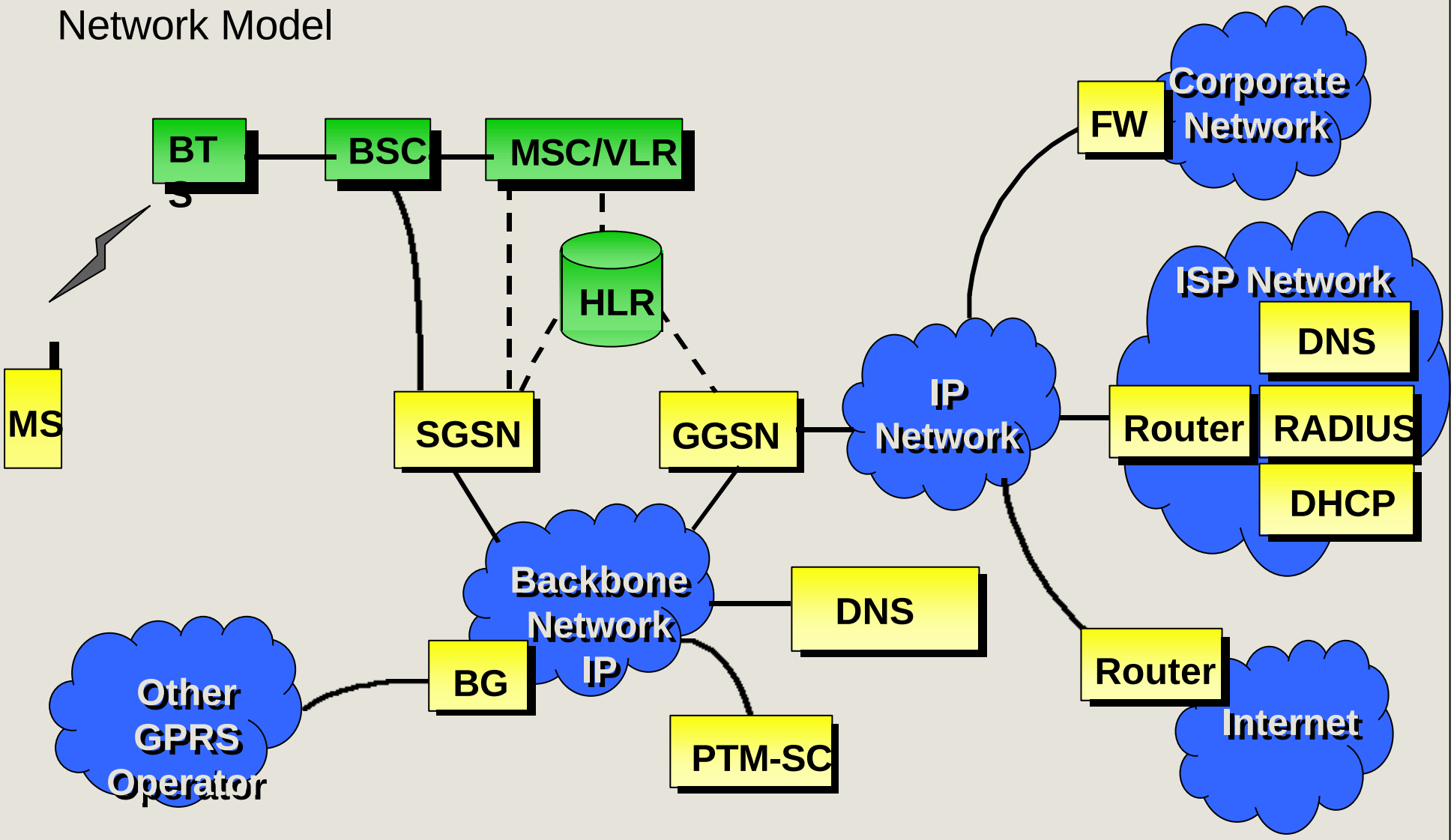
GPRS

Network Model



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GPRS – the Benefits

- Efficient radio usage
- Fast set-up/access time
- Packet data transmission all the way
- Higher bandwidth with multi-slot
- Reuse of infrastructure
- Flexible charging; data volume, time, service based, flat rate
- Circuit- and packet services, co-exists
- One subscription
- Open interfaces

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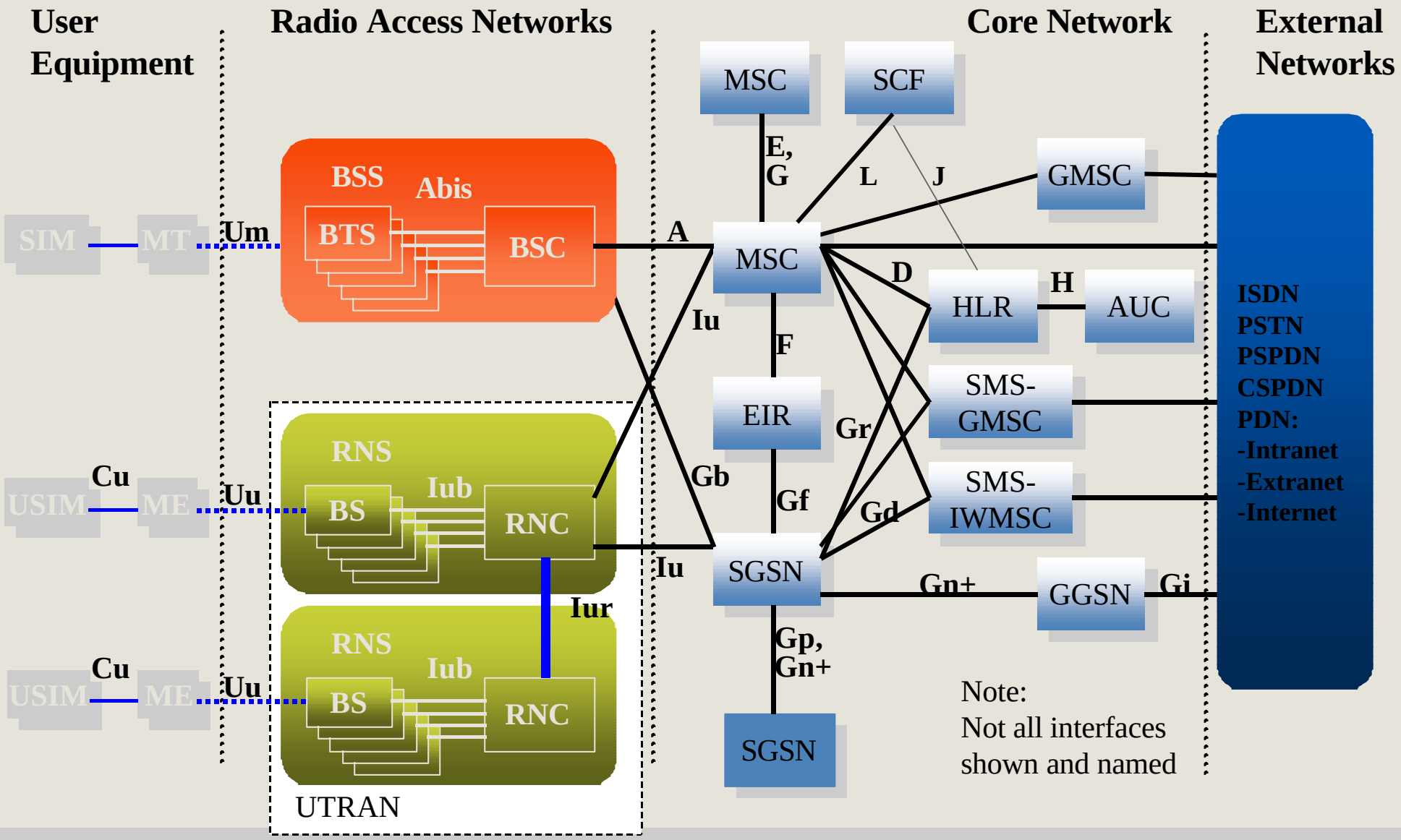
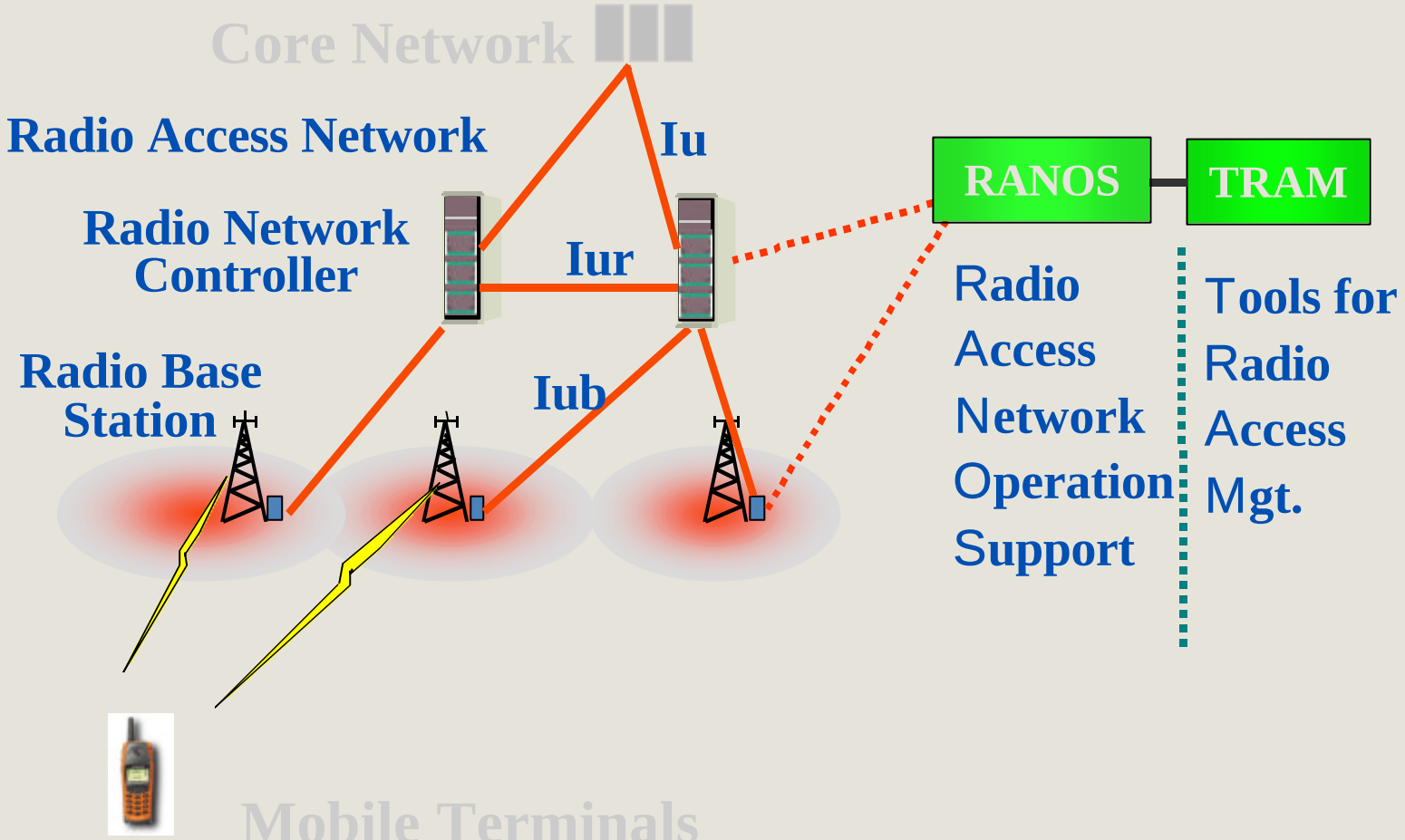
3GPP R'99 Reference model



Radio network overview



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UTRAN Mission

- UTRAN provides Radio Access Bearers (RAB) services for information transfer between the MS and CN with a certian Quality of Service (QoS)
- The RAB can be characterized by:

  - Transfer mode (streaming, frame-assured, frame unassured)
  - Traffic type (guaranteed constant bit rate, guaranteed minimum rate, non guaranteed prioritized, non-guaranteed best effort)
  - Bit rate (peak bit rate, average, minimum)
  - Qos (bit error rate, frame error rate, packet loss, delay)

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Example of Mapping of Services to Radio Access Bearers

Service	RAB	Motivation
Speech-AMR	Speech	
Video service	Circuit 128 (conversational)	A video service will require data transfer at low delay. A high data rate is required for the quality aspect of the video link.
Ftp service	Circuit 64 (conversational)	A conversational class bearer is used since it is expected that the user will not send bursty traffic but long constant streams of data. The medium data rate is a design choice; no requirements for the maximum data rate have been given.
Internet Web service	Packet 64/384 (interactive)	This service does not require low delay data and therefore an interactive (packet) RAB can be used. The medium/high data rate in the UL/DL is a design choice chosen due to the strong asymmetry of the traffic volume.

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Main UTRAN functions (1/2)

- Overall System Access control
  - Admission control
  - Congestion Control
  - System Information broadcasting
  - Radio channel ciphering and deciphering
- Mobility
  - Handover
  - SRNS Relocation

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Main UTRAN functions (2/2)

- Radio Resources management and control
  - Radio Reources configuration and operation
  - Radio Environment Survey
  - Macro-diversity Control
  - Radio Bearer Control
  - Allocation and de-allocation of radio bearers
  - Radio protocol functions
  - RF power control and setting
  - Radio Channel coding/decoding

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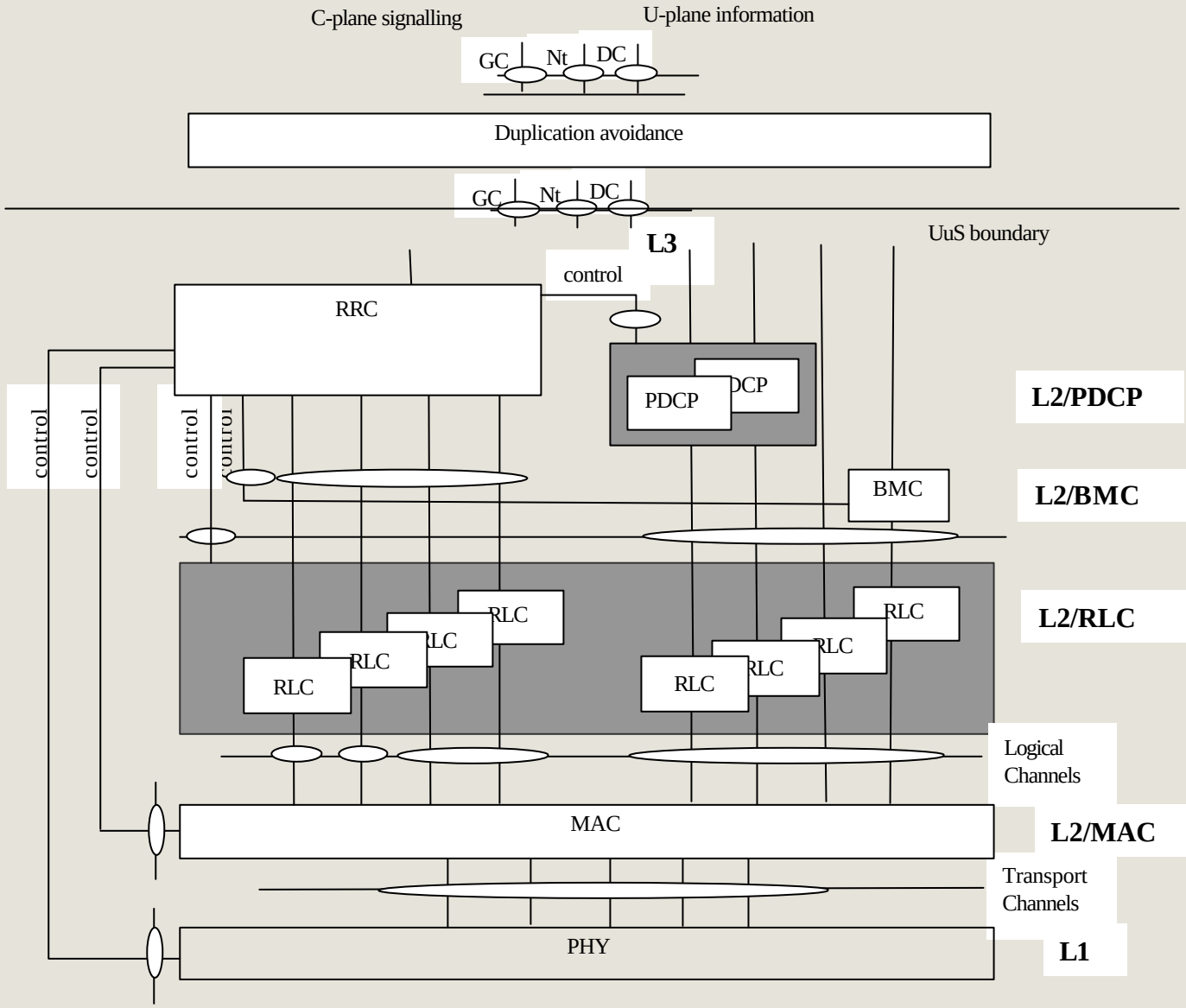
Radio Interface Protocol Architecture



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Physical Layer (1/2)

- Macrodiversity distribution/combining and soft handover execution
- Error detection on transport channels and indication to higher layers
- FEC encoding/decoding of transport channels
- Multiplexing of transport channels and demultiplexing of coded composite transport channels
- Rate matching (data multiplexed on DCH)

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Physical Layer (2/2)

- Mapping of coded composite transport channels on physical channels
- Power weighting and combining of physical channels
- Modulation and spreading/demodulation and despreading of physical channels
- Frequency and time (chip, bit, slot, frame) synchronisation
- Radio characteristics measurements including FER, SIR, Interference Power, etc., and indication to higher layers
- Inner loop power control

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Medium Access Control

- Format Selection
- Priority management
- UE identification
- Mux/demux over transport channels
- ...

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Radio Link Control

- Segmentation and Reassembling
- Header Compression
- Concatenation
- Padding
- Error Correction
- ...

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Radio Resource Control

- Establishment, reconfiguration and release of Radio Bearers
- Paging
- Control of QoS
- Measurements
- ...

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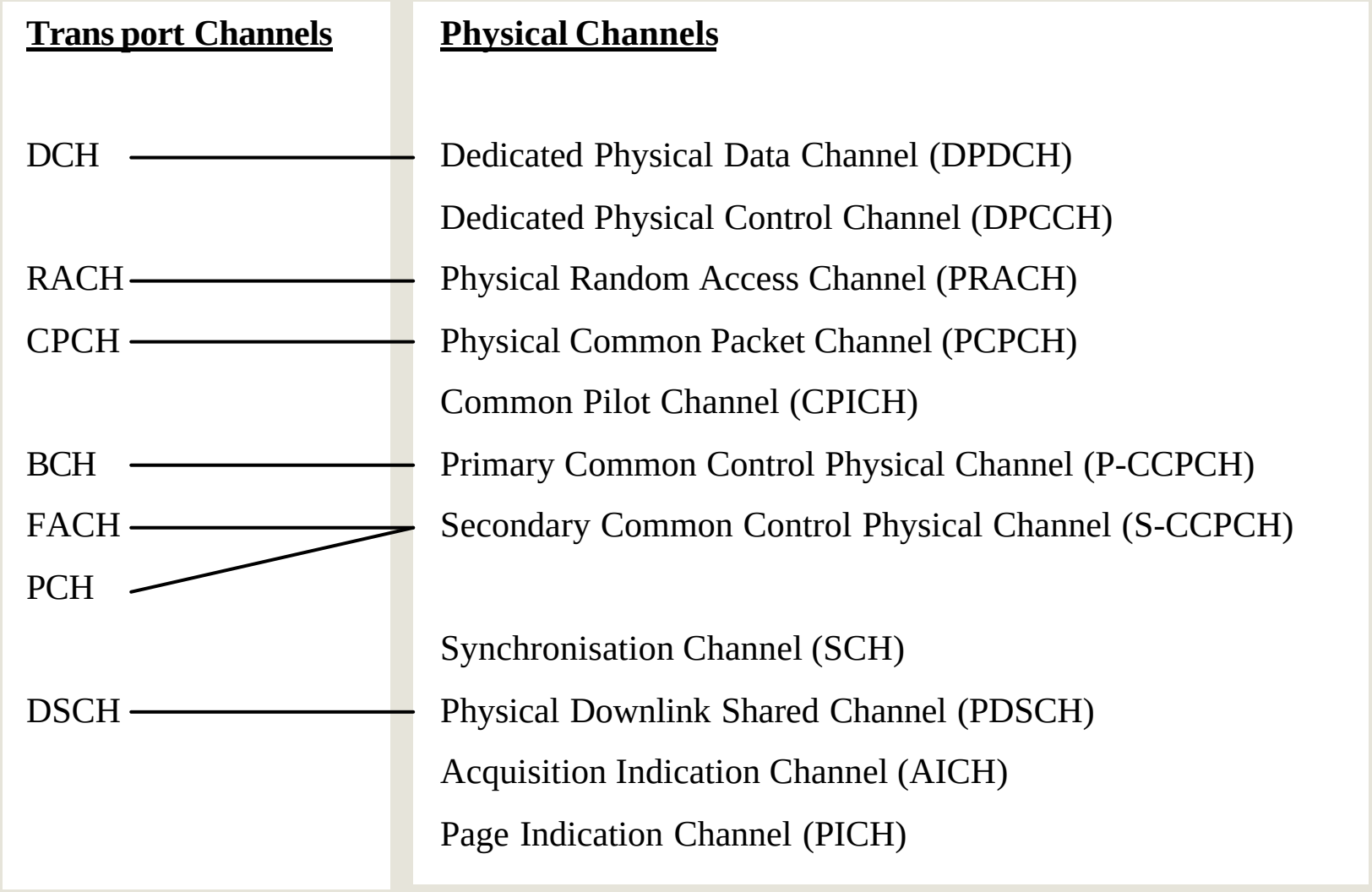
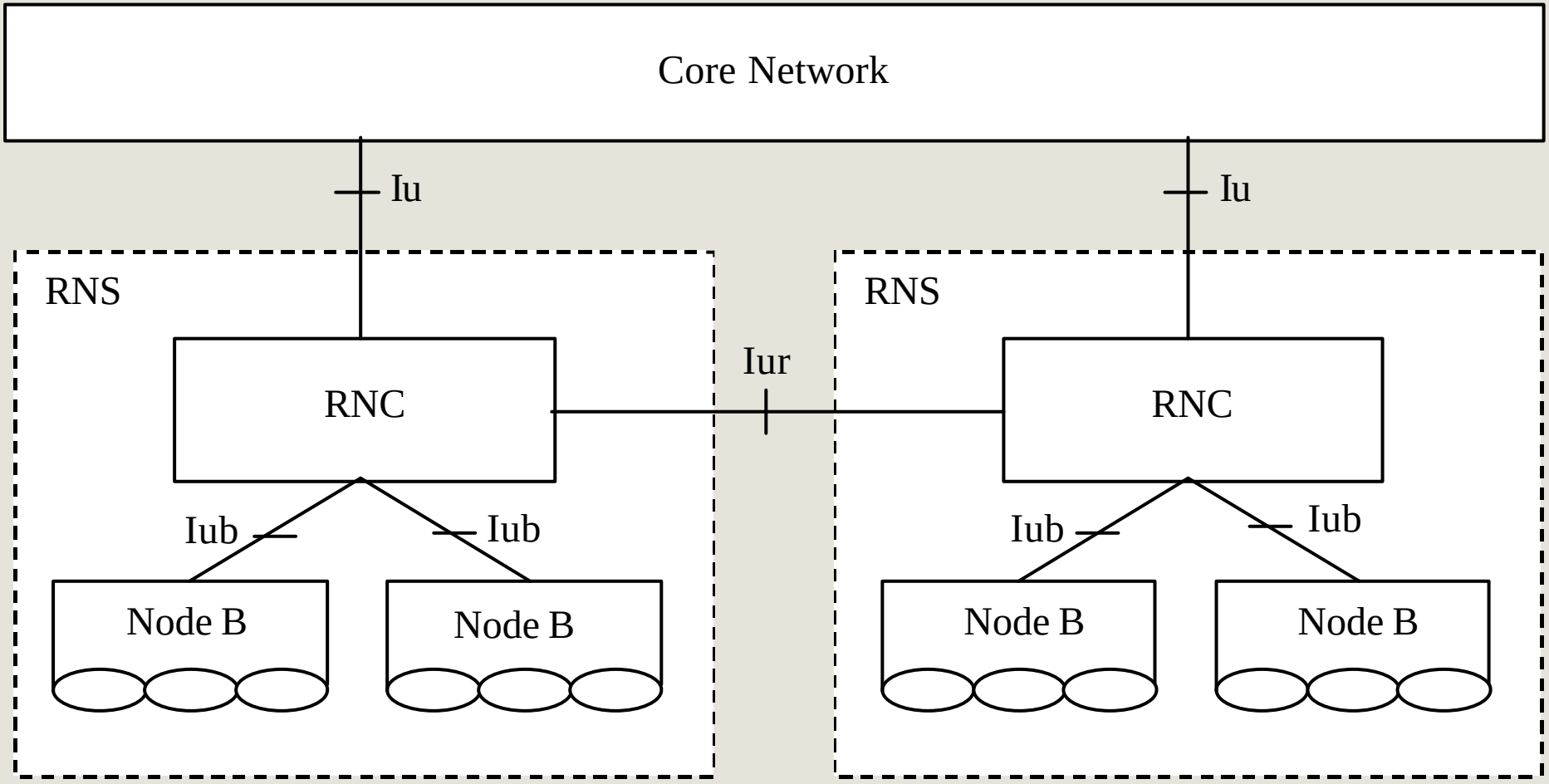
Radio Resources Control

- Handover
- Cell selection/re-selection
- Quality of Service
- Measurements

Mapping Physical vs Transport



Access Network Architecture



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Access Network - Interfaces

- AAL2 (ATM adaptation layer type 2) on Iub and Iur (user data and signalling)
- AAL2 for user data toward Circuit Switched Core Network (Iu)
- IP over AAL5 for user data toward packet Switched Core Network (Iu)

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Access Network - Protocols

- RANAP (Radio Access Network Application Part): Iu
- RNSAP (Radio Network System Application Part): Iur
- NBAP (Node B Application Protocol): Iub

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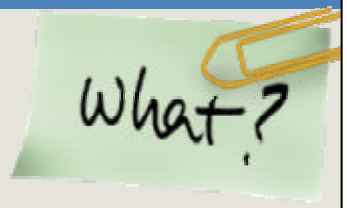
Why Packet and ATM in WCDMA



- Voice is a variable rate service
- New data applications are packet based
- WCDMA air interface is optimised for packet services
- Emerging real time video services are implemented as constant bit rate services, UDI
- ATM supports mixed services, voice, packet and UDI - real time and best effort.
- WCDMA is standardised with ATM transport

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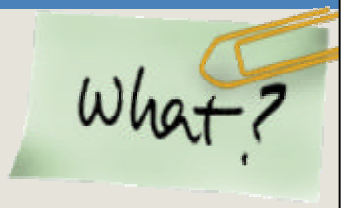
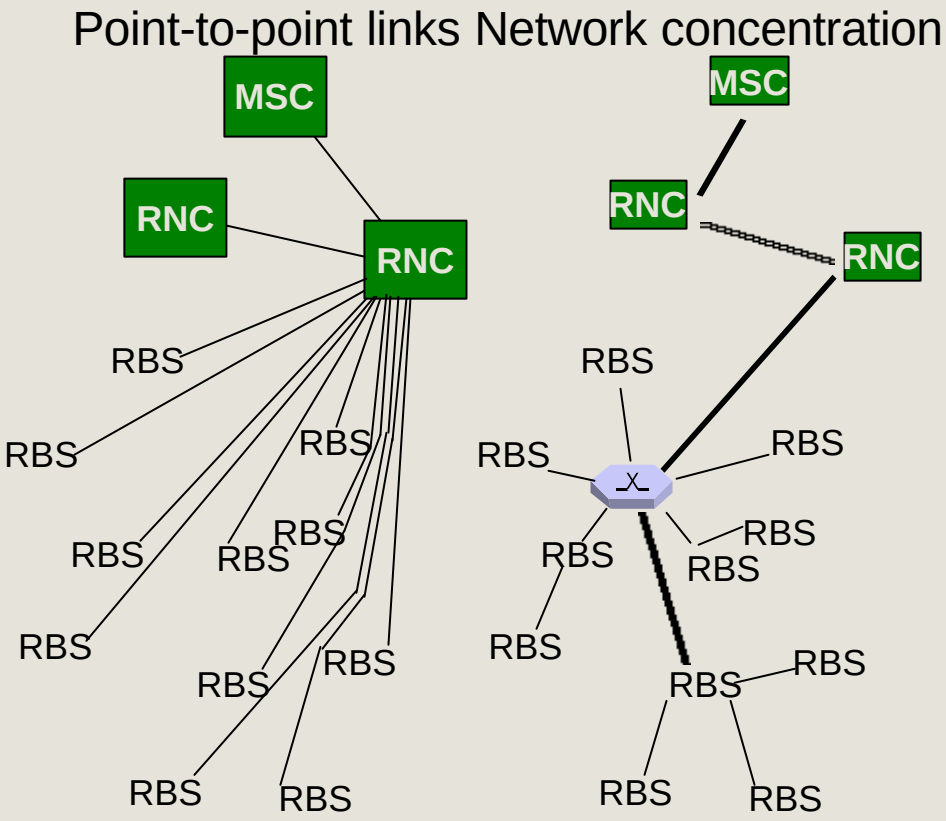
Transmission Networks for WCDMA



- Point-to-point links
  - Low speed ports
  - "Organic" growth
  - **Network concentration**
    - **Few high speed links concentration through**
      - **ATM switches**
      - **SDH/PDH network**
  - **Mix when needed**



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FDD & TDD modes

FDD

(Frequency Division Duplexing),

DS-CDMA radio access,

“paired band” uplink/downlink

TDD

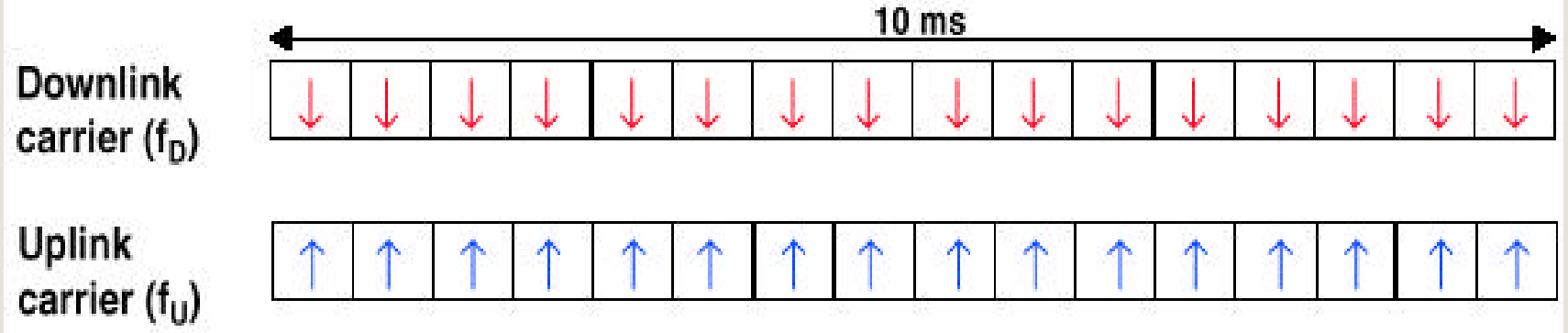
(Time Division Duplexing),

ibryd radio access TDMA/ CDMA,

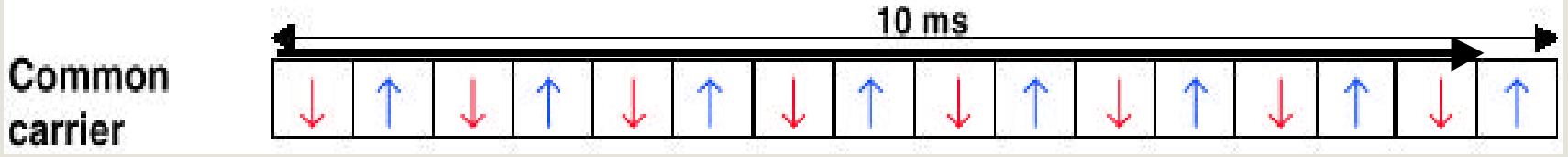
“unpaired band”

FDD & TDD duplexing

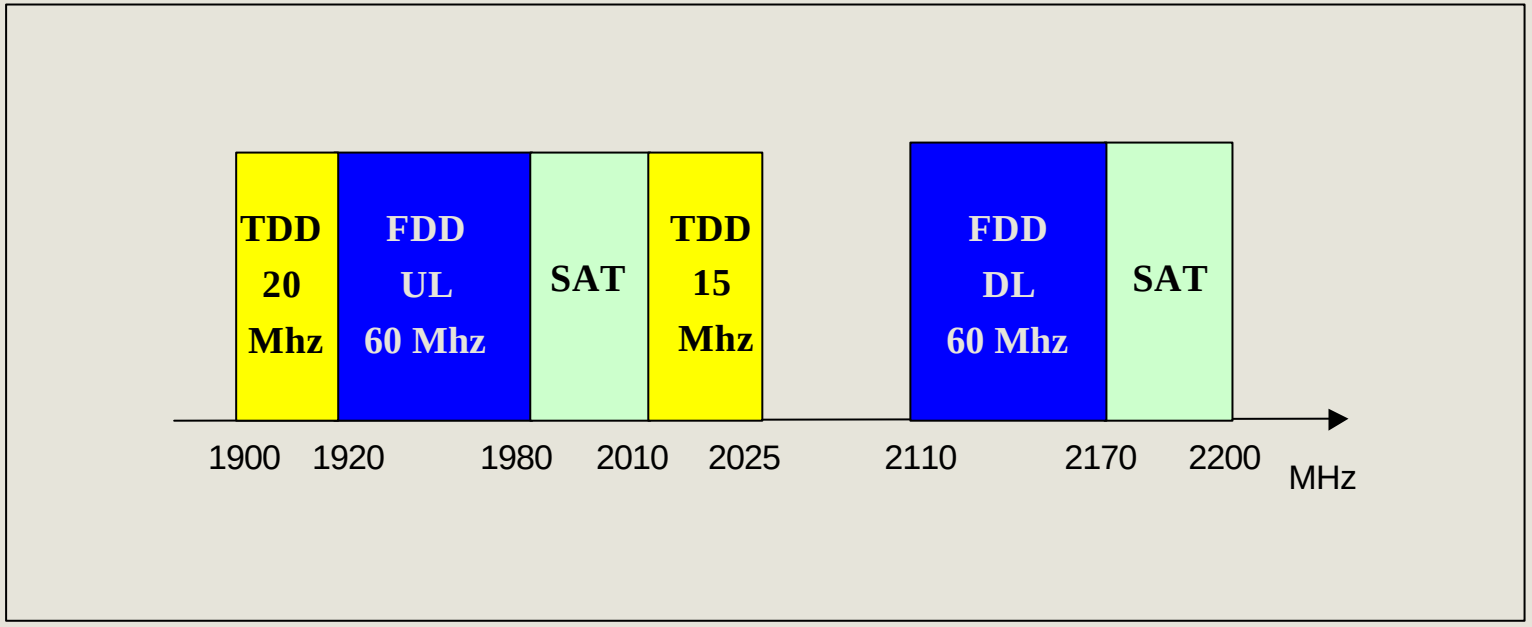
FDD (Frequency Division Duplex)



TDD (Time Division Duplex)



UMTS frequencies in Europe



- **FDD**: Frequency Division Duplex (symmetric transmission)
- **TDD**: Time Division Duplex (asymmetric transmission)

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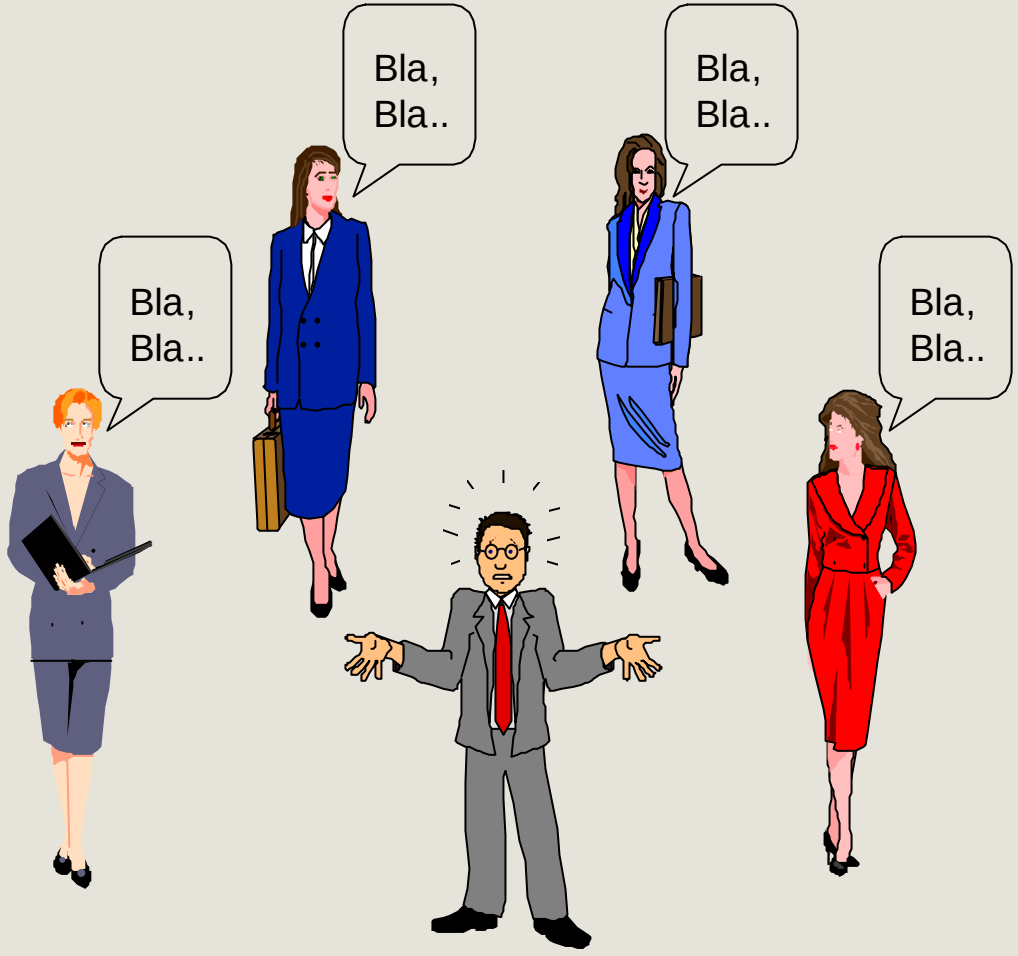
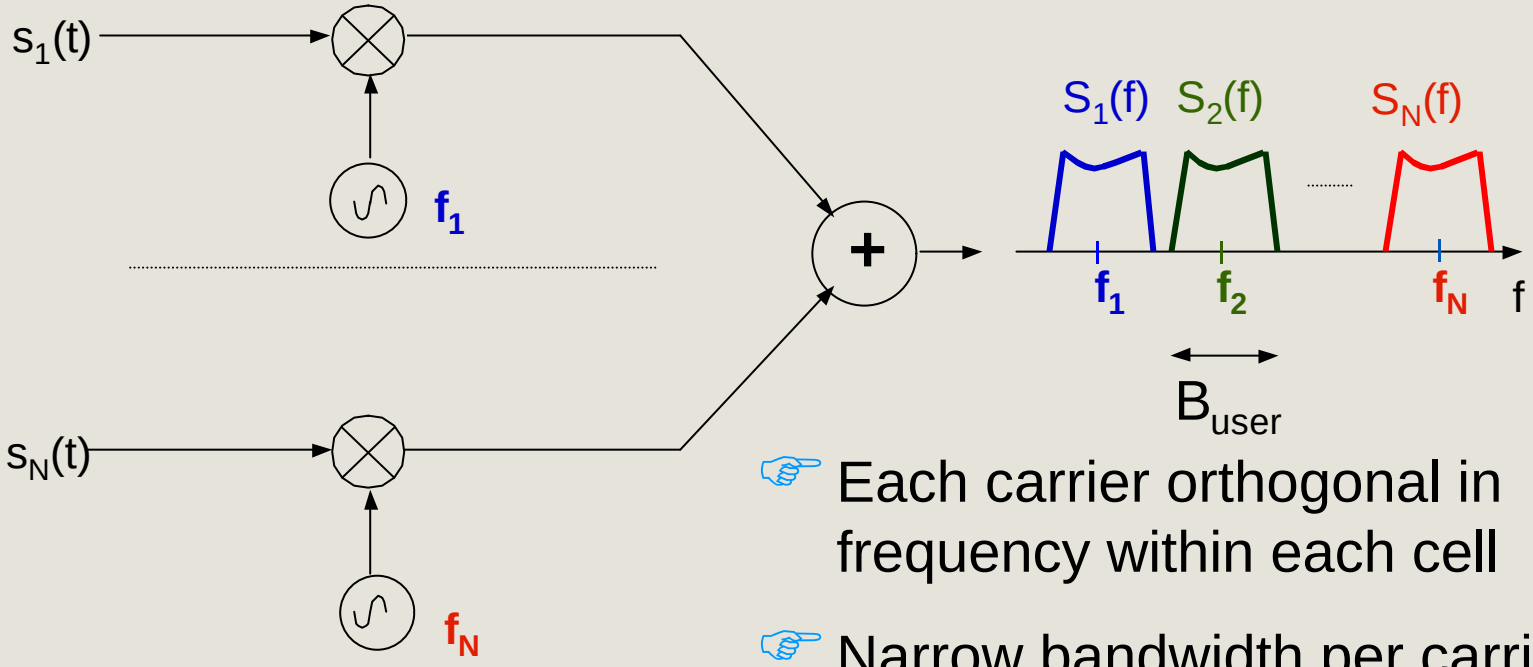
Multiple Access Problem

- More users want to access the resource simultaneously.
- How can be shared the physical resource among users?
- How is possible to understand each user?

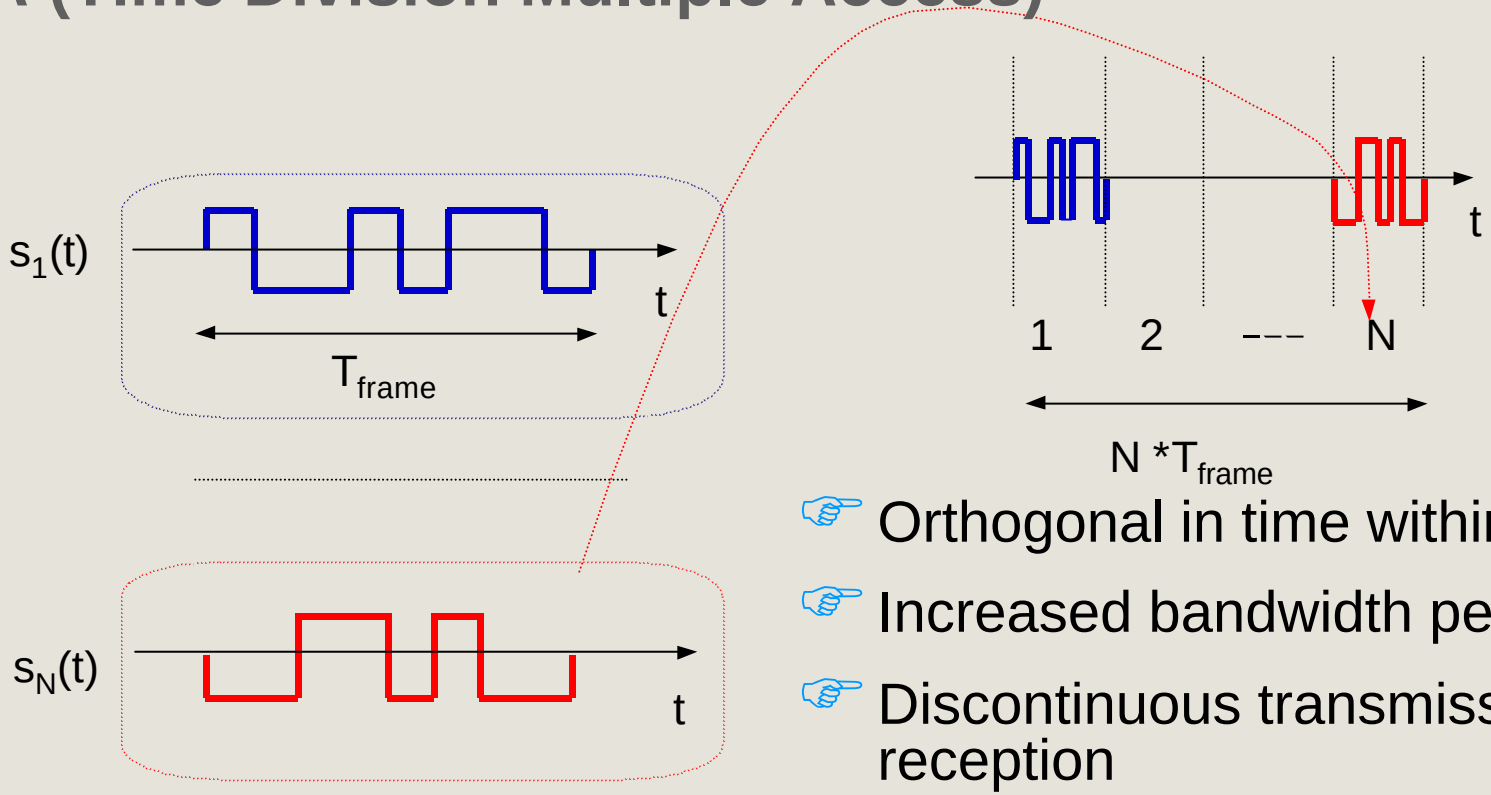


FDMA (Frequency Division Multiple Access)



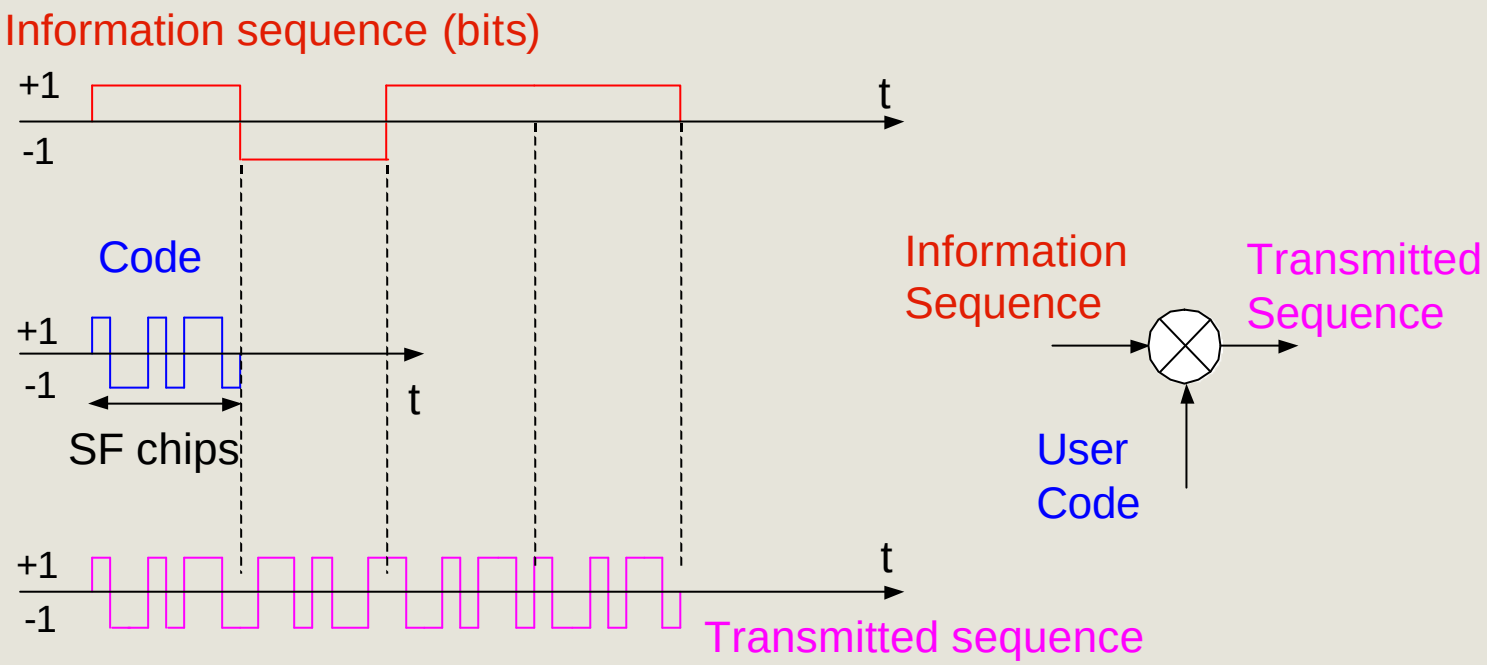
- Each carrier orthogonal in frequency within each cell
- Narrow bandwidth per carrier
- Continuous transmission and reception
- No synchronization in time

TDMA (Time Division Multiple Access)



- Orthogonal in time within cell
- Increased bandwidth per carrier
- Discontinuous transmission and reception
- Increased peak power
- Synchronization in time
- GSM = FDMA 200 KHz + TDMA 8 slot/frame

CDMA (Code Division Multiple Access)



- Separate users through different codes (Radio bandwidth
  SF -Spreading Factor- times broader than information bandwidth
- Large bandwidth
- Continuous transmission and reception

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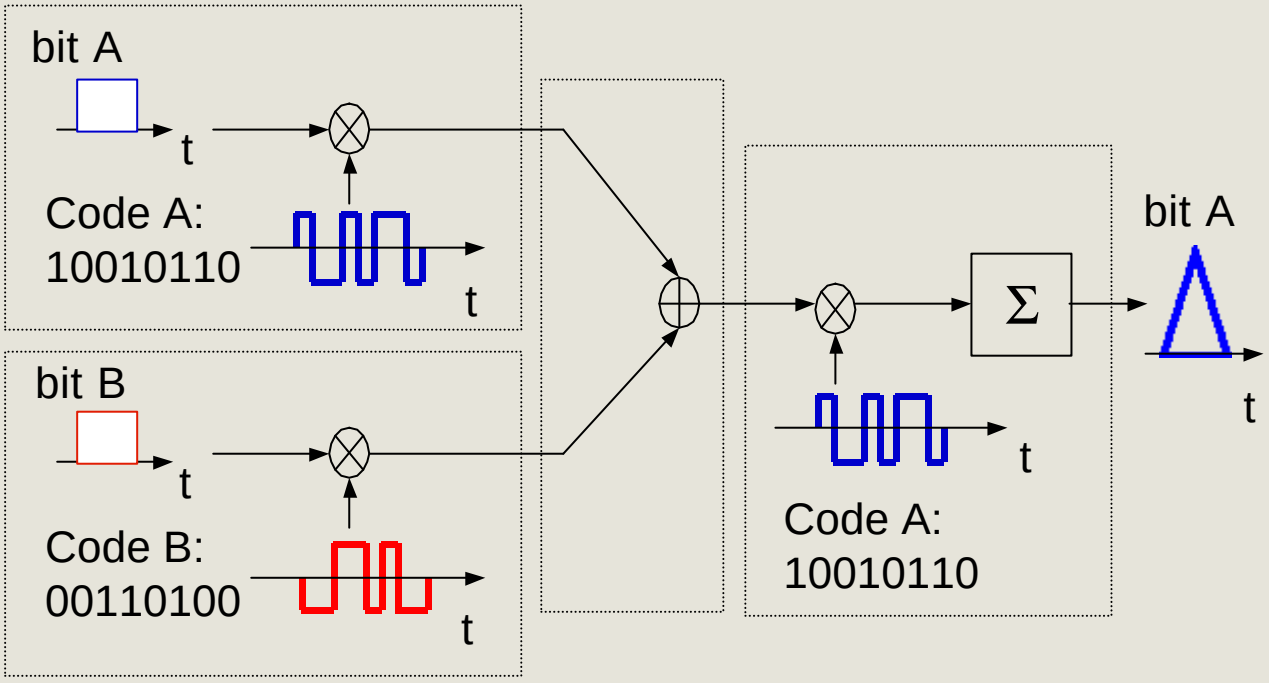
WCDMA: foreword

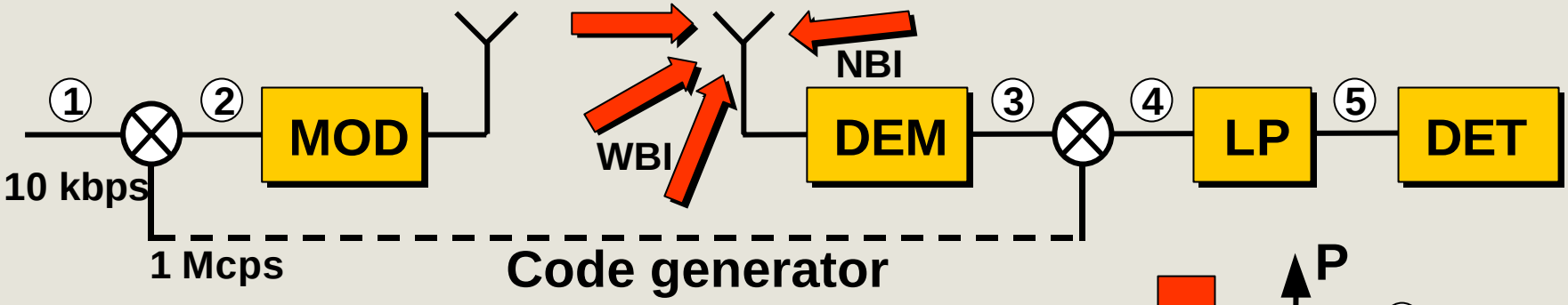
- New dictionary respect to the GSM
  - Bit = one digit of information (data or control) addressed to the other side
  - Chip = one digit transmitted on the air interface
  - Code = sequence of binary digits
  - Spreading = the way to be “broadcasted”
  - Scrambling = the way to come out

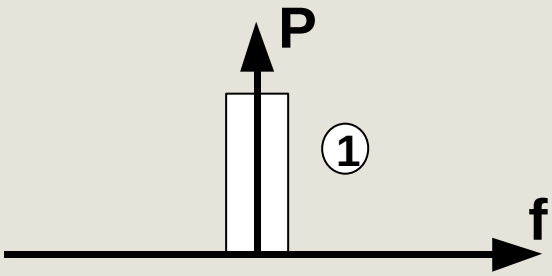
CDMA (Code Division Multiple Access)

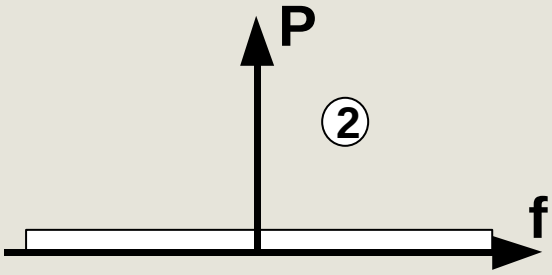


Transmitters ("Spreaders") ***Radio Channel*** ***Receiver A ("Despreader")***

DS-CDMA – Principles

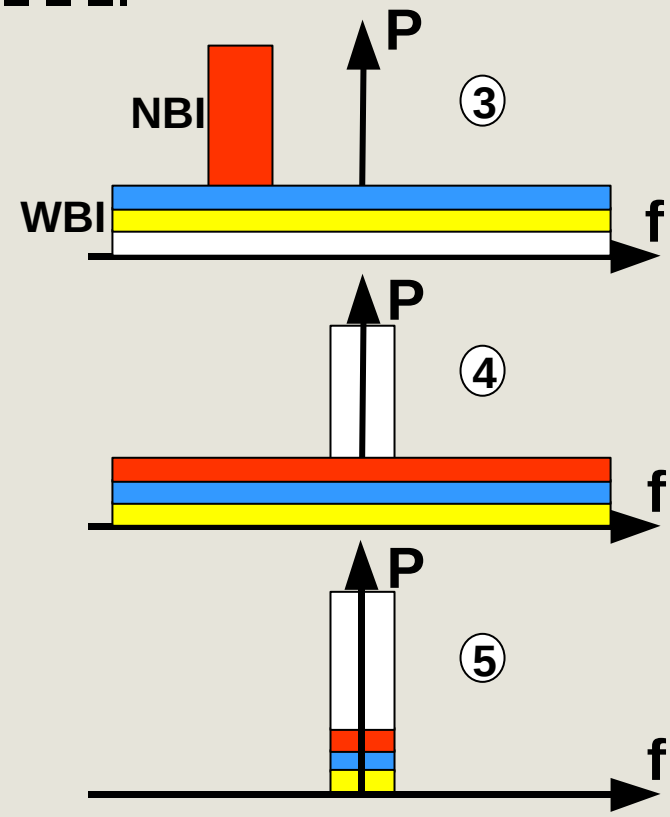




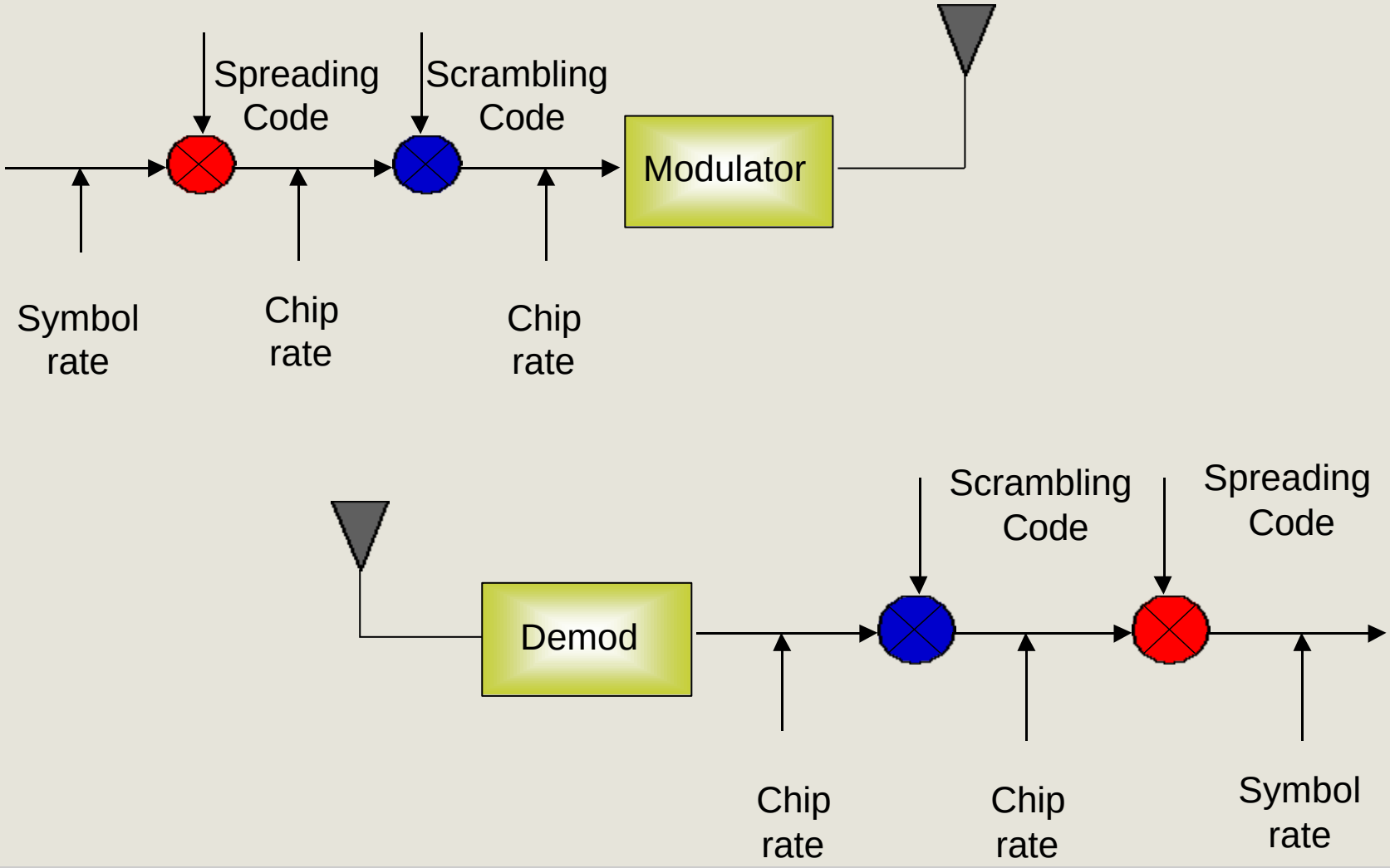


Processing gain
Spreading factor

$$G = \frac{R_{chip}}{R_{bit}}$$

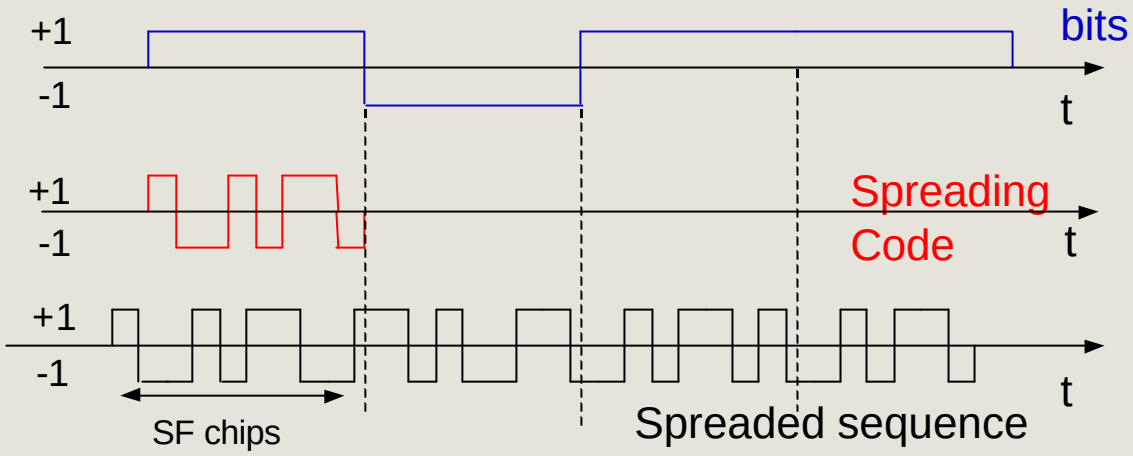


Spreading & scrambling

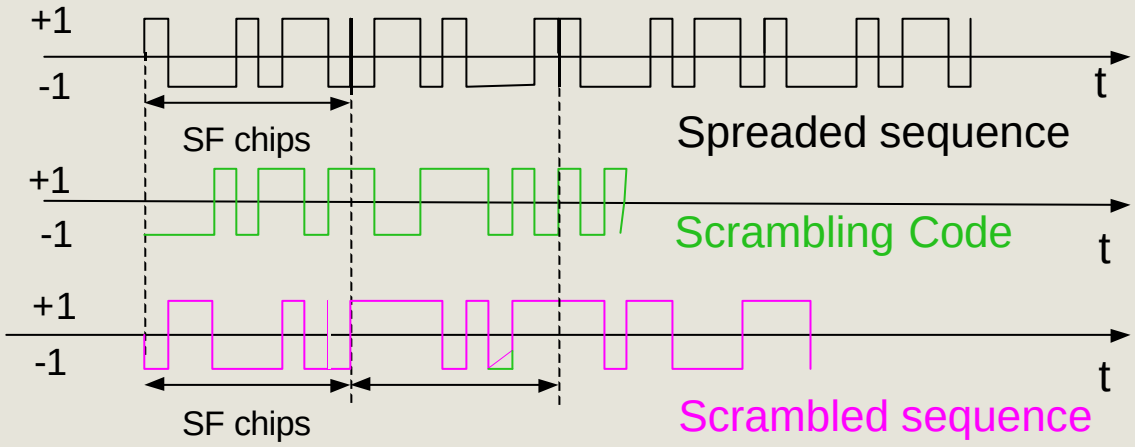


UMTS Spreading and Scrambling codes

- *Spreading codes:*



- *Scrambling codes:*



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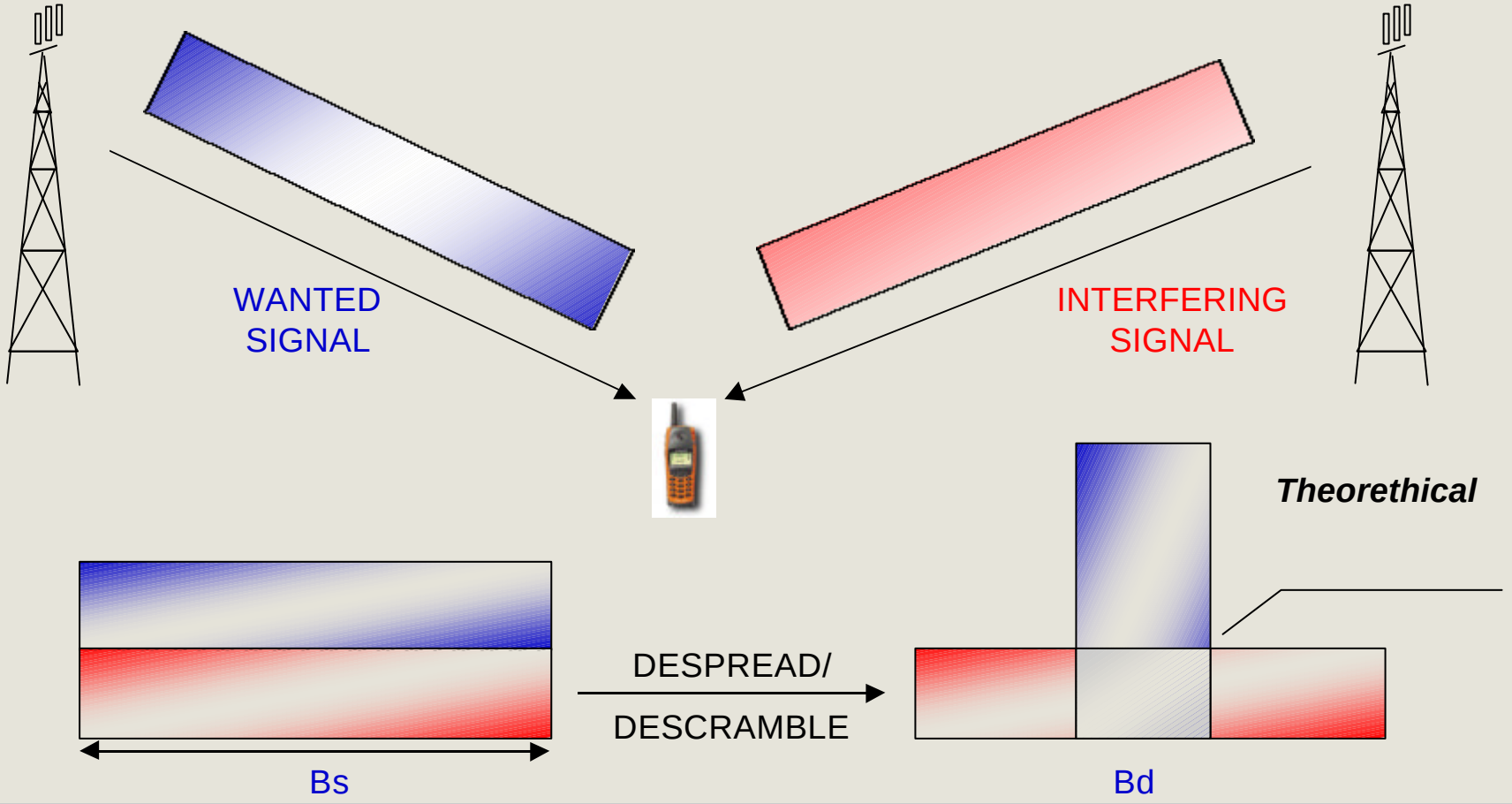
Why spreading

- *Spreading codes:*
  - *Widen the band $1/T_b$ ® $1/T_c$*
  - *Characterise the users and user services in downlink*
  - *Characterise the user services in uplink*
  - *OVSF (Orthogonal Variable Spreading Factor)*

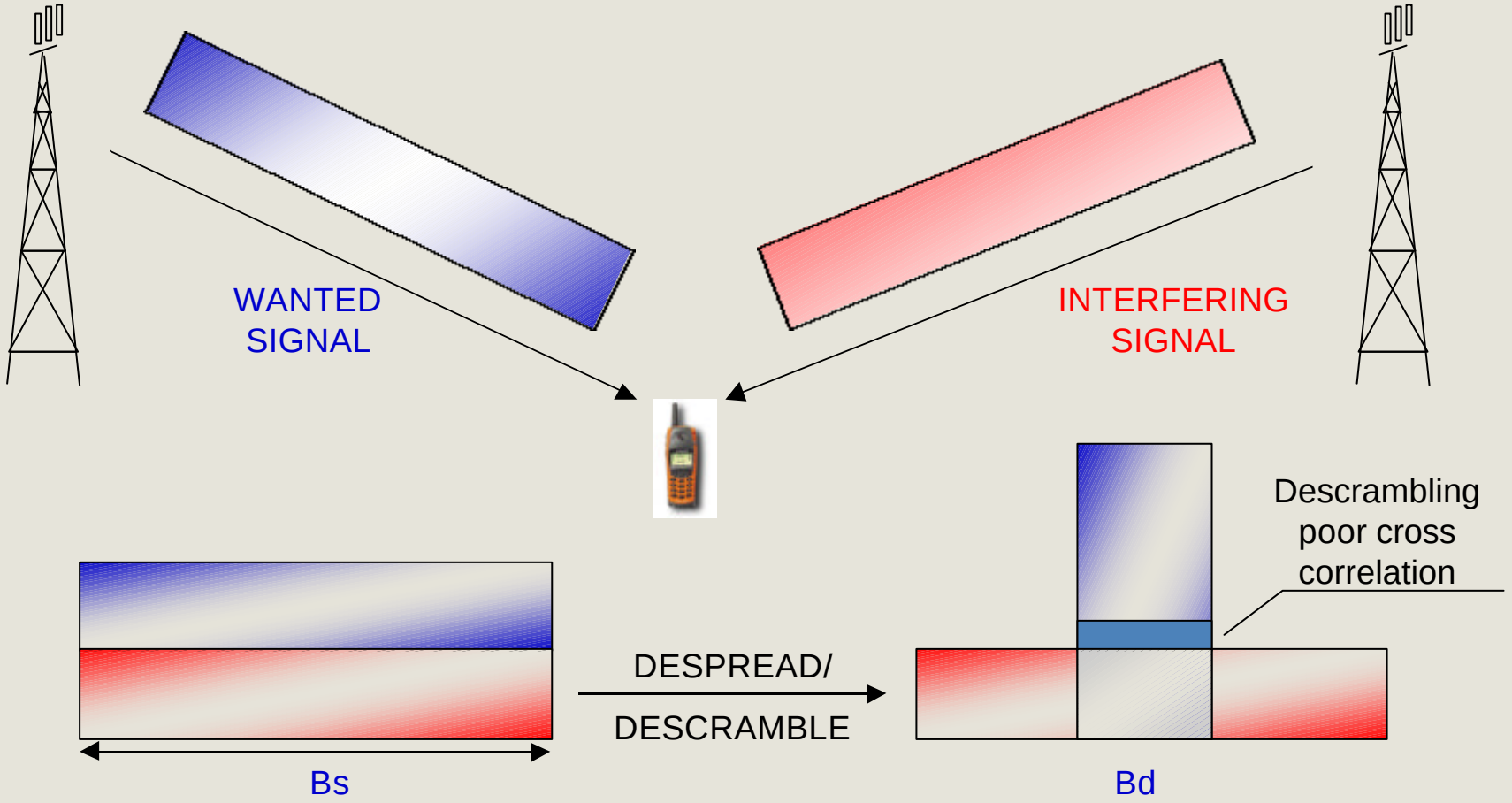
Why scrambling

- *No interference if orthogonal codes apply*



Why scrambling

- *Code clash can occure in downlink*



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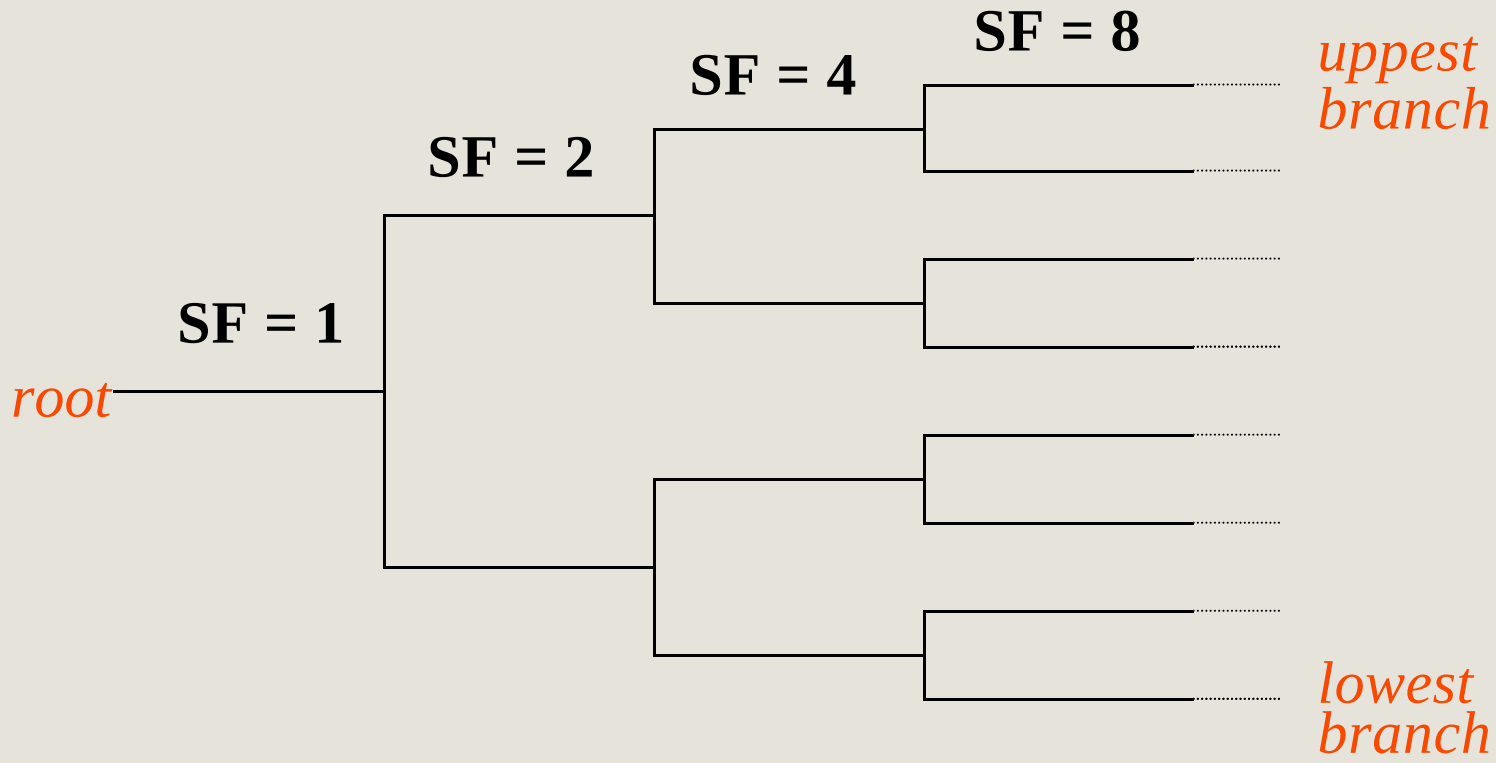
OVSF code tree



- *orthogonality only out of the branch*
- *# available codes ° SF*
- *completely orthogonal if exactly synchronized*

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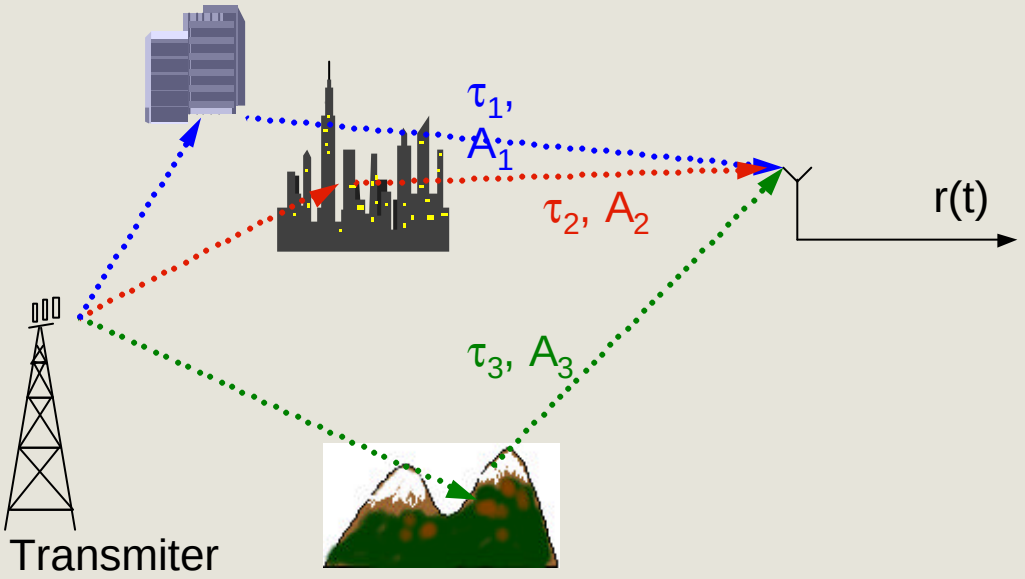
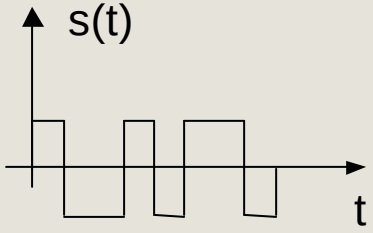
Code orthogonality

- *Orthogonality definition*
  - *Chip by chip multiplication of two orthogonal codes and sum over code length give always null result*
- *Ortogonality function*
  - *A signal that is the composition (sum) of many messages coded with different words arrives at the receiver together with noise and external interference*
  - *The deconvolution of the received signal with the code word allows the recognition of the original message*

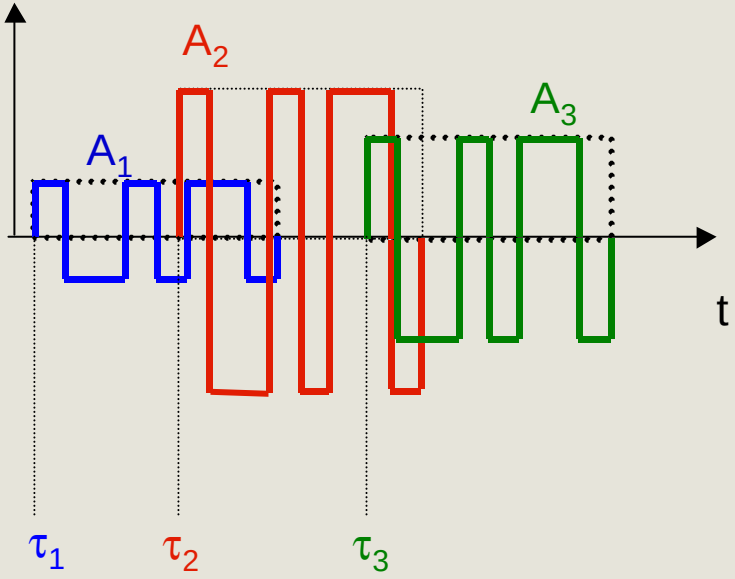
CDMA in multipath channel

Multipath Radio Channel:





$r(t)=A_1 s(t-\tau_1) + A_2 s(t-\tau_2) + A_3 s(t-\tau_3)$



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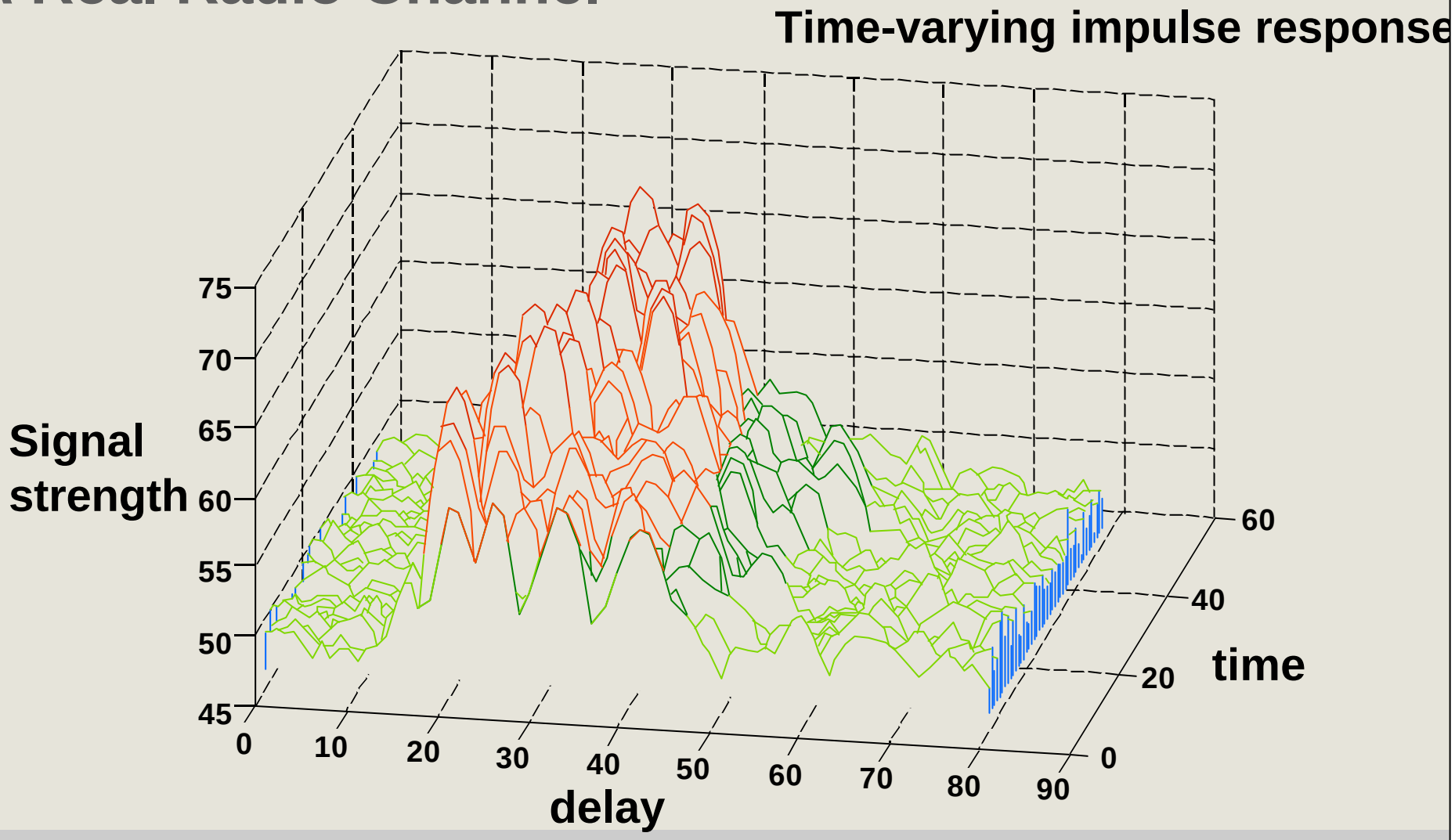
A Real Radio Channel



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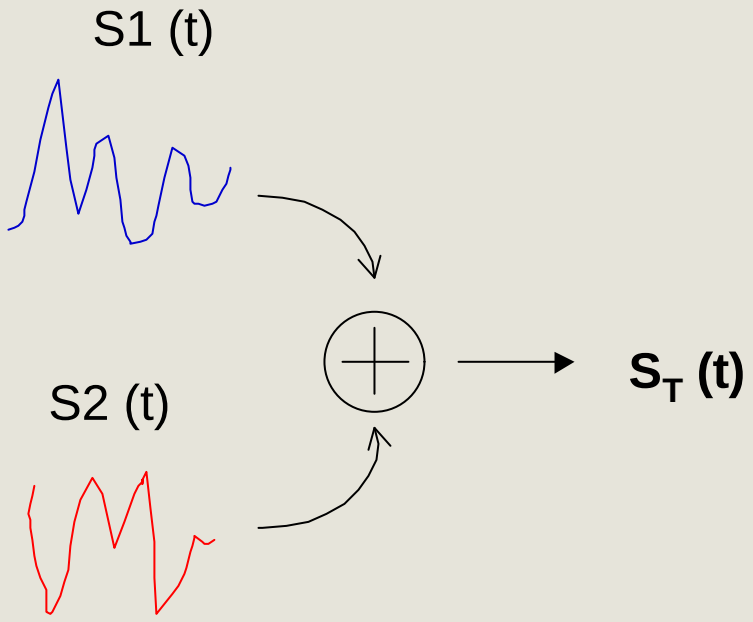
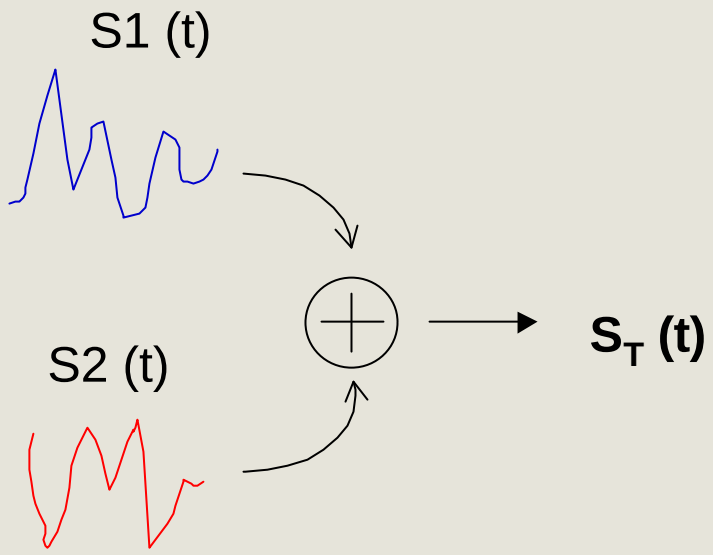
Diversity

- *Signals must be added coherently*
- *Three basic combining technique:*
  - *Selection diversity*
  - *Equal gain combining*
  - *Maximum ratio combininig*



Diversity

- *Selection diversity*
  - *switching control applayed*
- *Equal gain combining*
  - *co-phasing and sum*
- *Maximum ratio combininig*
  - *co-phasing, weighting (SIR) and sum*



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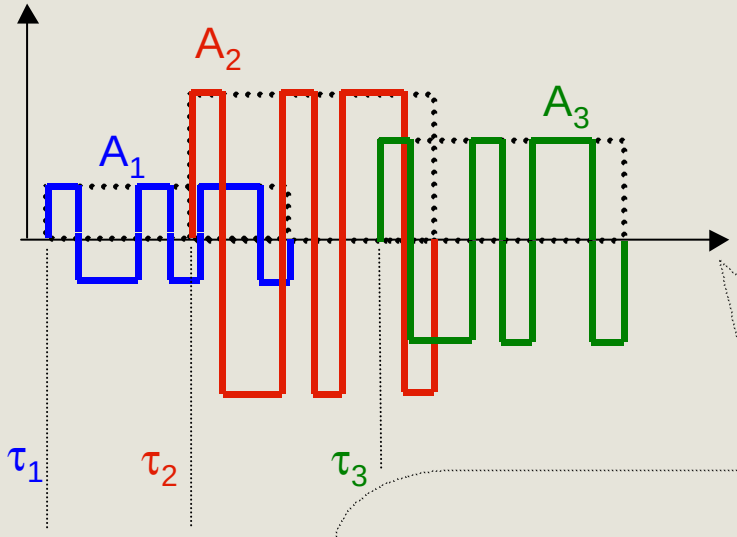
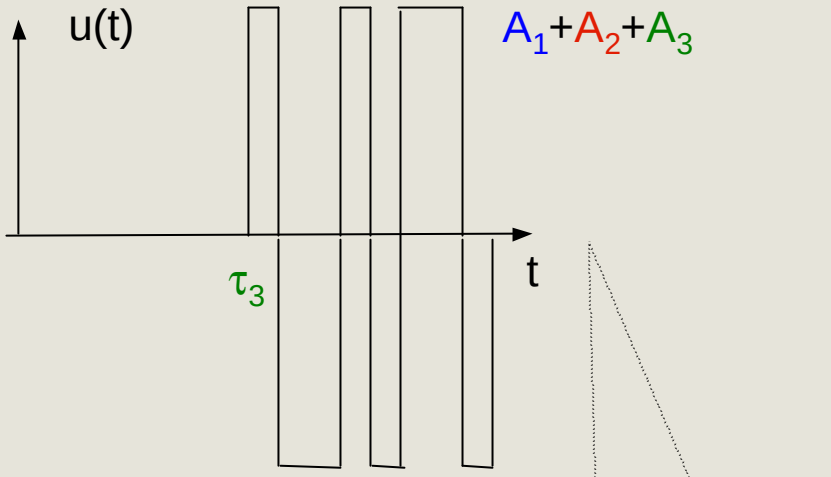
CDMA multipath mitigation

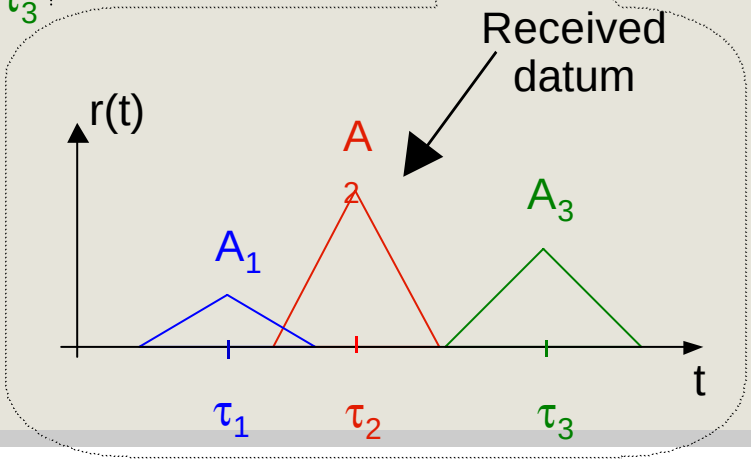
At the Receiver:

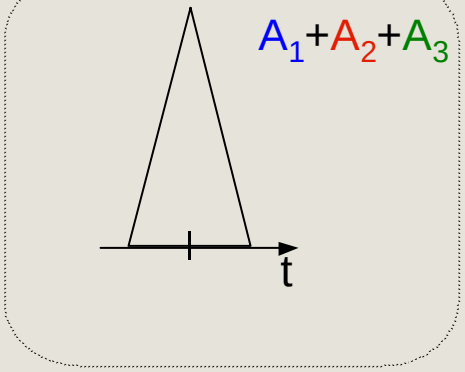


Coherent combiner

(Rake receiver,matched filter)







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The RAKE Receiver

- Takes advantage of multipath propagation
- Each multipath component is called a “finger”
- Needs to estimate relative delay and amplitude for each finger!

- The Rake receiver combines multipath components with a separation in time >= one chip period T_{chip}

  Example: 4 Mcps => T_{chip} = 2.5 µs => 75m
- Increased chip rate =>

  Resolves more paths (requires more processing)

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  - **- La struttura del sistema UMTS (R'99)**
  - **- L'accesso radio CDMA e TDMA**
  - **- Le caratteristiche della nuova/e banda/e**
  - **- La copertura a livelli ed in funzione della mobilità**
  - **- Le prestazioni della nuova copertura**
  - **- References (www.3gpp.org)**

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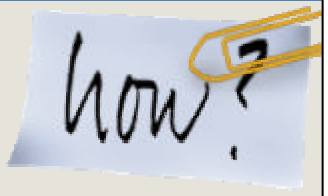
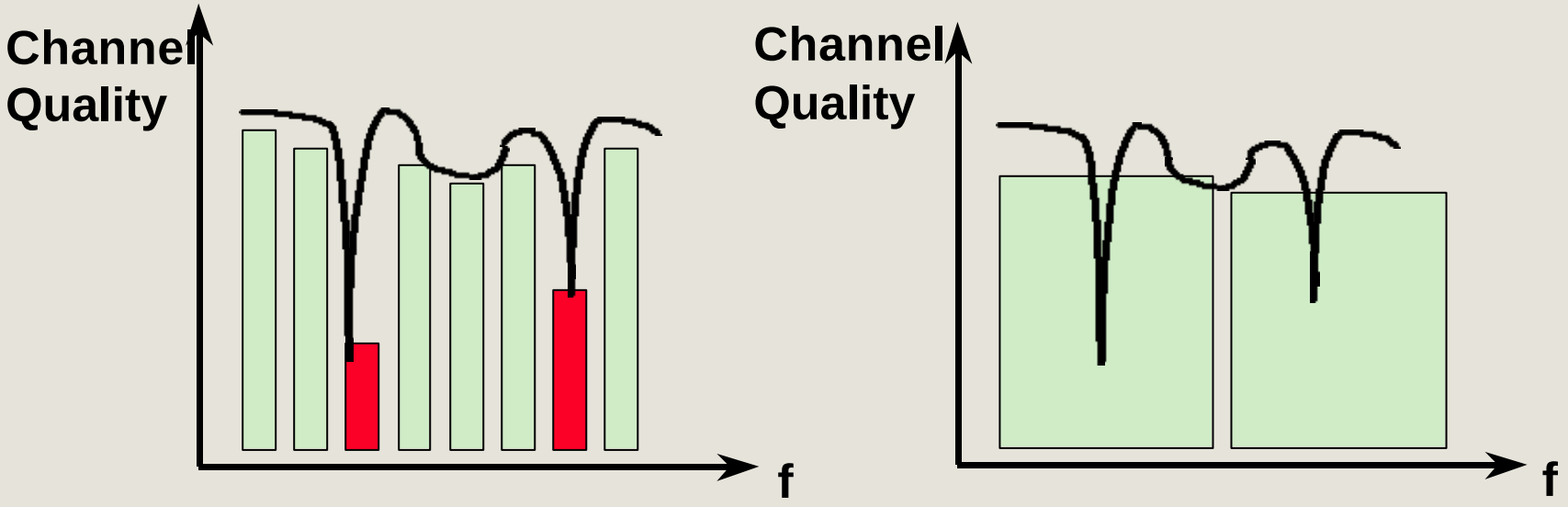
UTRA Standard ETSI/3GPP

Multiple access mode	DS-CDMA
Duplexing	FDD
Channel Separation	200kHz
Channel Bandwidth	5 MHz
Chip Rate	3.84 Mcps
BS comunication mode	Asyncronous
Frame period	15 slot per frame (10 ms)
Spreading Factors	4, 8, 16, 32, 64, 128, 256, 512
Spreading Modulation	QPSK (DL); dual channel QPSK (UL)

WCDMA - Wideband Carrier



- Frequency diversity
  - Capacity and coverage gain
- High data rates require wider frequency bands
- Variable data rates are simplified with wider bands



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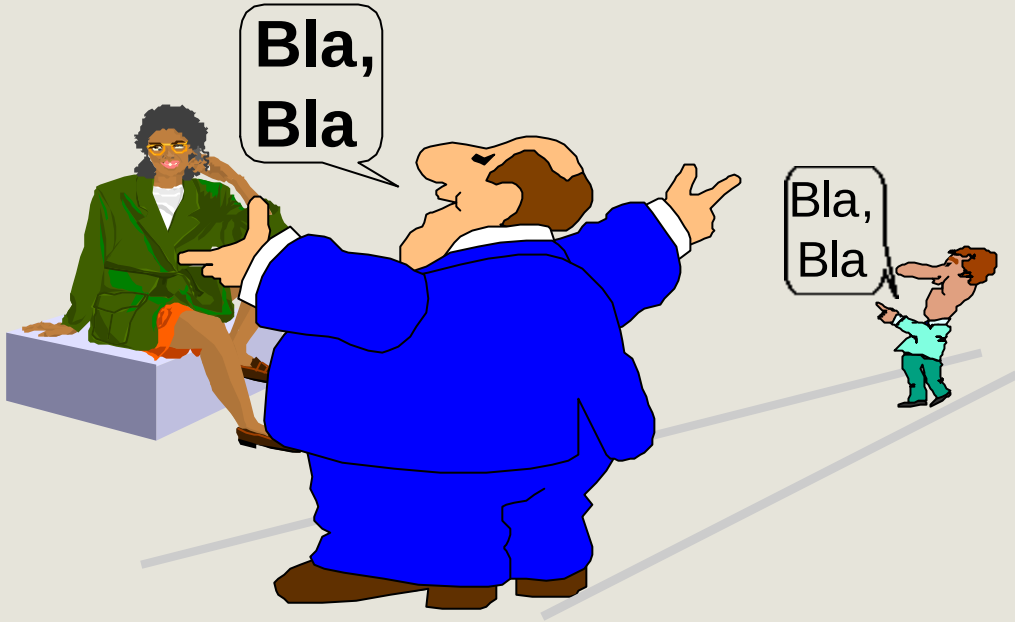
“Near-far problem”



- MSs closer BS may create too much interference.
- Requirements: fast power control in MS
- Target: all MSs received in the BTS with the same power

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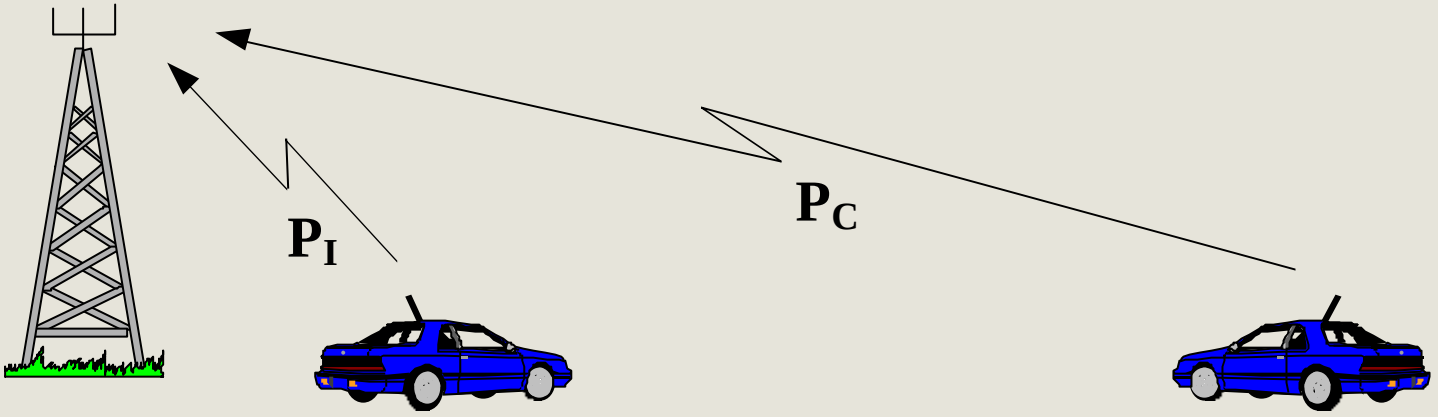
Why Power Control? Up-link issue



Worst case: P_C(dB) – P_I(dB) = – 80 dB!

Interferers are rejected by the processing gain:

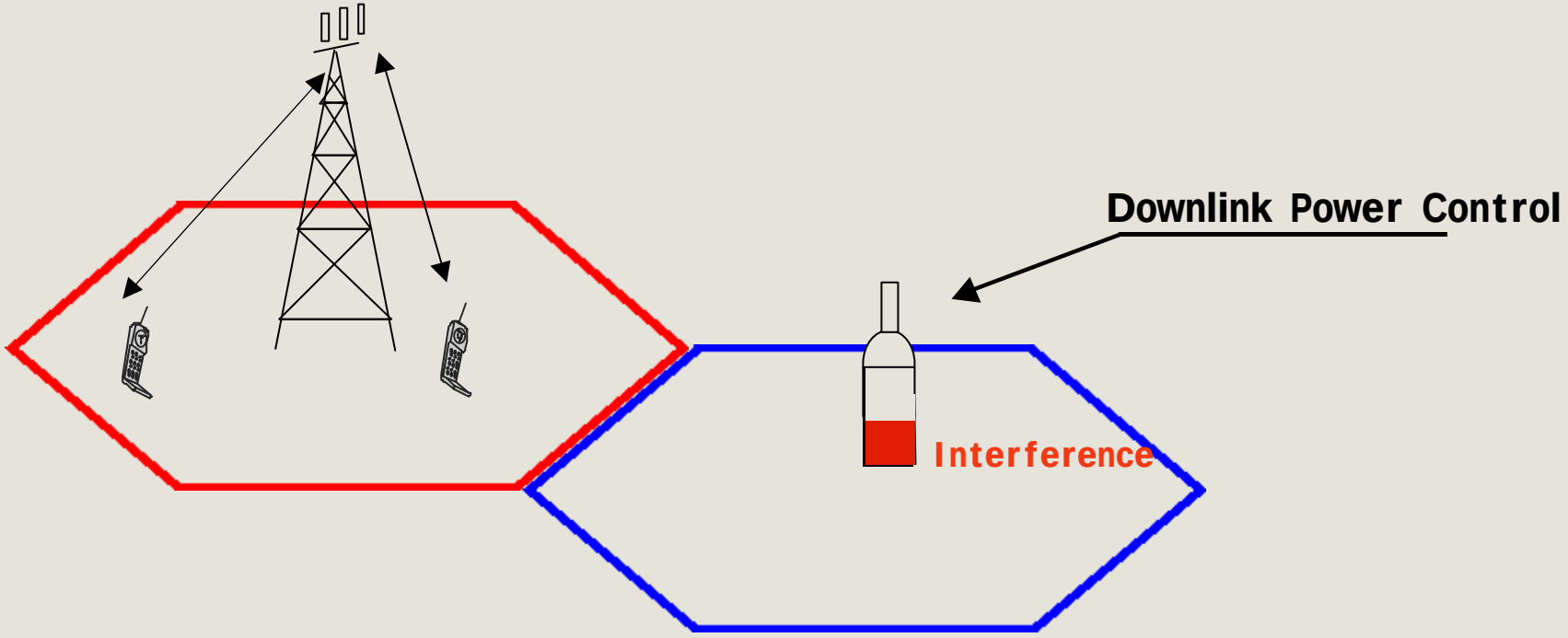
$$g = \frac{R_{chip}}{R_{bit}} = \frac{10^6}{10^4} = 100 \text{ ® } 20 \text{ dB}$$

$$\text{Þ } \frac{C}{I} = -80 + 20 = -60 \text{ dB!}$$

Power control is essential in DS-CDMA systems!

“Near-far problem”

- *The downlink issue*
- Power received by UE is the same for every channel but:



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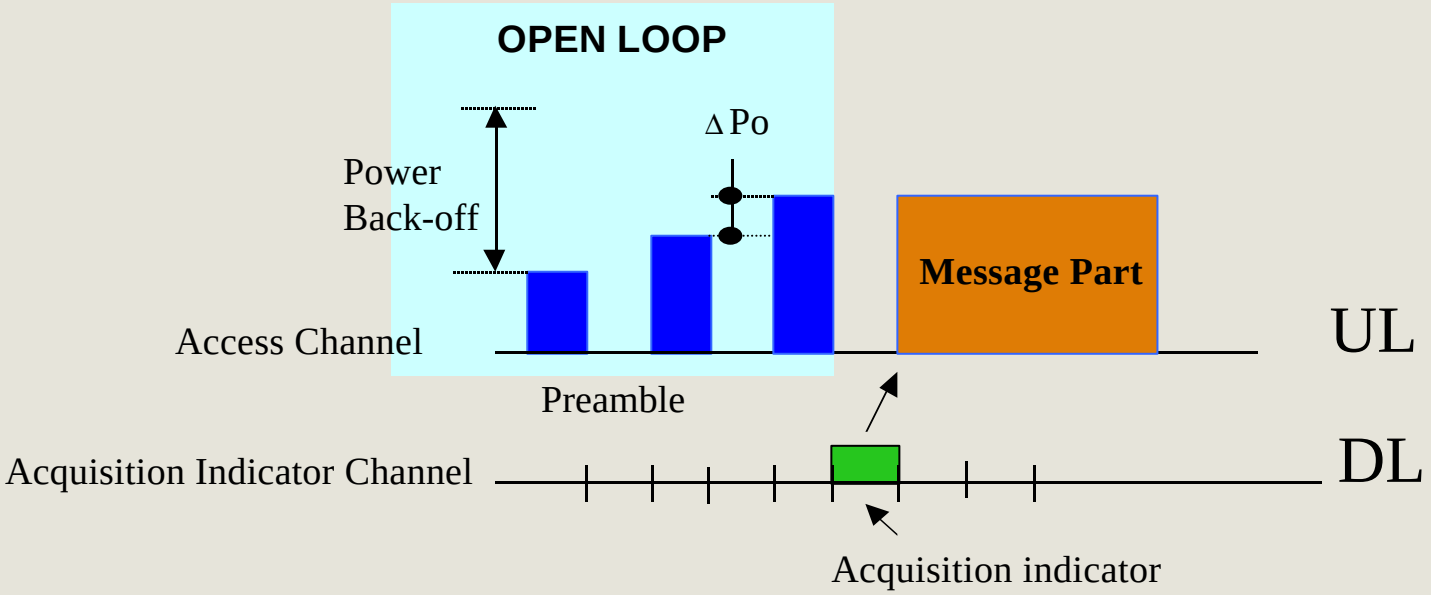
Power allocation

- Power allocated depends on:
  - User location: pathloss
  - Simultaneous users present: load intereference
  - Site configuration (omni / 3sector): intercell interference
  - Required QoS: SIR target
  - Service required: process gain

Power Control

- *Open loop in common channels*
- *The physical channel PRACH is power controlled by means of preamble ramping*



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Power Control

- *Inner loop in dedicated channels*
- *This function, located in the RBS, controls the transmit power of the uplink dedicated physical channels in order to keep the SIR of these channels at a given SIRtarget.*
- *RBS sends the Transmit Power Control (TPC) Commands to the UE on the downlink dedicated physical control channel.*
- *A TPC command indicates that a UE should either increase or decrease the transmit power of 1 dB in every slot of a DPCCH and its associated DPDCH simultaneously.*

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Power Control

- *Outer loop in dedicated channels*
- *This function, located in the RNC, controls the quality of the Radio Connection in terms of BLER.*
- *This is done by setting and adjusting the SIRtarget value for the Uplink Inner Loop Power Control.*

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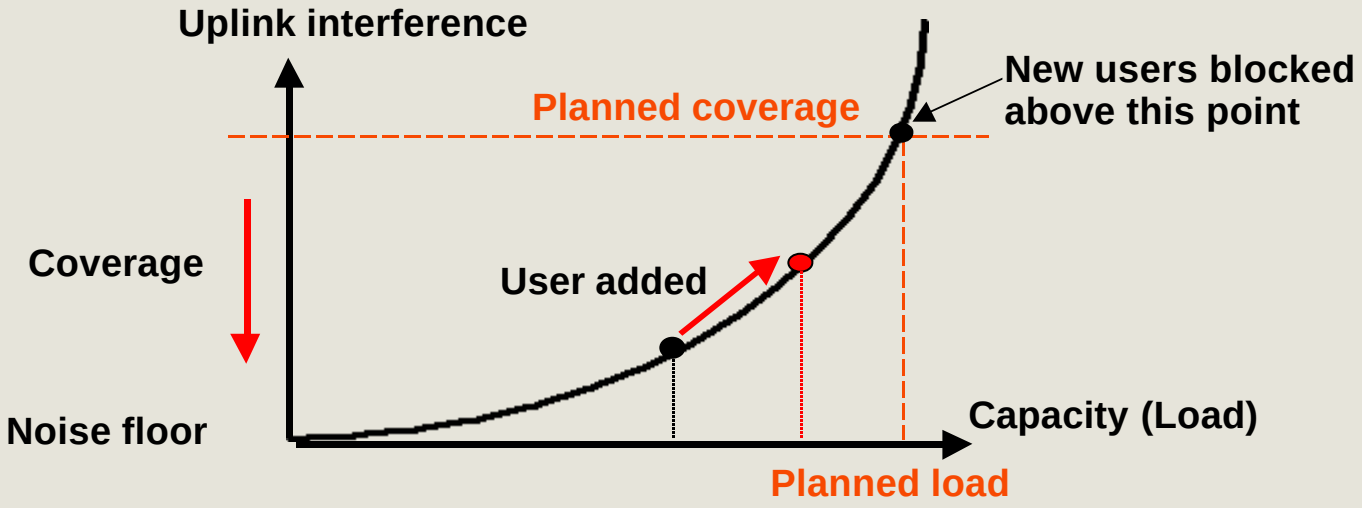
Coverage vs. Capacity

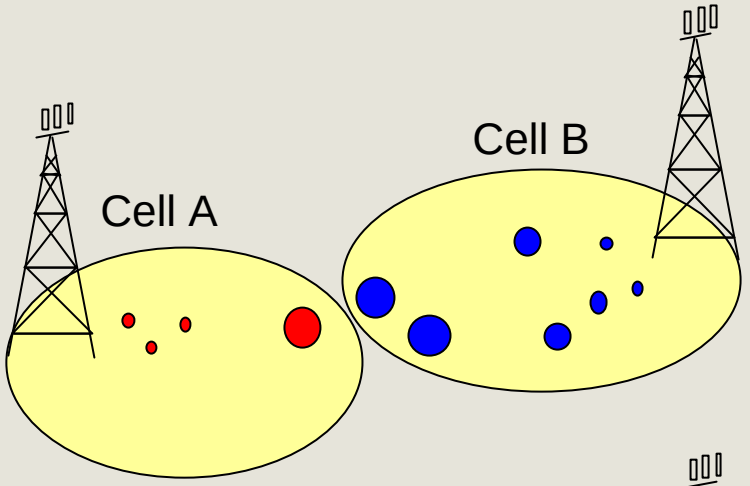
- More load (more capacity) ⇒ more interference ⇒ higher received signal power ⇒ more output power ⇒ ⇒ if not possible, less coverage



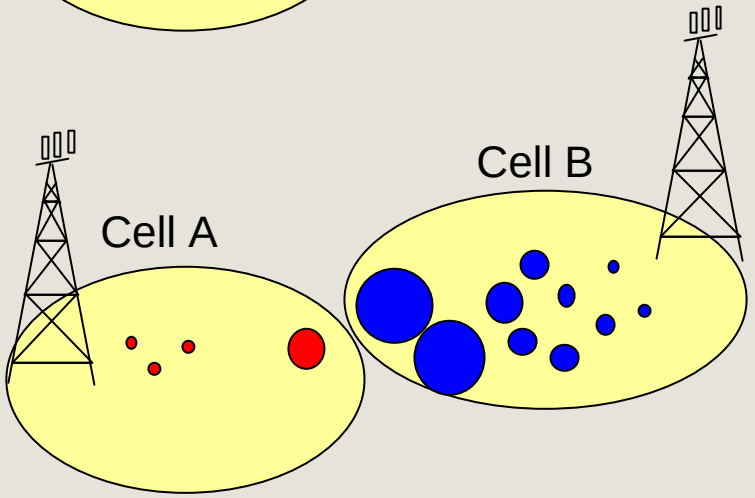
Trade-off between capacity and coverage!!

CDMA: cell breathing (1/2)

- *Uniform traffic distribution and low load: MS Tx power depends mainly on pathloss.*

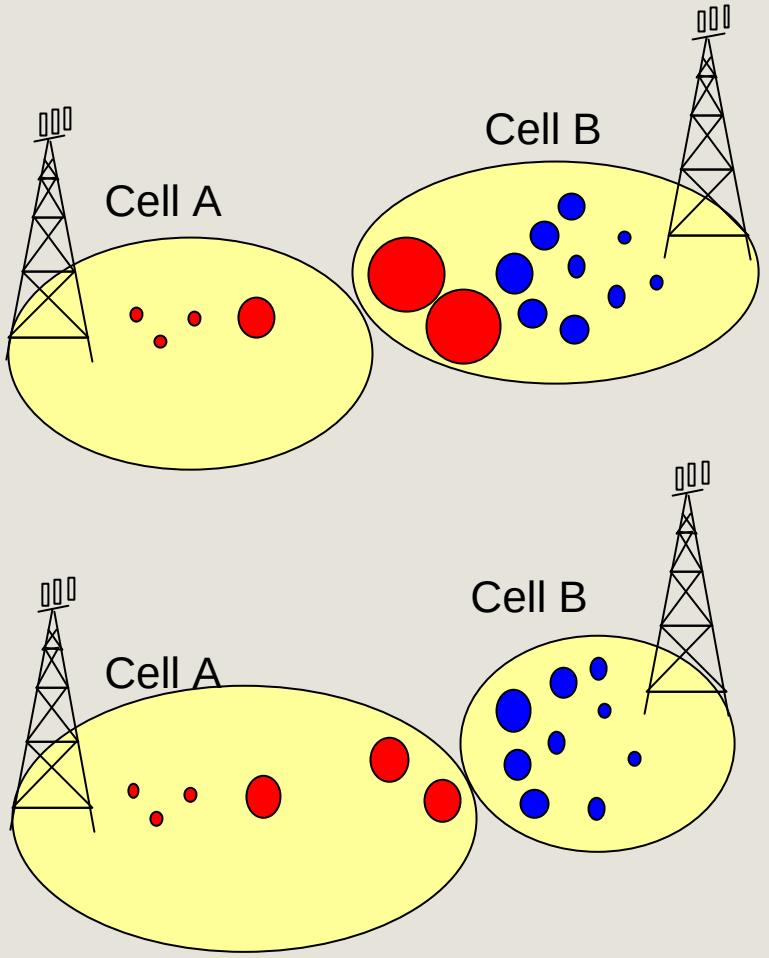


- *Raising traffic in a cell: users in that cell are forced to increase the Tx power level in order to react to increased interference.*



CDMA: cell breathing (2/2)

- *It is possible that Tx power used by some users is higher than that sufficient to be received by the unloaded cell, even though it is at a higher pathloss.*
- *Served area of the two cells varies as a function of the relative load, because in the unloaded cell also farther connections can be kept at low power.*



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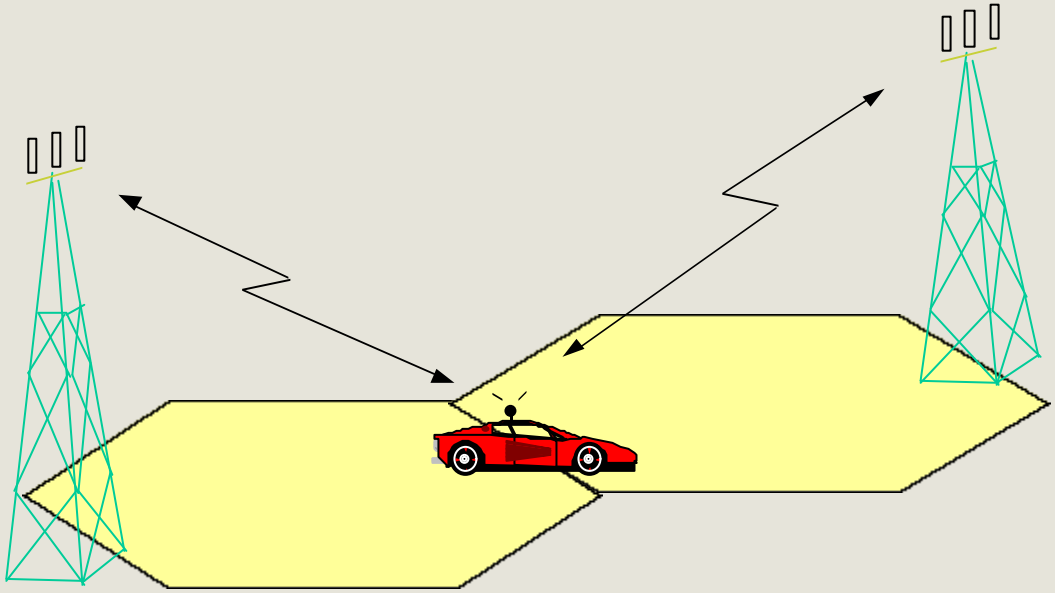
Soft-Handover

- *Soft Handover: simultaneous radio link between MS and different BTSs*
- *Softer Handover: simultaneous radio link between MS and different sectors of the same site.*



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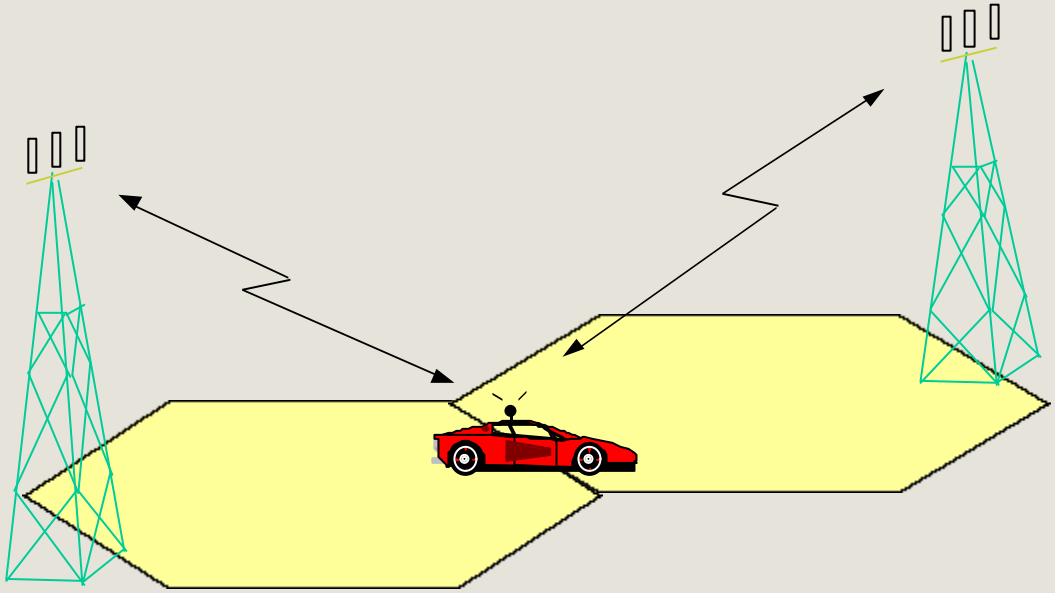
Soft-Handover

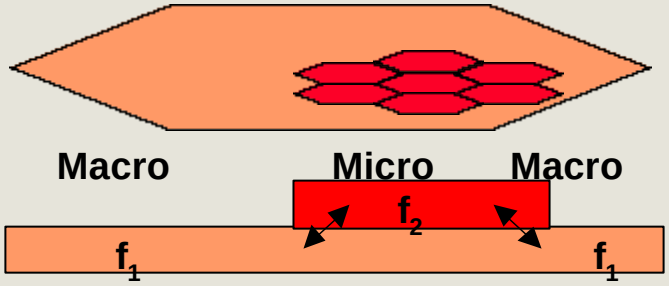
- *Advantages*
  - *SHO gain at cell border*
  - *Macrodiversity*
  - *Reduced Tx power (!)*
- *Disadvantages*
  - *Code waste*



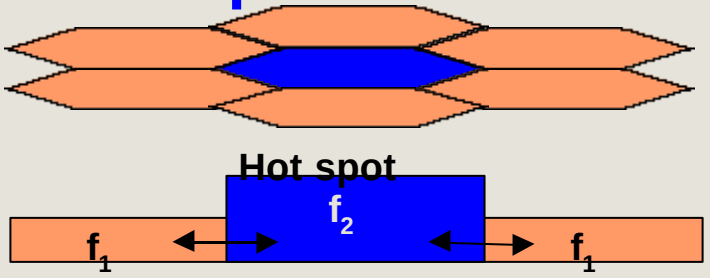
Hard handover

- *Inter-System:*
  - *FDD ↔ TDD*
  - *WCDMA ↔ GSM*
- *Inter- Frequency:*
  - *HCS*
  - *Hot - Spot*
- *Intra - Frequency:*
  - *TDD ↔ TDD*

HCS-scenario

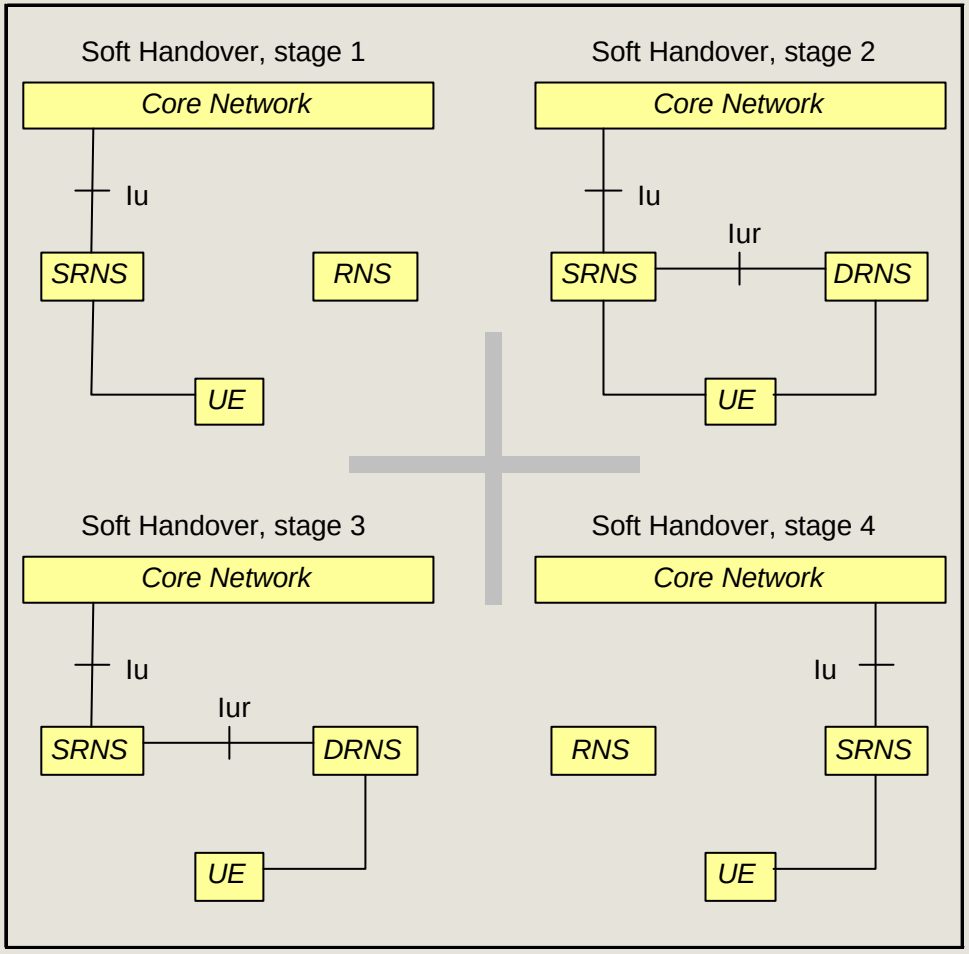


Hot-spot scenario



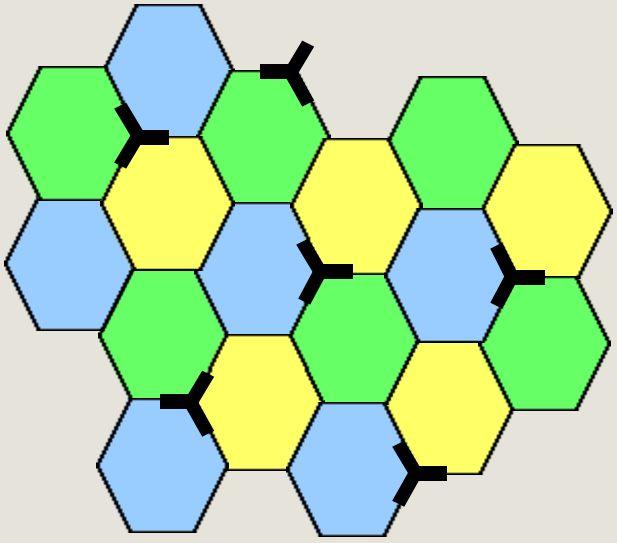
Handover

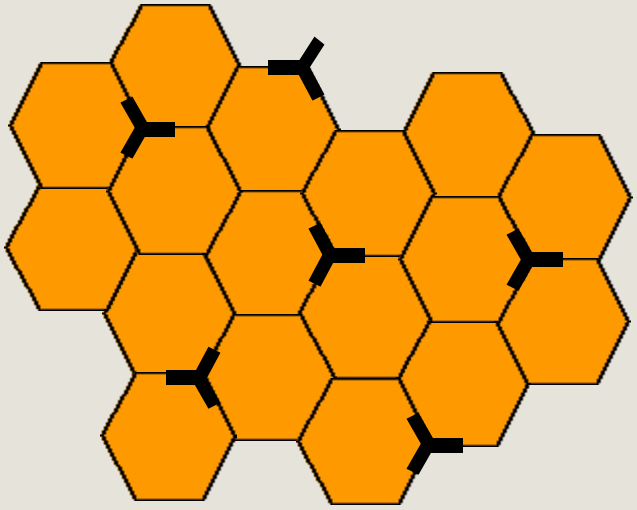
- *Soft-HO with cell belonging to different RNS*
  - *Serving-RNS: RNC controls the connection*
  - *Drift-RNS: only data transit*



Frequency re-use

Re-use coefficient 1/1:



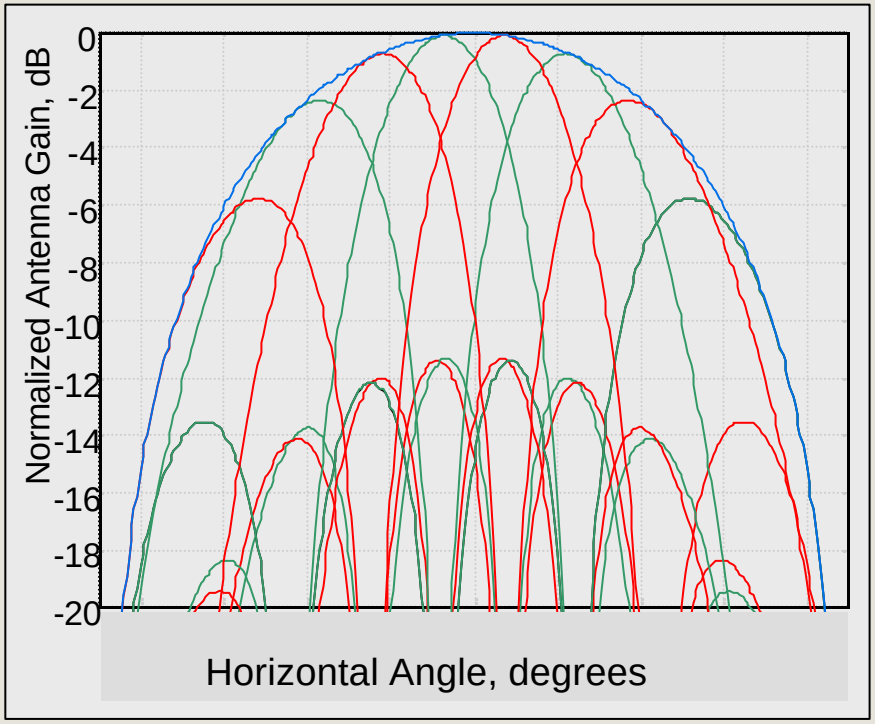


- Example FDMA/TDMA: re-use 1/3
- Cell planning = coverage & frequency planning

- CDMA: re-use 1/1 : No frequency-planning!!!
- Cell Planning = service coverage & code allocation.

What's next

- *Smart antenna: switching multibeam*
  - *adaptive antenna concept*
  - *more lobes within the cell*
  - *switched beam per user*
  - *improved SIR*
  - *no wasted power*



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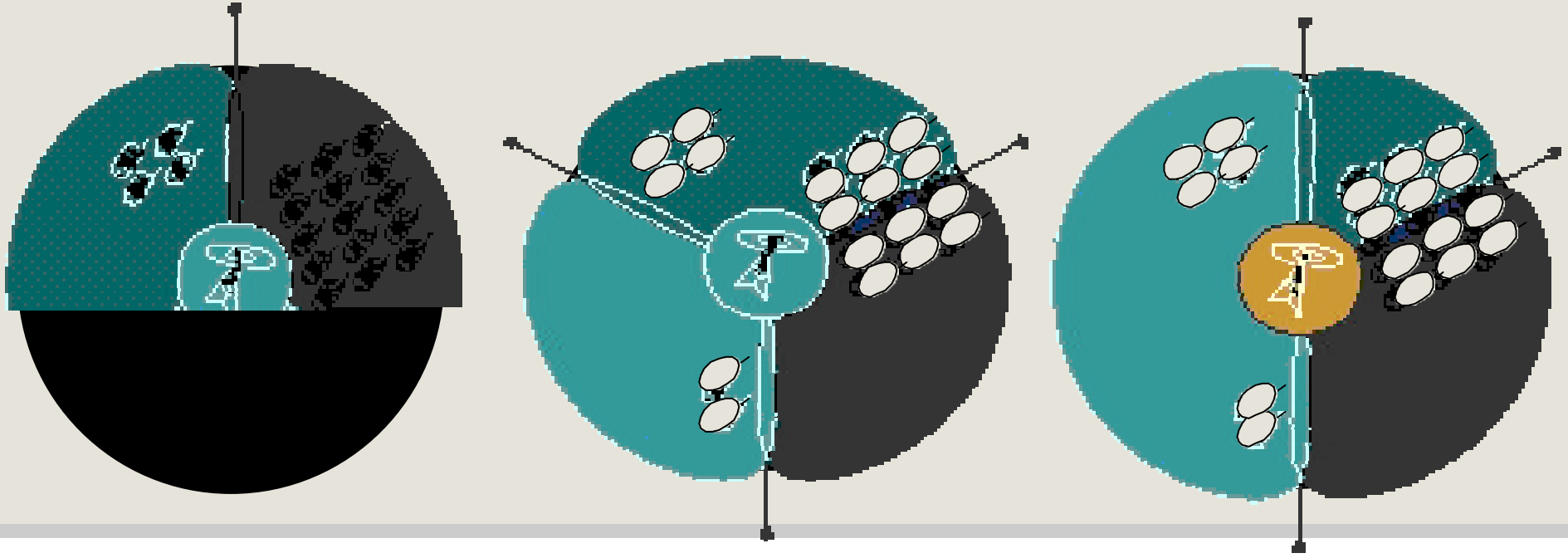
What's next

- *Smart antenna: load balancing*
  - *Adaptive antenna concept*
  - *Horizontal beamwidth is a function of cell load*
  - *Efficient handling of the radiated power*



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What's next

- *Voice over IP over wirless*
  - *Up to 70% of voice packets contain header information*
  - *ROHC algorithm (RObust Header Compression)*
  - *Header compression down to 3% percent of the original size of header information*
  - *More compression profiles for different channel condintions*
  - *Based on checksum and local header repairing*

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WCDMA

- **High service flexibility needed**
  - Variable bit rate: from very low (few kbit/s) up to 2 Mbit/s
  - Variable delay: from real-time traffic (e.g. speech) to best-effort IP traffic
  - Variable error rate: from 10^{-6} bit error rate to 10% frame error rate
  - Variable symmetry: from symmetrical (e.g. speech) to asymmetrical (e.g. WWW)
  - Variable number of parallel services with different characteristics for one user
- **More dynamic network behaviour**
  - Frequency re-use = 1
  - Slow and fast control loops
  - Service quality, range, traffic load and MS transmission power balancing
- **Co-existense of 2nd and 3rd generation systems**
  - Seamless handovers

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  - **- La struttura del sistema GSM ed il GPRS**
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  - **- Le caratteristiche della nuova/e banda/e**
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  - **- References (www.3gpp.org)**

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Table 1: Cell Type Classification according to COST 231

Cell type	Typical cell radius	Typical position of base station antenna
Macro-cell (large cell)	1 km to 30 km	Outdoor; mounted above medium rooftop level, heights of all surrounding buildings are below base station antenna height.
Small macro-cell	0.5 km to 3 km	Outdoor; mounted above medium rooftop level, heights of all surrounding buildings are above base station antenna height.
Micro cell	Up to 1 km	Outdoor; mounted below medium roof-top level.
Pico-cell/indoor	Up to 500 m	Indoor or outdoor (mounted below medium roof-top level)

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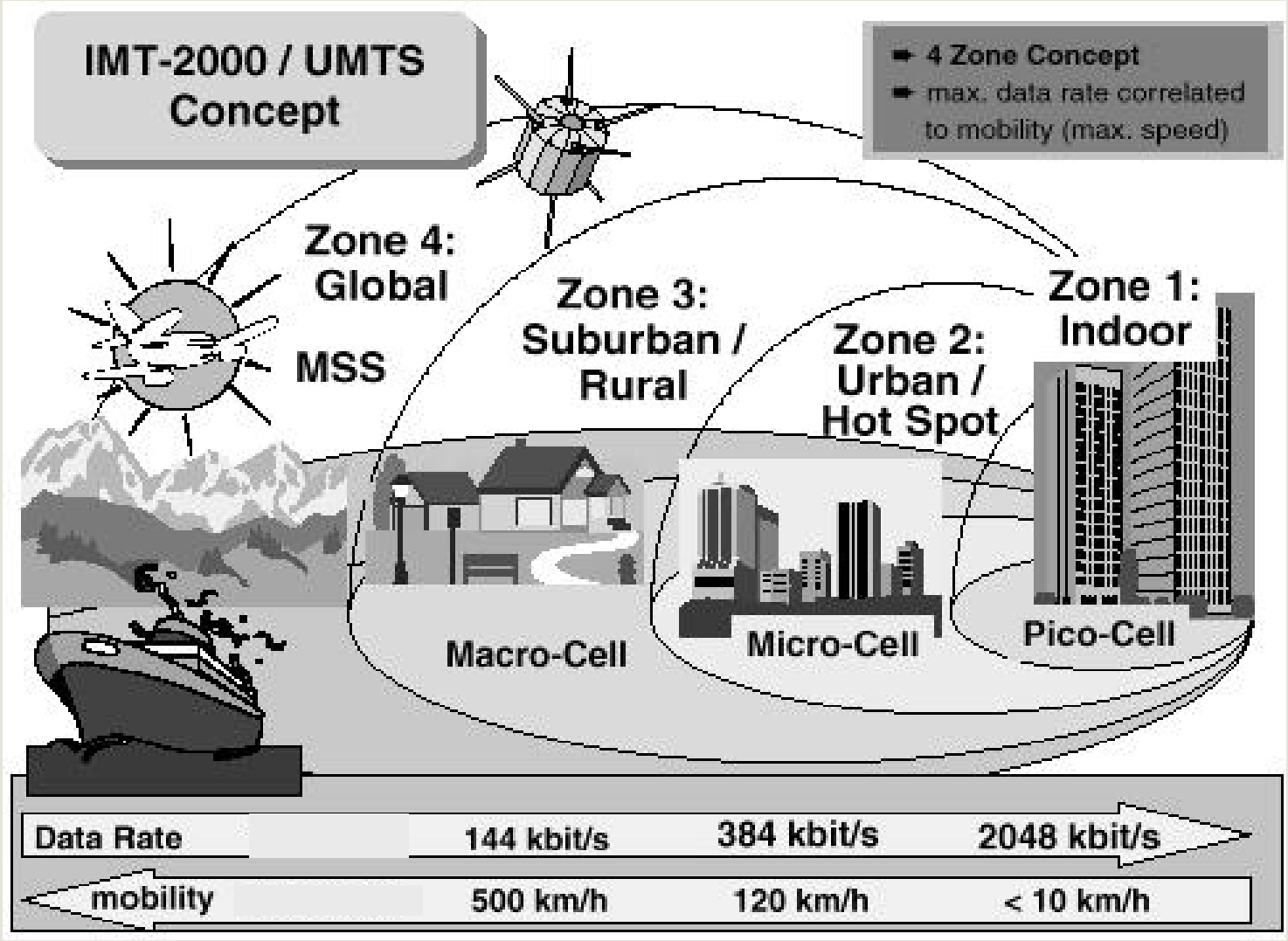
UMTS Radio Network



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RADIO NETWORK DIMENSIONING

Input

- Environment: Urban, Suburban, Rural,…
- Area: [sqkm]
- No of users
- No of frequencies
- Services: Speech, 64 kbps circuit data, 144 kbps packet data,... (traffic per subscriber, GoS or channel utilisation)
- Coverage
  - Indoor, Outdoor, in car,..
  - % area coverage

Basic coverage and capacity estimation

Output

- Number of RBS
- Traffic/RBS
- Coverage and traffic for each individual RBS

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A COMMON PROCESS FOR NETWORK DIMENSIONING

- The network dimensioning process for a WCDMA radio access presents a new different approach compared to a GSM network:
  - the coverage/capacity (radio resources per service) is not fixed in the WCDMA but depends on the network load. The changes of the load cause system interference variations due to the frequency sharing at same time.
  - while in the case of a GSM network the process considers the Power balance between uplink and downlink, for a WCDMA network, the dimensioning starts with the uplink for which the interference can be estimated fixing the system load.

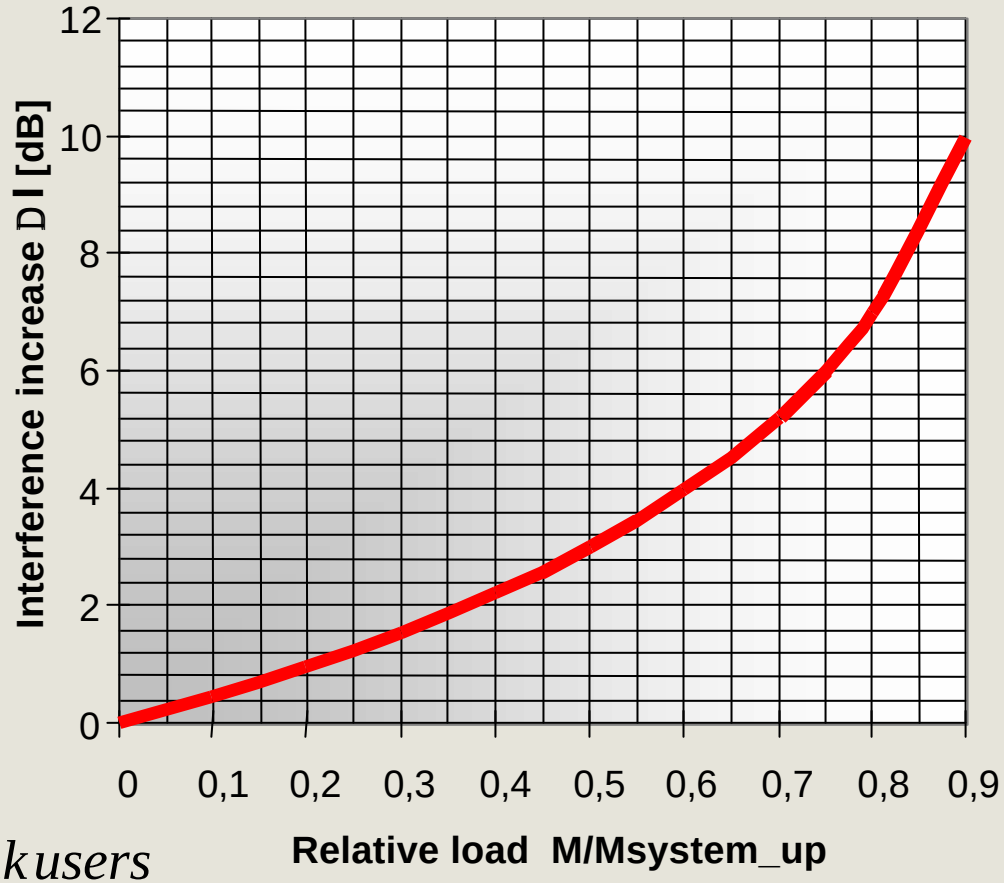
Uplink Capacity and Coverage

- Uplink interference level [dB] above noise as a function of the load

$$\Delta I_{ul} = -10 * log(1 - \frac{M}{M_{system\_up}})$$

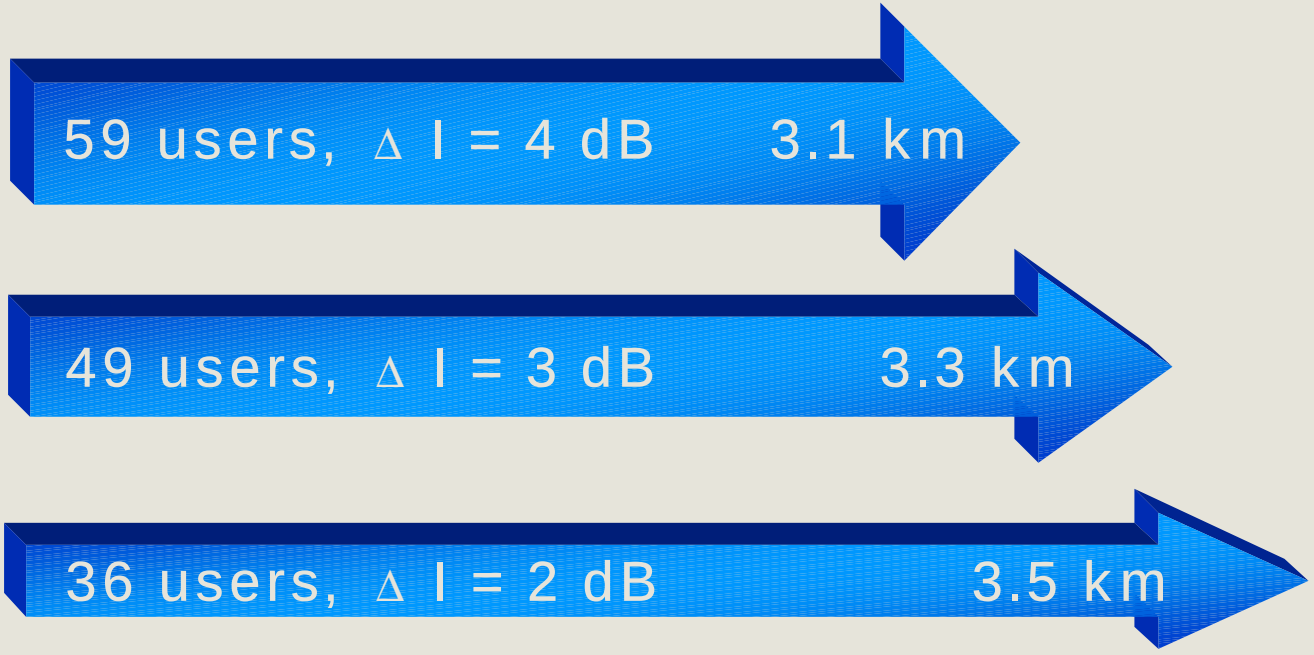
$$M = Number\ of\ users$$

$$M_{system\_up} = Max\ number\ of\ uplink\ users$$



Uplink Capacity and Coverage

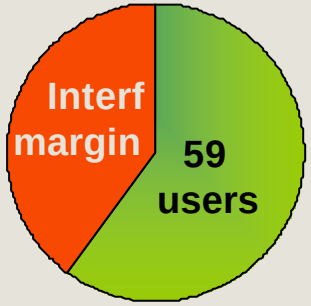
Example of flexibility between capacity and coverage



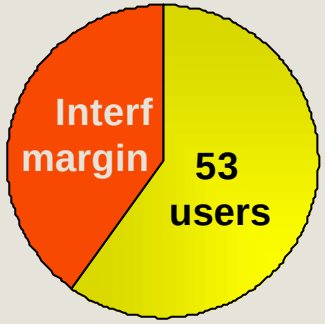
Note: based on 5 MHz bandwidth, 12.2 kbit/s speech (50% voice activity), Pedestrian A 3 km/h channel model, Outdoor coverage in an urban environment

Uplink Capacity and Coverage

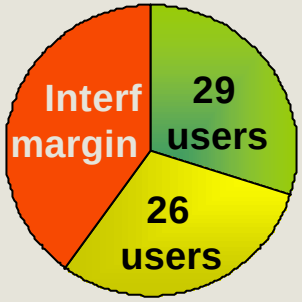
- Example of uplink capacity/sector in a 5 MHz band and for 60% loading



Speech 0.36 Mbit/s /sector



UDD144 0.91 Mbit/s /sector



UDD144 & Speech 0.62 Mbit/s/sector

Note: based on 5 MHz bandwidth, 12.2 kbit/s speech (50% voice activity) and UDD144 Pedestrian A 3 km/h, Urban environment

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Comparisons with GSM 1800

- capacity comparison

Example of capacity comparison

	WCDMA	GSM
Total operator bandwidth	15 MHz	15 MHz
No of carriers	3	75
No of channels/carrier	65 (60% load)	8
Re-use pattern	1	6 (average)
Carriers/Sector	3	12.5
Speech channels/sector	195	100

Note: 13 kbit/s speech (50% voice activity), Pedestrian A 3 km/h, Urban environment, sensitivity according to ITU submission

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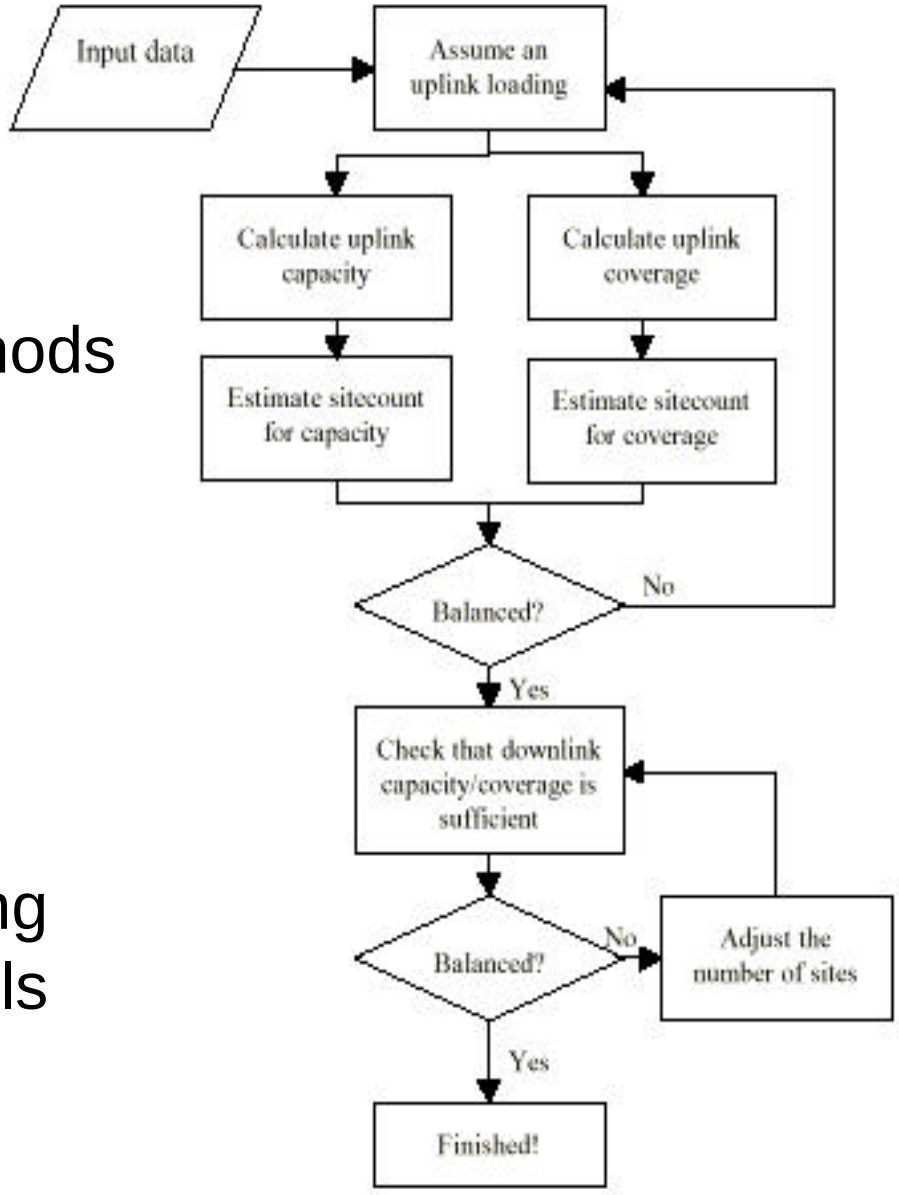
Dimensioning Process

- One out of many possible methods for dimensioning
- Balancing between UL/DL, Capacity (Load) and Range
- Advanced/detailed dimensioning requires Network Planning Tools

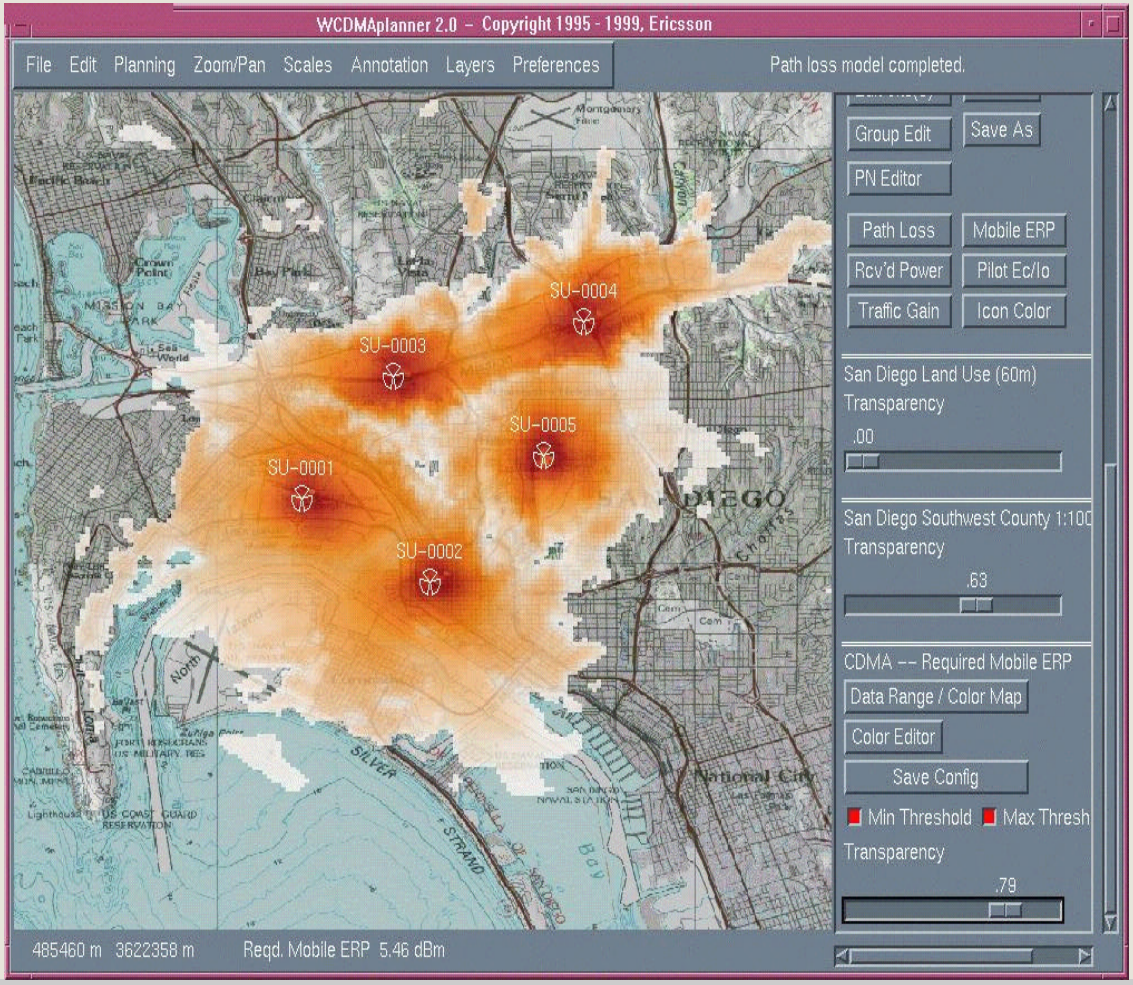


Example of Initial Radio Network Deployment

Using a Design Tool gives a more detailed view

Example of information given by the design tool

- Detailed coverage and traffic for each RBS and service
- Handover areas
- Interference levels



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Specifications Produced by 3GPP TSG RAN

25.201 – Physical layer general description
25.211 – Transport channels and physical channels (FDD)
25.212 – Multiplexing and channel coding (FDD)
25.213 – Spreading and modulation (FDD)
25.214 – Physical layer procedures (FDD)
25.221 – Transport channels and physical channels (TDD)
25.222 – Multiplexing and channel coding (TDD)
25.223 – Spreading and modulation (TDD)
25.224 – Physical layer procedures (TDD)
25.231 – Physical layer - measurements

25.301 – Radio Interface Protocol Architecture
25.302 – Services Provided by the Physical Layer
25.303 – UE Functions and Inter-layer procedures in Connected Mode
25.304 – UE Functions Related to Idle Mode
25.321 – Medium Access Control (MAC) Protocol Specification
25.322 – Radio Link Control (RLC) Protocol Specification
25.331 – Radio Resource Control (RRC) Protocol Specification

25.101 – UE radio transmission and reception (FDD)
25.102 – UE radio transmission and reception (TDD)
25.103 – RF parameters in support of Radio Resource Management
25.104 – BTS radio transmission and reception (FDD)
25.105 – BTS radio transmission and reception (TDD)
25.141 – Base station conformance testing (FDD)
25.142 – Base station conformance testing (TDD)
25.143 – Base station EMC

25.401 – RAN Overall Description
25.410 – General aspects & Principles of Iu interface between CN and RAN
25.411 – Iu interface Layer 1
25.412 – Iu interface signalling transport
25.413 – Iu interface CN-RAN signalling
25.414 – Iu interface data transport & transport signalling
25.415 – Iu interface CN-RAN user plane protocols
25.420 – General aspects & Principles of Iur interface
25.421 – Iur interface Layer 1
25.422 – Iur interface signalling transport
25.423 – Iur interface RNC-RNC signalling
25.424 – Iur interface data transport & transport signalling for CCH data streams
25.425 – Iur interface user plane protocols for CCH data streams
25.426 – Iur & Iub interface data transport & transport signalling for DCH data streams
25.427 – Iur & Iub interface user plane protocol for DCH data streams
25.430 – General aspects & Principles of Iub interface
25.431 – Iub interface Layer 1
25.432 – Iub interface signalling transport
25.433 – Iub interface RNC-Node B signalling
25.434 – Iub interface data transport & transport signalling for CCH data streams
25.435 – Iub interface RNC-Node B user plane protocols for CCH data streams

In total 53 specifications!