192620010
Mobile & Wireless Networking

Lecture 5:
Cellular Systems (UMTS / LTE) (1/2)

[Schiller, Section 4.4]

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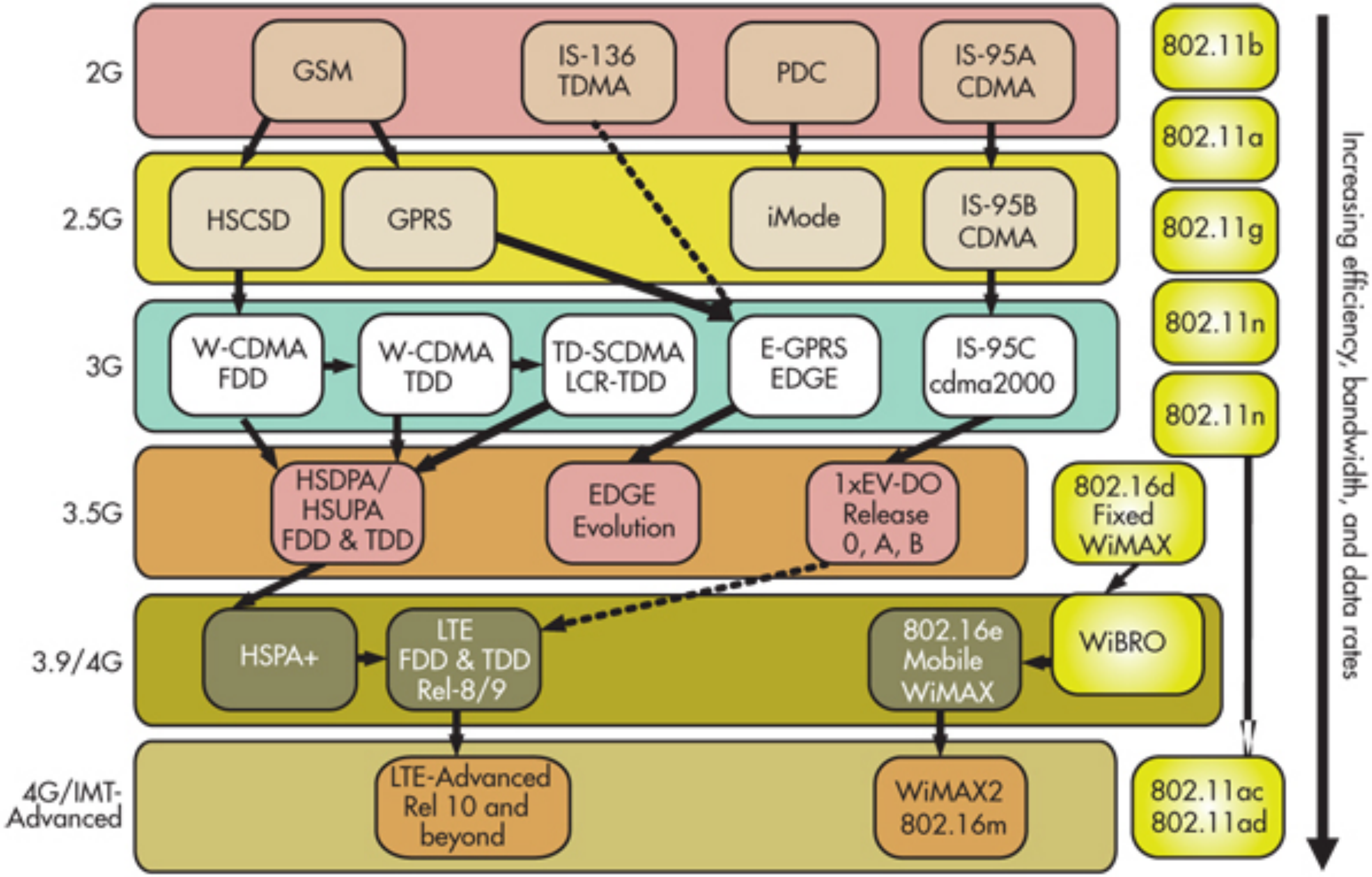
Cellular Systems (UMTS / LTE) (1/2)

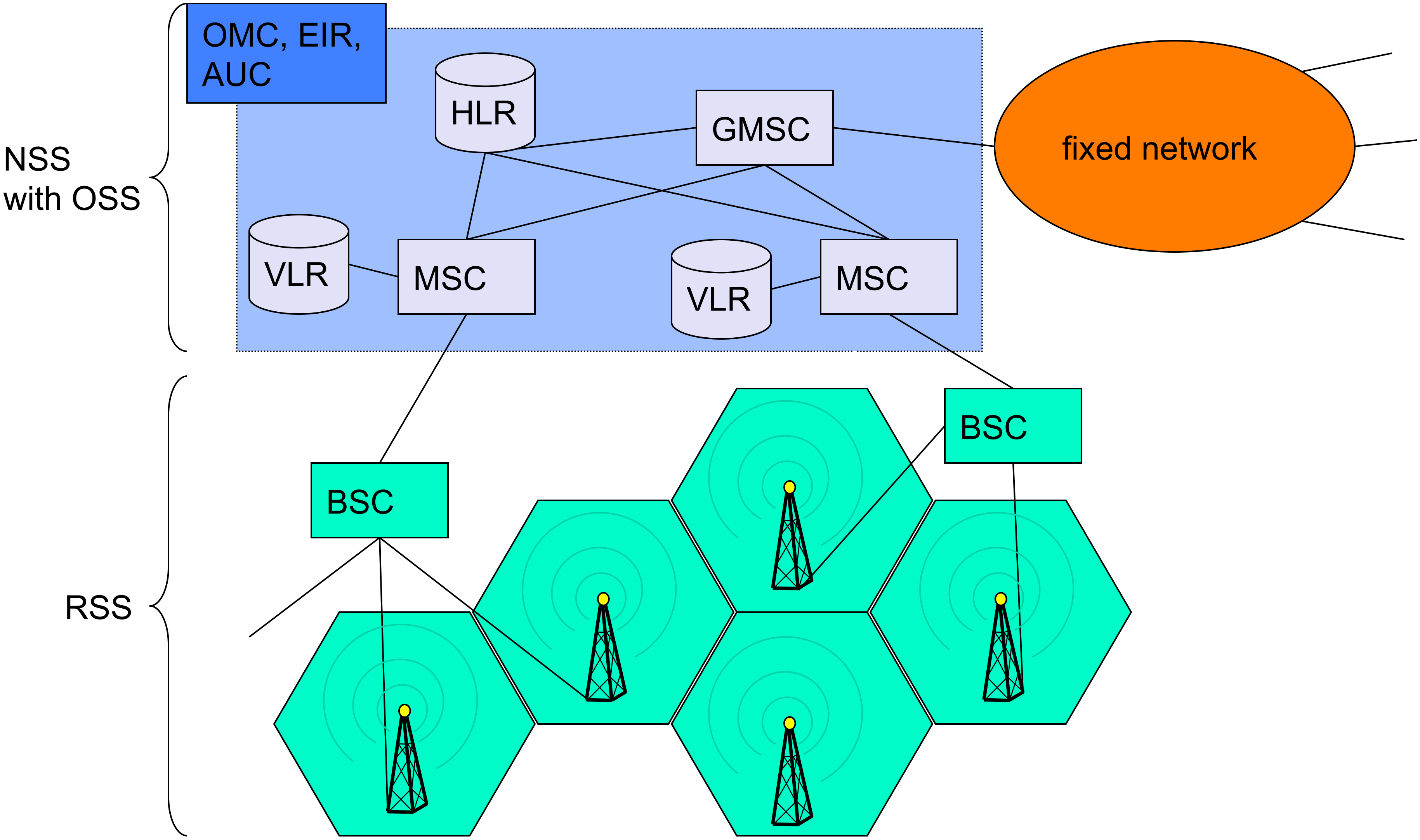
- Evolution of cellular systems
- GSM
  - GSM Network Architecture
  - GSM radio interface
  - GPRS
  - EDGE
- 3G UMTS
  - UMTS Network Architecture
  - Wideband CDMA

Evolution of cellular systems

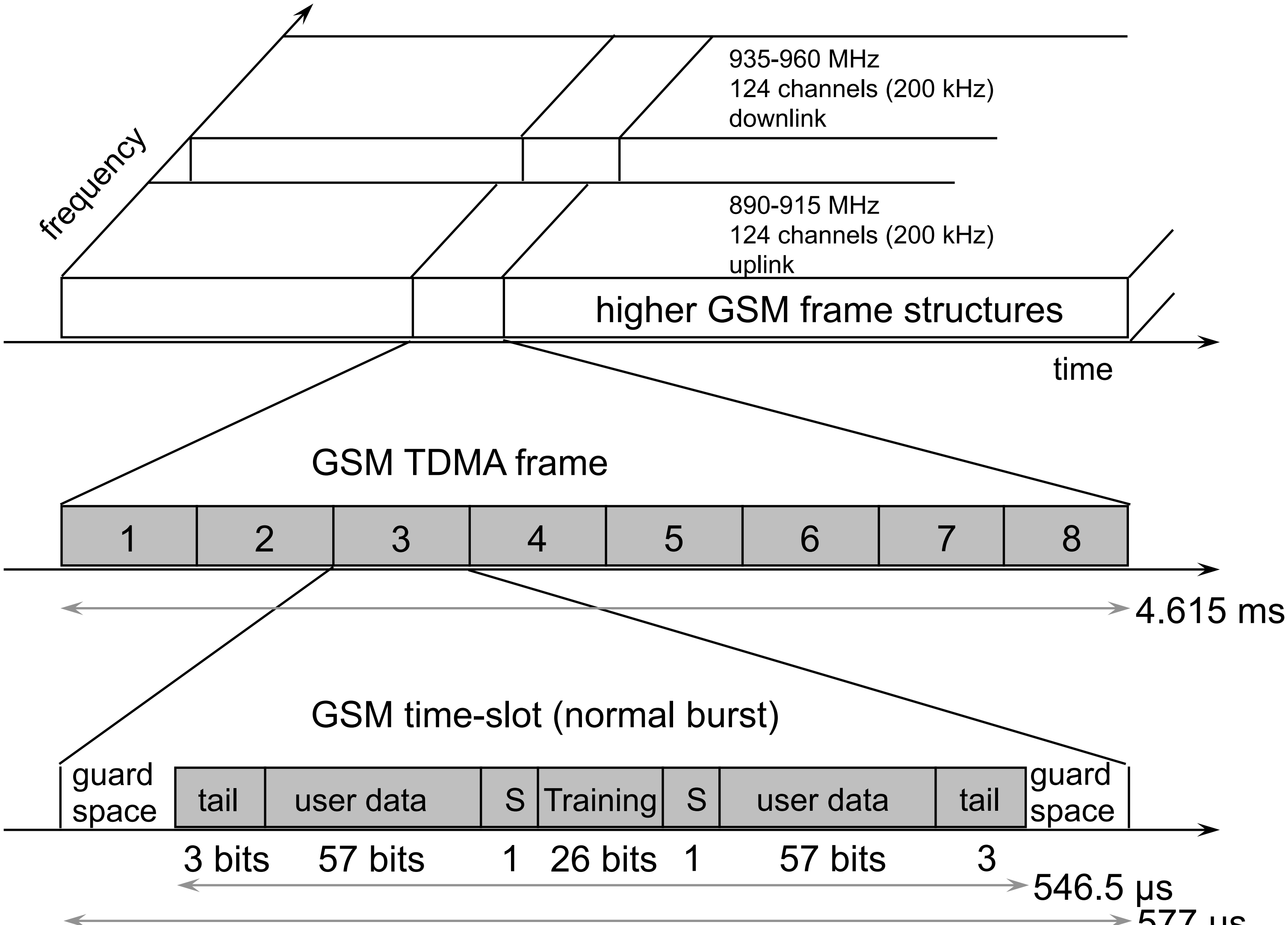


Source: Agilent Technologies, 2012

GSM Architecture



GSM Radio Interface: TDMA/FDMA



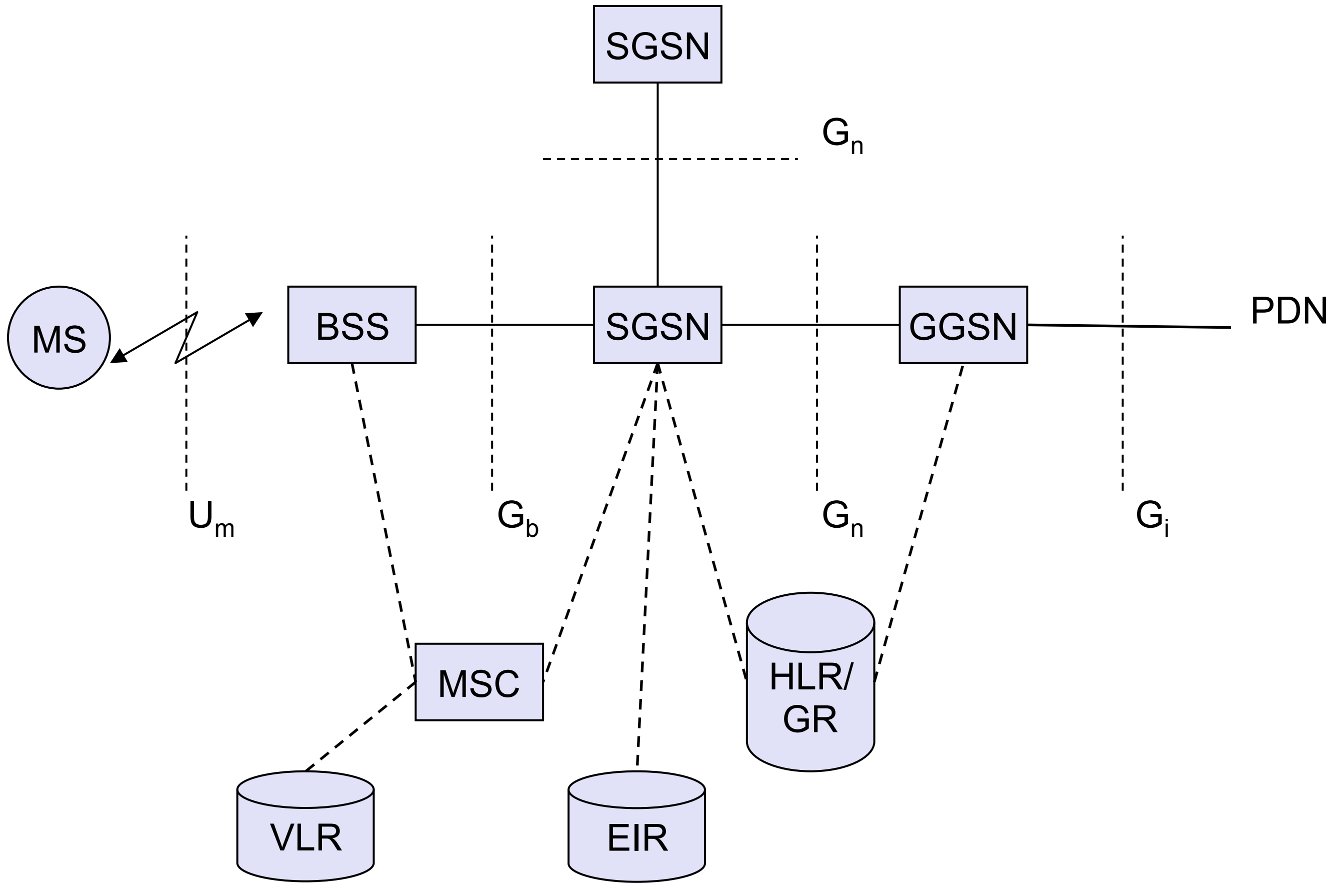
GPRS (General Packet Radio Service)

- packet switching
- using free slots only if data packets ready to send
- (~reservation Aloha)
- Few changes to base station (software)
- New core network architecture (router-based)

Class	Receiving slots	Sending slots	Maximum number of slots
1	1	1	2
2	2	1	3
3	2	2	3
5	2	2	4
8	4	1	5
10	4	2	5
12	4	4	5

Coding scheme	1 slot	2 slots	3 slots	4 slots	5 slots	6 slots	7 slots	8 slots
CS-1	9.05	18.2	27.15	36.2	45.25	54.3	63.35	72.4
CS-2	13.4	26.8	40.2	53.6	67	80.4	93.8	107.2
CS-3	15.6	31.2	46.8	62.4	78	93.6	109.2	124.8
CS-4	21.4	42.8	64.2	85.6	107	128.4	149.8	171.2

GPRS architecture and interfaces



EDGE

EDGE (Enhanced Data rates for GSM Evolution):

- New modulation technique: 8PSK instead of GMSK (bitrate x3)
- Can be combined with GPRS
- Adaptive Modulation and Coding
- Incremental Redundancy (Hybrid ARQ)
- New BS hardware

Coding and modulation scheme (MCS)	Bandwidth (kbit/s/slot)	Modulation
MCS-1	8.80	GMSK
MCS-2	11.2	GMSK
MCS-3	14.8	GMSK
MCS-4	17.6	GMSK
MCS-5	22.4	8-PSK
MCS-6	29.6	8-PSK
MCS-7	44.8	8-PSK
MCS-8	54.4	8-PSK
MCS-9	59.2	8-PSK

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UMTS architecture (original release (R99))

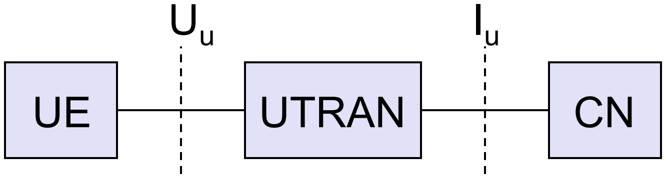
UTRAN (UMTS Terrestrial Radio Access Network)

- Cell level mobility
- Radio Network Subsystem (RNS)
- Encapsulation of all radio specific tasks

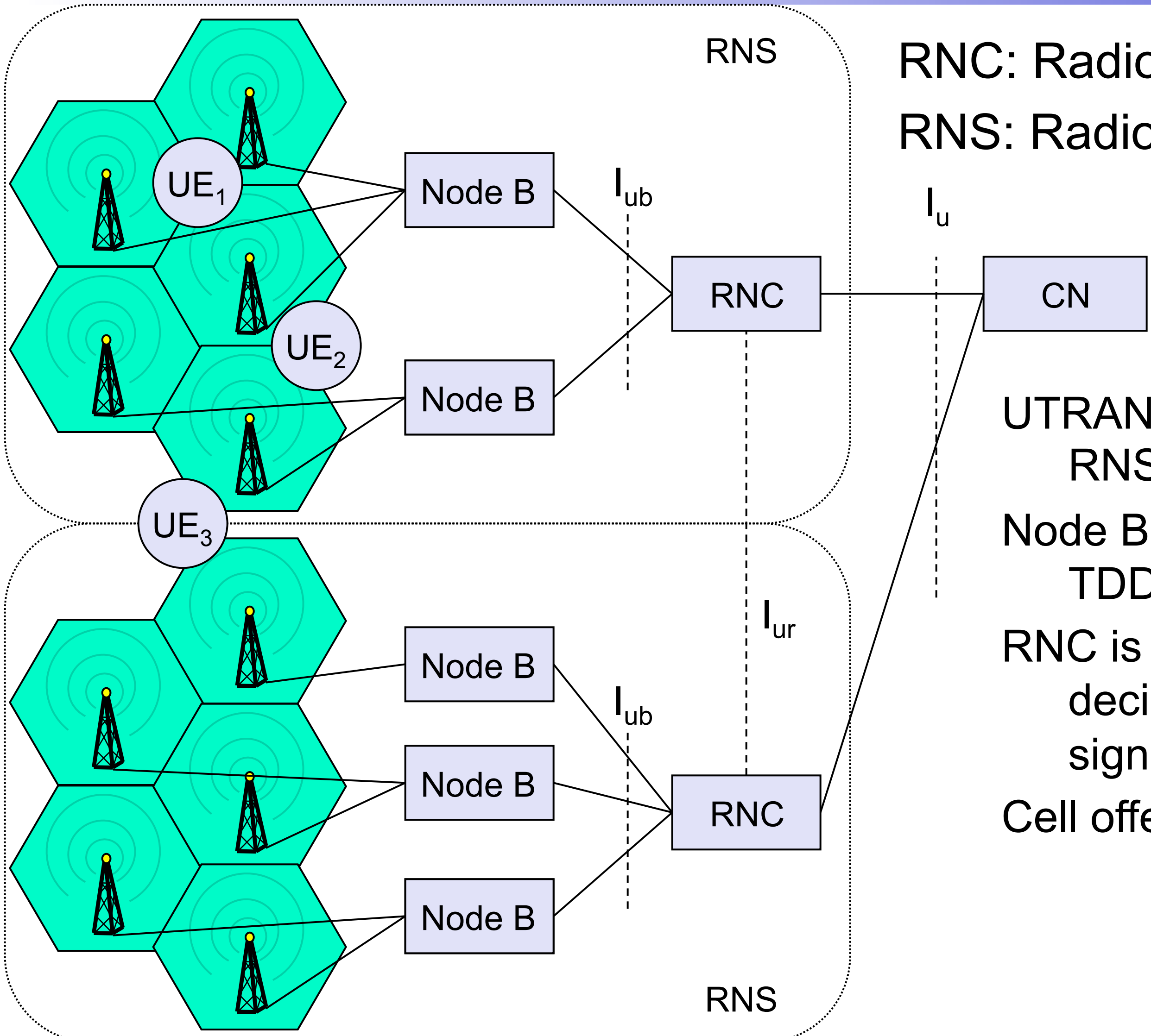
UE (User Equipment)

CN (Core Network)

- Inter system handover
- Location management if there is no dedicated connection between UE and UTRAN



UTRAN architecture

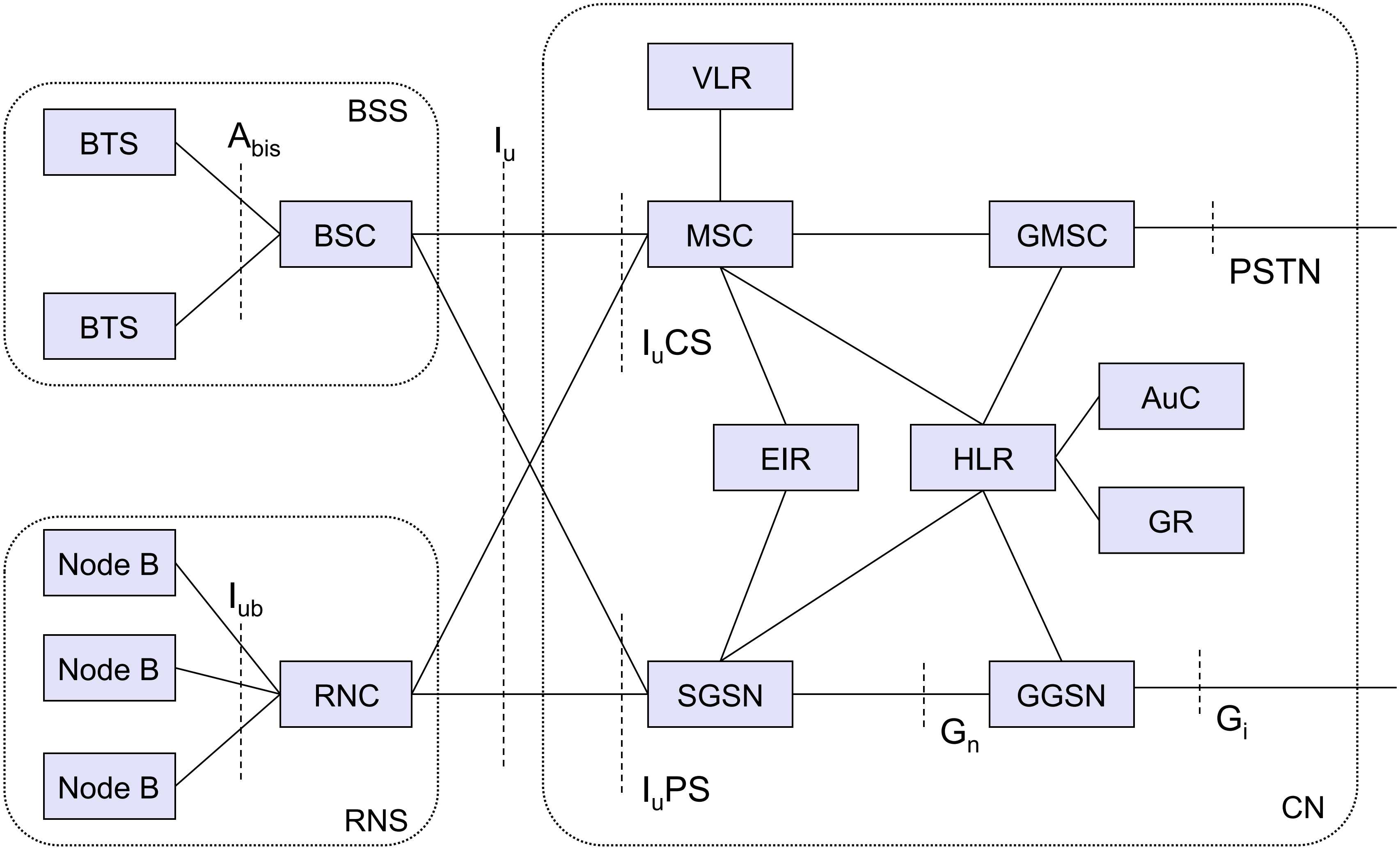


RNC: Radio Network Controller

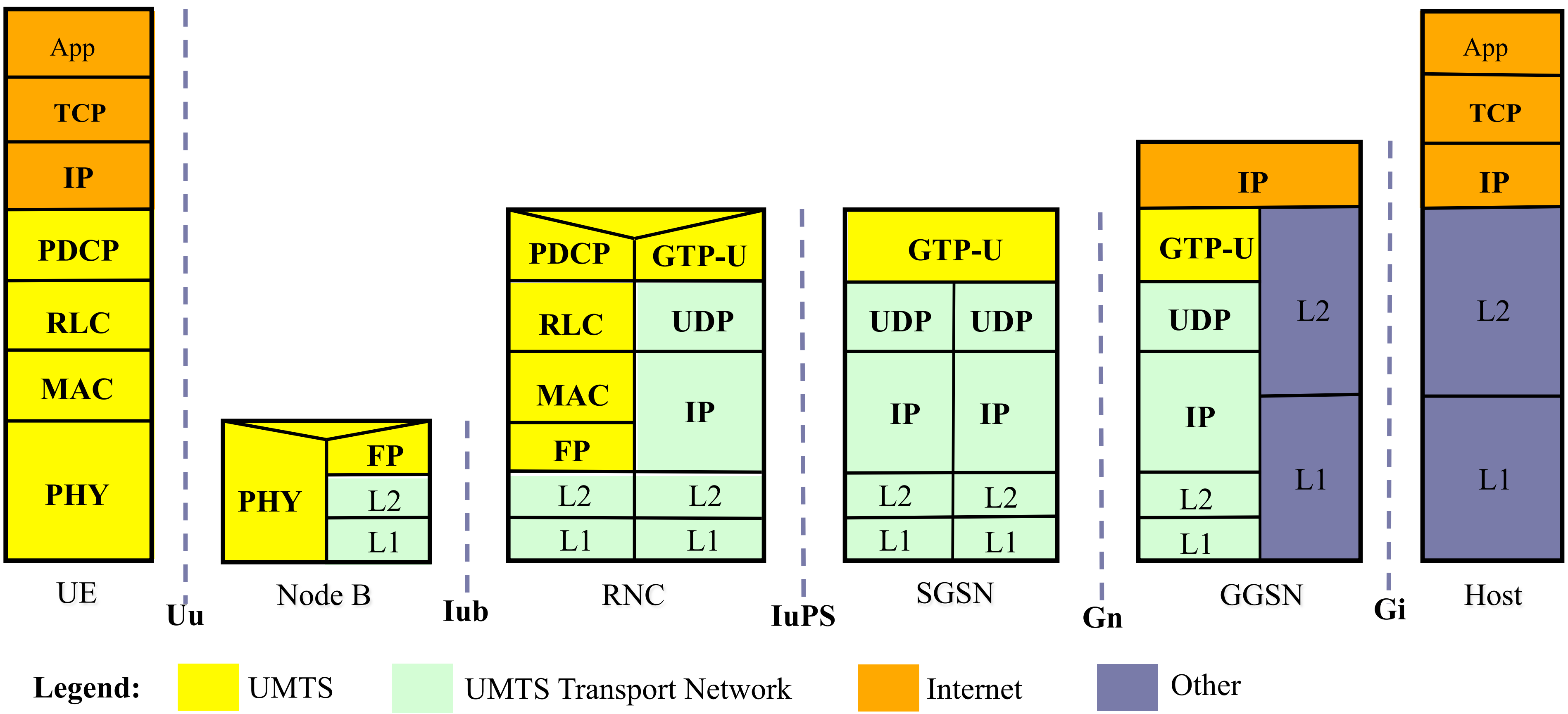
RNS: Radio Network Subsystem

- UTRAN comprises several RNSs
- Node B can support FDD or TDD or both
- RNC is responsible for handover decisions requiring signalingto the UE
- Cell offers FDD or TDD

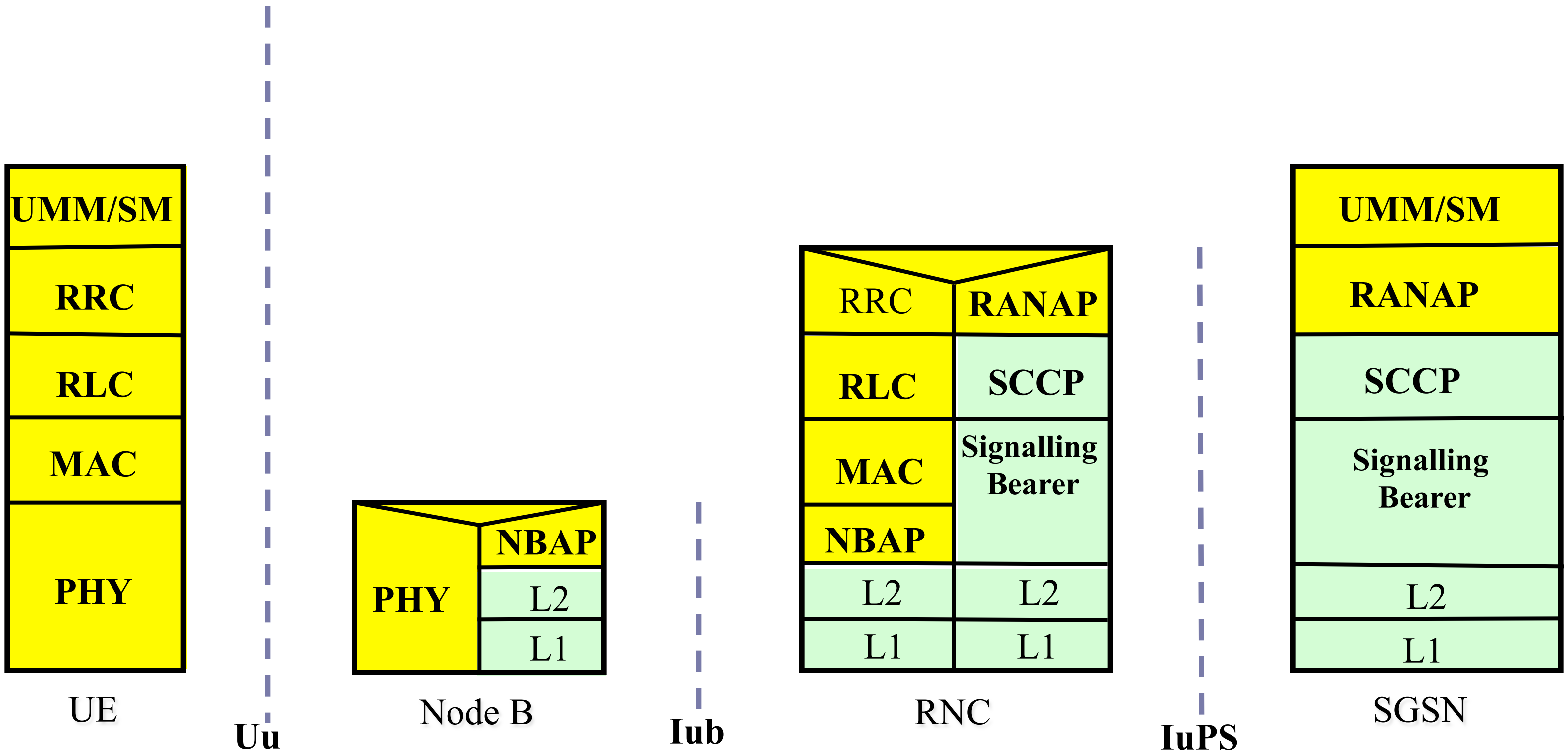
Core network: architecture



UMTS Protocol Architecture - User Plane



UMTS Protocol Architecture – Control Plane



Legend: UMTS | UMTS Transport Network

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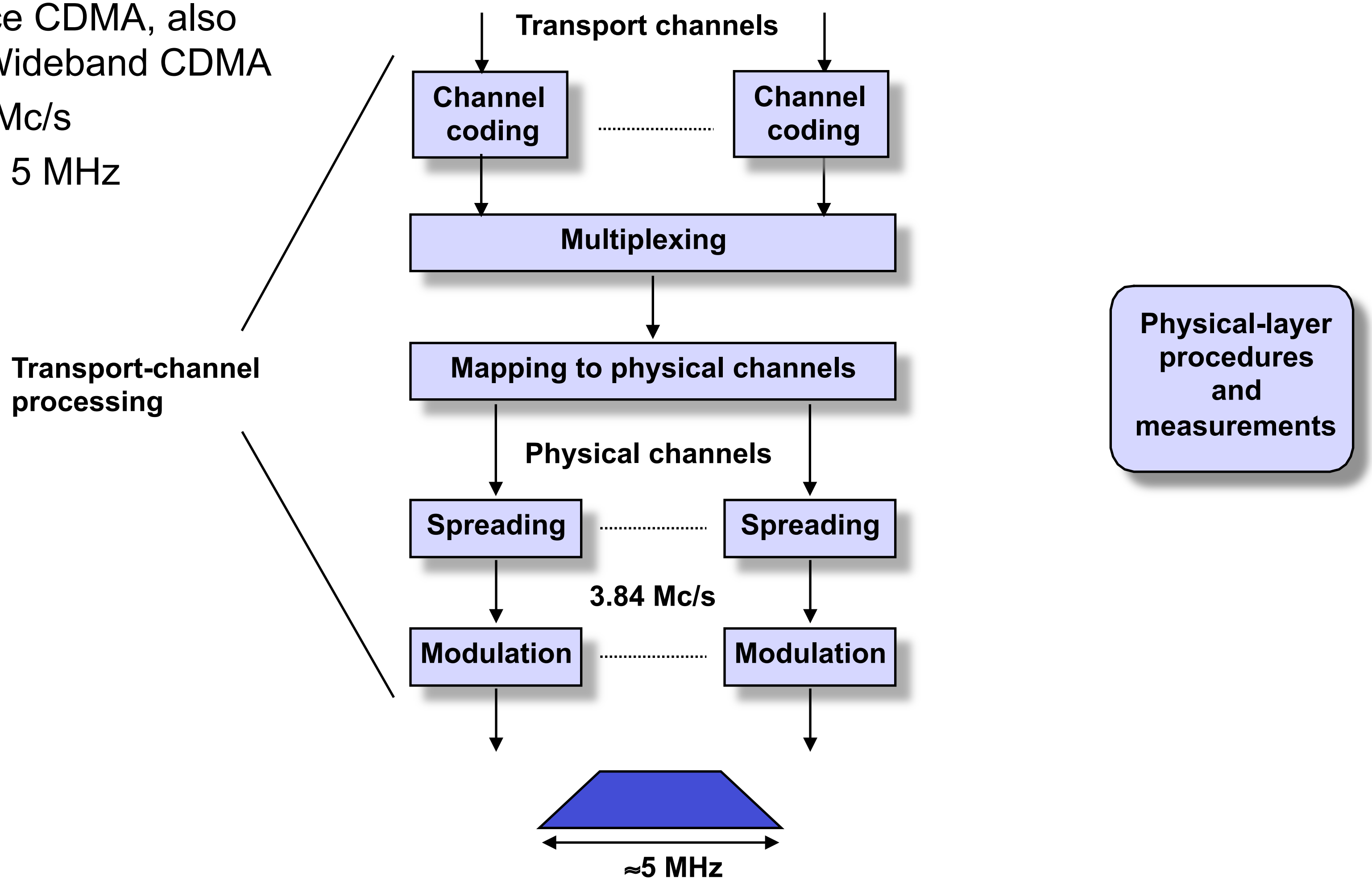
Wideband CDMA

Direct Sequence CDMA, also known as Wideband CDMA

Chip rate 3.84 Mc/s

Carrier spacing 5 MHz



How do we spread the data?

The operation of spreading in a CDMA system is divided into two separate parts

- Spreading code = Scrambling code + Channelization code

Scrambling

- Separates different mobiles (in uplink) and different cells/sectors (in downlink)

Channelization

- Separates different physical channels that are transmitted on the same scrambling code
- The purpose of channelization is most evident in the downlink

Spreading and scrambling of user data

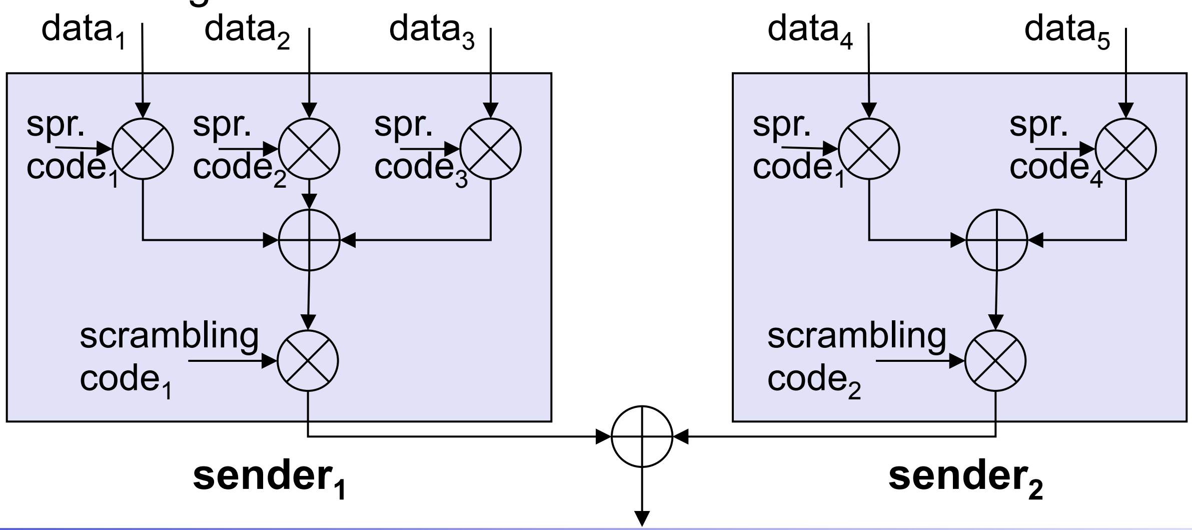
Constant chipping rate of 3.84 Mchip/s

Different user data rates supported via different spreading factors

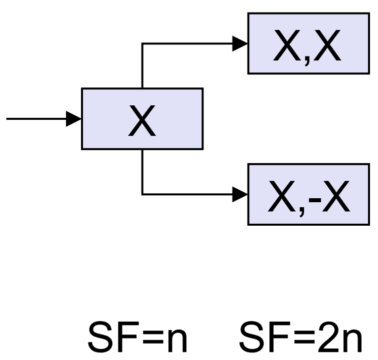
- higher data rate: less chips per bit and vice versa

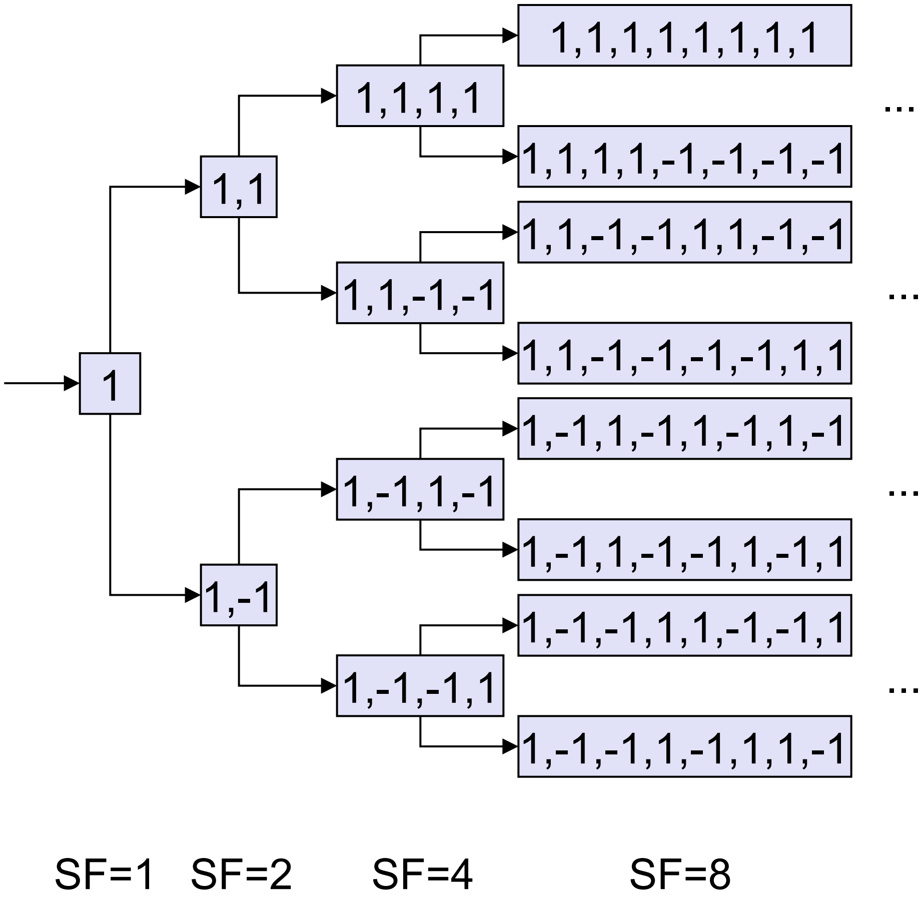
User separation via unique, quasi orthogonal scrambling codes

- users are not separated via orthogonal spreading codes
- much simpler management of codes: each station can use the same orthogonal spreading codes
- precise synchronisation not necessary as the scrambling codes stay quasi-orthogonal

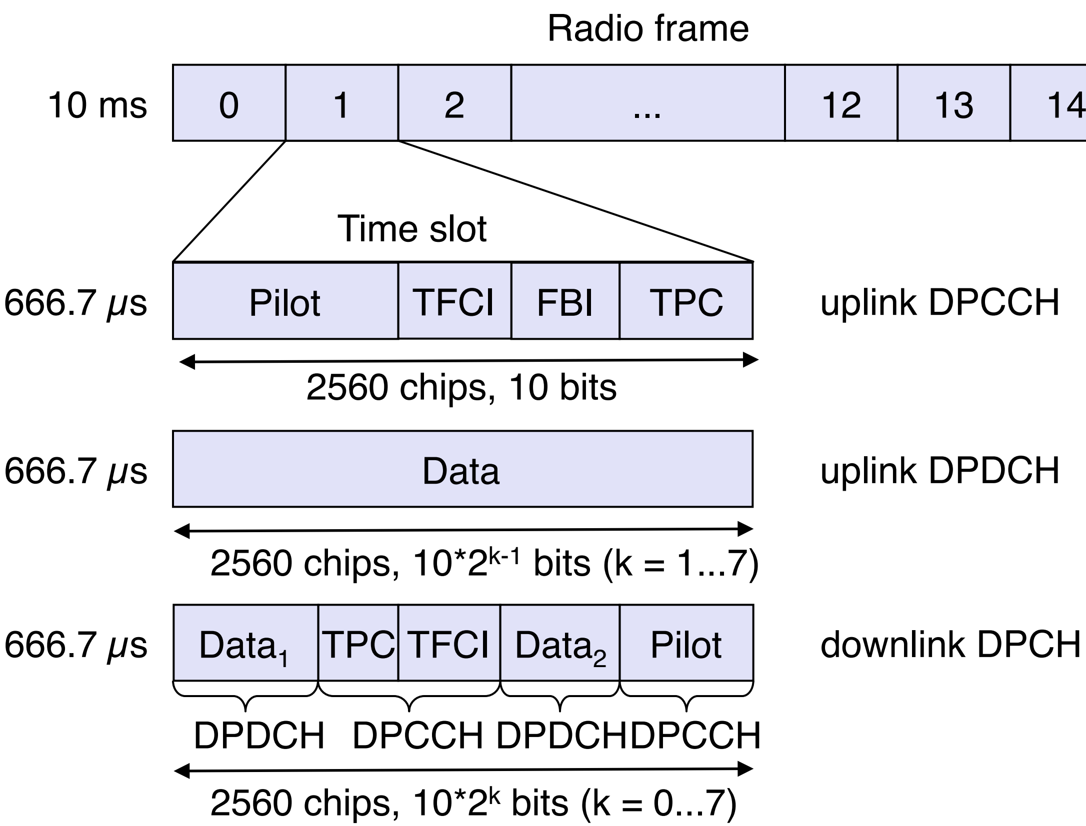


Orthogonal Variable Spreading Factor (OVSF) coding





UMTS FDD frame structure



W-CDMA

- 1920-1980 MHz uplink
- 2110-2170 MHz downlink
- chipping rate: 3.840 Mchip/s
- soft handover
- QPSK
- complex power control (1500 power control cycles/s)
- spreading: UL: 4-256; DL:4-512

FBI: Feedback Information
TPC: Transmit Power Control
TFCI: Transport Format Combination Indicator
DPCCH: Dedicated Physical Control Channel
DPDCH: Dedicated Physical Data Channel
DPCH: Dedicated Physical Channel

Slot structure NOT for user separation but synchronisation for periodic functions!

Bit rates and Spreading Factors

k	Spreading factor	Channel bit rate [kbps]		User bit rate (bef. coding) [kbps]	
		Uplink	Downlink	Uplink	Downlink
0	512	N/A	15 kbps	N/A	6 kbps
1	256	15 kbps	30 kbps	15 kbps	24 kbps
2	128	30 kbps	60 kbps	30 kbps	51 kbps
3	64	60 kbps	120 kbps	60 kbps	90 kbps
4	32	120 kbps	240 kbps	120 kbps	210 kbps
5	16	240 kbps	480 kbps	240 kbps	432 kbps
6	8	480 kbps	960 kbps	480 kbps	912 kbps
7	4	960 kbps	1920 kbps	960 kbps	1872 kbps

Fading

Path loss – fading due to distance

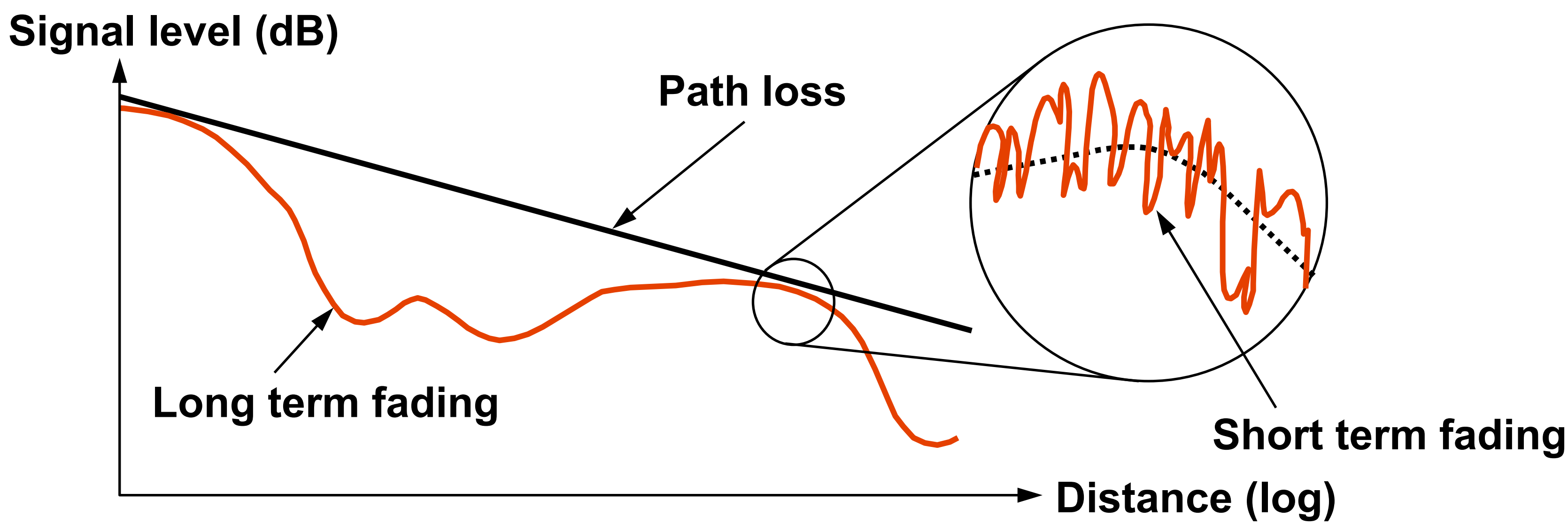
- 1/distance$^{\alpha}$ (α between 3 and 4)

Long term (slow) fading – caused by shadowing

- Log-normal

Short term (fast) fading – caused by multipath propagation

- Rayleigh fading amplitude



Purpose of Power Control

Goal

- mobile station transmitted power is controlled such that all users in the cell experience the same SIR (Signal to Interference Ratio) at the base station receiver

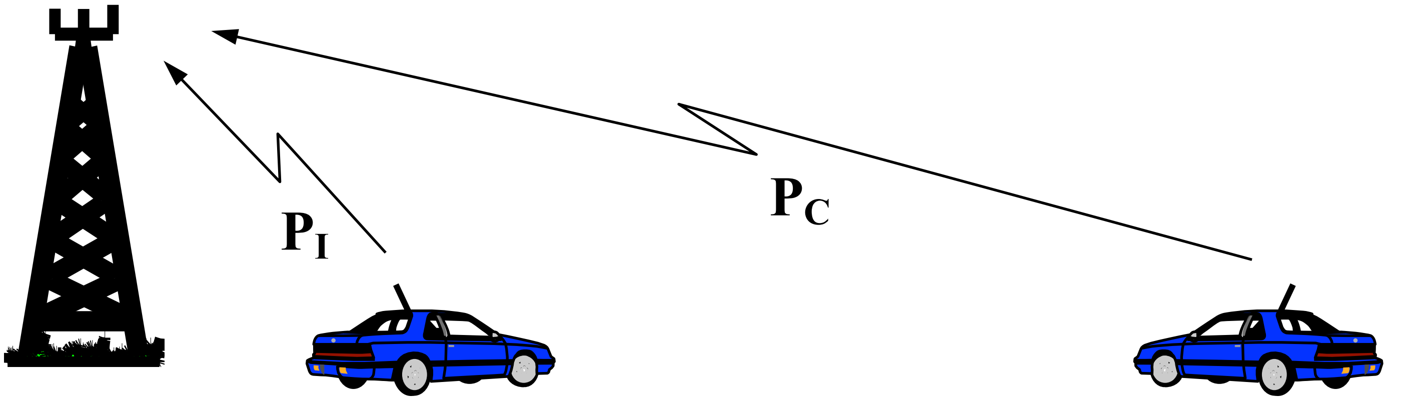
Open Loop (initial power setting)

- compensate for pathloss and slow fading
- uses downlink pilot channel

Closed Loop (fast power control)

- compensates also for fast fading
- needs dedicated downlink control channel for power control commands

Dynamic Range of Power Control



Worst case: $P_C(\text{dB}) - P_I(\text{dB}) = -80$ **dB!**

Interferers are rejected by the processing gain:

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

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

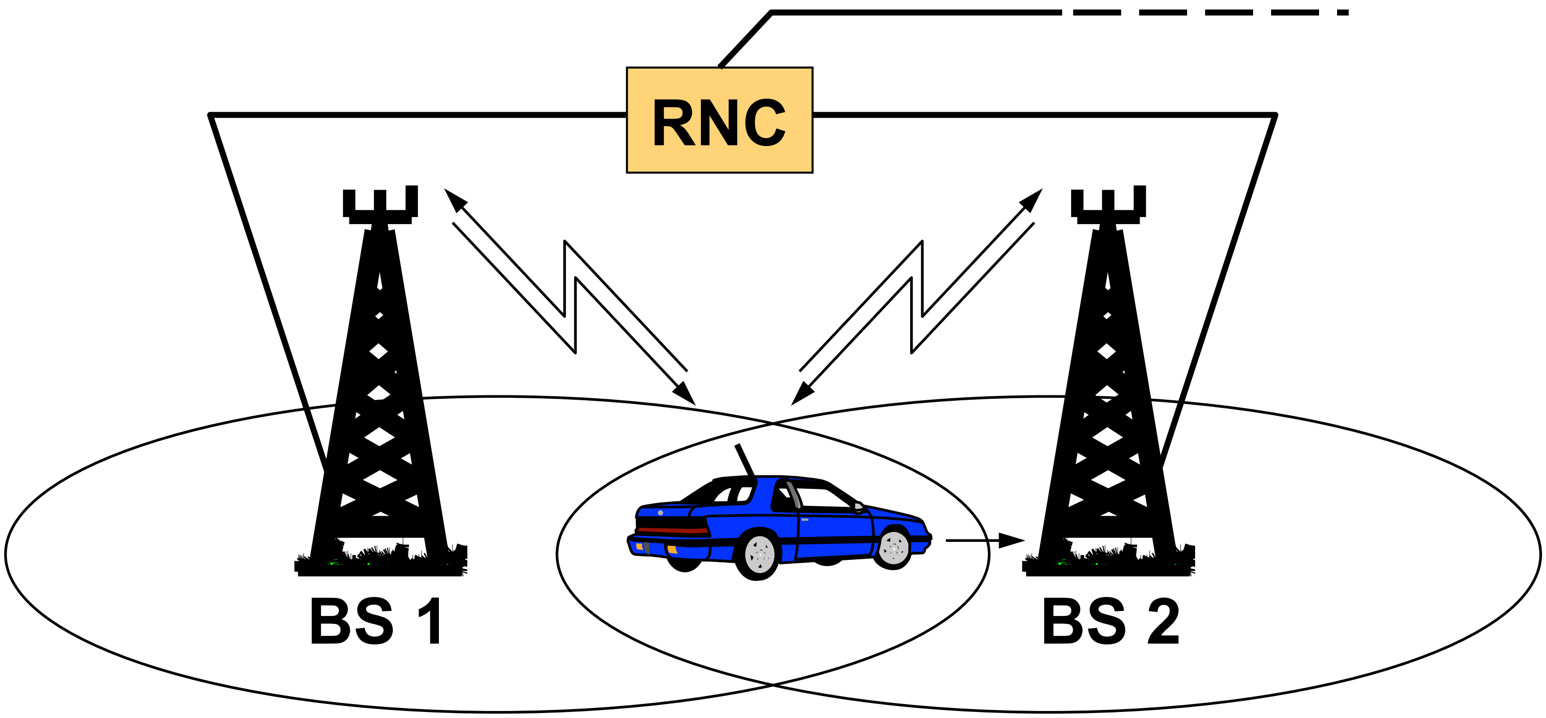
Power control with a large dynamic range is essential!

Why Soft Handover?

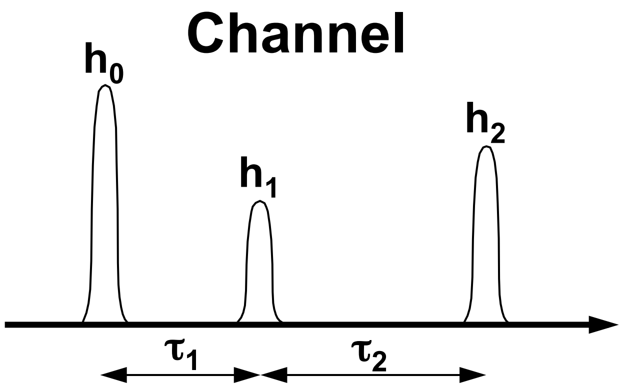
Soft handover essential for power control

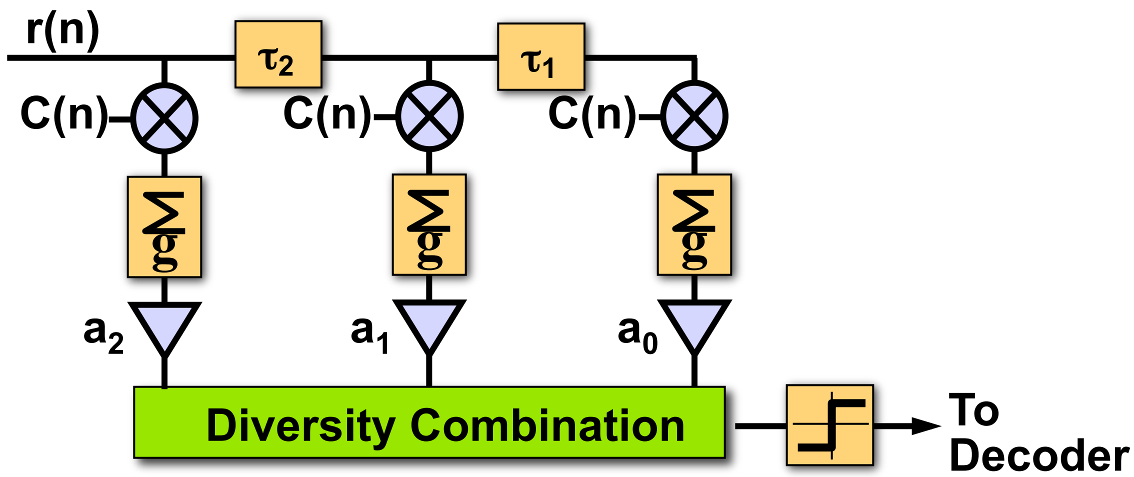
Soft handover reception

- combines signals from different base stations

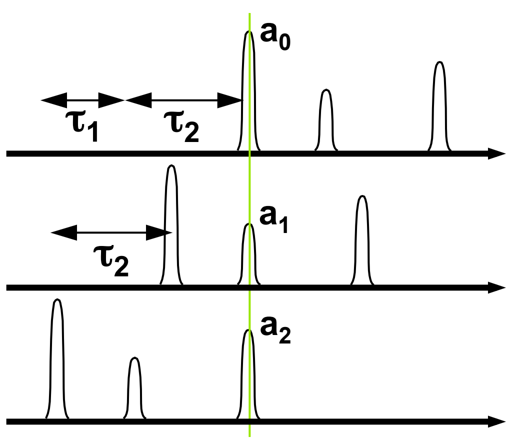


Time Dispersion – Rake receiver – Channel Estimation

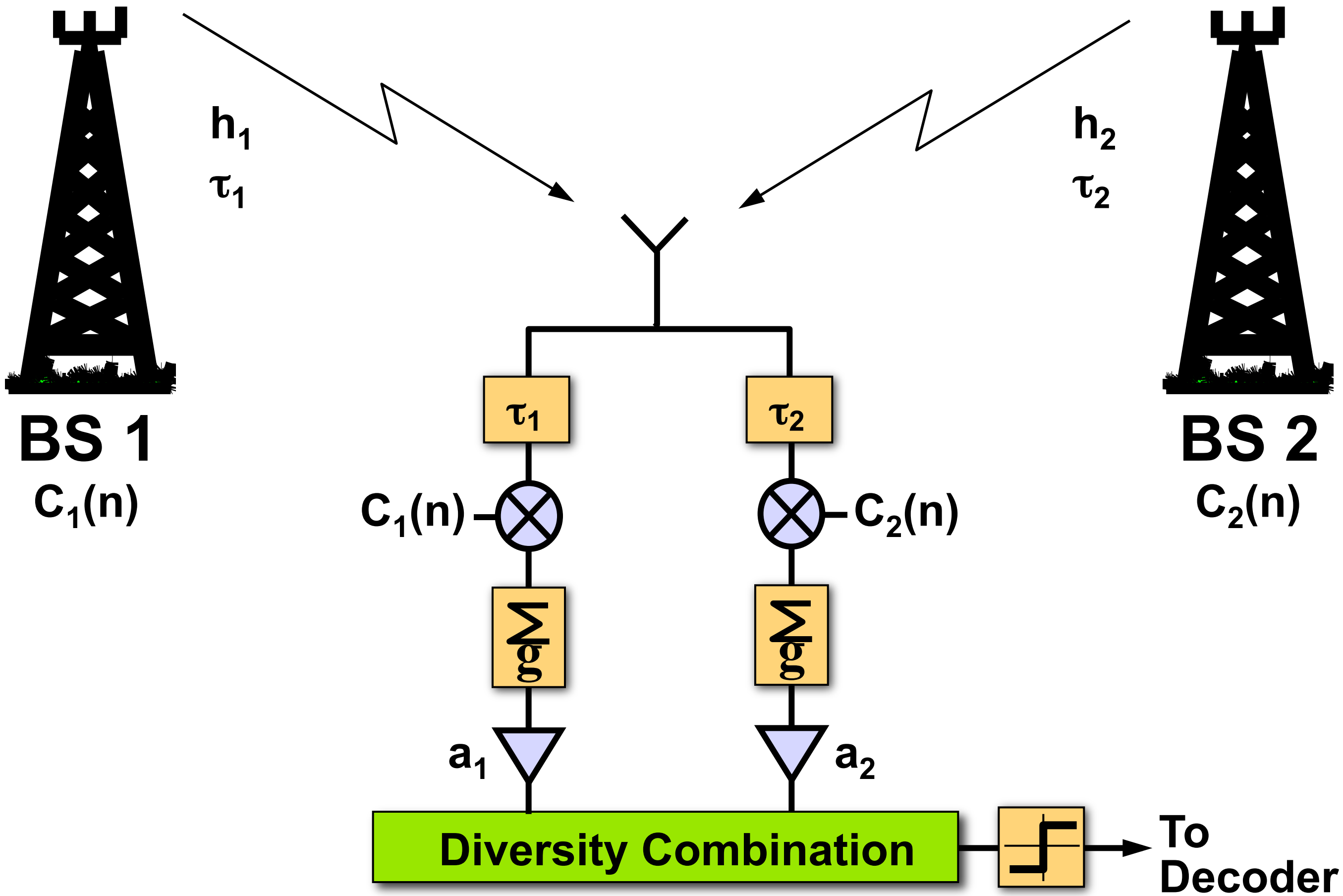




Diversity Combination	Channel Estimation	a_2	a_1	a_0
Selective	Delay	0	0	1
Equal gain	Delay	1/3	1/3	1/3
Maximum Ratio	Delay and complex amplitudes	h_2^*	h_1^*	h_0^*



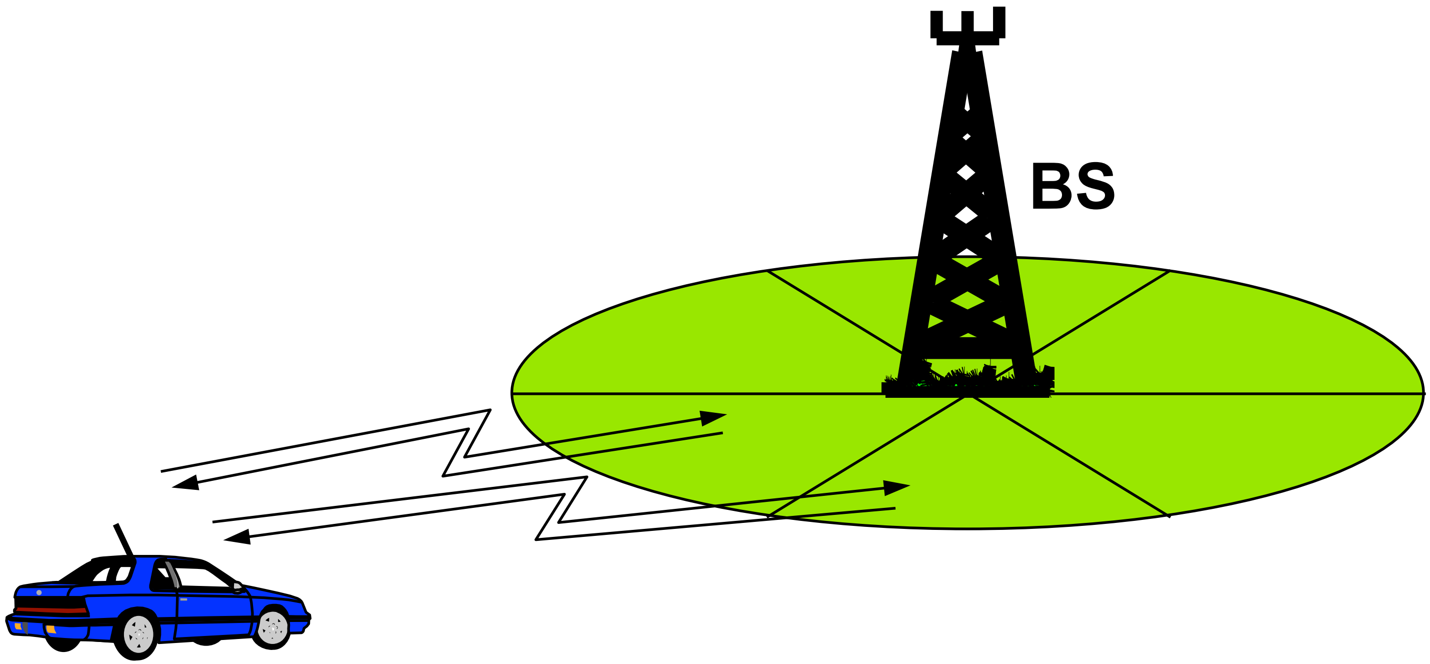
Mobile Soft Handover Implementation with Rake Receiver



Softer Handover

Softer handover reception

- combines signals from one base station

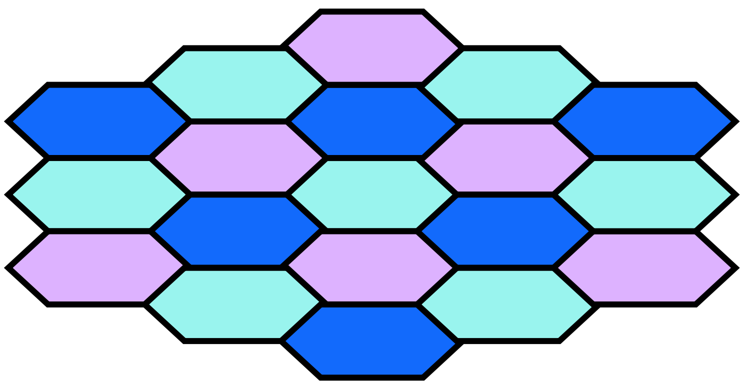


One cell reuse is typical for CDMA

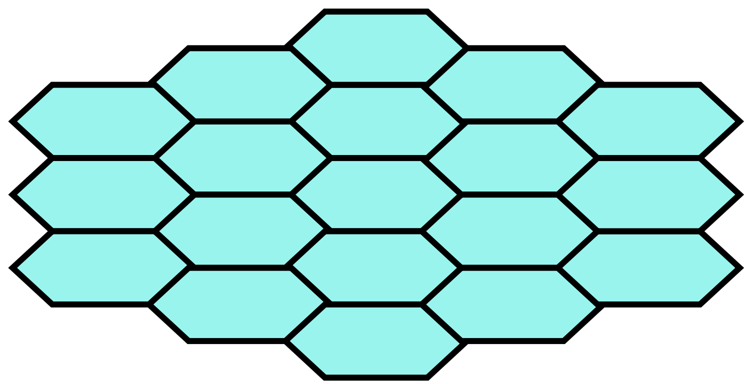
In CDMA, all cells use the same carrier frequency (frequency reuse = 1)

- makes soft handover possible
- requires efficient power control
- makes system load control more complex

FDMA/TDMA (reuse > 1)



CDMA (reuse = 1)



Capacity

WCDMA capacity limited by

- Amount of interference that can be tolerated
- Amount of interference generated by each user
- Amount of downlink orthogonal codes

Any reduction in generated interference directly improves capacity

- Voice activity
- Bursty transmission (packet-like services)
- Narrow-beam antennas

Resource Planning versus Power Planning

GSM (TDMA)

- Frequency planning
- Slot assignment

CDMA

- Increased output power ⇒ increased interference ⇒ lower capacity
- Power planning!

Reducing interference (by any means) ⇒ direct increase of capacity

Cellbreathing

GSM

- Users have their own dedicated time(/frequency) slot
- Number of users in cell does not directly influence cell size

UMTS

- Cellsize is closely related to cell capacity
- Capacity is determined by signal to noise ratio
- Interference adds to the noise:
  - other cells
  - other users in the same cell
- If there is a lot of noise, users at the cell border cannot increase their signal any further → cannot communicate
- So: cell size decreases as number of active users increases: Cell breathing
- Number of active users should be limited
- This complicates cell planning

Cell breathing: example