Mobilné systémy 3. generácie
UMTS

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KTL FEI STU
2009

Prehľad prednášok

- UMTS
- HSDPA, EUL
- HSPA evolution
- LTE
- LTE-Advanced

Nasadené technológie

- GSM worldwide (~ 720 networks)
  - EDGE almost worldwide (~ 300 networks)
- UMTS (~ 300 networks)
  - HSDPA (~ 290 networks)
  - EUL (~ 90 networks)

3GPP

- CDMA2000 (~ 250 networks)
  - EV-DO Rel.0 (~ 90 networks)
  - EV-DO Rev.A (~ 10 networks)

3GPP2

- FLASH-OFDM
  - USA, Slovakia

proprietary

- Mobile WiMAX
  - South Korea (WiBro)
  - Sprint (2008)

IEEE 802.16

Dnešné možnosti

- GSM/GPRS/EDGE
  - mainly voice oriented service
  - downlink up to 300 kbps
  - uplink up to 200 kbps

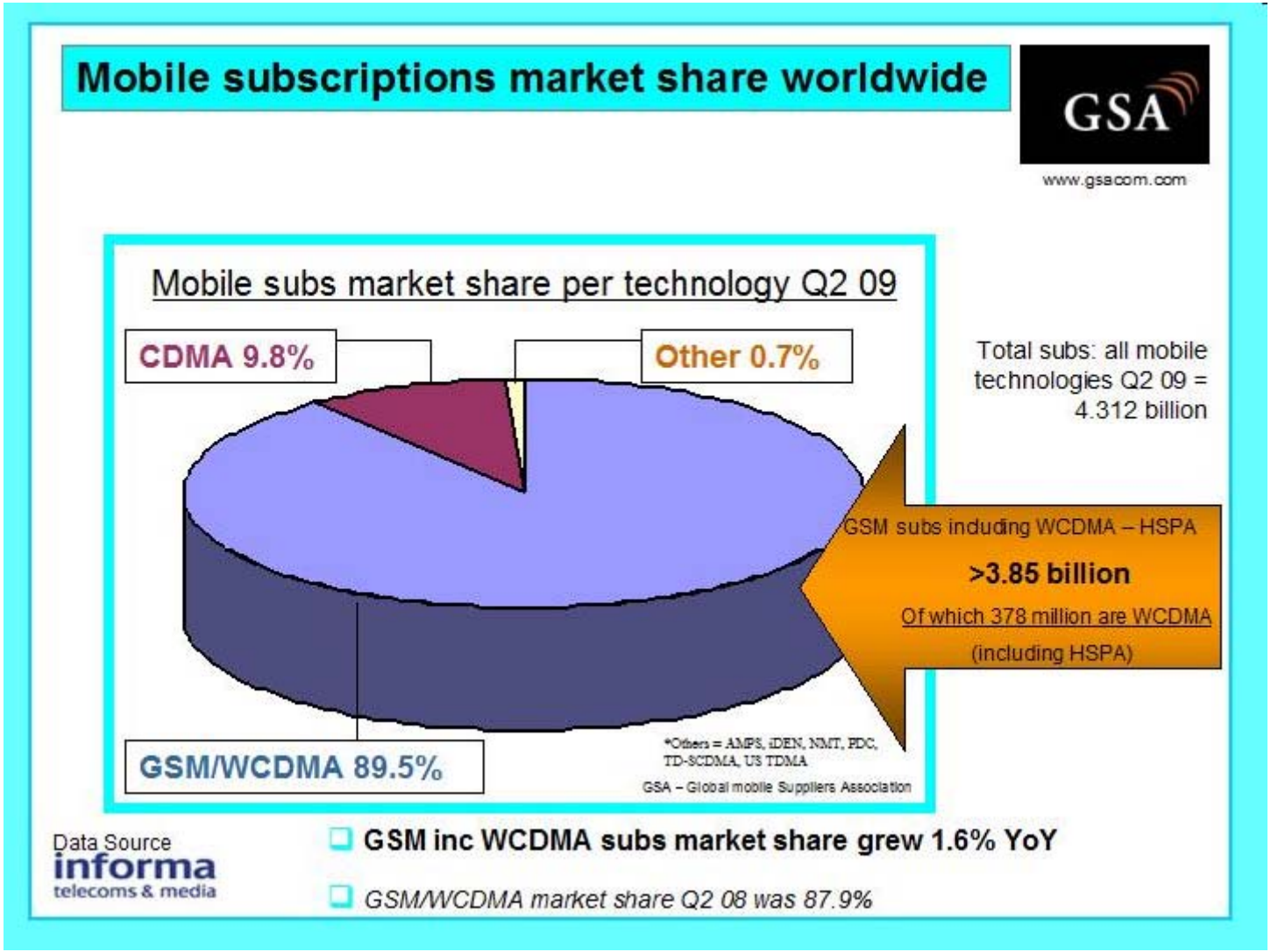
- UMTS/HSDPA/EUL
  - higher voice capacity
  - UMTS DL/UL 384 kbps
  - HSDPA up to 28 Mbps
  - EUL up to 5,8 Mbps

- FLASH-OFDM
  - pure IP architecture
  - DL up to 5,3 Mbps
  - UL up to 1,8 Mbps

- CDMA2000 EV-DO
  - packet services only
  - DL up to 3,1 Mbps
  - UL up to 1,8 Mbps

- WiBro / Mobile WiMAX
  - packet services only
  - DL up to 3 / 10 Mbps
  - UL up to 1,2 / 2,5 Mbps

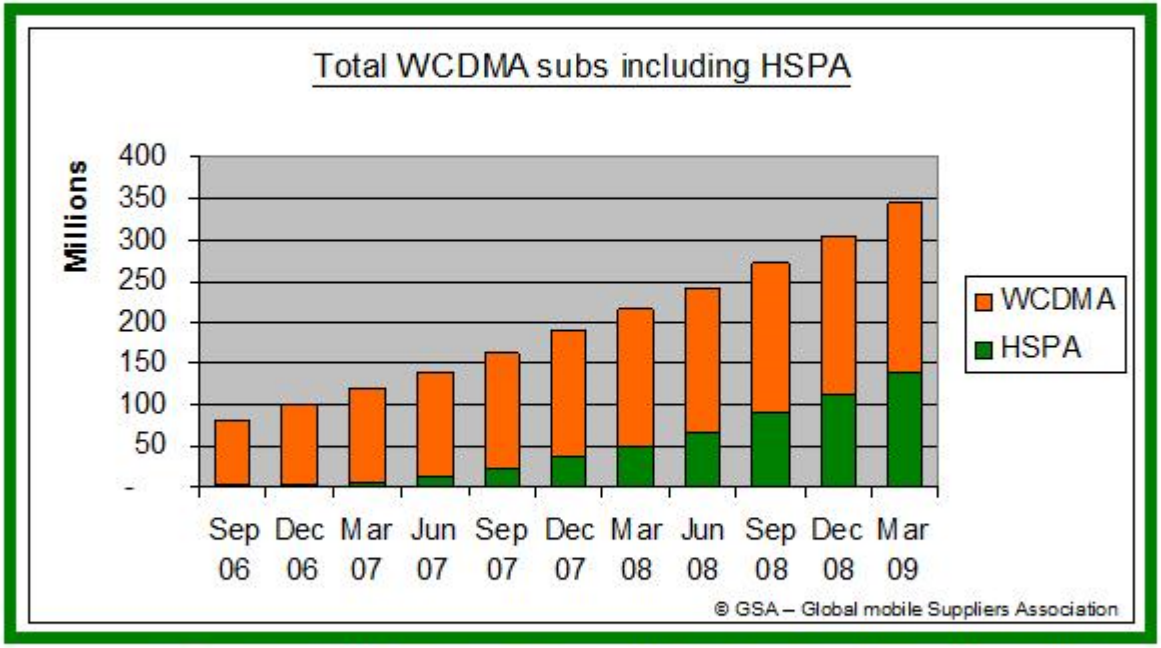
Prečo UMTS?


Mobile subscriptions market share worldwide
GSA
www.gsacom.com
Mobile subs market share per technology Q2 09
CDMA 9.8%
Other 0.7%
Total subs: all mobile technologies Q2 09 = 4.312 billion
GSM subs induding WCDMA – HSPA
>3.85 billion
Of which 378 million are WCDMA
(including HSPA)
GSM/WCDMA 89.5%
*Others = AMPS, iDEN, NMT, PDC, TD-SCDMA, US TDMA
GSA – Global mobile Suppliers Association
Data Source
informa
telecoms & media
GSM inc WCDMA subs market share grew 1.6% YoY
GSM/WCDMA market share Q2 08 was 87.9%

Prečo UMTS?

Total WCDMA subs including HSPA

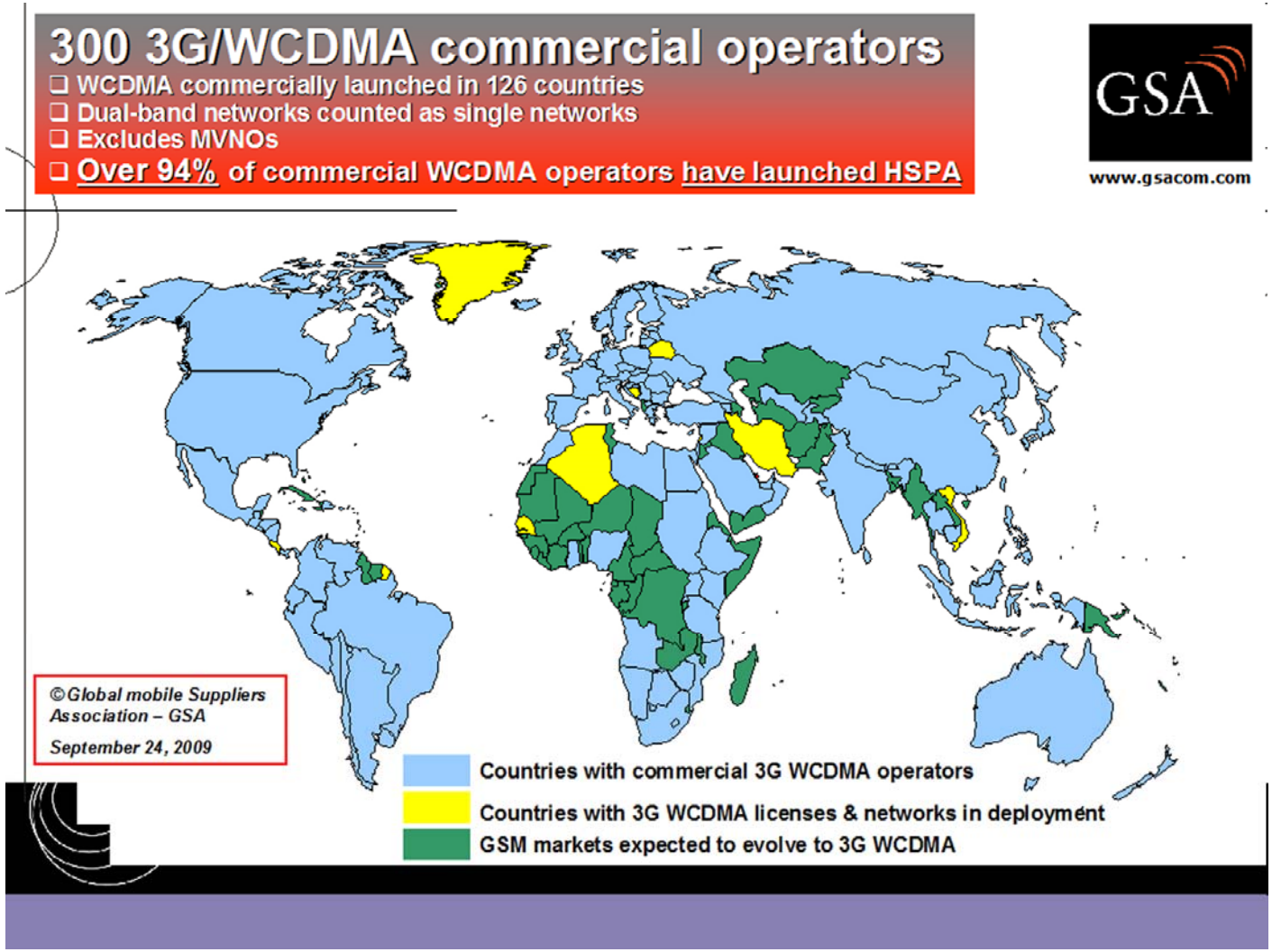
GSA
www.gsacom.com



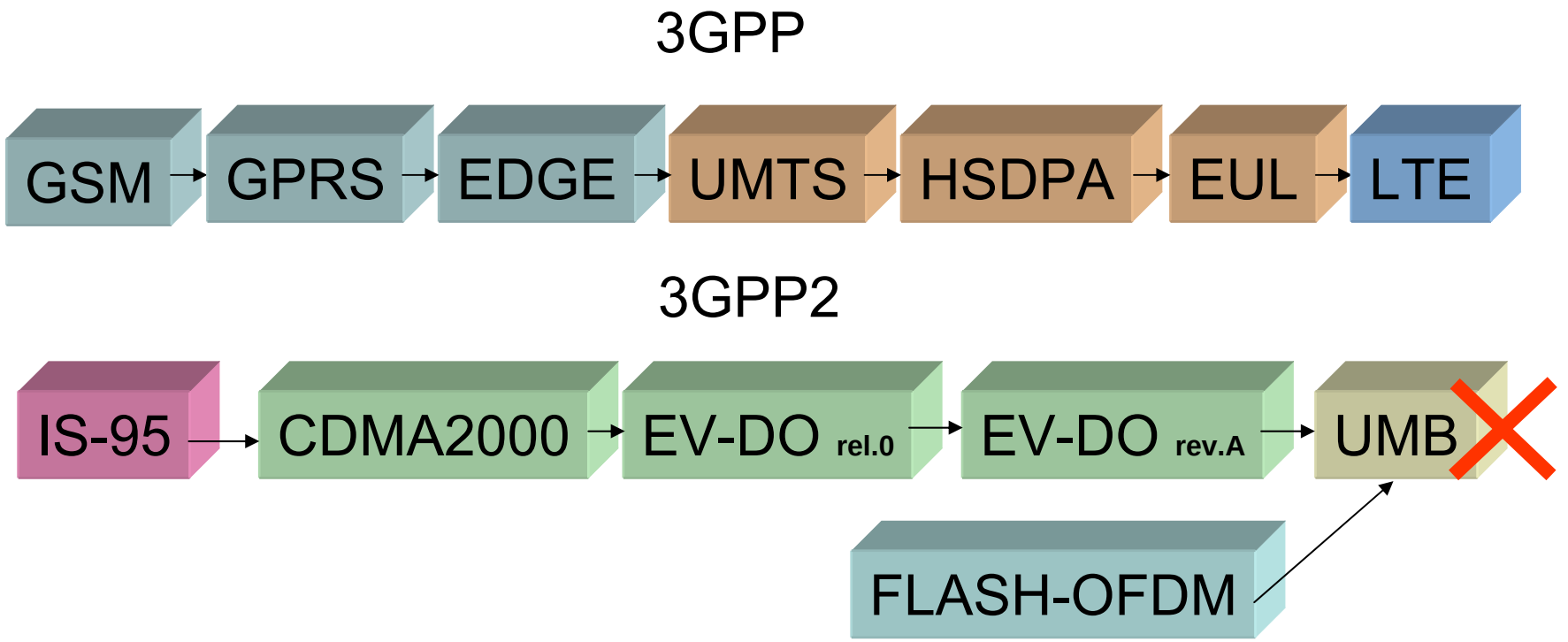
- Total WCDMA subs Q1 09 = 344 million incl. 140 million HSPA
- HSPA subs represents 40.7% share of WCDMA (vs. 23.8% Q1 08)
- HSPA share of WCDMA subs in Q1 09 = > 70%

Data Source
informa
telecoms & media

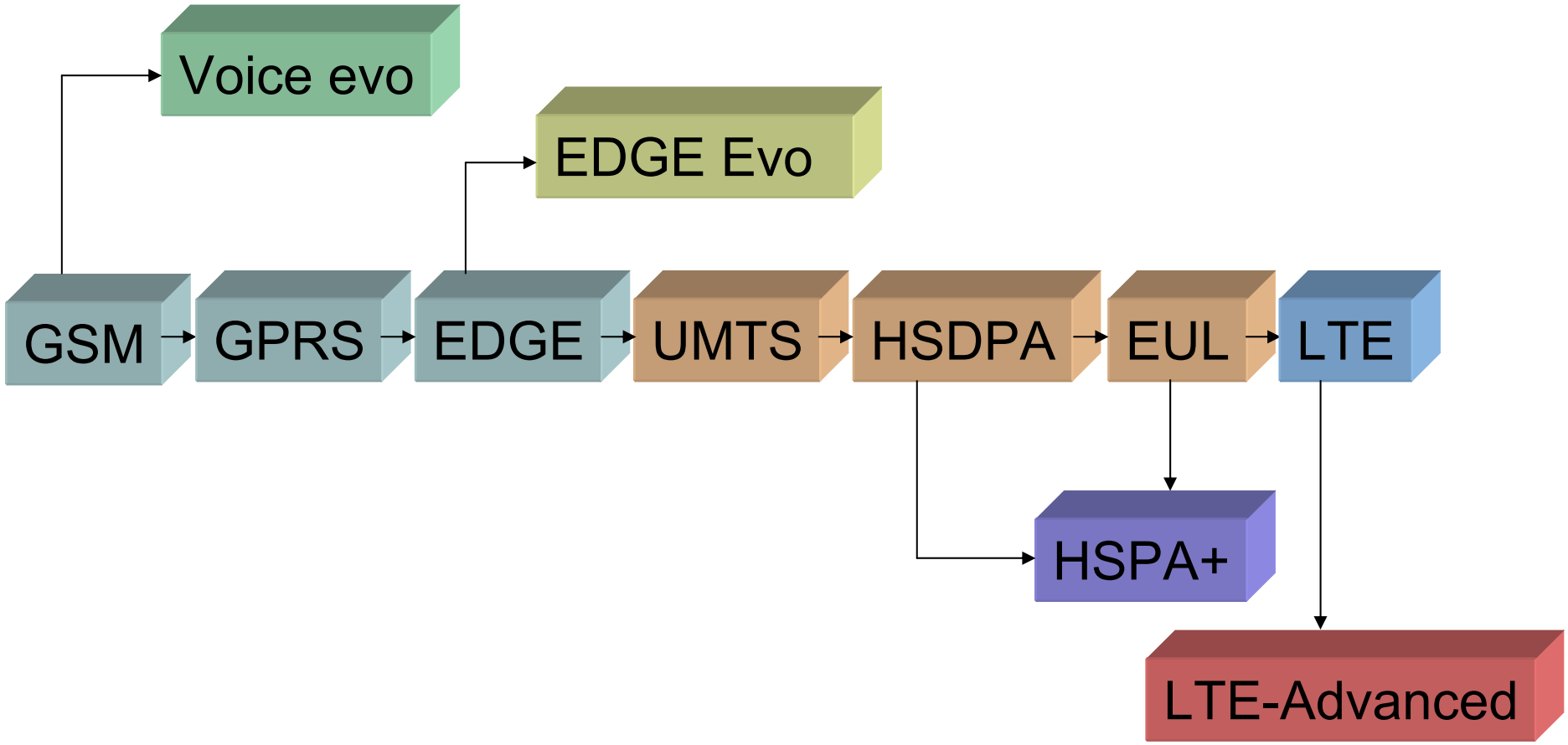
Prečo UMTS?


300 3G/WCDMA commercial operators
❑ WCDMA commercially launched in 126 countries
❑ Dual-band networks counted as single networks
❑ Excludes MVNOs
❑ Over 94% of commercial WCDMA operators have launched HSPA
GSA
www.gsacom.com
©Global mobile Suppliers Association – GSA
September 24, 2009
Countries with commercial 3G WCDMA operators
Countries with 3G WCDMA licenses & networks in deployment
GSM markets expected to evolve to 3G WCDMA

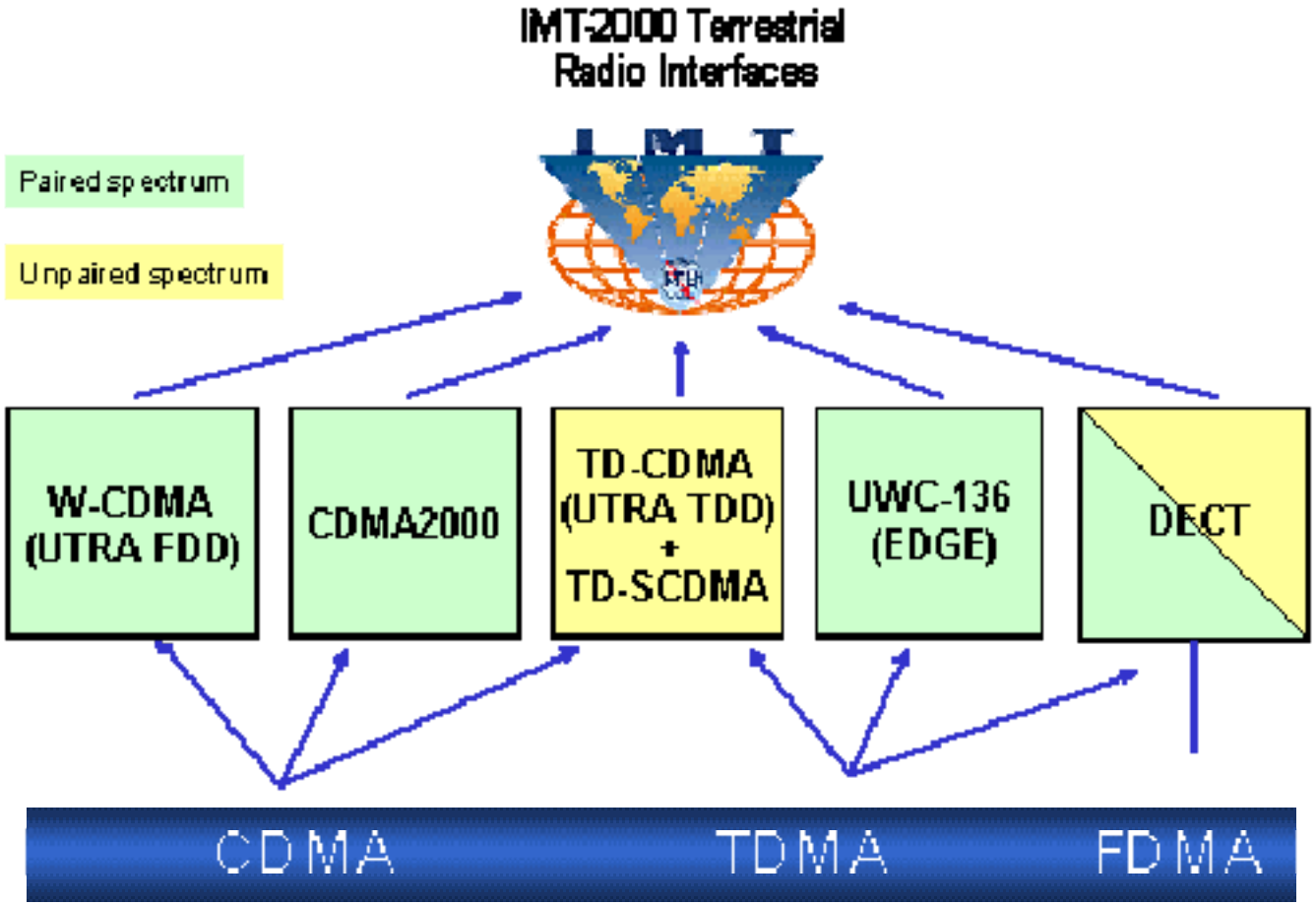
Evolúcia štandardov



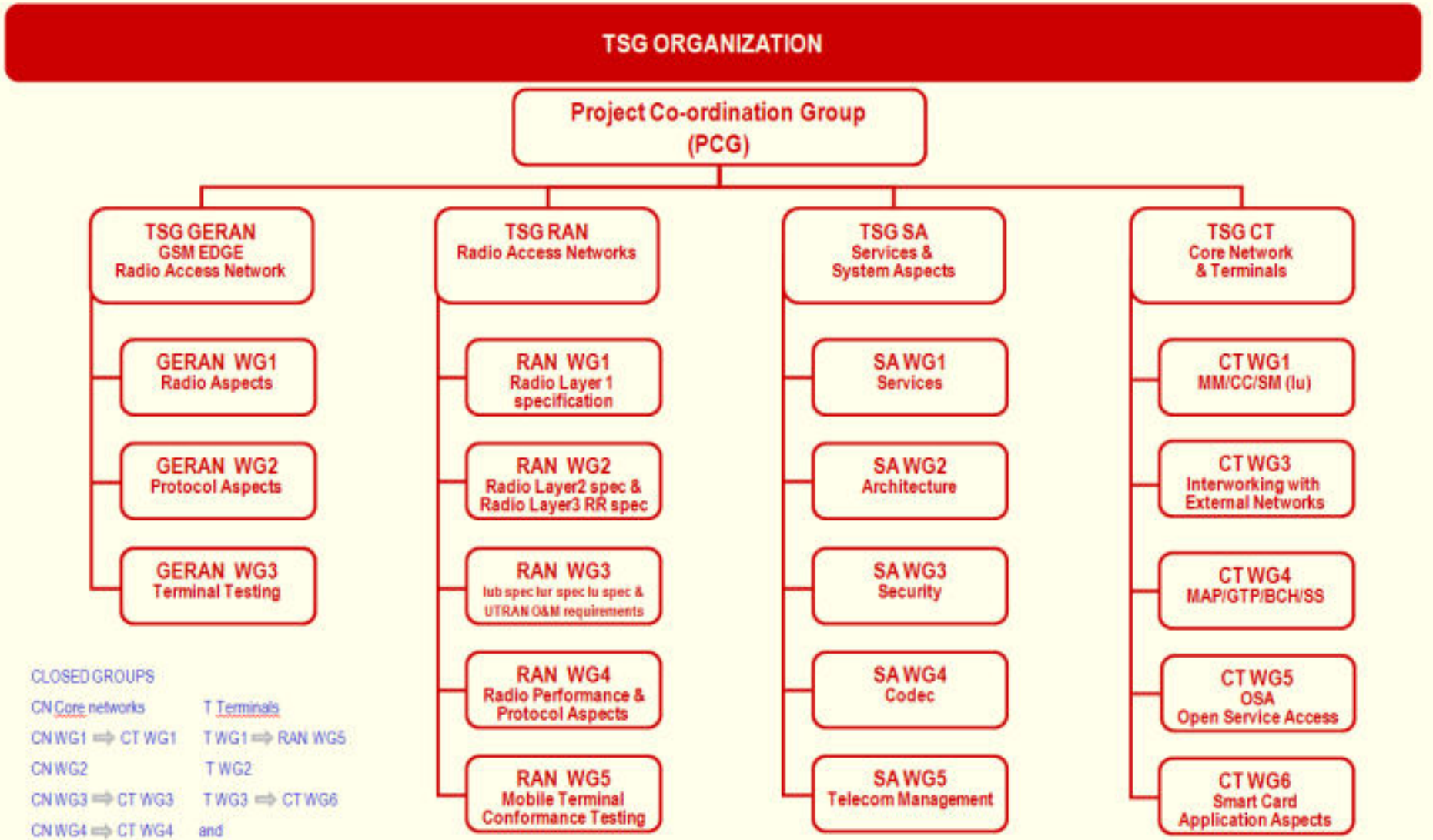
Evolúcia štandardov



IMT-2000


IMT-2000 Terrestrial
Radio Interfaces
Paired spectrum
Unpaired spectrum
W-CDMA
(UTRA FDD)
CDMA2000
TD-CDMA
(UTRA TDD)
+
TD-SCDMA
UWC-136
(EDGE)
DECT
CDMA
TDMA
FDMA

3GPP

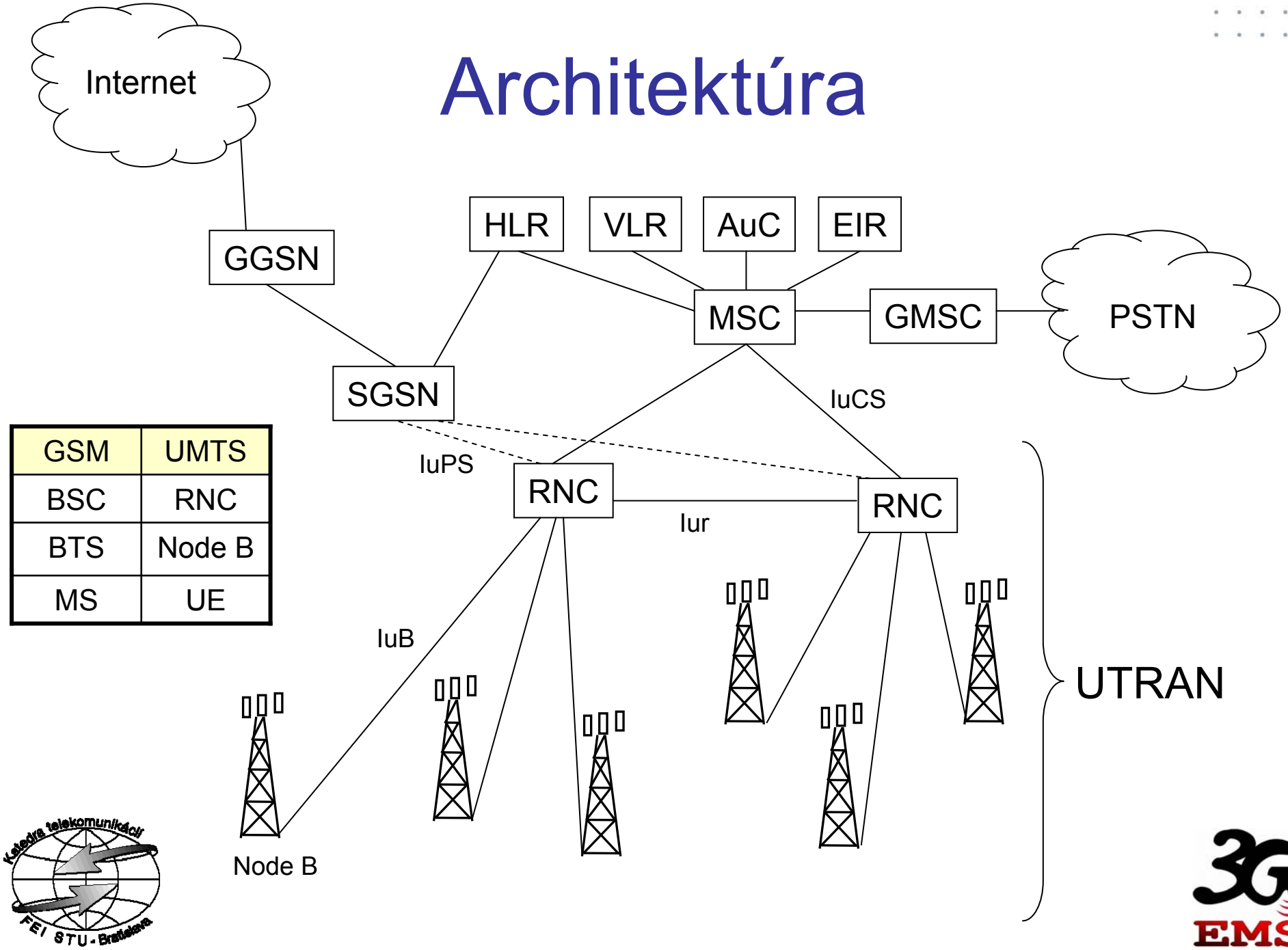

TSG ORGANIZATION
Project Co-ordination Group (PCG)
TSG GERAN GSM EDGE Radio Access Network
GERAN WG1 Radio Aspects
GERAN WG2 Protocol Aspects
GERAN WG3 Terminal Testing
TSG RAN Radio Access Networks
RAN WG1 Radio Layer 1 specification
RAN WG2 Radio Layer2 spec & Radio Layer3 RR spec
RAN WG3 Iub spec Iur spec Iu spec & UTRAN O&M requirements
RAN WG4 Radio Performance & Protocol Aspects
RAN WG5 Mobile Terminal Conformance Testing
TSG SA Services & System Aspects
SA WG1 Services
SA WG2 Architecture
SA WG3 Security
SA WG4 Codec
SA WG5 Telecom Management
TSG CT Core Network & Terminals
CT WG1 MM/CC/SM (Iu)
CT WG3 Interworking with External Networks
CT WG4 MAP/GTP/BCH/SS
CT WG5 OSA Open Service Access
CT WG6 Smart Card Application Aspects
CLOSED GROUPS
CN Core networks
CN WG1 ⇨ CT WG1
CN WG2
CN WG3 ⇨ CT WG3
CN WG4 ⇨ CT WG4
CN WG5 ⇨ CT WG5
T Terminals
T WG1 ⇨ RAN WG5
T WG2
T WG3 ⇨ CT WG6
and
GERAN WG4 ⇨ GERAN3
GERAN WG5 ⇨ GERAN3
April 2007

3GPP spec. list

Subject of specification series	3G/GSM R99 and later
Requirements	21 series
Service aspects ("stage 1")	22 series
Technical realization ("stage 2")	23 series
Signalling protocols ("stage 3") - user equipment to network	24 series
Radio aspects	25 series
CODECs	26 series
Data	27 series
Signalling protocols ("stage 3") -(RSS-CN)	28 series
Signalling protocols ("stage 3") - intra-fixed-network	29 series
Programme management	30 series
Subscriber Identity Module (SIM / USIM), IC Cards. Test specs.	31 series
OAM&P and Charging	32 series
Security aspects	33 series
UE and (U)SIM test specifications	34 series
Security algorithms (3)	35 series
Evolved UTRA aspects	36 series

www.3gpp.org

Architektúra



GSM	UMTS
BSC	RNC
BTS	Node B
MS	UE

Roadmap

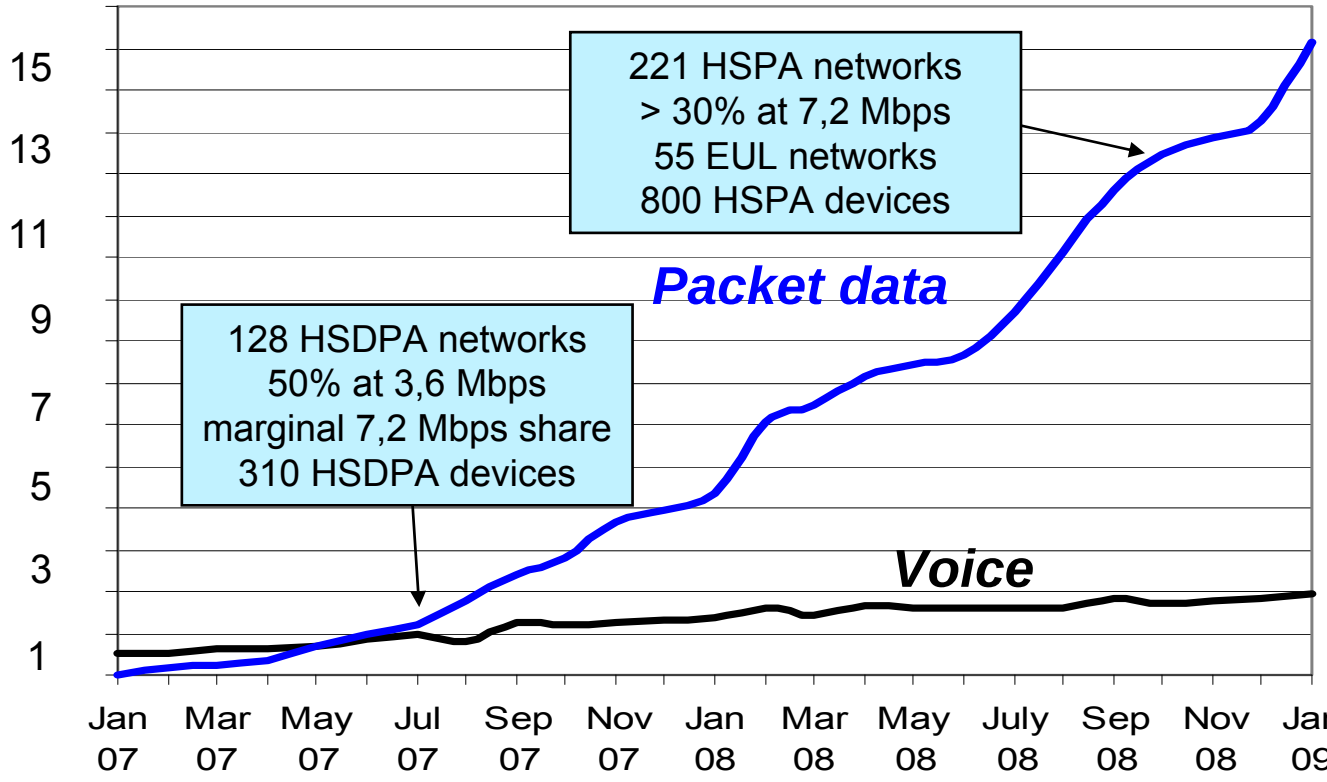
3GPP releases

	Rel.99/4	Rel.5	Rel.6	Rel.7	Rel.8	Rel.9
	WCDMA	HSDPA	EUL	HSPA+	HSPA+	HSPA+
	QPSK	16QAM	multi code	MIMO, 64QAM, 16QAM UL	DC	Comb
DL Mbit/s	0.384	14.4	14	28	42	168
UL Mbit/s	0.384	0.384	5.8	12	12	24
Latency (ms)	~150	~75	~50	~30	~30	~30

LTE

3G – voice or data?

Relative Network Load – RNC level



Data is surpassing voice on 3G since 2 years

Rádiová prístupová sieť- UTRAN

- Komponenty
  - Node B
  - RNC
- Multiplexná technika
  - CDMA
- Duplexný mód
  - FDD
  - TDD

Funkcie Node B

- Air interface Transmission / Reception
- Modulation / Demodulation
- CDMA Physical Channel coding
- Micro Diversity (Soft Handover)
- Error Handling
- Closed loop power control

Funkcie RNC

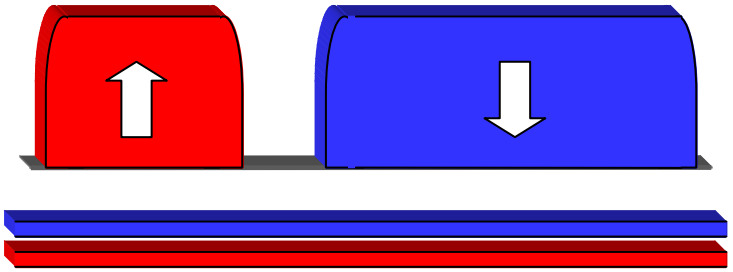
- Radio Resource Control
- Admission Control
- Channel Allocation
- Power Control Settings
- Handover Control
- Macro Diversity (Soft Handover)
- Ciphering
- Segmentation / Reassembly
- Broadcast Signaling
- Open Loop Power Control

Duplexný mód

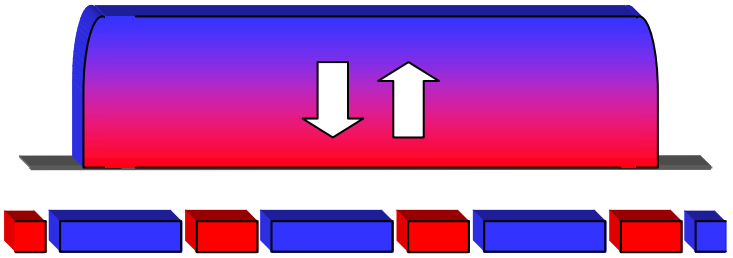
- **Frequency division duplex**
  + symetric traffic (e.g. voice)
  + higher average power
    => less Node Bs
  - higher complexity (HW)
  - channel measurements must be reported

- **Time division duplex**
  + asymetric traffic (data)
  + channel measurements are precise
  - lower average power
  - strict synchronization needed
  - higher delays

FDD



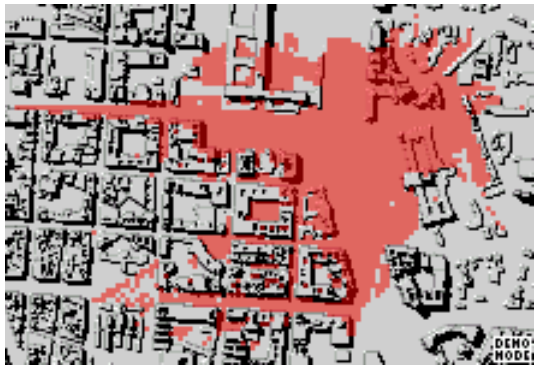
TDD



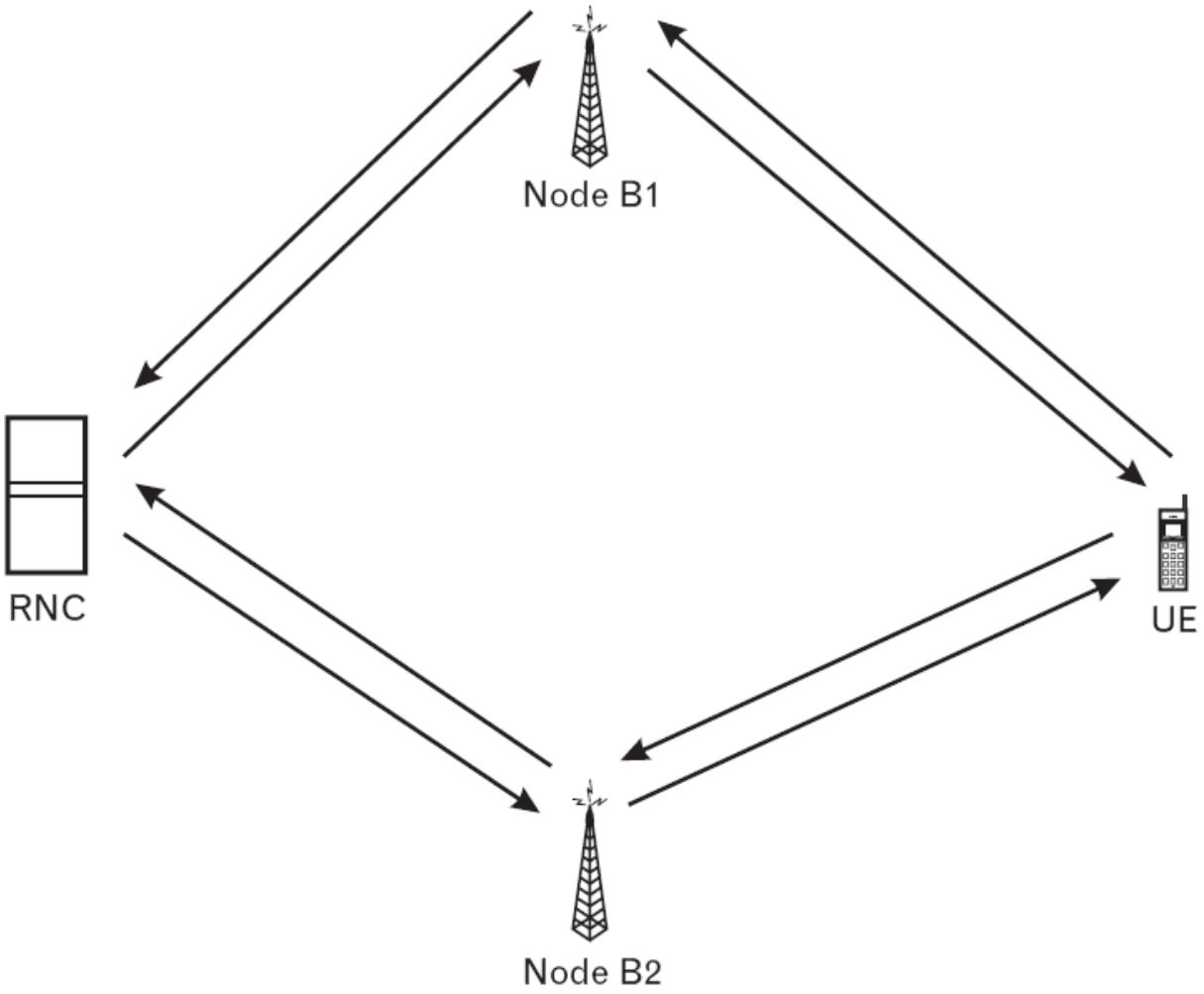
CDMA

- Interference limited system
- Sequences selection is crucial
- Power control needed
- Soft handover possible

- 5 MHz channel
- 3,84 Mchip/s



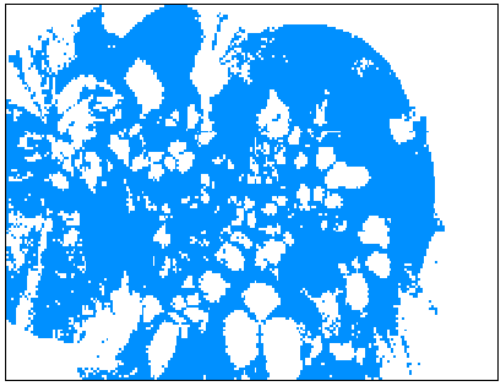
Soft handover



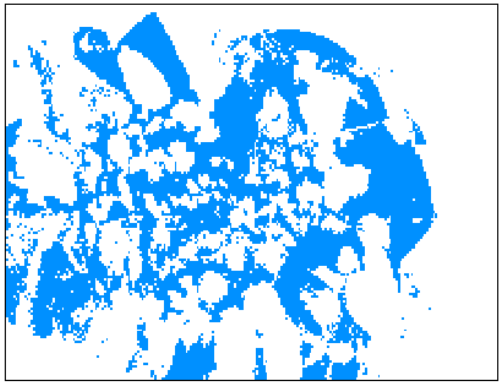
Importance of Soft Handover

- Graphs show probability of excessive interference in neighbouring cell
- Active set size of 4 was agreed as mandatory for UEs

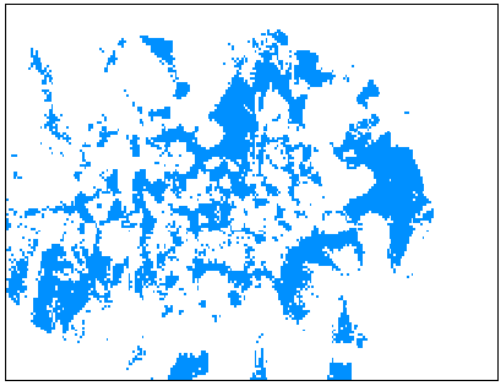
1 user/cell, AS max = 1



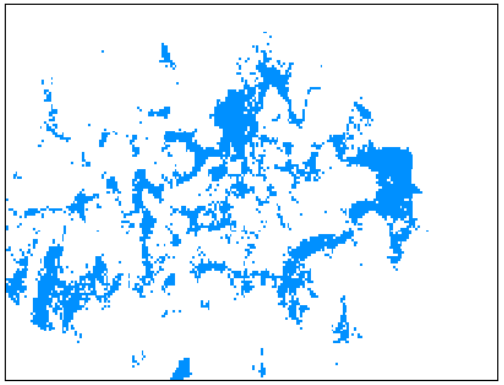
1 user/cell, AS max = 2



1 user/cell, AS max = 3

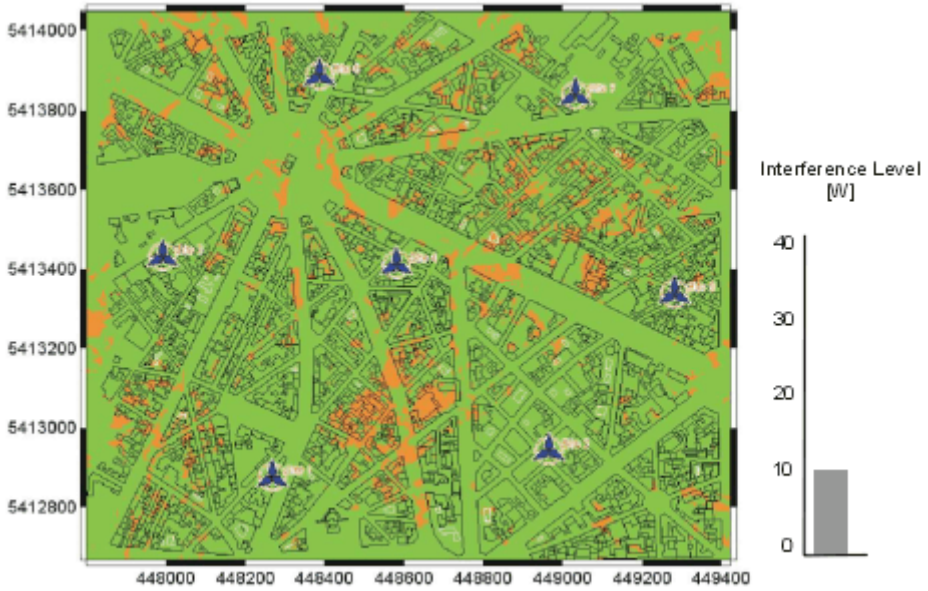


1 user/cell, AS max = 4

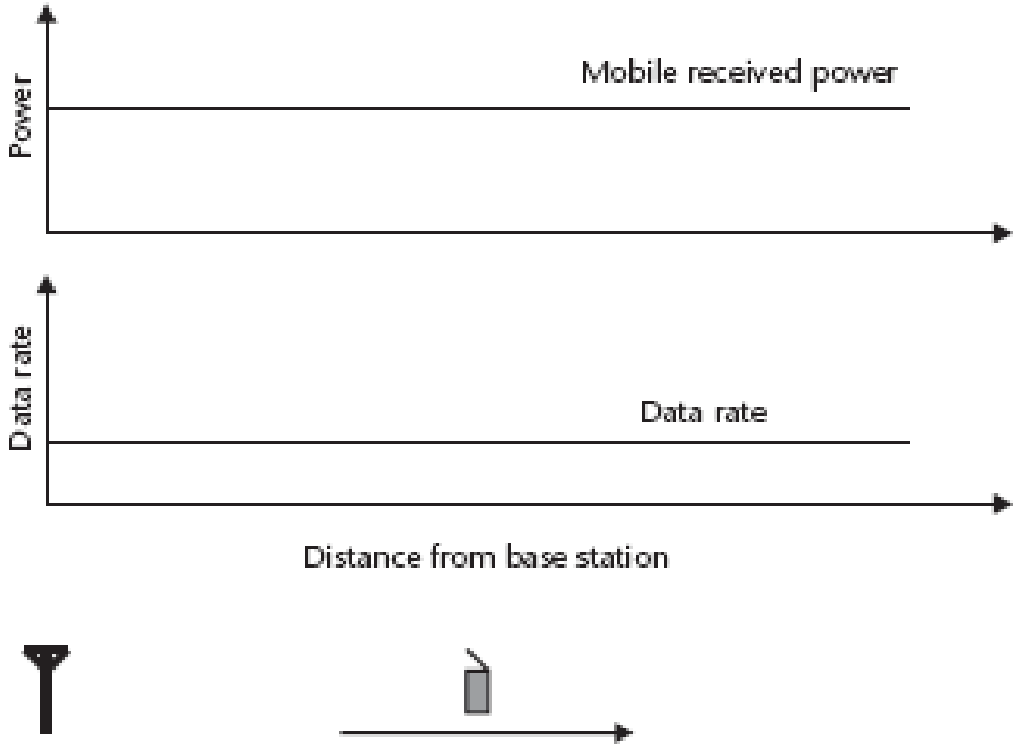


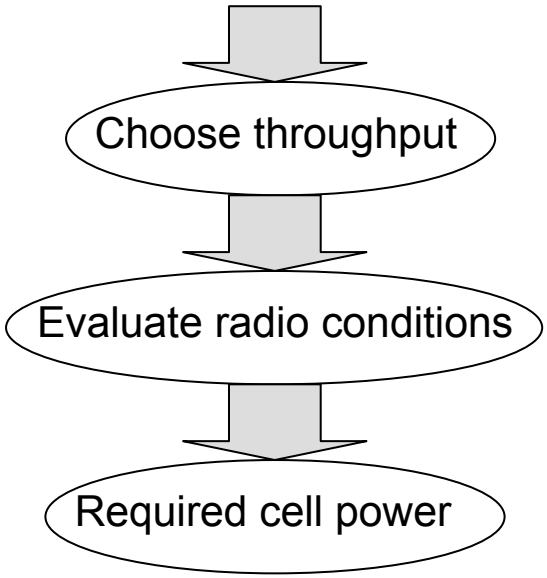
Why power control?

- NEAR – FAR effect
  - High interference between users & cell breathing



Power control



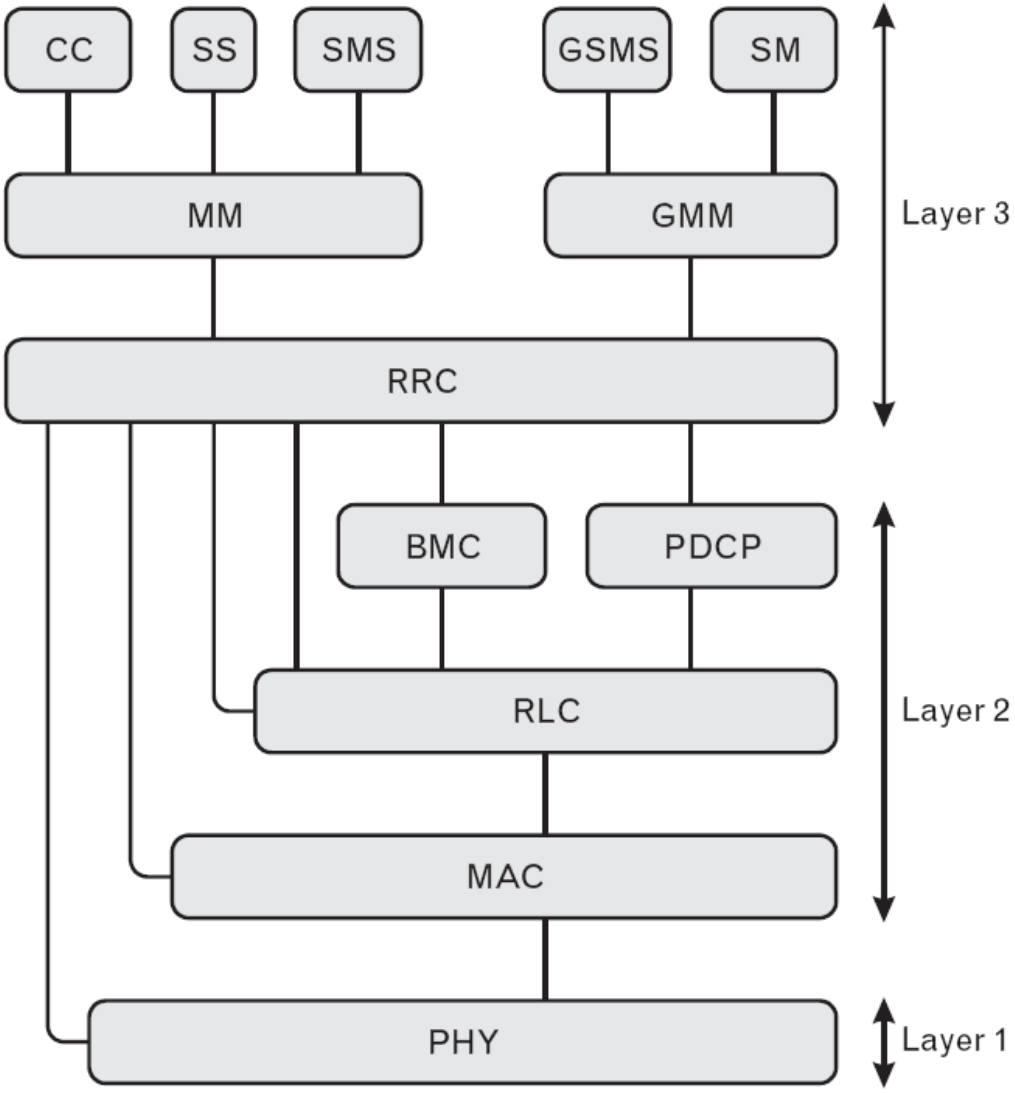


- Circuit switched services are guaranteed
- Packet switched services are best effort

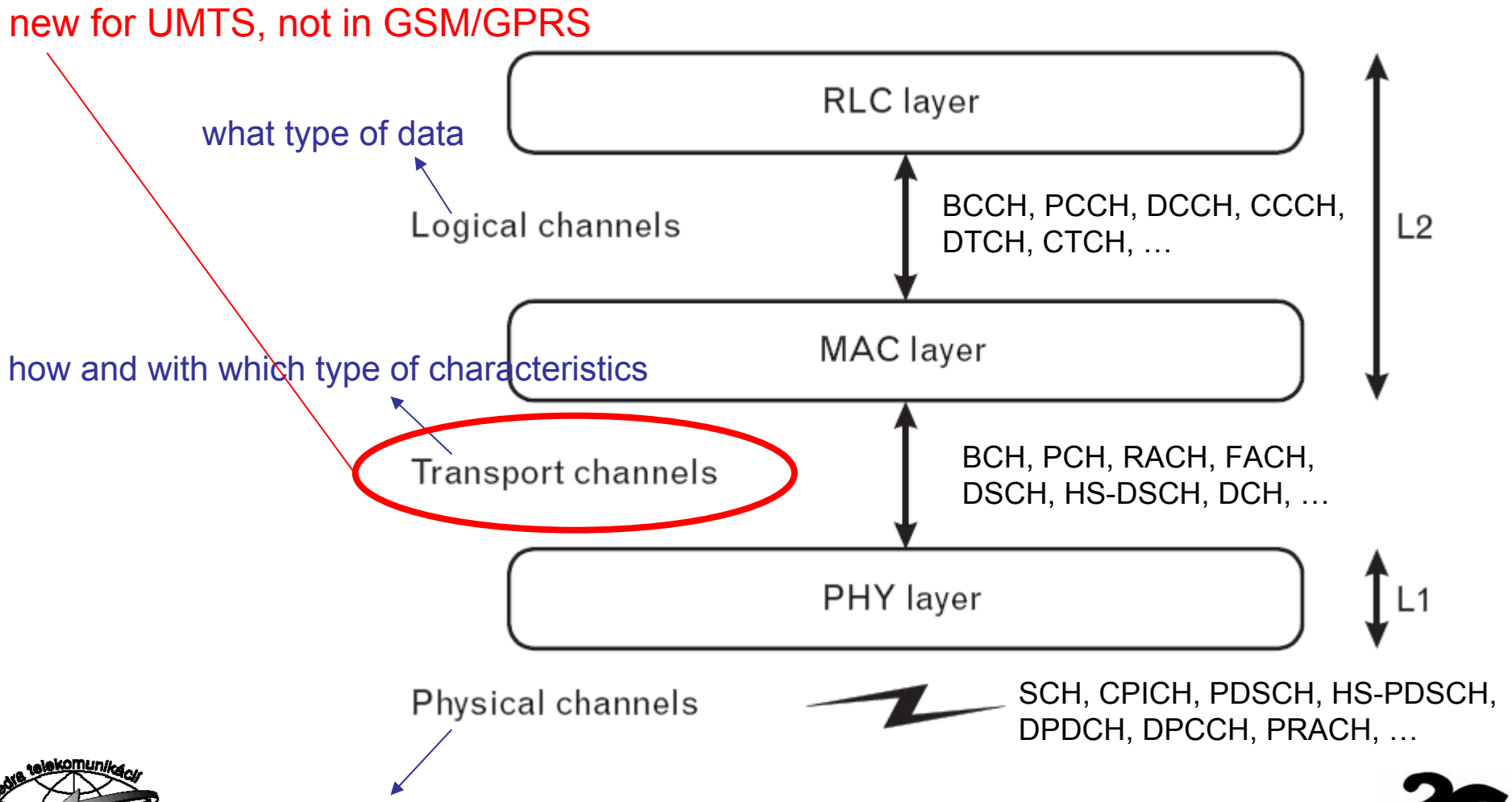
Power control

- Open loop
  - initial access to the network
- Closed loop
  - INNER loop
    - Guarantee link quality (keep desired SIR)
    - 1500 times per second (Hz)
  - OUTER loop
    - Minimize transmit power by setting SIR target for inner loop
    - Estimate SIR target based on BLER

Air interface protocol model



Channel concept



Logical channels

- Control channels
  - Common (P2M)
  - Dedicated (P2P)

- Traffic channels
  - Common
  - Dedicated

Transport channels

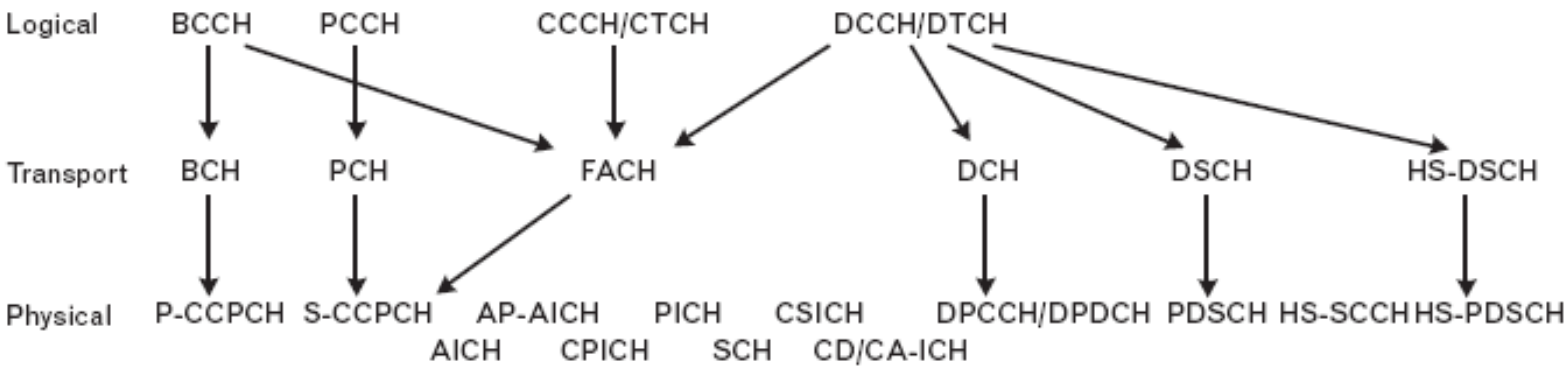
- Common channels

- Dedicated channel
  - DCH (UL & DL)

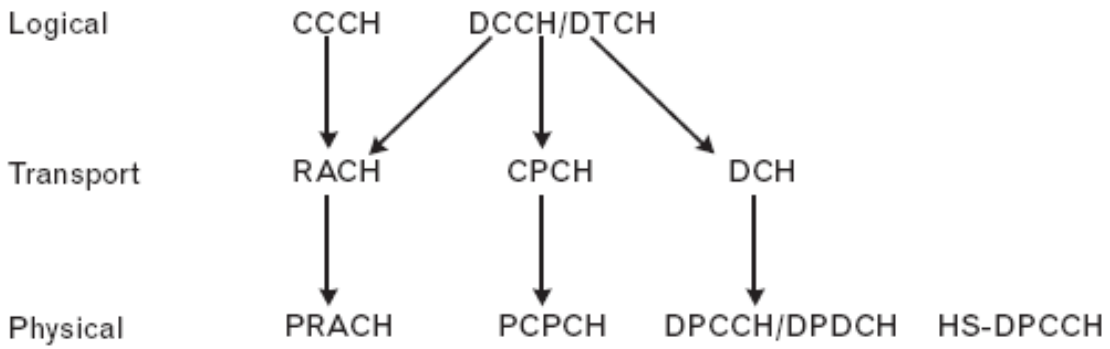
Physical channels

- Synchronization
- Pilot
- Paging
- Dedicated Physical Data Channel
- Dedicated Physical Control Channel
- High Speed Physical Downlink Shared Channel
- …

Channels

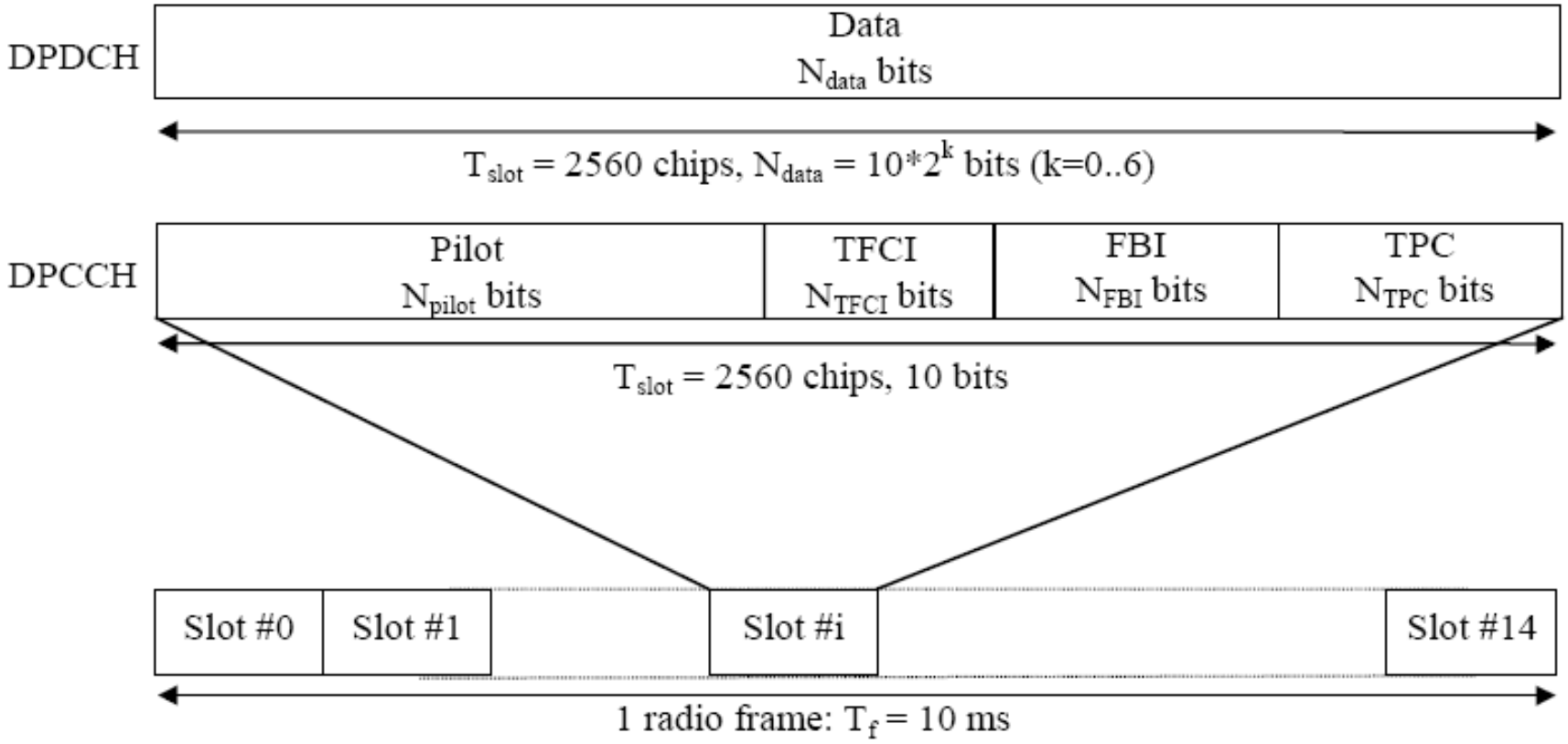


downlink



uplink

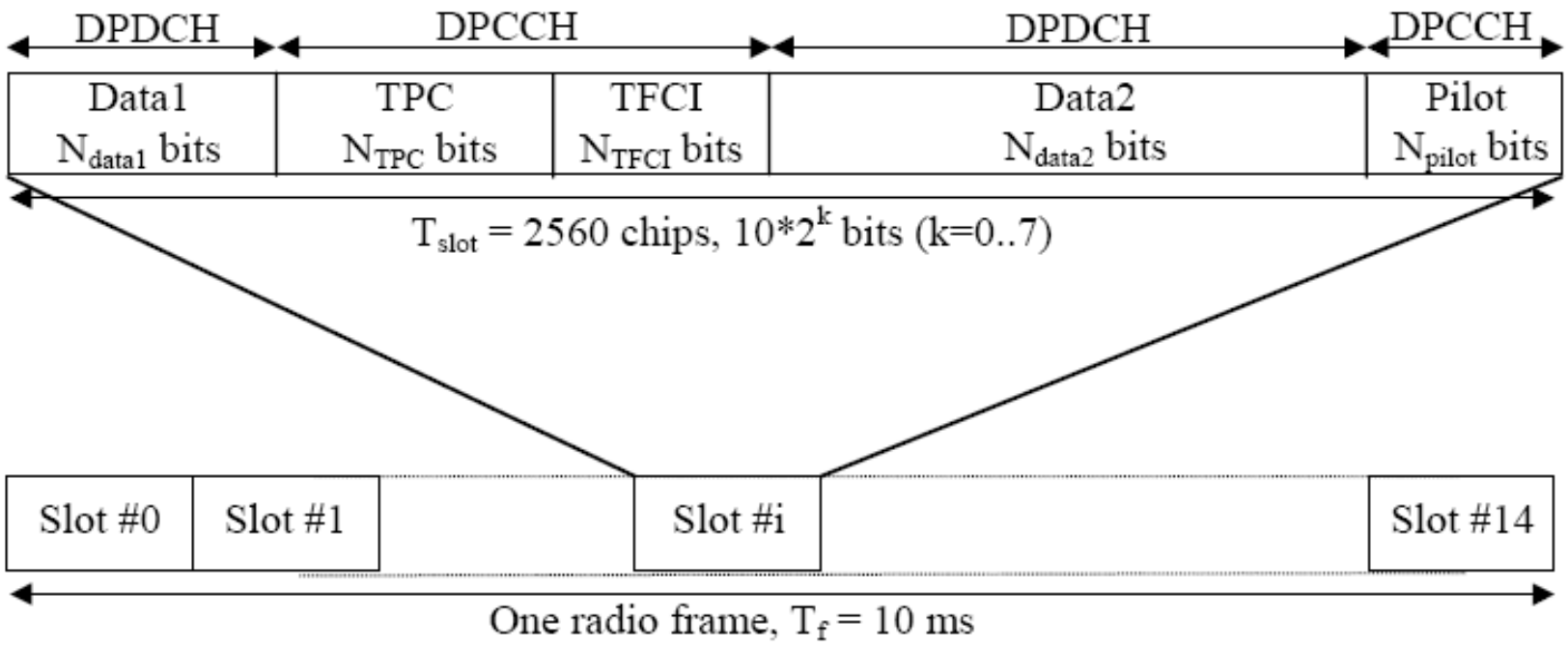
Channel structure - UL



Channel structure - UL

Slot Format #i	Channel Bit Rate (kbps)	Channel Symbol Rate (ksps)	SF	Bits/ Frame	Bits/ Slot	N_{data}
0	15	15	256	150	10	10
1	30	30	128	300	20	20
2	60	60	64	600	40	40
3	120	120	32	1200	80	80
4	240	240	16	2400	160	160
5	480	480	8	4800	320	320
6	960	960	4	9600	640	640

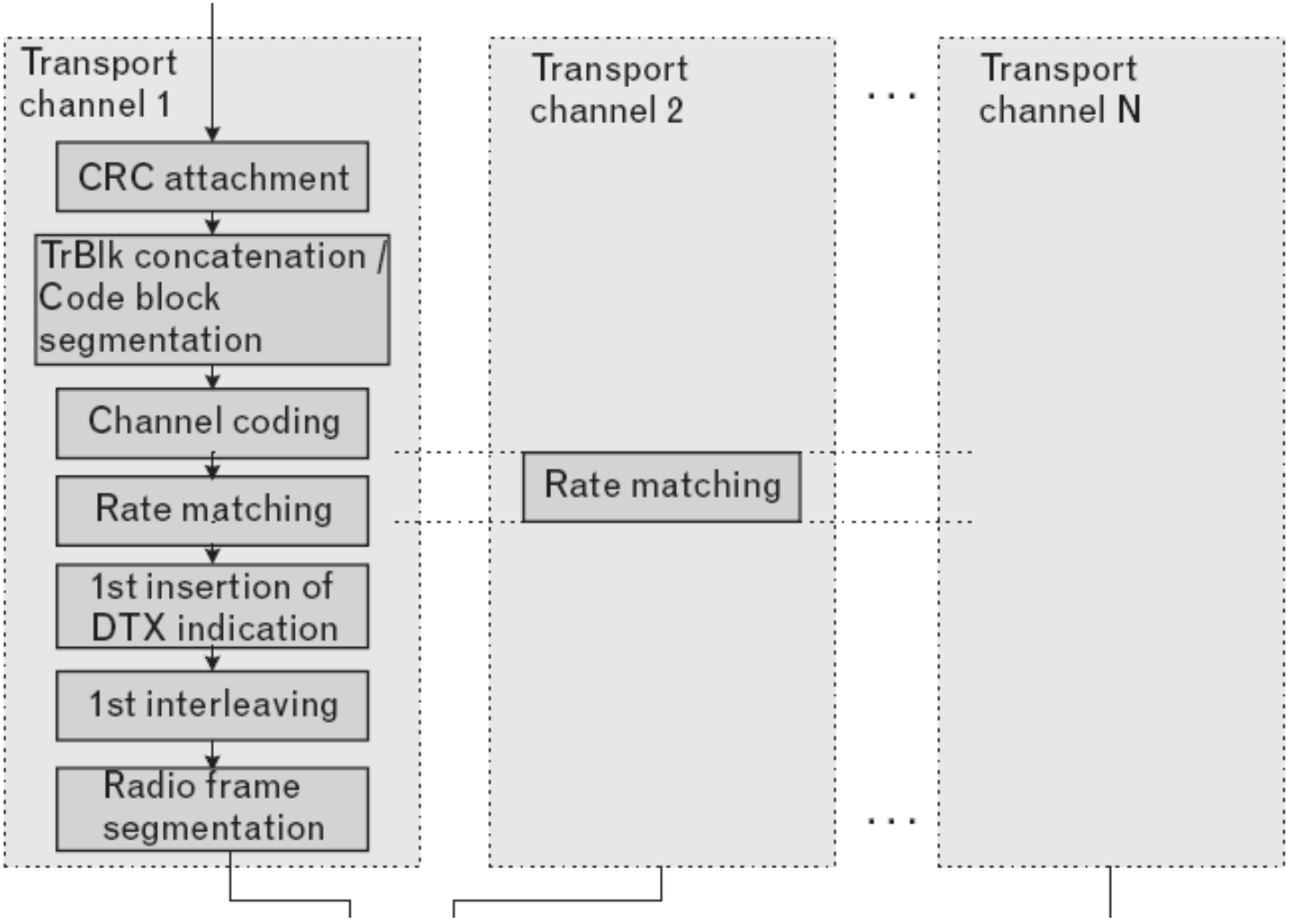
Channel structure - DL



Channel structure - DL

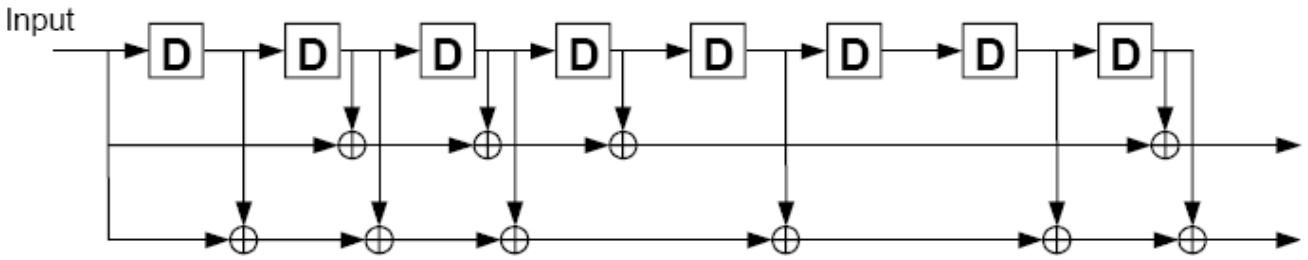
Slot Format #i	Channel Bit Rate (kbps)	Channel Symbol Rate (ksps)	SF	Bits/ Slot	DPDCH Bits/Slot		DPCCH Bits/Slot			Transmitted slots per radio frame N_{Tr}
					N_{Data1}	N_{Data2}	N_{TPC}	N_{TFCI}	N_{Pilot}	
0	15	7.5	512	10	0	4	2	0	4	15
0A	15	7.5	512	10	0	4	2	0	4	8-14
0B	30	15	256	20	0	8	4	0	8	8-14
1	15	7.5	512	10	0	2	2	2	4	15
14B	960	480	8	640	112	464	16	16*	32	8-14
15	960	480	8	640	120	488	8	8*	16	15
15A	960	480	8	640	120	480	8	16*	16	8-14
15B	1920	960	4	1280	240	976	16	16*	32	8-14
16	1920	960	4	1280	248	1000	8	8*	16	15
16A	1920	960	4	1280	248	992	8	16*	16	8-14

Fyzická vrstva - DL

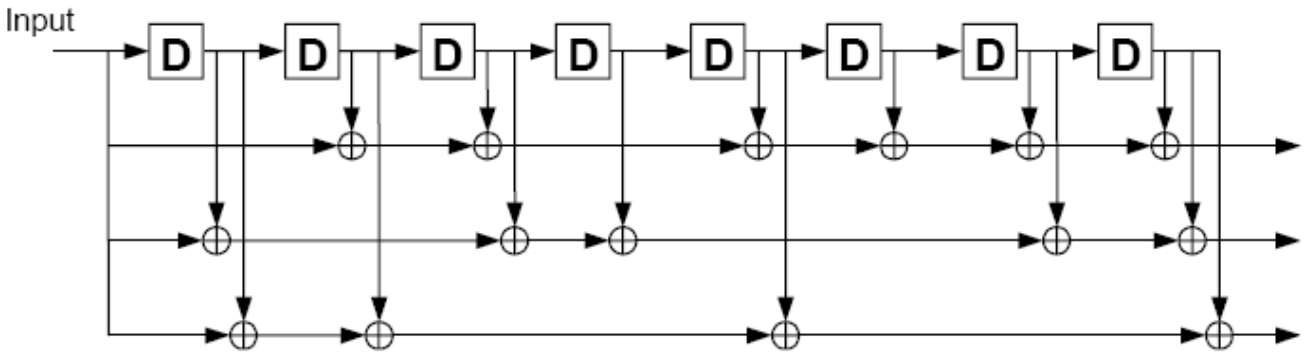


Channel Coding

Type of TrCH	Coding scheme	Coding rate
BCH	Convolutional coding	1/2
PCH		
RACH		
DCH, FACH		1/3, 1/2
	Turbo coding	1/3

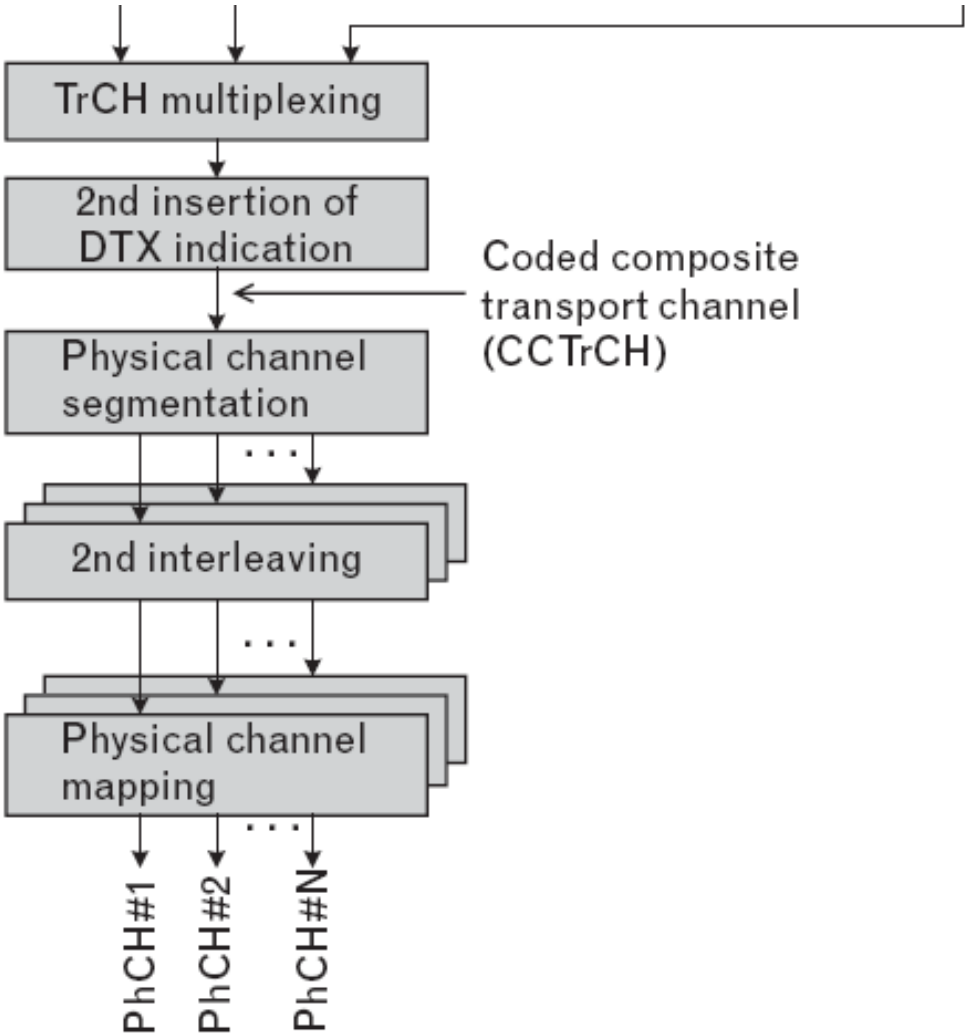


(a) Rate 1/2 convolutional coder

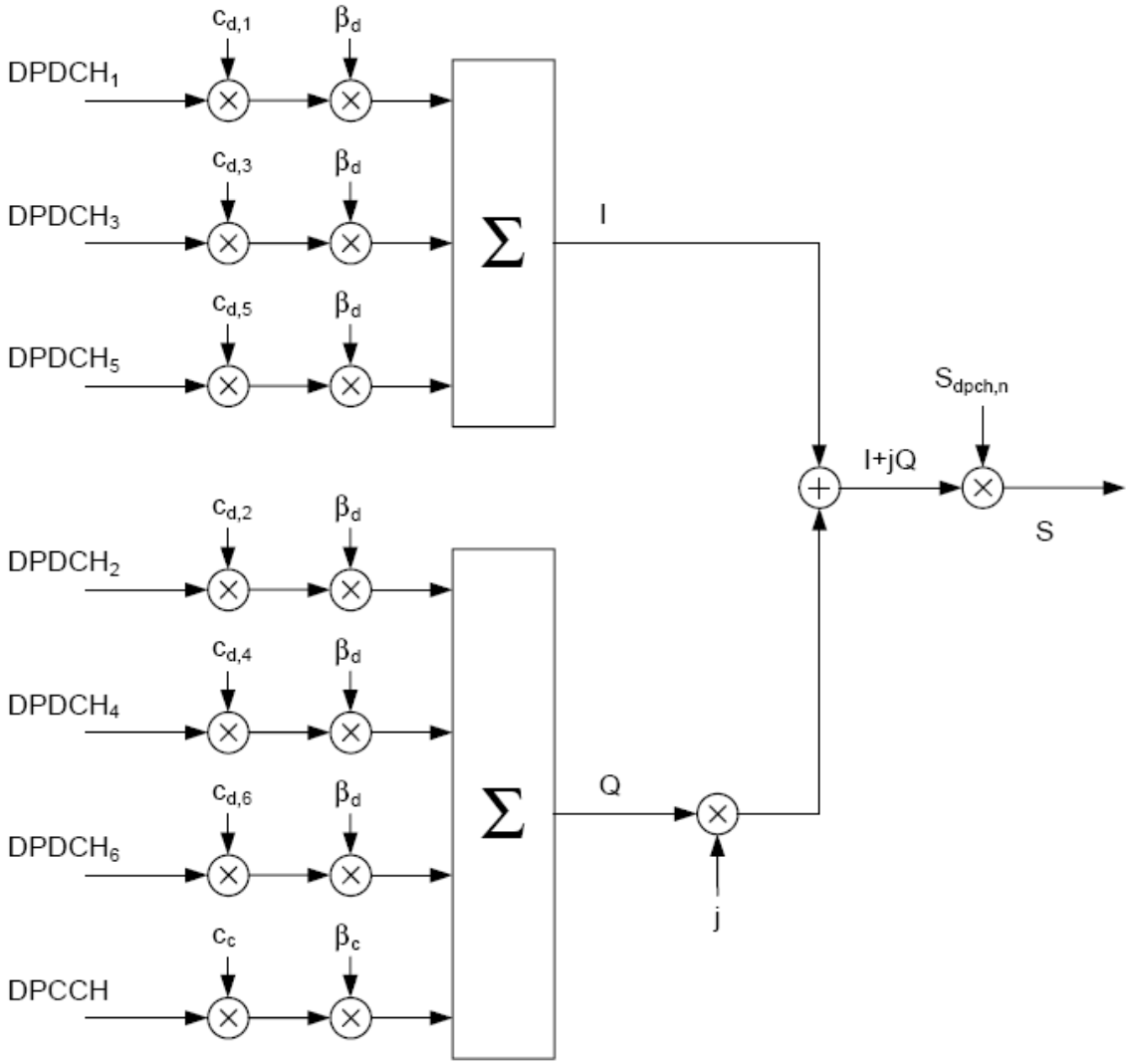


(b) Rate 1/3 convolutional coder

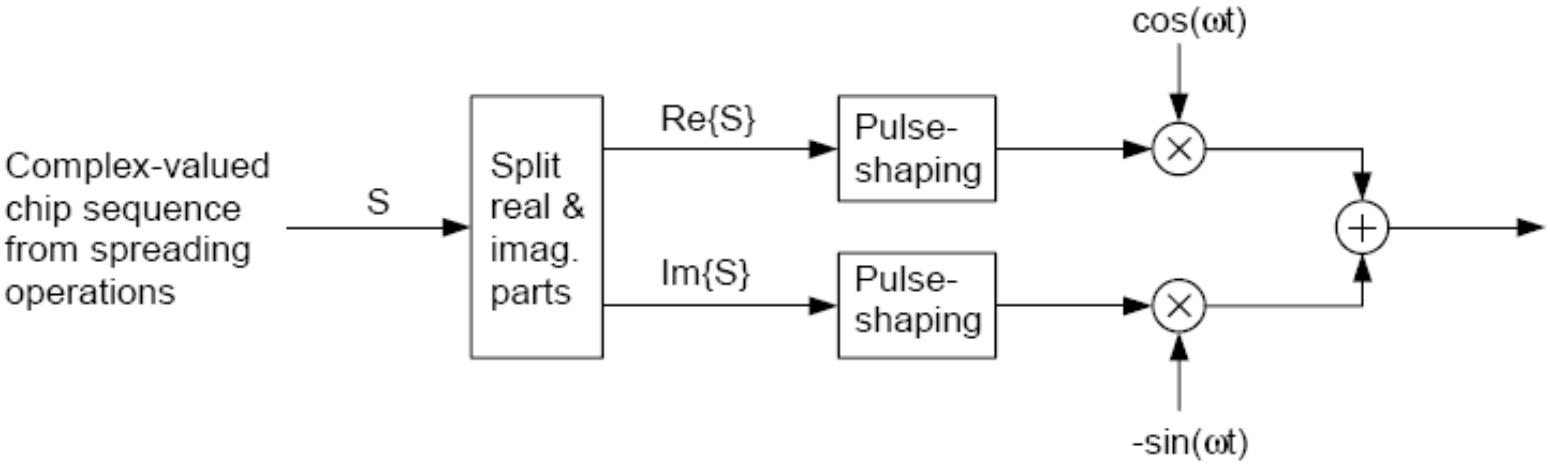
Fyzická vrstva - DL



Spreading - UL



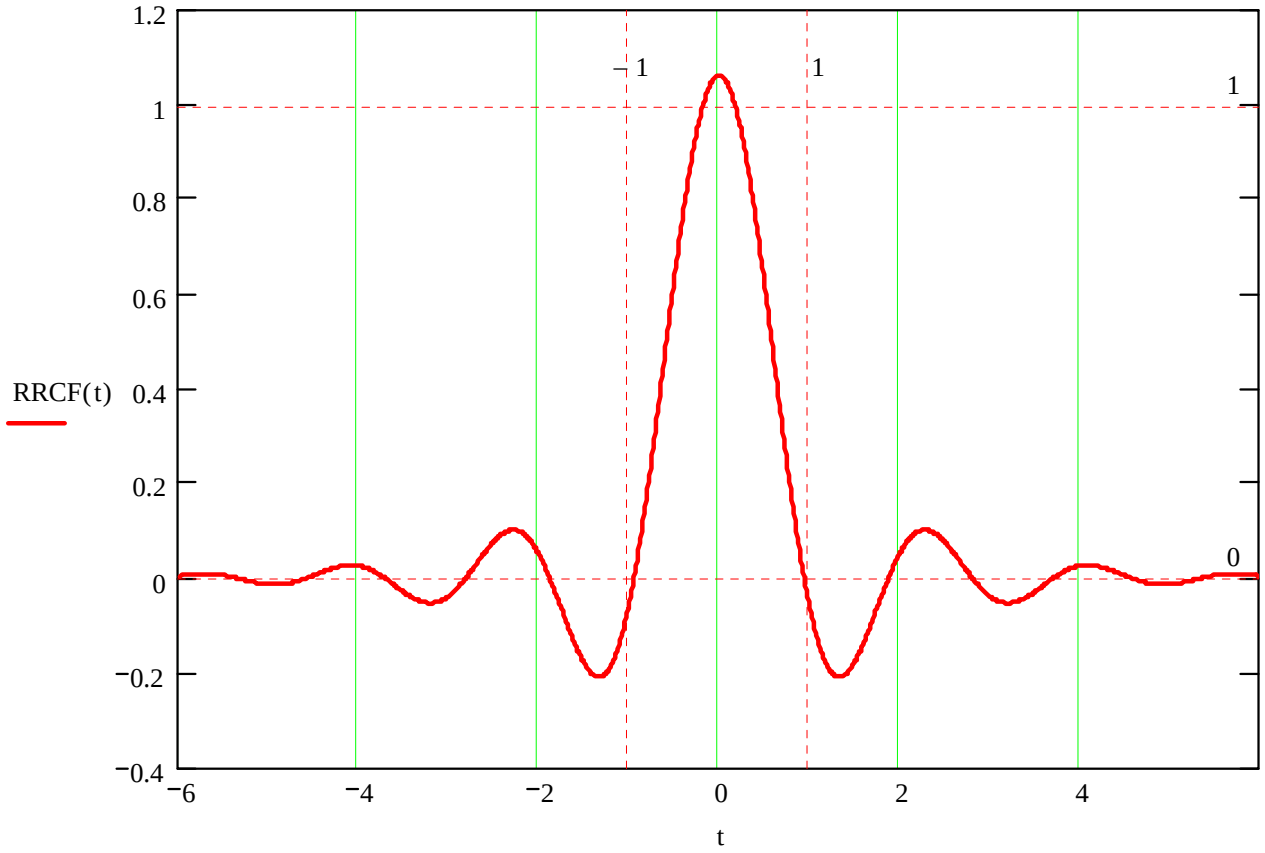
Modulation - UL



root-raised cosine (RRC) with roll-off α =0.22

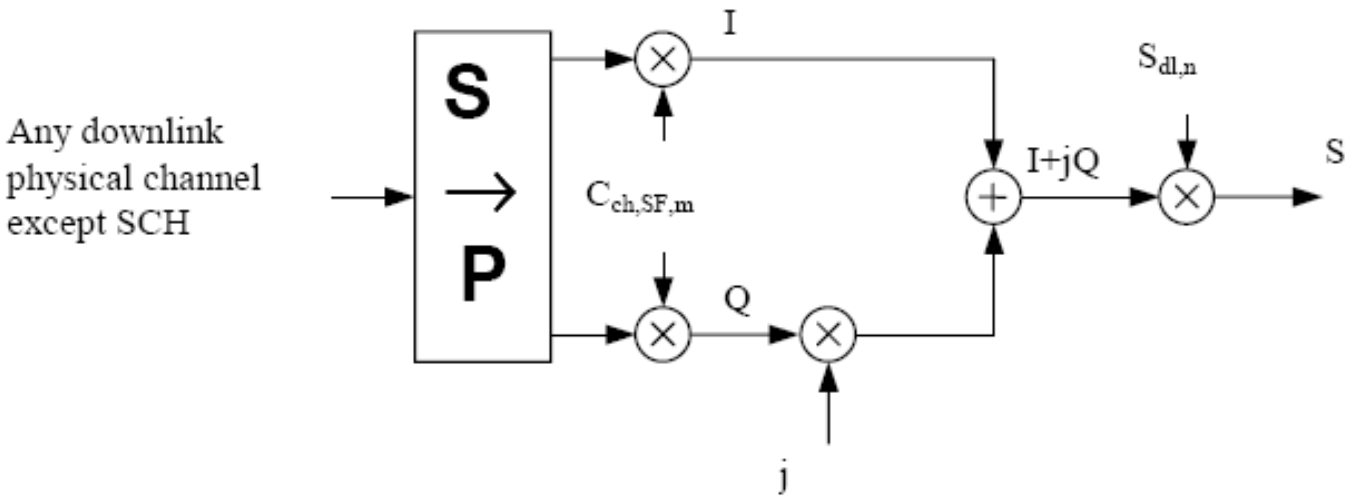
$$RC_0(t) = \frac{\sin\left(\pi \frac{t}{T_C}(1-\alpha)\right) + 4\alpha \frac{t}{T_C}\cos\left(\pi \frac{t}{T_C}(1+\alpha)\right)}{\pi \frac{t}{T_C}\left(1-\left(4\alpha \frac{t}{T_C}\right)^2\right)}$$

RRCF impulse response

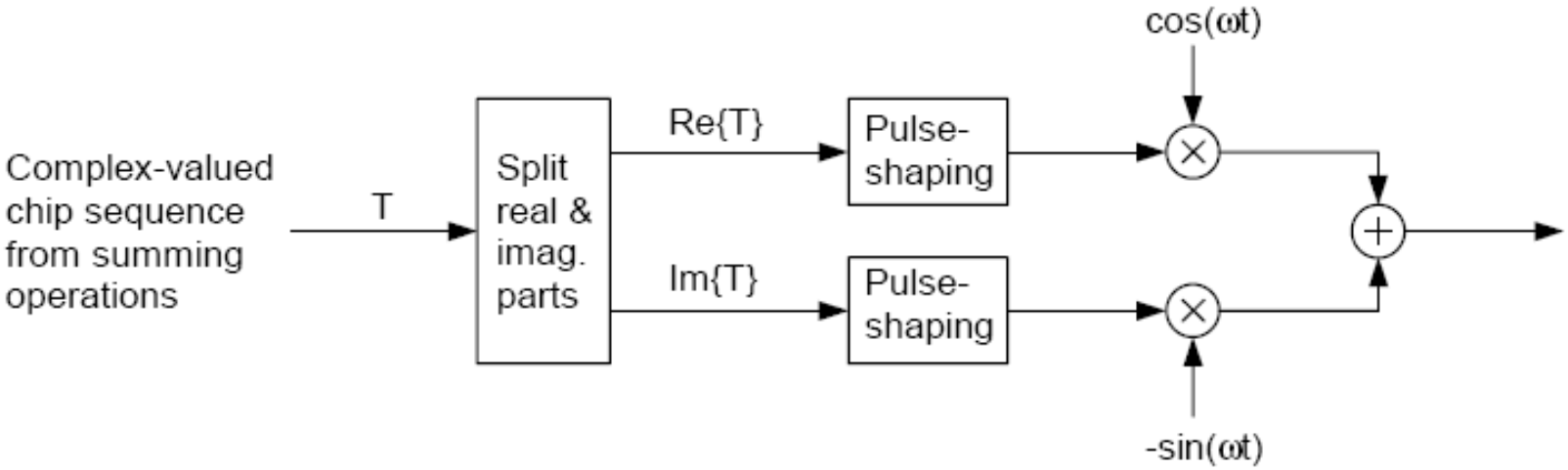


normalized Tc = 1 (Tc = 26,042 μs)

Spreading - DL



Modulation - DL



root-raised cosine (RRC) with roll-off α =0.22

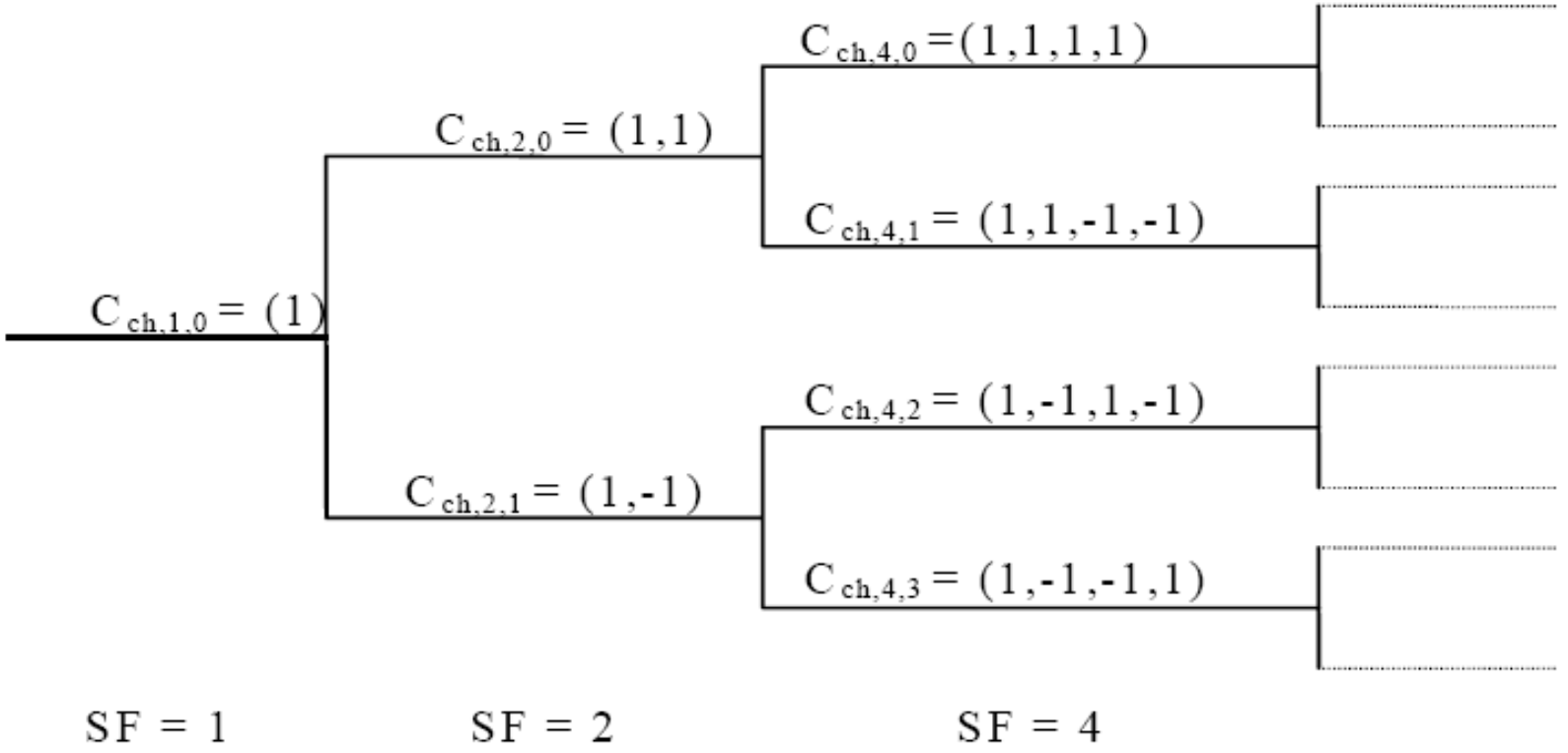
$$RC_0(t) = \frac{\sin\left(\pi \frac{t}{T_C}(1-\alpha)\right) + 4\alpha \frac{t}{T_C}\cos\left(\pi \frac{t}{T_C}(1+\alpha)\right)}{\pi \frac{t}{T_C}\left(1-\left(4\alpha \frac{t}{T_C}\right)^2\right)}$$

Codes

	Synchronisation Codes	Channelisation Codes	Scrambling Codes, UL	Scrambling Codes, DL
Type	Gold Codes Primary Synchronization Codes (PSC) and Secondary Synchronization Codes (SSC)	Orthogonal Variable Spreading Factor (OVSF) codes sometimes called Walsh Codes	Complex-Valued Gold Code Segments (long) or Complex-Valued S(2) Codes (short) Pseudo Noise (PN) codes	Complex-Valued Gold Code Segments Pseudo Noise (PN) codes
Length	256 chips	4-512 chips	38400 chips / 256 chips	38400 chips
Duration	66.67 µs	1.04 µs - 133.34 µs	10 ms / 66.67 µs	10 ms
Number of codes	1 primary code / 16 secondary codes	= spreading factor 4 ... 256 UL, 4 ... 512 DL	16,777,216	512 primary / 15 secondary for each primary code
Spreading	No, does not change bandwidth	Yes, increases bandwidth	No, does not change bandwidth	No, does not change bandwidth
Usage	To enable terminals to locate and synchronise to the cells' main control channels	UL: to separate physical data and control data from same terminal DL: to separate connection to different terminals in a same cell	Separation of terminal	Separation of sectors

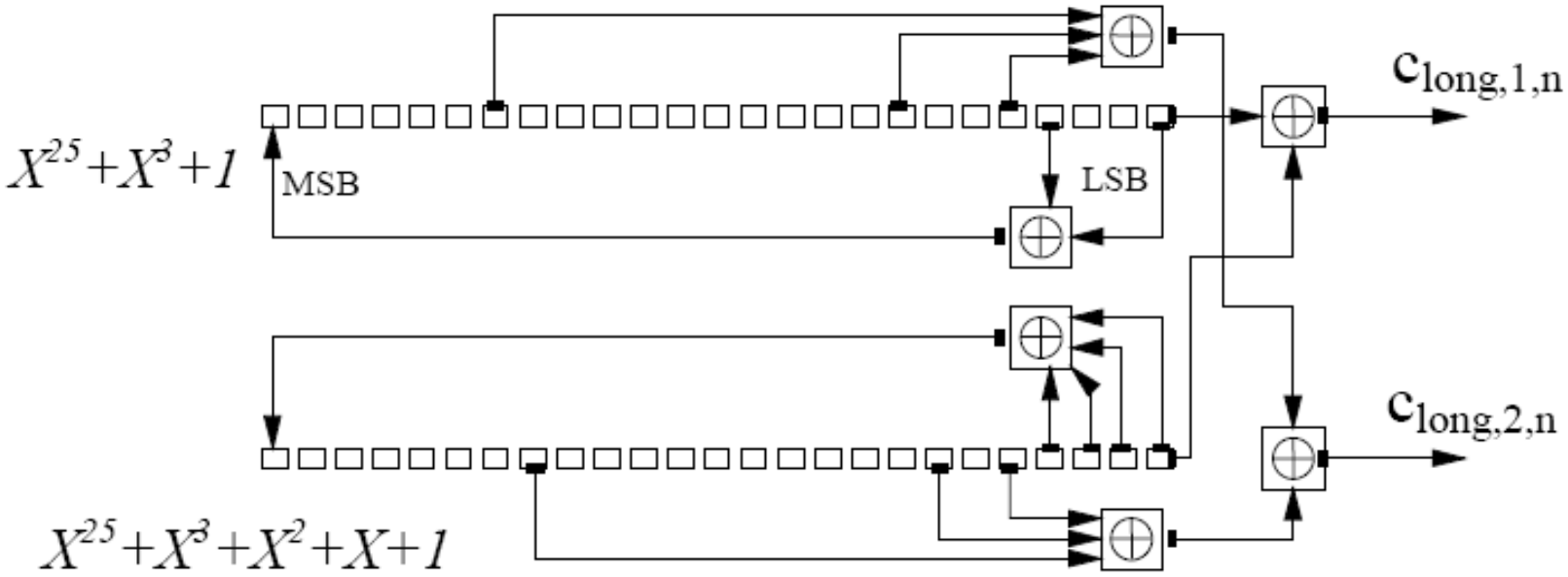
$2^{18}-1 = 262,143$

OVSF


$C_{ch,1,0} = (1)$
$C_{ch,2,0} = (1,1)$
$C_{ch,2,1} = (1,-1)$
$C_{ch,4,0} = (1,1,1,1)$
$C_{ch,4,1} = (1,1,-1,-1)$
$C_{ch,4,2} = (1,-1,1,-1)$
$C_{ch,4,3} = (1,-1,-1,1)$
SF = 1
SF = 2
SF = 4

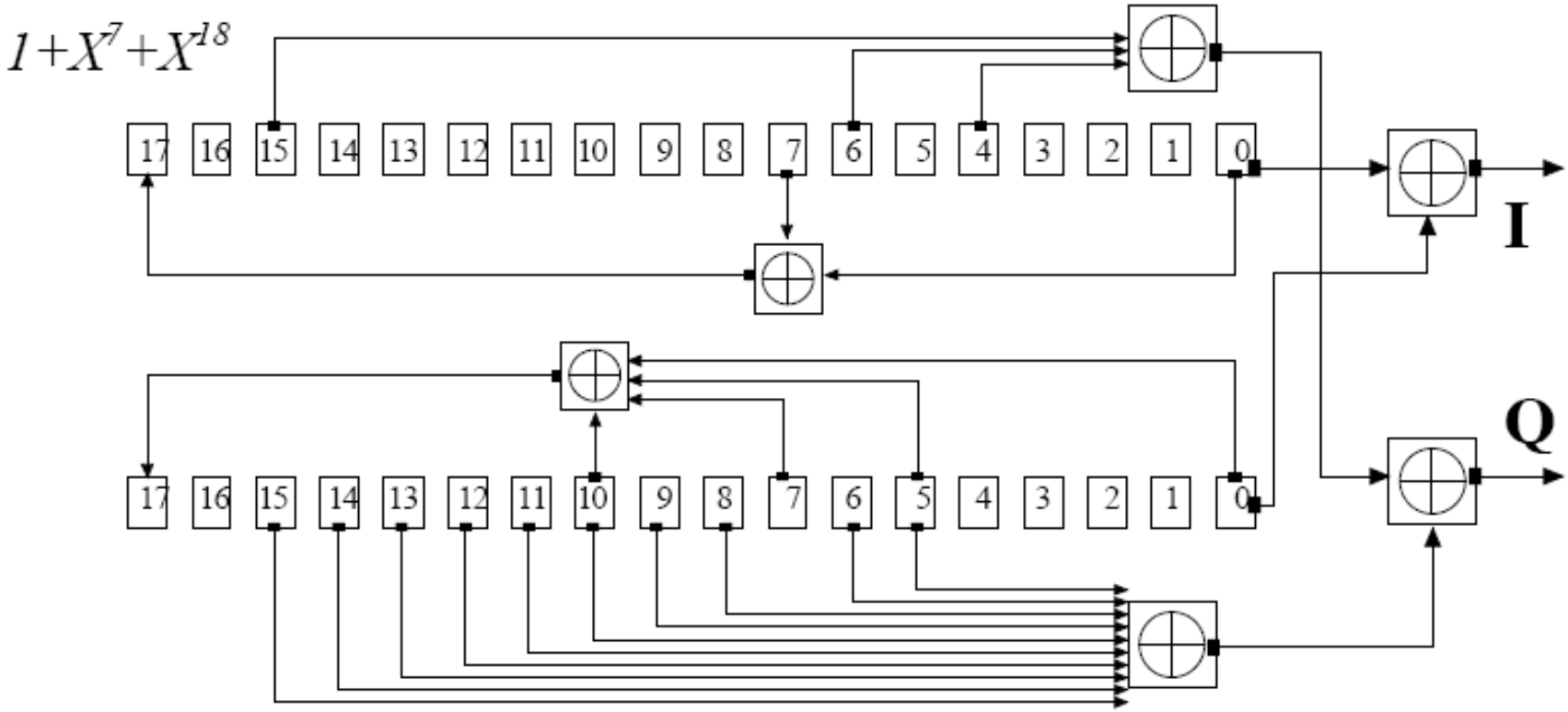
Scrambling codes - UL

(long code)



$$C_{long,n}(i) = c_{long,1,n}(i)\left(1 + j(-1)^i c_{long,2,n}\left(2\lfloor i/2 \rfloor\right)\right)$$

Scrambling - DL



$1+X^5+X^7+X^{10}+X^{18}$

Spreading & scrambling

$$s_j^{DS}(t) = \sum_{i=-\infty}^{+\infty} \sum_{k=0}^{K^{DS}-1} a_j(i)\, b_j(k)\, c_j(k + iK^{DS})\, p_c(t - kT_c - iT_s)$$

Received signal

$$r^{DS}(t) = \sum_{j=1}^{J} r_j^{DS}(t) + n(t)$$

$$r_j^{DS}(t) = \int_{-\infty}^{+\infty} s_j^{DS}(t-\tau)\, h_j(\tau;\, t)\, d\tau = \sum_{l=1}^{J} \beta_{l,j}(t)\, s_j^{DS}(t-\tau_l)$$

Detection

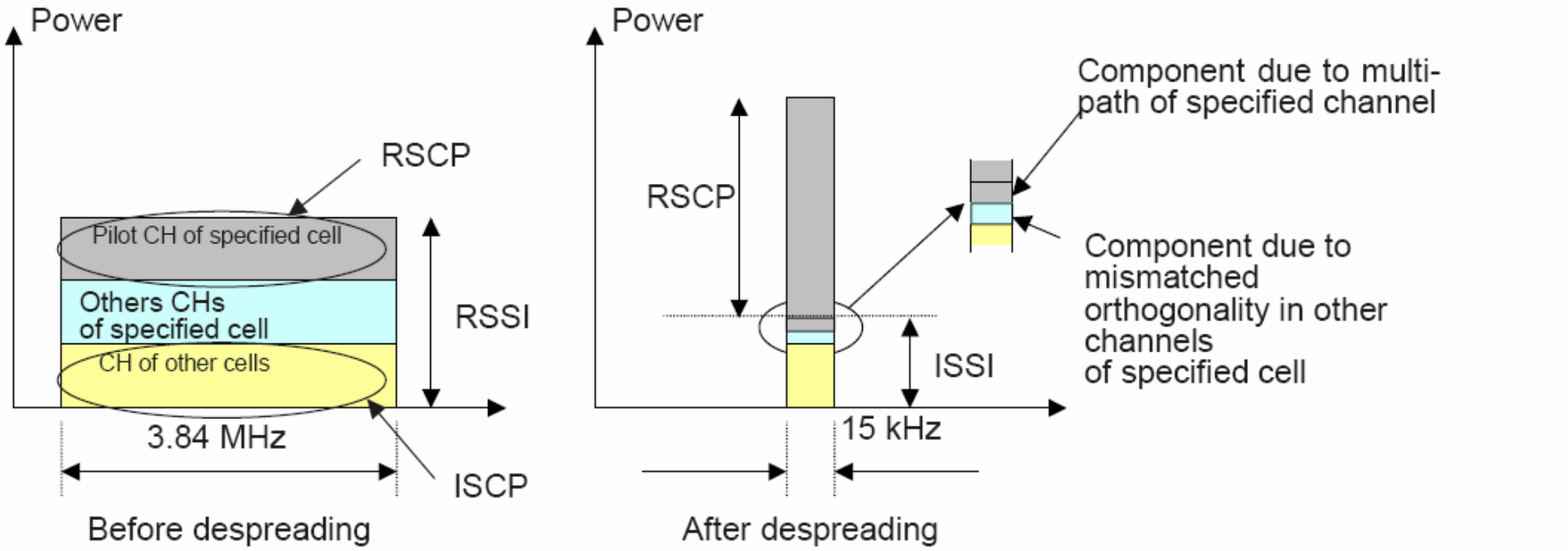
$$D_{j'}^{DS}(i) = D_{j'}^{DS}(t = iT_s)$$

$$= \sum_{l=1}^{I} \beta_{l,j'}^{*}(iT_s) \frac{1}{T_s} \int_{iT_s+\tau_l}^{(i+1)T_s+\tau_l} b_{j'}^{*}(k)\, c_{j'}^{*}(k + iK^{DS})$$

$$\times\, p_c(t - kT_c - iT_s - \tau_l)\, r^{DS}(t)\, dt$$

I = number of fingers of RAKE receiver

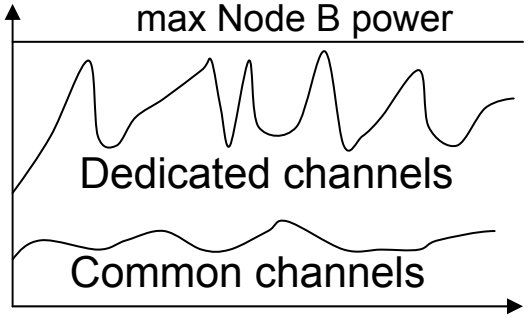
Measurements



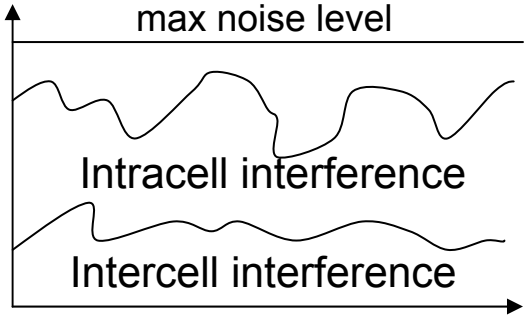
RSSI: Receive signal strength indicator (total receive signal power within 3.84 MHz band)
RSCP: Receive signal code power (of Pilot channel CPICH)
ISCP: Interference signal code power
ISSI: Interference signal code power after despreading (ISSI = ISCP/SF)
SF: Spreading factor (of CPICH = 256)
SIR: Signal to interference ratio SIR = RSCP/ISSI = (RSCP/ISCP) x SF
Ec/No: Ec/No = RSCP/RSSI

Limiting factors

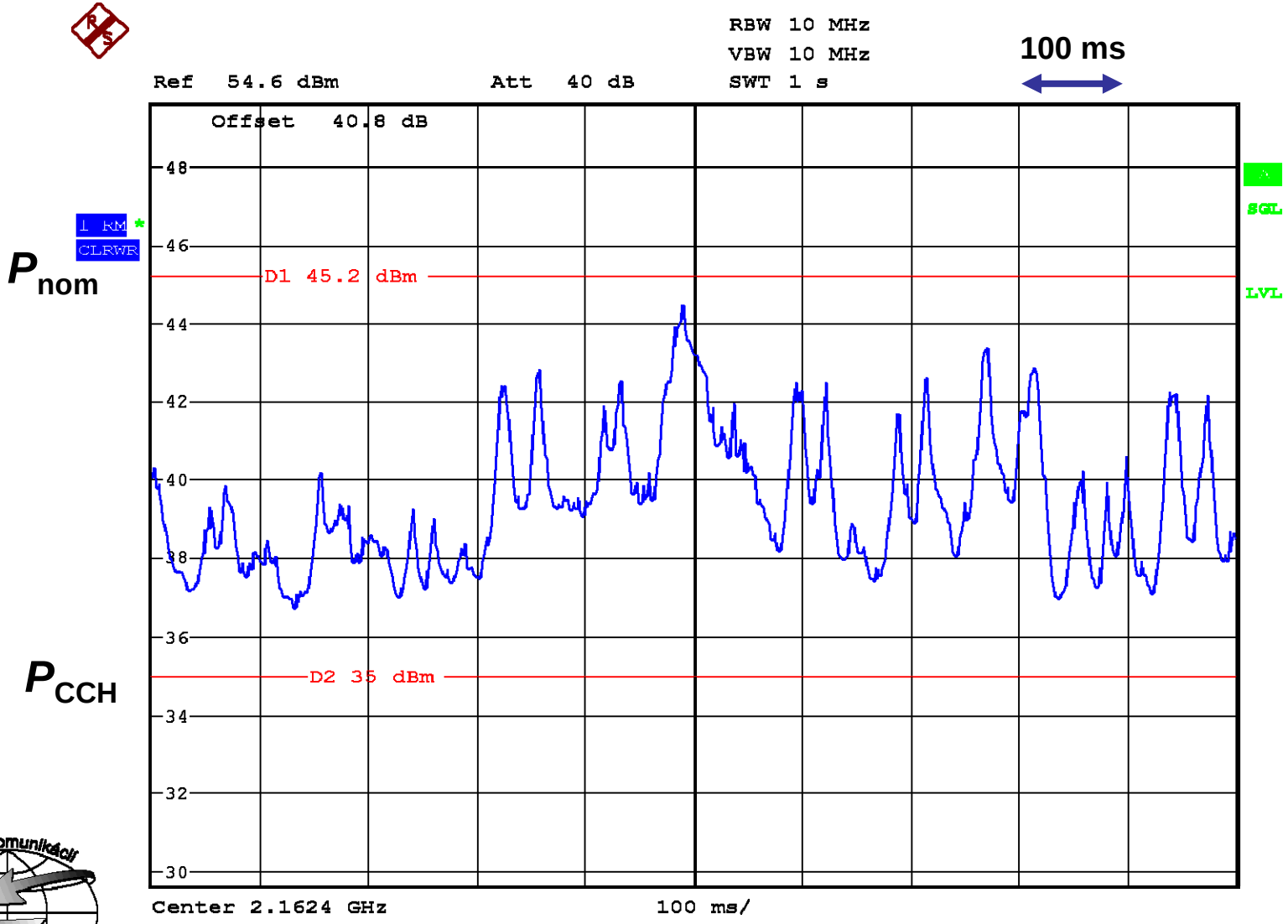
- Downlink is power limited



- Uplink is interference limited



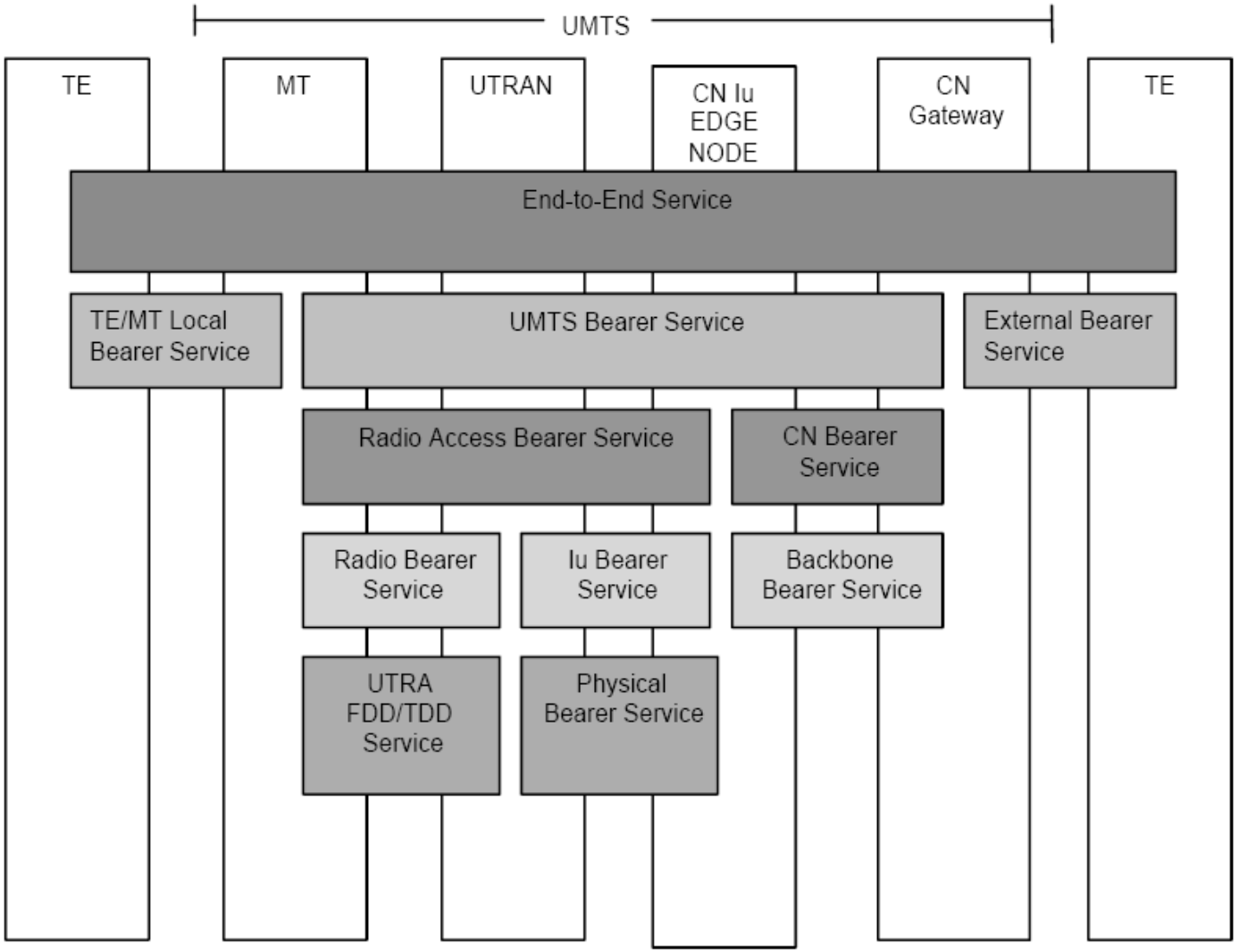
Power dynamics



P_{nom}

P_{CCH}

Services & RABs



Services & RABs

- New service: Video Call

RAB type	Rate [kbps]
CS voice	12,2
CS video call	64
CS Streaming	57
PS Best Effort	64/128/384