UMTS – High Speed Downlink Packet Access (HSDPA)

R&S 1CM-T

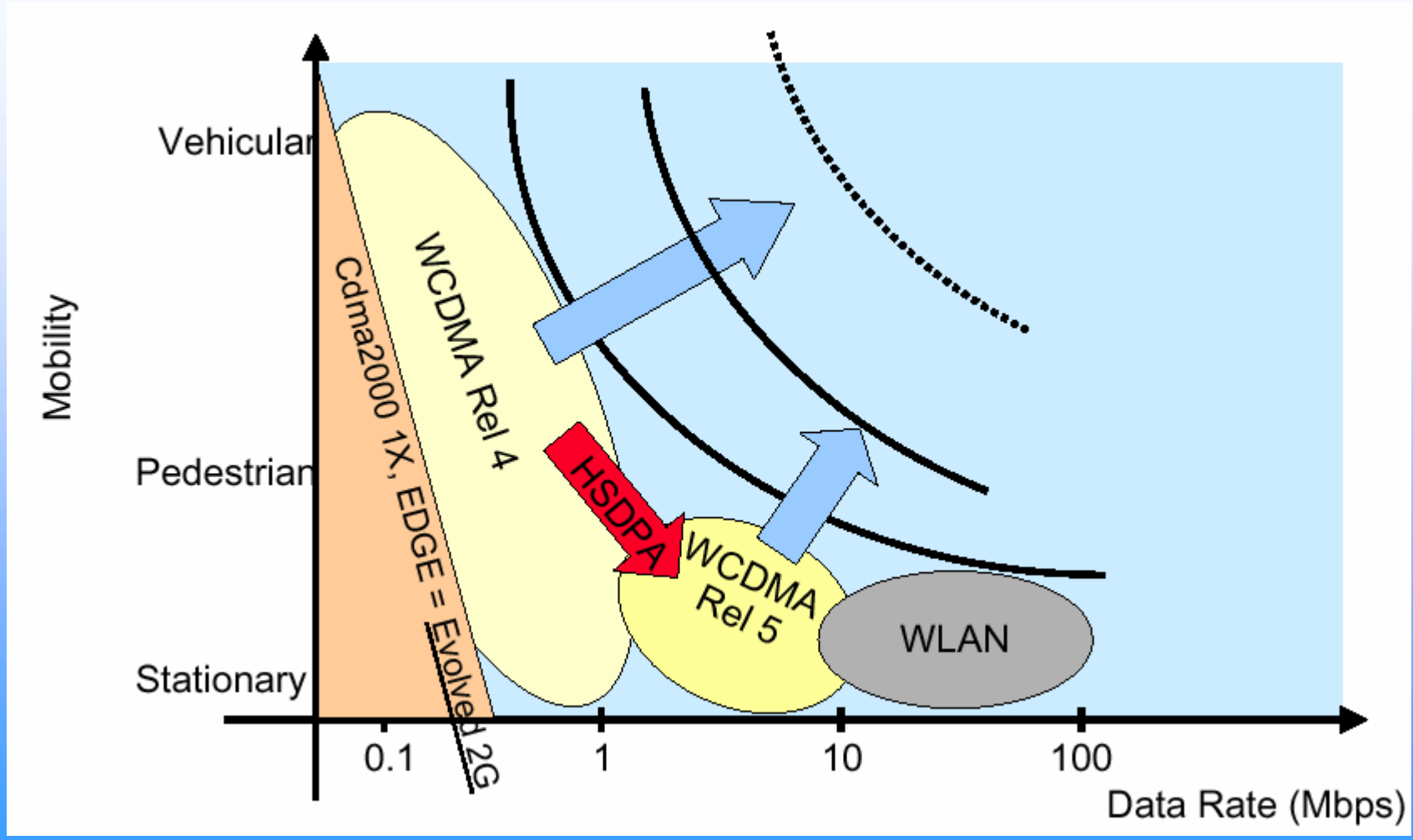
ROHDE&SCHWARZ

High Speed Downlink Packet Access (HSDPA):

- HSDPA is designed to support data rates of up to 10 Mbps (14Mbps)
- Co-existence with R99 in the same frequency band (5 MHz) **à** usage of free resources
- Used for Best Effort and background services

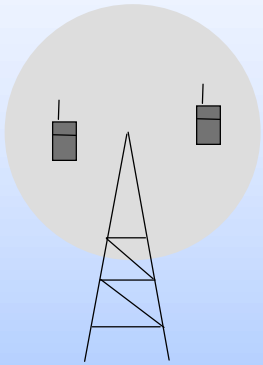
This seminar will focus on HSDPA in the UMTS FDD mode

HSDPA Scenario



HSDPA Common-Dedicated Channel

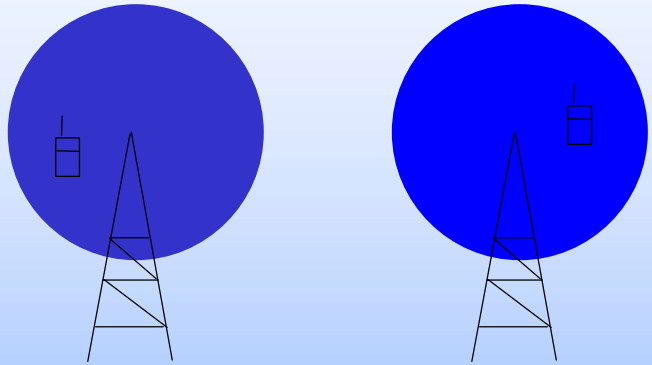
Common Channel



Common physical resource
Identification by in-band UE-ID

à UL: PRACH, PCPCH
à DL: P-CCPCH, (BCH)
S-CCPCH (PCH,FACH)

Dedicated Channel



Dedicated physical resource

à UL: PDCH
à DL: PDCH

HSDPA Common-Dedicated Channel

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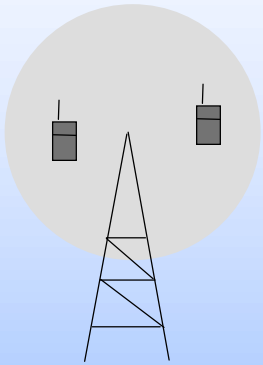
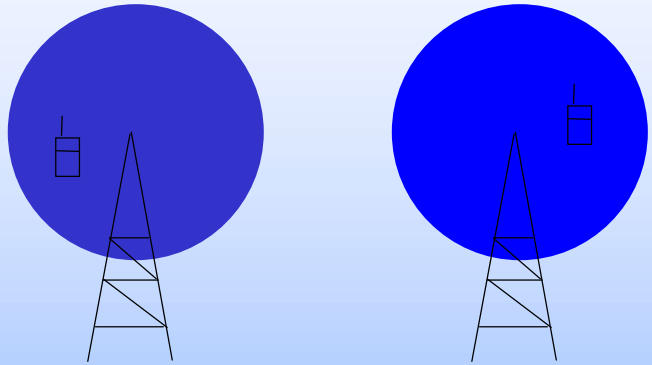
Common Channel



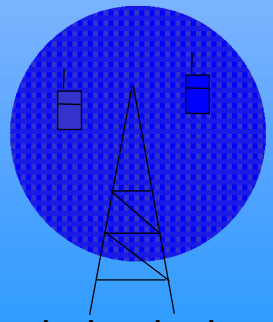
Common physical resource
Identification by in-band UE-ID

Dedicated Channel



Dedicated physical resource

Shared Channel



Shared physical resource
Identification by in-band UE-ID

- à R99: DSCH
- à R5: HSDPA

HSDPA What is new ?

3 slot TTI (2 ms)

CQI: Channel Quality Indication

AMC: Adaptive Modulation and Coding

Constellation re-arranging (16 QAM)

H-ARQ: Hybrid Automatic Repeat Request

N-channel SAW: N-channel Stop And Wait protocol

MAC-hs: New MAC instance

HSDPA physical/transport channel

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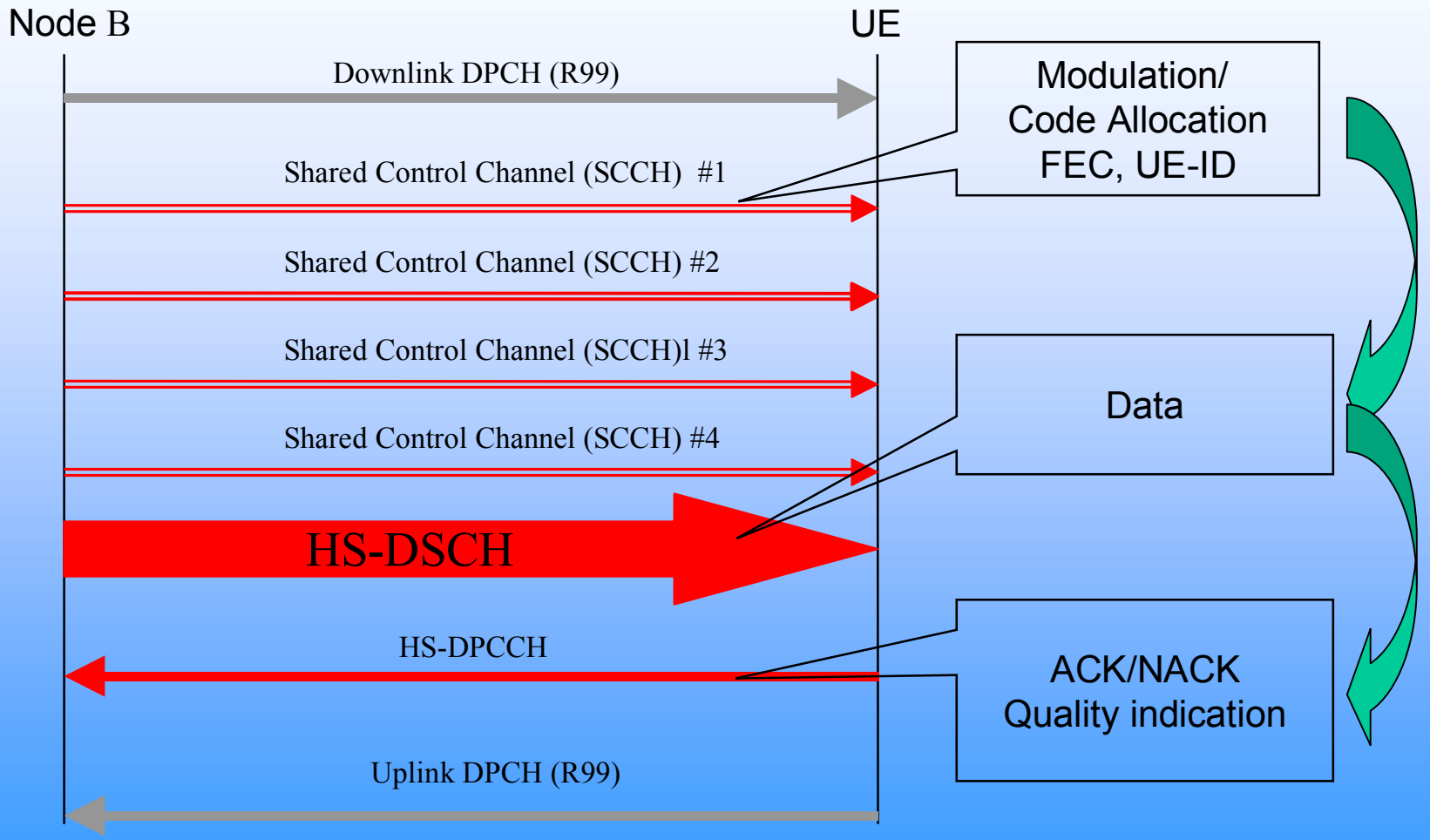
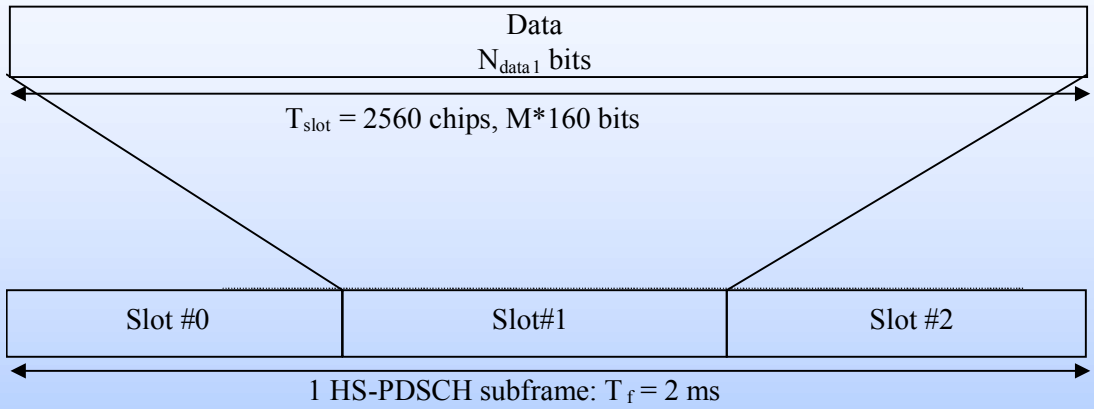
- fixed spreading factor SF = 16 for HS-(P)DSCH
- QPSK and 16 QAM modulation
- static TTI length = 3 x T_{slot} = 2 ms
- fixed CRC size: 24 bits
- FEC: Only 1/3 turbo coding (R99 turbo coder)

HSDPA channel structure

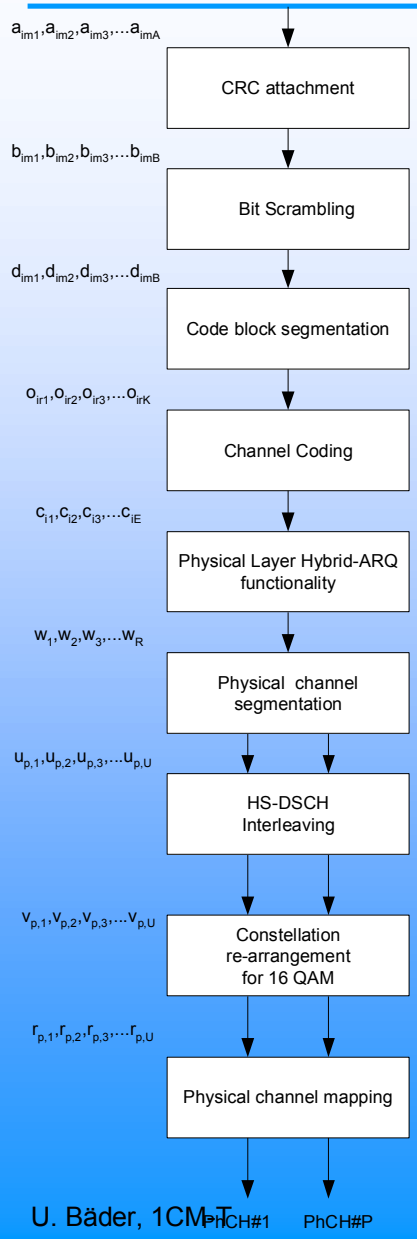


HSDPA HS-DSCH



Slot format #i	Channel Bit Rate (kbps)	Channel Symbol Rate (ksps)	SF	Bits/ HS-DSCH subframe	Bits/ Slot	Ndata	M
0(QPSK)	480	240	16	960	320	320	**2**
1(16QAM)	960	240	16	1920	640	640	**4**

HSDPA Channel Coding



Only one HS-DSCH per CCTrCh

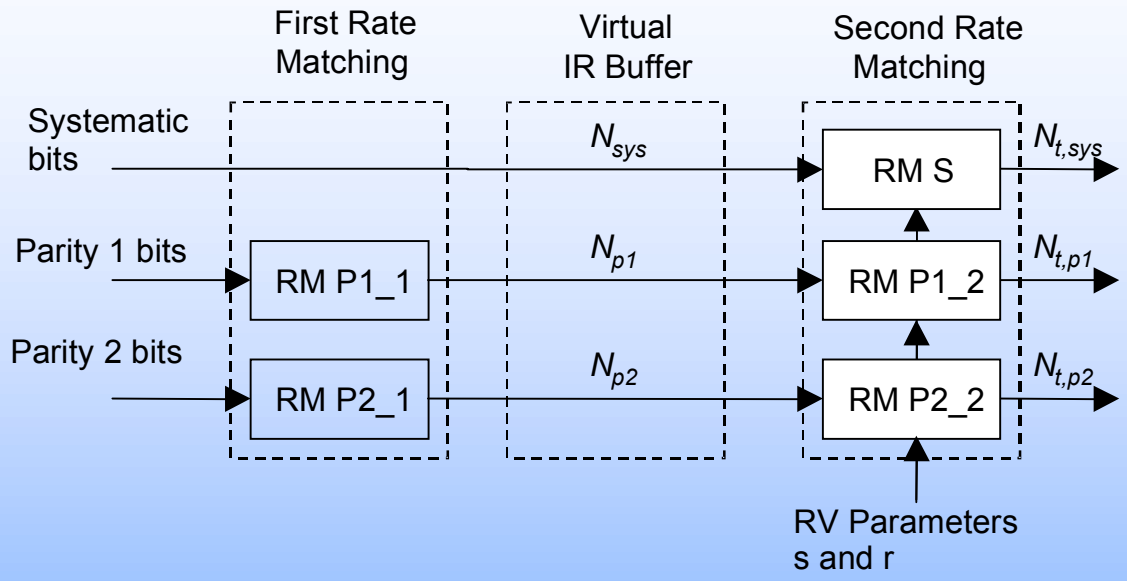
CRC size fixed: 24 bit

Max. code block size 5114 bits

1/3 turbo code as in R99

variable redundancy

HSDPA channel coding



s-parameter: systematic bits indication
s=0, s=1: systematic bits preferred

r- parameter: redundancy indication

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ARQ: incorrect packets are transmitted again (layer 2 function)

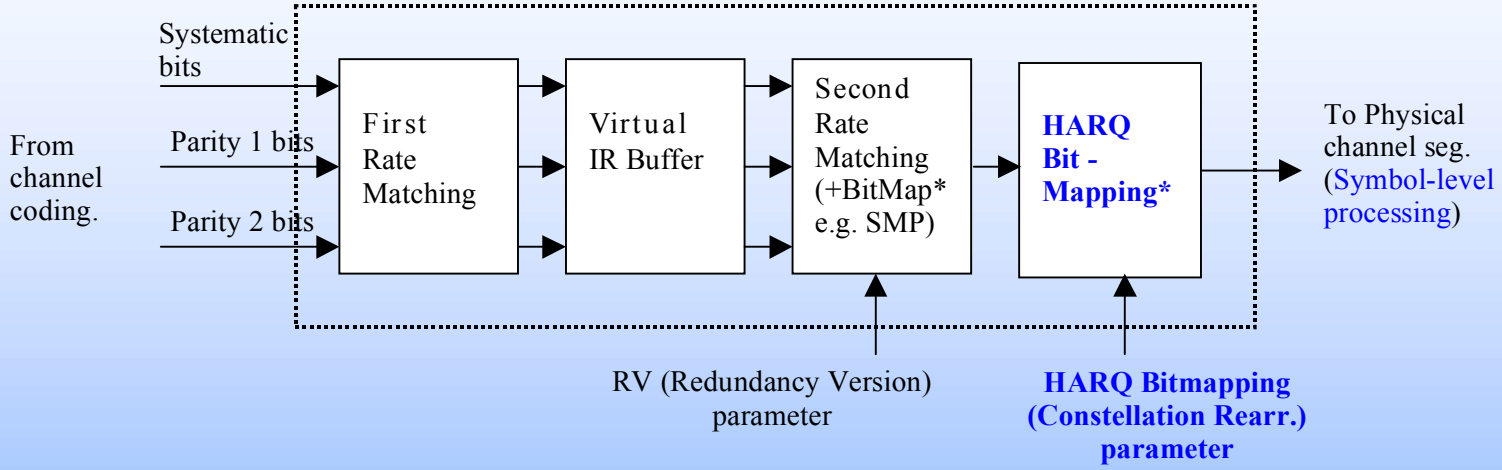
H-ARQ:

Typ I: Coding is applied to transmission packets (separate layer 1 and layer 2 functionality)

Typ II: retransmission of packet information with additional or incremental redundancy (re-transmission is not self-decodeable)

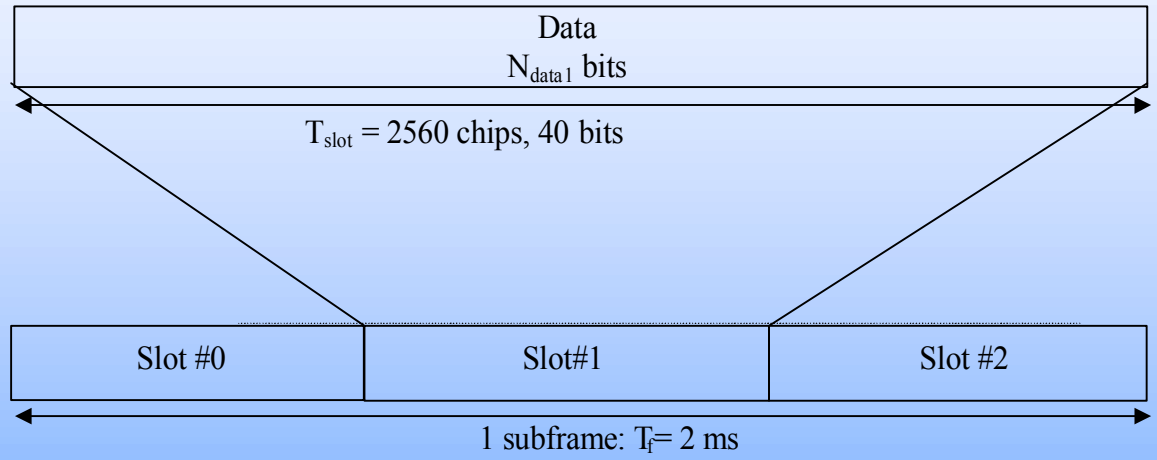
Typ III: retransmission of packet information is self-decodeable but could be send with less power (Chase combining:
1. transmission = re-transmission)

HSDPA H-ARQ bitmapping



* required for 16-QAM operation only

HS-SCCH frame structure



The spreading factor is fixed SF=128.
The Channel Coding depends on the different information fields.

HSDPA HS-SCCH information

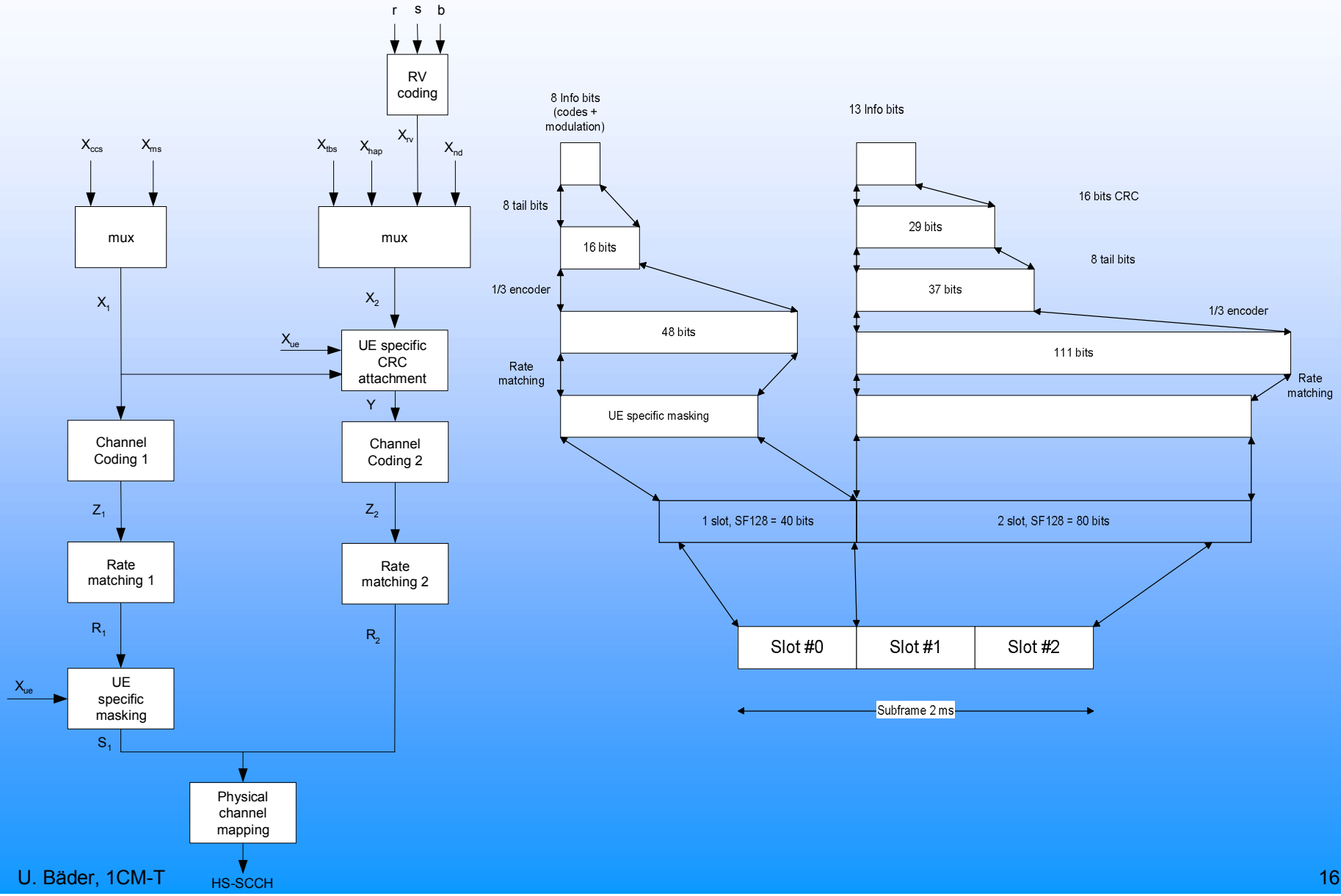
A HS-SCCH subframe contains the following information:

- Channelization-code-set information (7 bits): $x_{ccs,1}, x_{ccs,2}, \ldots, x_{ccs,7}$
- Modulation scheme information (1 bit): $x_{ms,1}$
- Transport-block size information (6 bits): $x_{tbs,1}, xt_{bs,2}, \ldots, x_{tbs,6}$
- Hybrid-ARQ process information (3 bits): $x_{hap,1}, x_{hap,2}, x_{hap,3}$
- Redundancy and constellation version (3 bits): $x_{rv,1}, x_{rv,2}, x_{rv,3}$
- New data indicator (1 bit): $x_{nd,1}$
- *UE identity (16 bits):* $x_{ue,1}, x_{ue,2}, \ldots, x_{ue,16}$

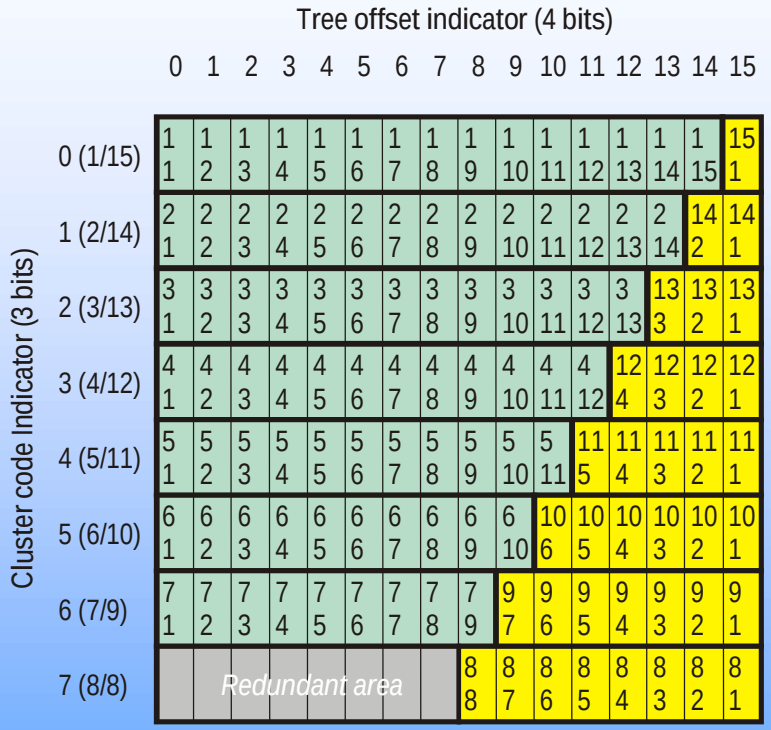
One UE can receive up to 4 HS-SCCH channels.

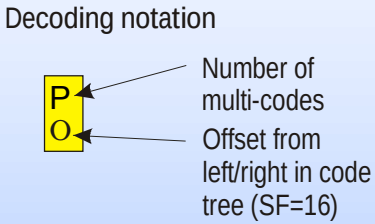
Note: If a UE was scheduled in an HS-SCCH it only needs to receive that HS-SCCH in the following frame.

HSDPA SCCH structure



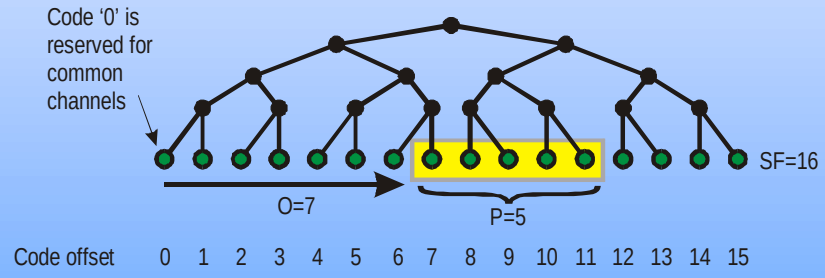
HS-SCCH à HS-DSCH Code allocation





- Spreading factor of the HS-DSCH is fixed SF = 16,
- For one UE a cluster of codes can be allocated:

$C_{ch,16,O} \cdots C_{ch,16,O+P-1}$



code group indicator:

$x_{ccs,1}, x_{ccs,2}, x_{ccs,3} = \min(P-1, 15-P)$

code offset indicator:

$x_{ccs,4}, x_{ccs,5}, x_{ccs,6}, x_{ccs,7} = |O-1-\lfloor P/8 \rfloor * 15|$

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•HS-DSCH modulation can be: QPSK
16 QAM

depending on the UE category.

•The value of $x_{ms,1}$ is derived from the modulation:

$$x_{ms,1} = \begin{cases} 0 & if \quad QPSK \\ 1 & if \quad 16QAM \end{cases}$$

HS-SCCH à HS-DSCH redundancy version

RV coding for 16QAM

X_{rv} (value)	s	r	b
0	1	0	0
1	0	0	0
2	1	1	1
3	0	1	1
4	1	0	1
5	1	0	2
6	1	0	3
7	1	1	0

Parameter for constellation re-arrangement

Priorisation of systematic bits*

RV coding for QPSK

X_{rv} (value)	s	r
0	1	0
1	0	0
2	1	1
3	0	1
4	1	2
5	0	2
6	1	3
7	0	3

Parameter for changing puncturing or repetition* scheme

à $x_{rv,1}$, $x_{rv,2}$, $x_{rv,3}$

*In case of repetition both parameters *r* and *s* change the repetition scheme

HS-SCCH **à** HS-DSCH transport block size

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- The transport block size is signalled by th TFRI (= Transport Format Resource Indicator). TFRI is a 6 bit value: $x_{tbs,1}$, $x_{tbs,2}$, …, $x_{tbs,6}$.
- For each combination of allocated HS-DSCH channel code set and modulation scheme 0..62 transport block sizes exist.
- Formula to calculate the transport block size from the TFRI is given in 25.321
- The value 111111 (or K_i = 63) is reserved for TrBlkSizes where no mapping exists in the case of retransmission.

- Examples:

a)
QPSK, 5 code channels:

TFRI	TrBlkSize (bits)
..	
4	1651
5	1681
6	1711
7	1742
...	

b)
TrBlkSize (bits): 1593

Channel codes		TFRI
2	QPSK	54
3	QPSK	31
4	QPSK	15
5	QPSK	2

HS-SCCH **à** HS-DSCH HARQ info

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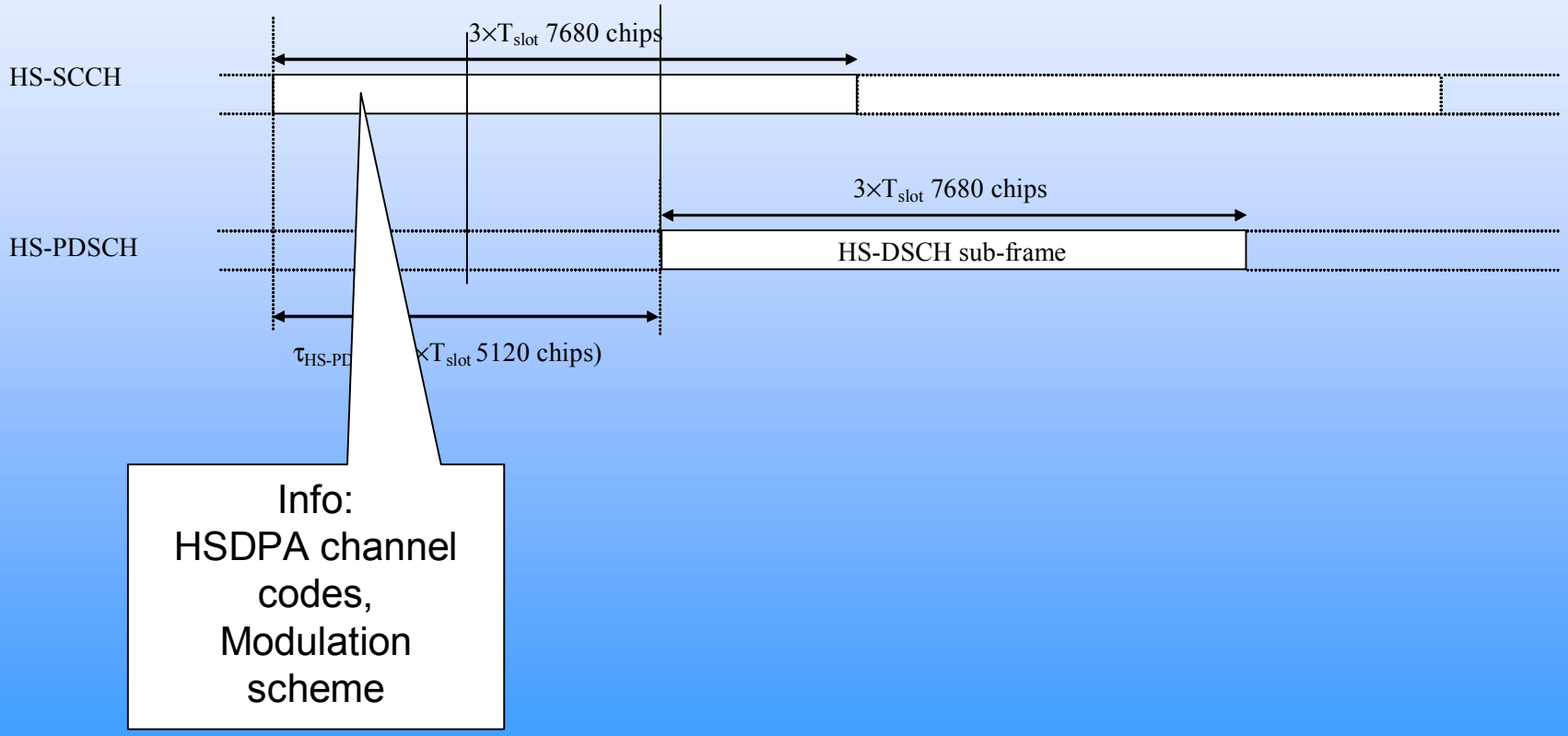
– Hybrid-ARQ process information (3 bits): $x_{hap,1}$, $x_{hap,2}$, $x_{hap,3}$

This value identifies the HARQ-process for which the data is transmitted

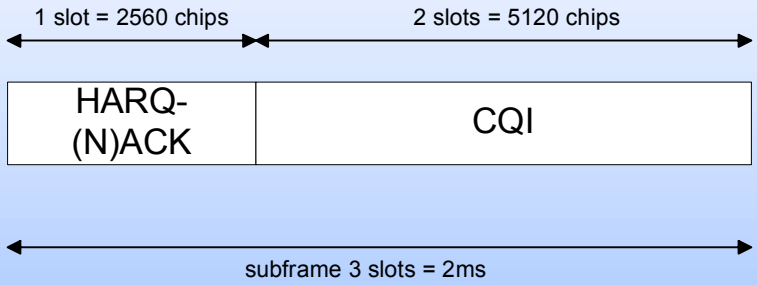
– New data indicator (1 bit): $x_{nd,1}$

This parameter indicates if the transmitted data is for the defined HARQ-process is new. The value is therefore toggled for new data, i.e. for a retransmission it has the same value as for the first transmission.

HSDPA DL timing

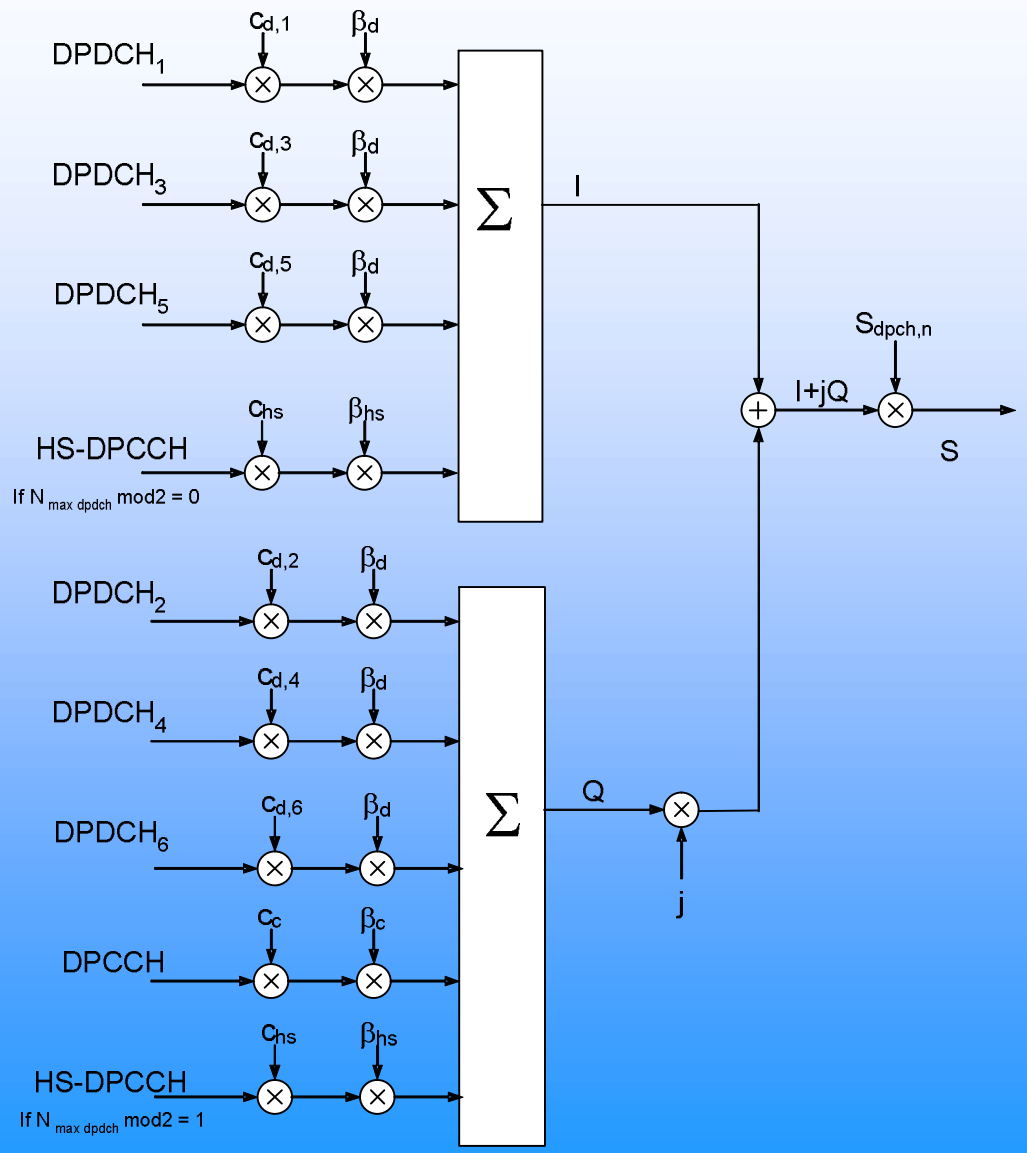


HS-DPCCH frame structure

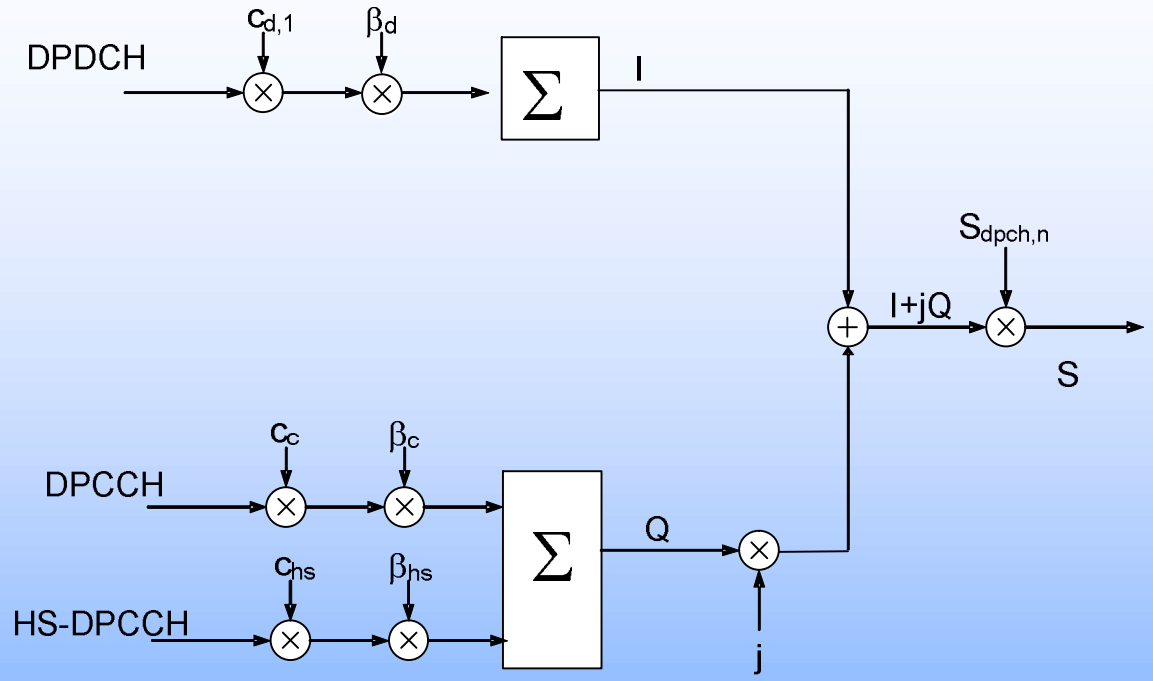


Subframe #i-1	Subframe #i	Subframe #i+1

UL channel structure



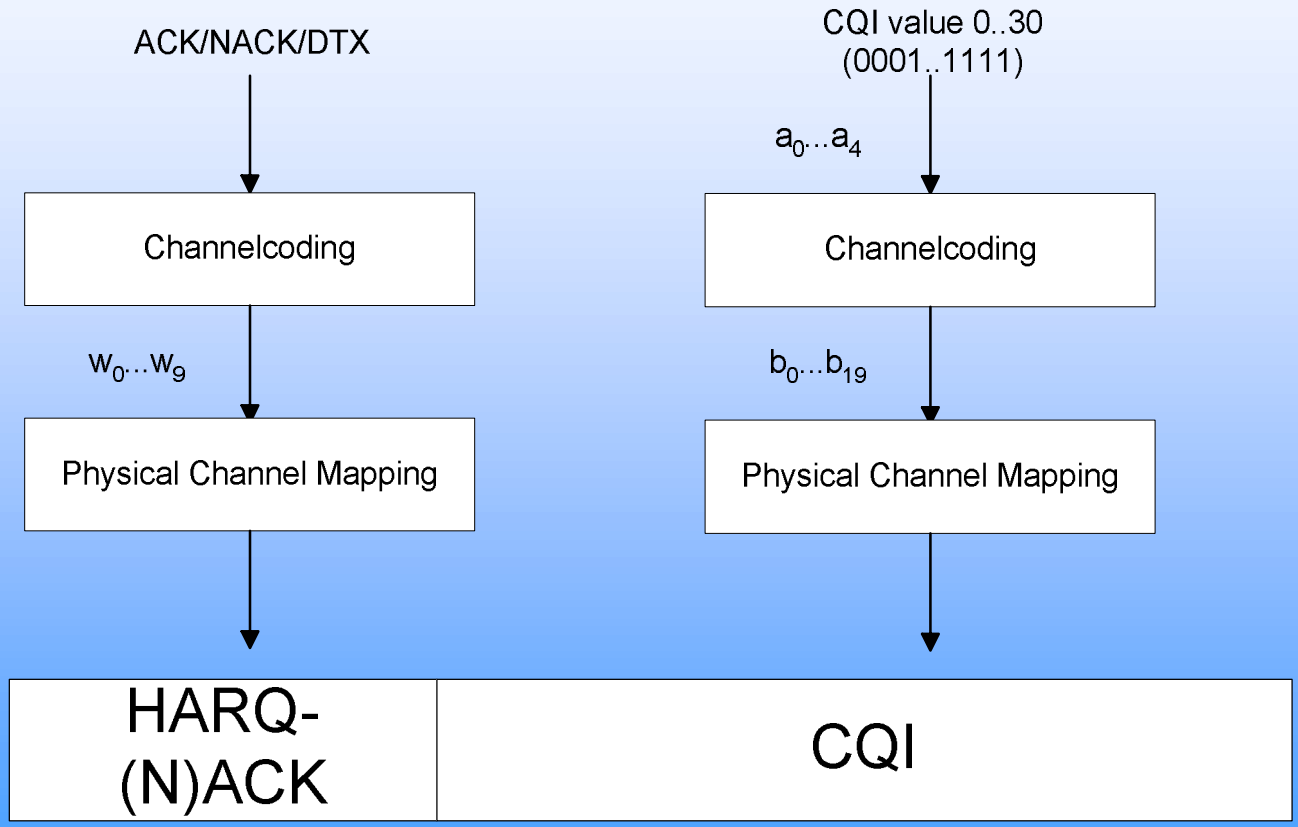
UL channel structure



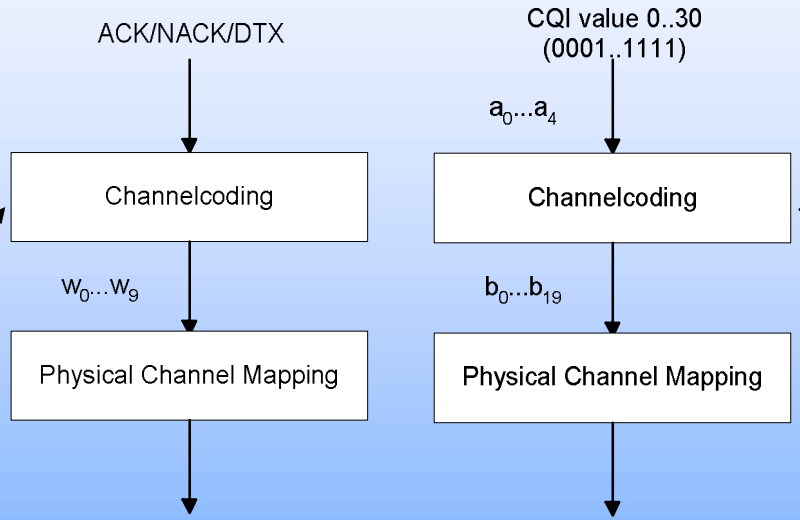
Power Offset $\Delta_{HS\text{-}DPCCH}$:

Δ_{ACK}, Δ_{NACK} and Δ_{CQI}

Signalling values for D_{ACK}, D_{NACK} and D_{CQI}	Quantized amplitude ratios for $10^{\left(\frac{\Delta_{HS-DPCCH}}{20}\right)}$
8	30/15
7	24/15
6	19/15
5	15/15
4	12/15
3	9/15
2	8/15
1	6/15
0	5/15


ACK/NACK/DTX
CQI value 0..30
(0001..1111)
$a_0...a_4$
Channelcoding
Channelcoding
$w_0...w_9$
$b_0...b_{19}$
Physical Channel Mapping
Physical Channel Mapping
HARQ-
(N)ACK
CQI

HS-DPCCH channel coding



i	$M_{i,0}$	$M_{i,1}$	$M_{i,2}$	$M_{i,3}$	$M_{i,4}$
0	1	0	0	0	1
1	0	1	0	0	1
2	1	1	0	0	1
3	0	0	1	0	1
4	1	0	1	0	1
5	0	1	1	0	1
6	1	1	1	0	1
7	0	0	0	1	1
8	1	0	0	1	1
9	0	1	0	1	1
10	1	1	0	1	1
11	0	0	1	1	1
12	1	0	1	1	1
13	0	1	1	1	1
14	1	1	1	1	1
15	0	0	0	0	1
16	0	0	0	0	1
17	0	0	0	0	1
18	0	0	0	0	1
19	0	0	0	0	1

$$b_i = \sum_{n=0}^{4} (a_n \times M_{i,n}) \bmod 2$$

HARQ-ACK message to be transmitted	w_0	w_1	w_2	w_3	w_4	w_5	w_6	w_7	w_8	w_9
ACK	1	1	1	1	1	1	1	1	1	1
NACK	0	0	0	0	0	0	0	0	0	0

CQI mapping table table

CQI mapping table for UE categories 1 to 6:

CQI value	Transport Block Size	Number of HS-PDSCH	Modulation	Reference power adjustment D	N_{IR}	X_{RV}
. . .	. . .	. . .	. . .	. . .	9600	0
9	931	2	QPSK	0		
10	1262	3	QPSK	0		
11	1483	3	QPSK	0		
12	1742	3	QPSK	0		
13	2279	4	QPSK	0		
14	2583	4	QPSK	0		
15	3319	5	QPSK	0		
16	3565	5	16-QAM	0		
17	4189	5	16-QAM	0		
18	4664	5	16-QAM	0		
19	5287	5	16-QAM	0		
20	5887	5	16-QAM	0		
21	6554	5	16-QAM	0		
22	7168	5	16-QAM	0		
23	7168	5	16-QAM	-1		
24	7168	5	16-QAM	-2		
. . .	. . .	. . .	. . .	. . .		

Channel configuration acc. to CQI
à PER <= 10 %

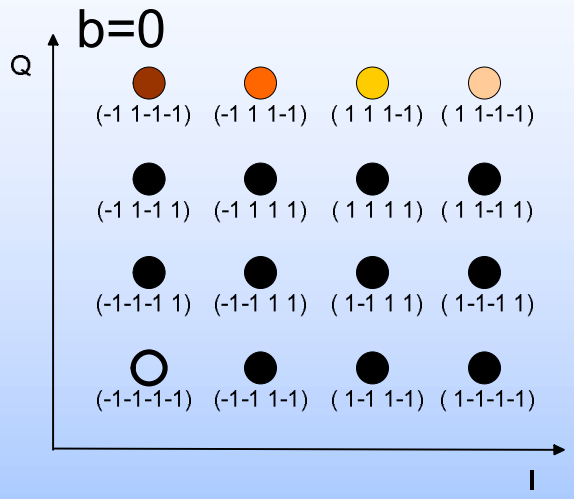
à *UE CQI test cases*

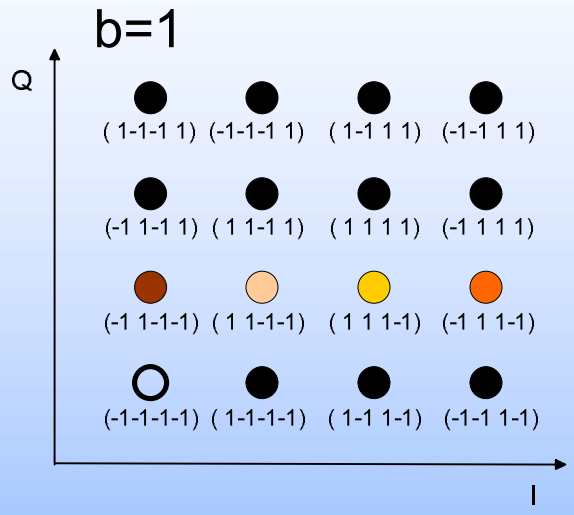
x0, x1, x2, x3 **à**

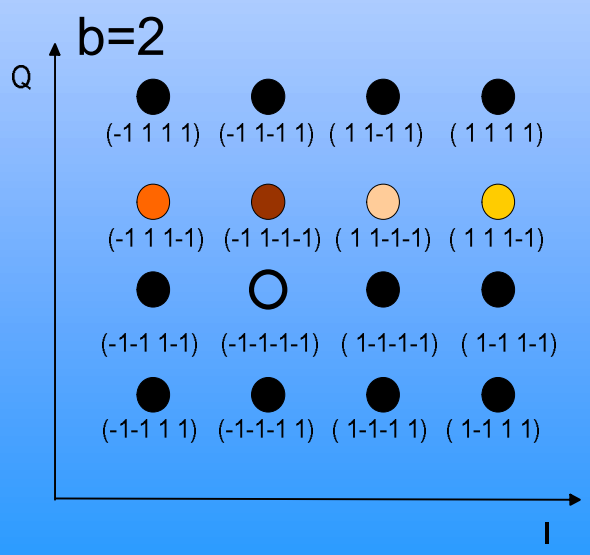
Constellation version parameter b:

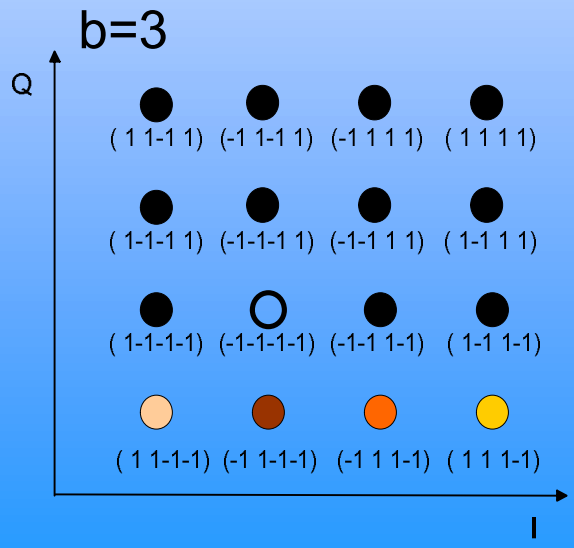
0: x0, x1, x2, x3
1: x2, x3, x0, x1
2: x0, x1, -x2, -x3
3: x2, x3, -x0, -x1

à y1, y2, y3, y4

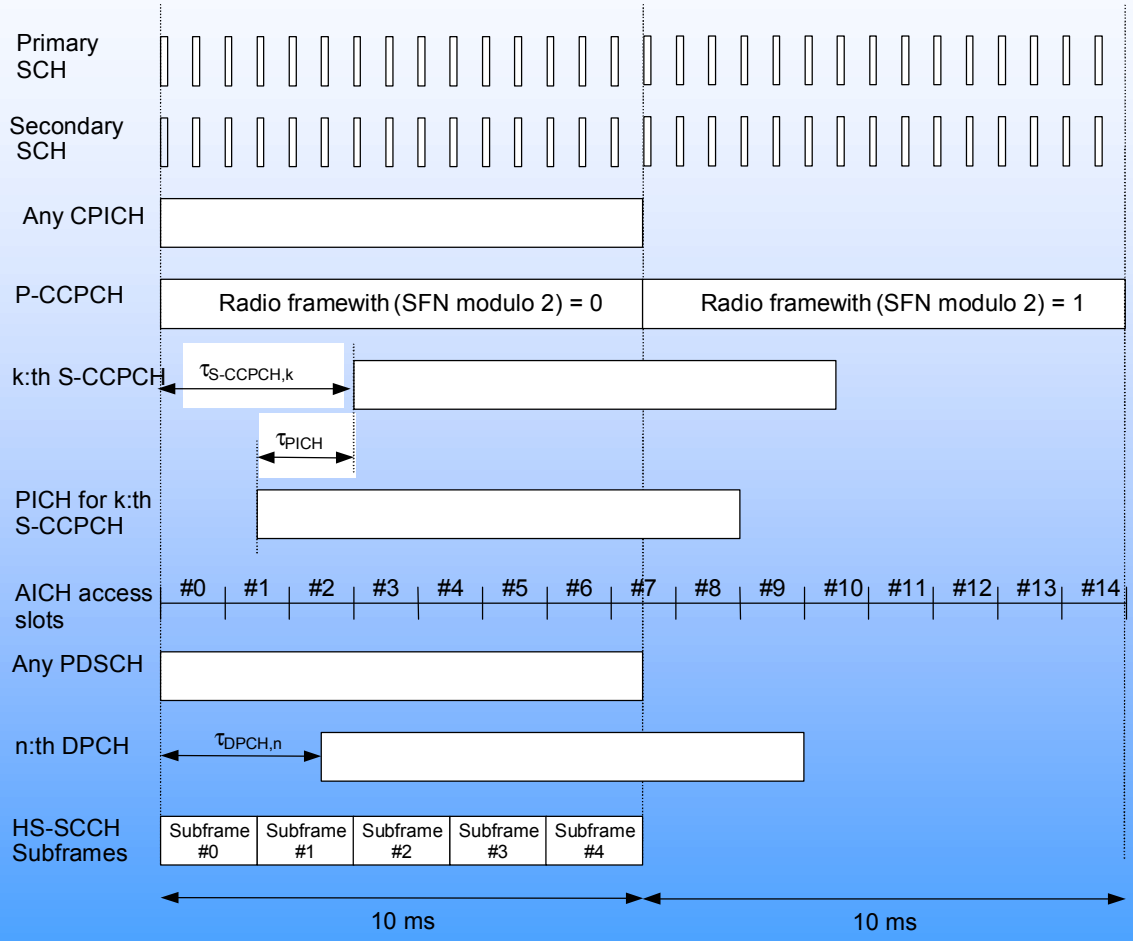

b=0
Q
I
(-1 1-1-1) (-1 1 1-1) (1 1 1-1) (1 1-1-1)
(-1 1-1 1) (-1 1 1 1) (1 1 1 1) (1 1-1 1)
(-1-1-1 1) (-1-1 1 1) (1-1 1 1) (1-1-1 1)
(-1-1-1-1) (-1-1 1-1) (1-1 1-1) (1-1-1-1)


b=1
Q
I
(1-1-1 1) (-1-1-1 1) (1-1 1 1) (-1-1 1 1)
(-1 1-1 1) (1 1-1 1) (1 1 1 1) (-1 1 1 1)
(-1 1-1-1) (1 1-1-1) (1 1 1-1) (-1 1 1-1)
(-1-1-1-1) (1-1-1-1) (1-1 1-1) (-1-1 1-1)

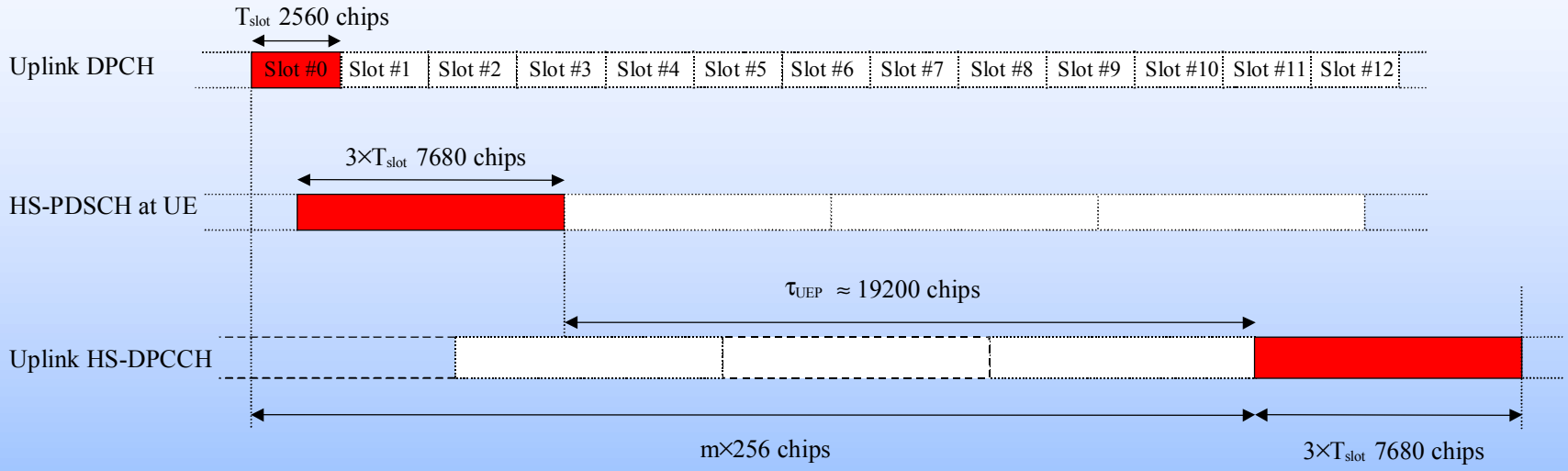

b=2
Q
I
(-1 1 1 1) (-1 1-1 1) (1 1-1 1) (1 1 1 1)
(-1 1 1-1) (-1 1-1-1) (1 1-1-1) (1 1 1-1)
(-1-1 1-1) (-1-1-1-1) (1-1-1-1) (1-1 1-1)
(-1-1 1 1) (-1-1-1 1) (1-1-1 1) (1-1 1 1)


b=3
Q
I
(1 1-1 1) (-1 1-1 1) (-1 1 1 1) (1 1 1 1)
(1-1-1 1) (-1-1-1 1) (-1-1 1 1) (1-1 1 1)
(1-1-1-1) (-1-1-1-1) (-1-1 1-1) (1-1 1-1)
(1 1-1-1) (-1 1-1-1) (-1 1 1-1) (1 1 1-1)

DL Channel Timing

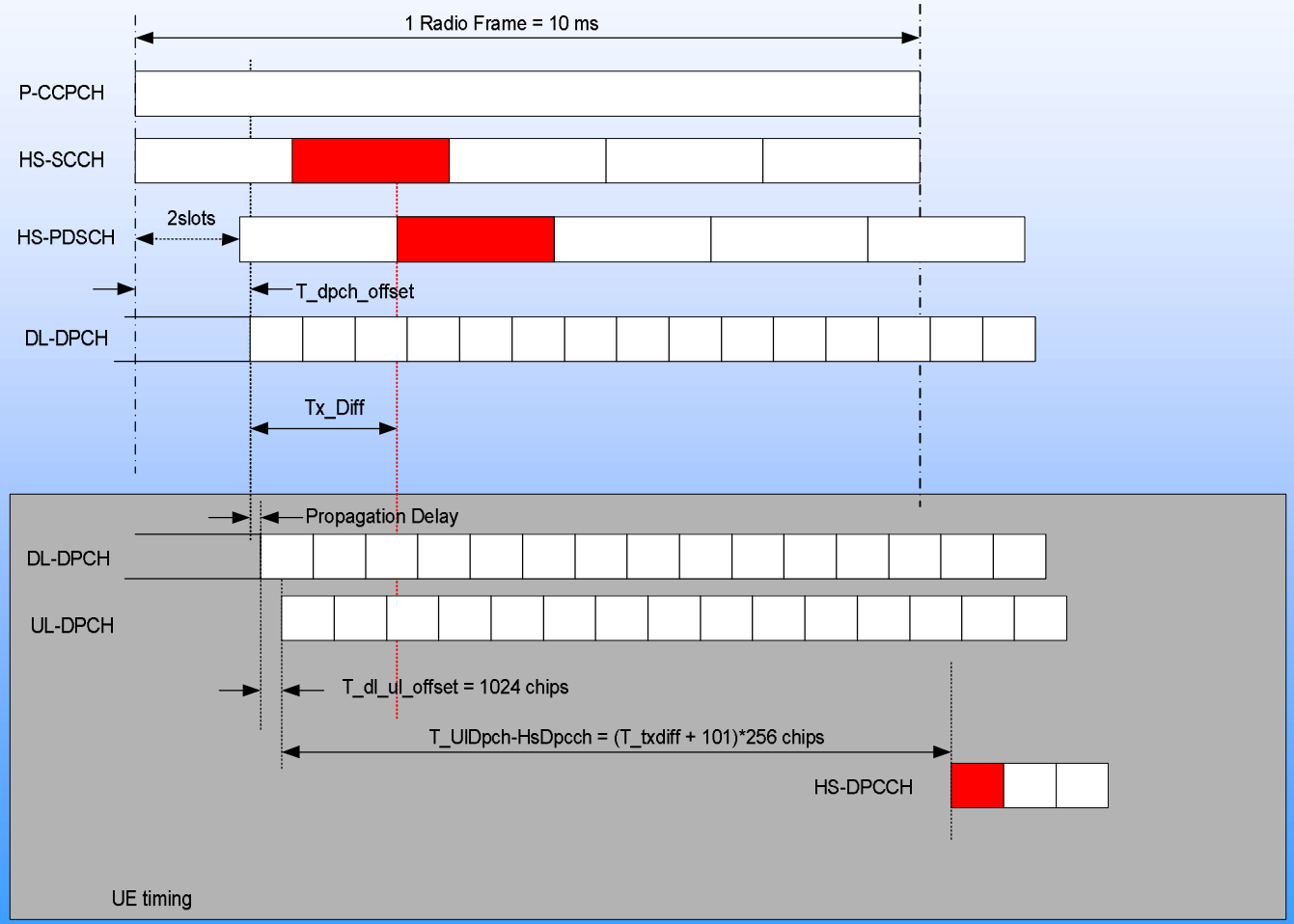


HSDPA UL HS-DPCCH Timing

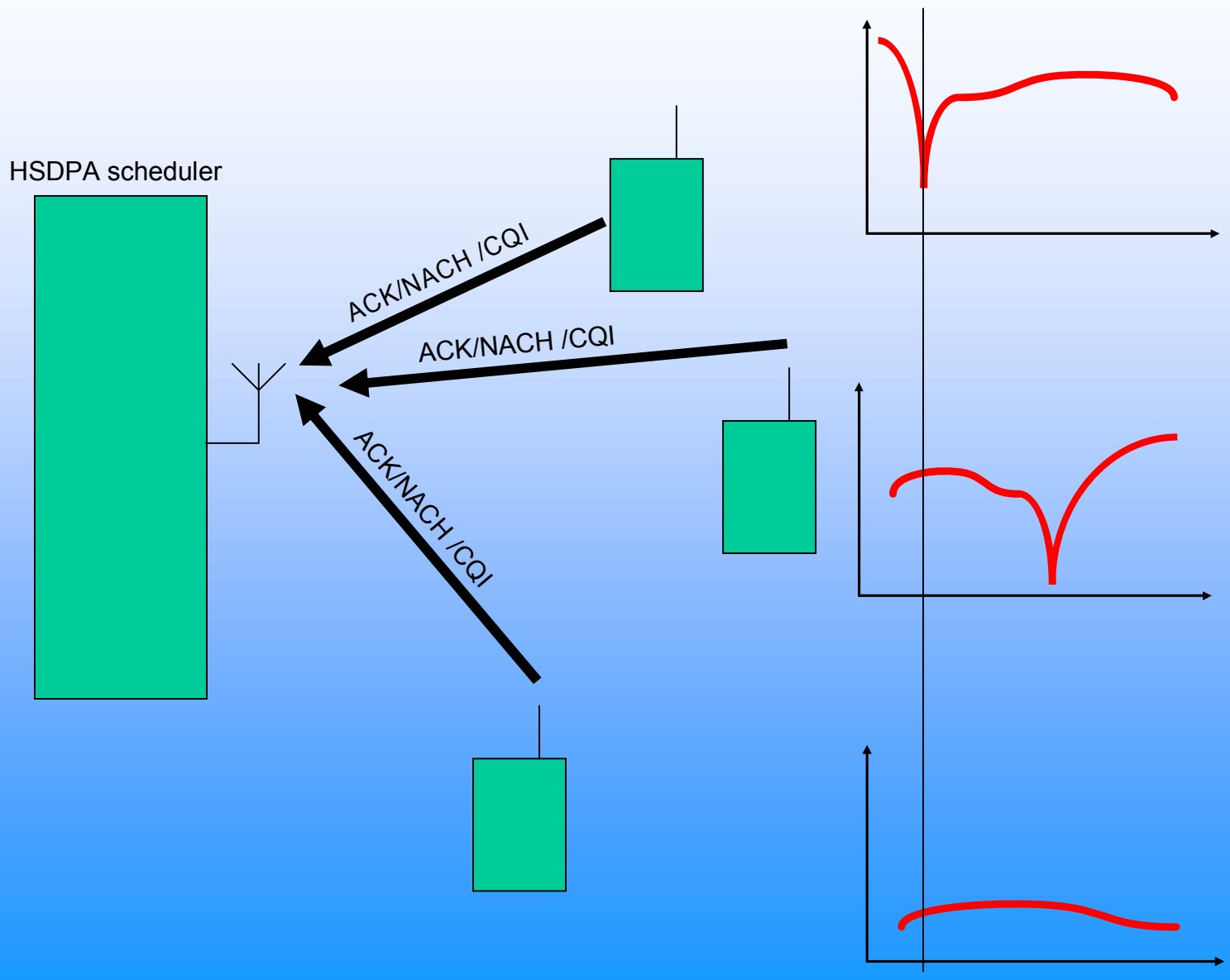


ACK/NACK processing time in UE ≈ 5 ms

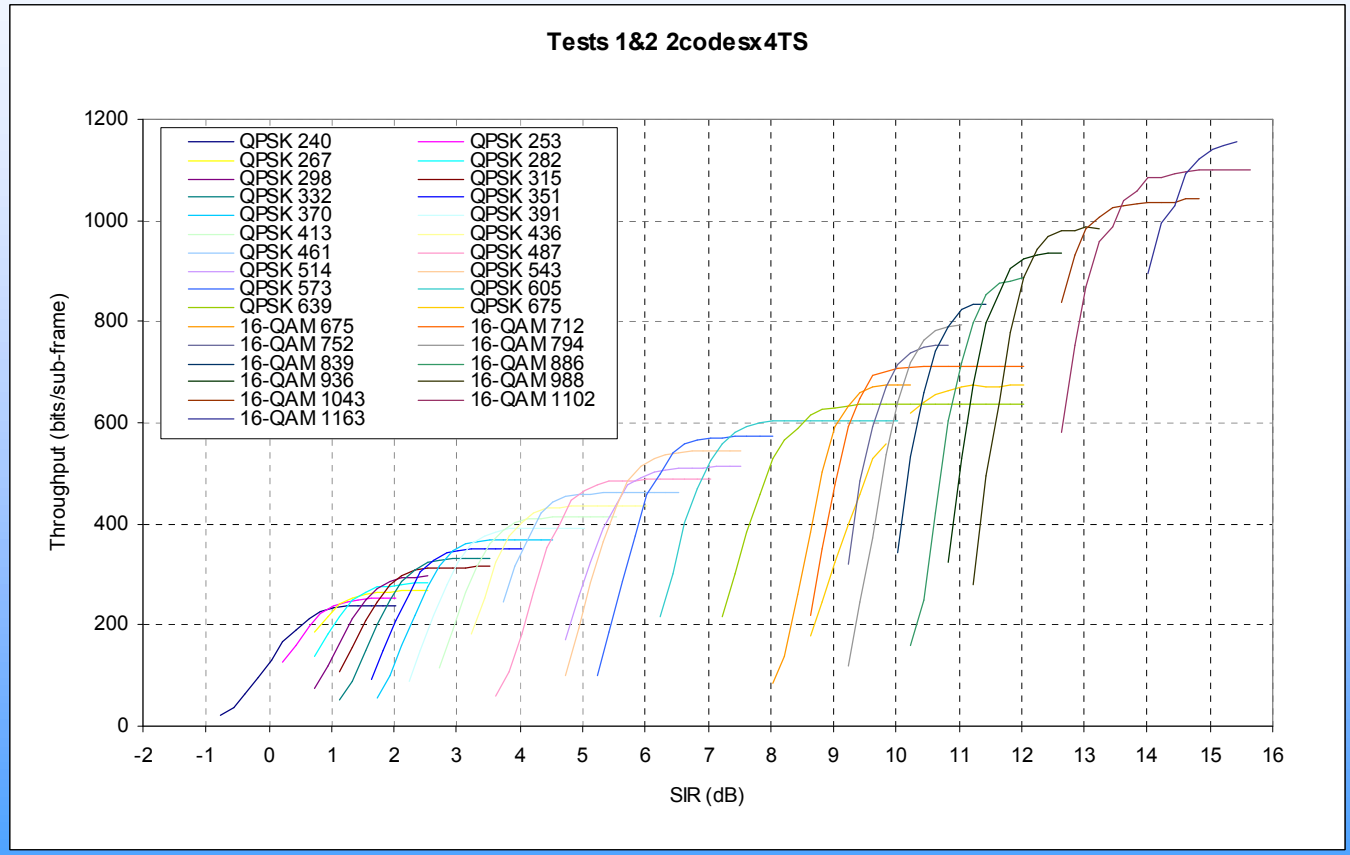
HSDPA timing



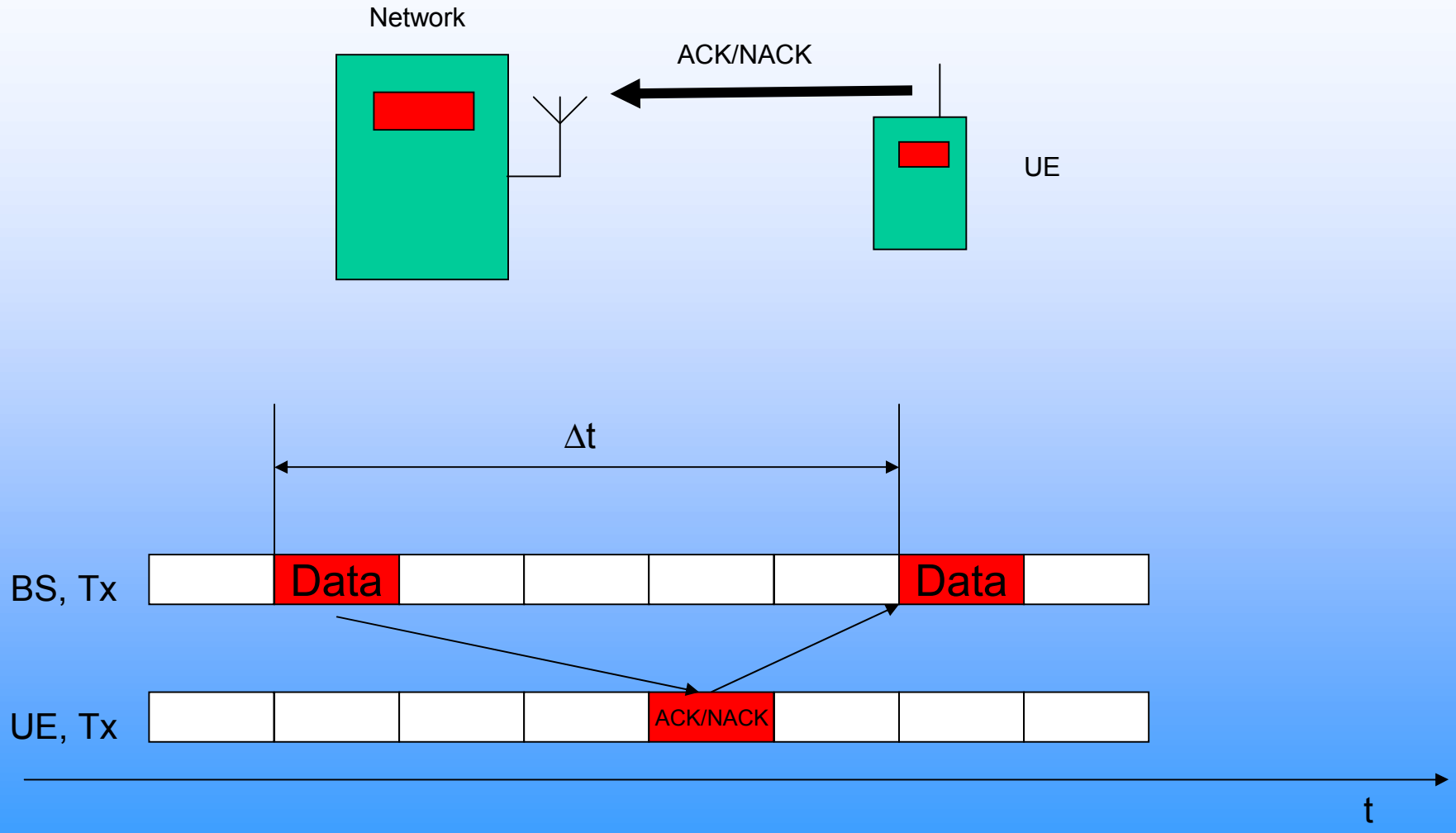
HSDPA CQI scheduler



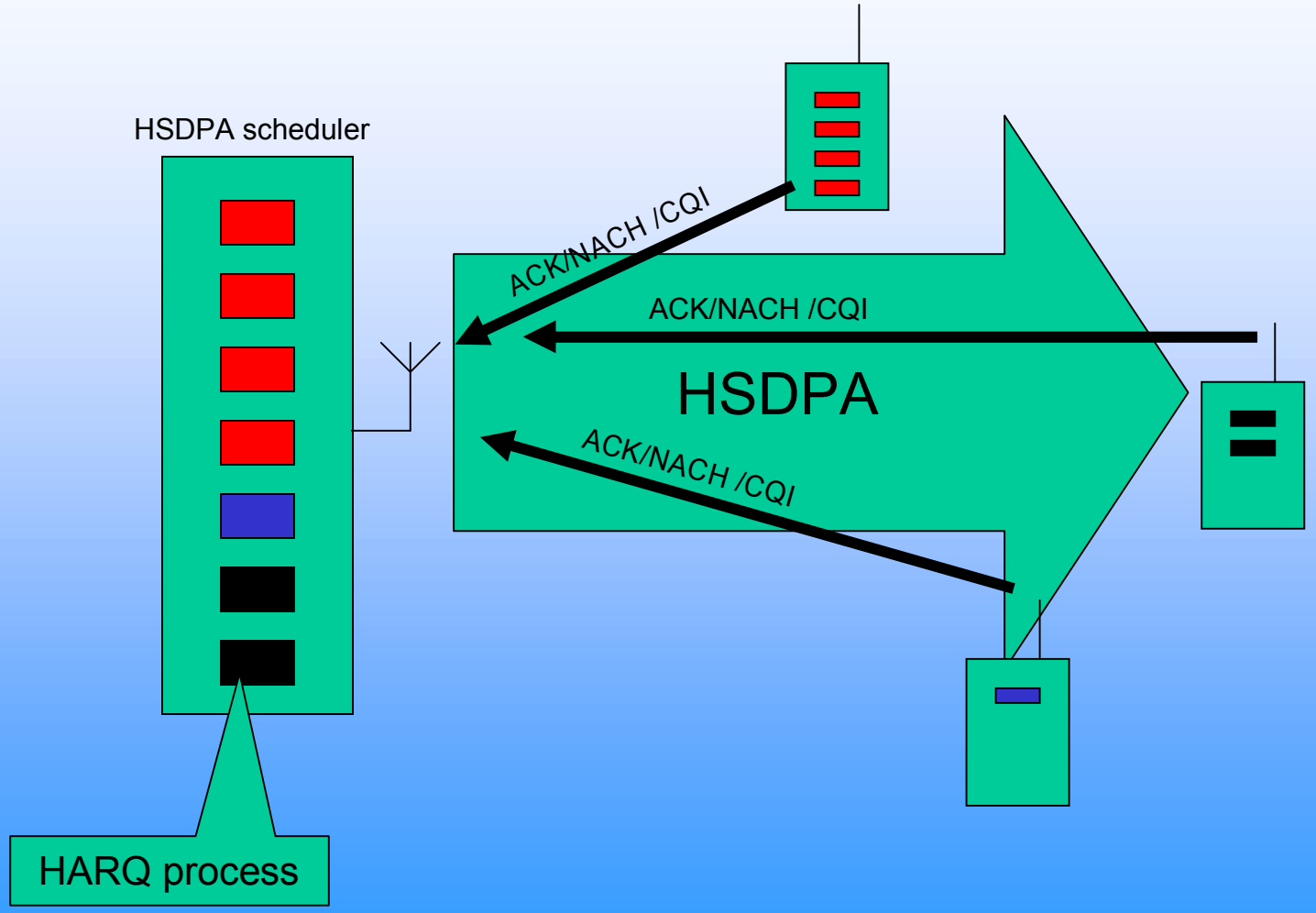
Adaptive modulation and coding (AMC)



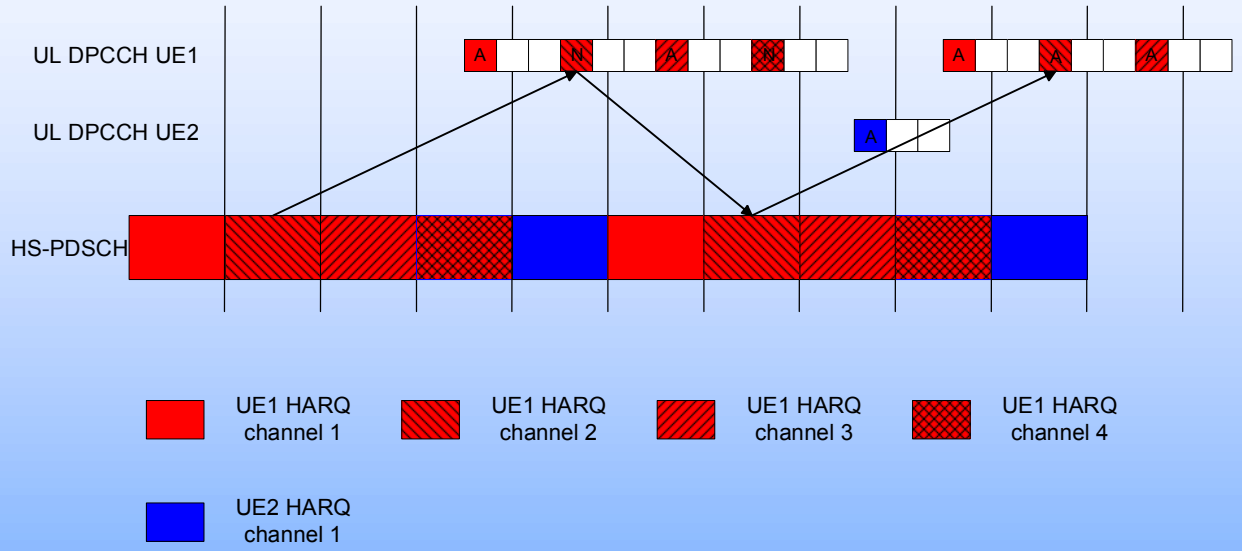
Stop and Wait Protocol (SAW)



HSDPA N-channel SAW ARQ scheduler



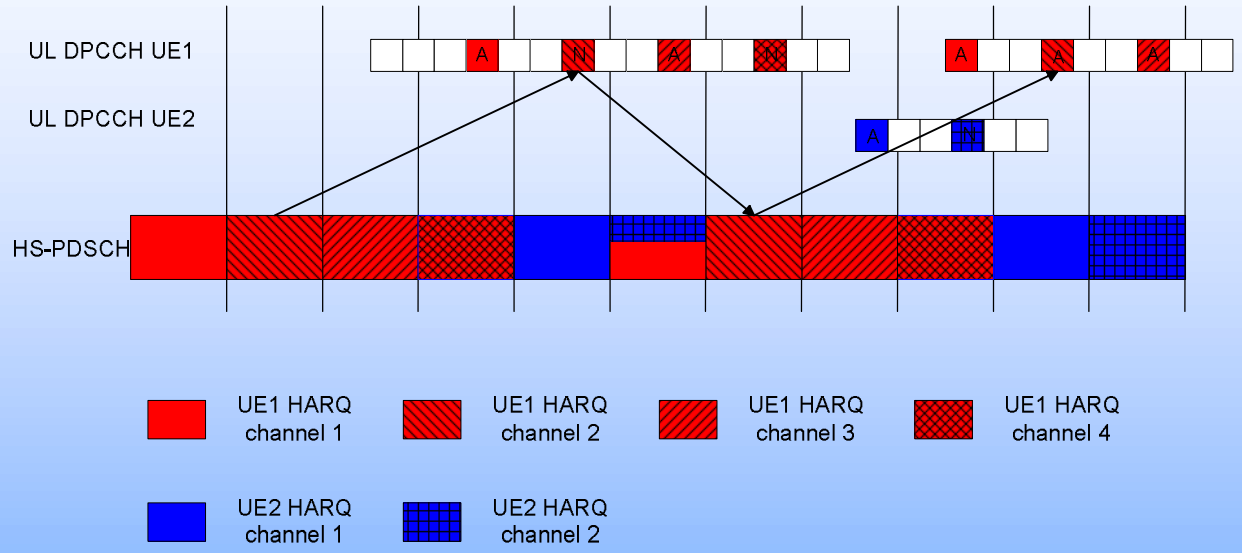
HSDPA N-channel SAW ARQ



asynchronous DL - synchronous UL

No. of H-ARQ process = 1..8 per UE

HSDPA N-channel SAW ARQ



asynchronous DL - synchronous UL

No. of H-ARQ process = 1..8 per UE

HSDPA UE Capability

ROHDE & SCHWARZ

HS-DSCH category	Maximum number of HS-DSCH codes received	Minimum inter-TTI interval	Maximum number of bits of an HS-DSCH transport block received within an HS-DSCH TTI	Total number of soft channel bits
Category 1	5	3	7298	19200
Category 2	5	3	7298	28800
Category 3	5	2	7298	28800
Category 4	5	2	7298	38400
Category 5	5	1	7298	57600
Category 6	5	1	7298	67200
Category 7	10	1	14411	115200
Category 8	10	1	14411	134400
Category 9	15	1	20251	172800
Category 10	15	1	27952	172800
Category 11*	5	2	3630	14400
Category 12*	5	1	3630	28800

1.2 Mbps class | 3.6 Mbps class | 7 Mbps class | 10 Mbps class

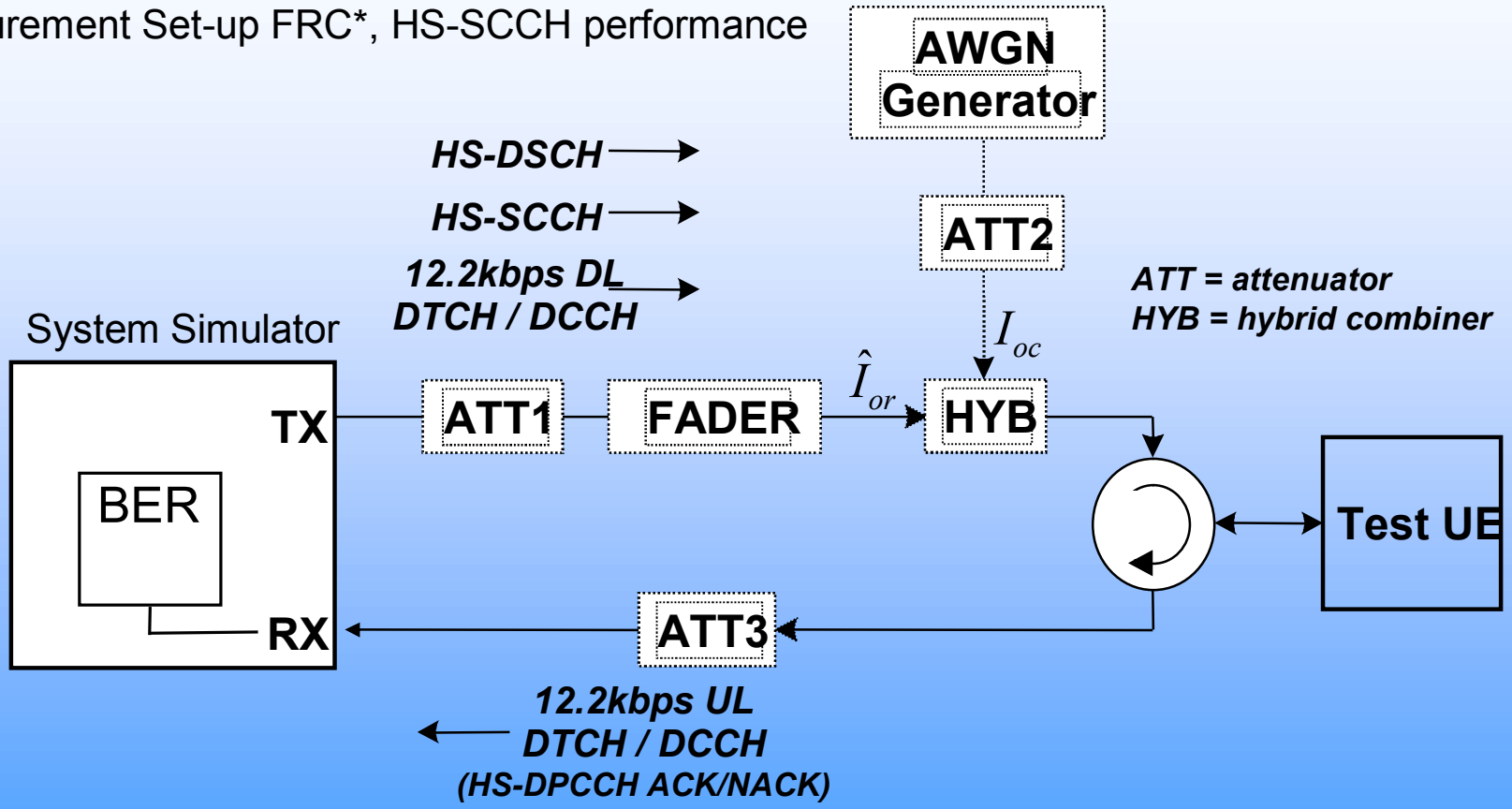
*QPSK only

ROHDE & SCHWARZ

HSDPA – UE Testing

ROHDE & SCHWARZ

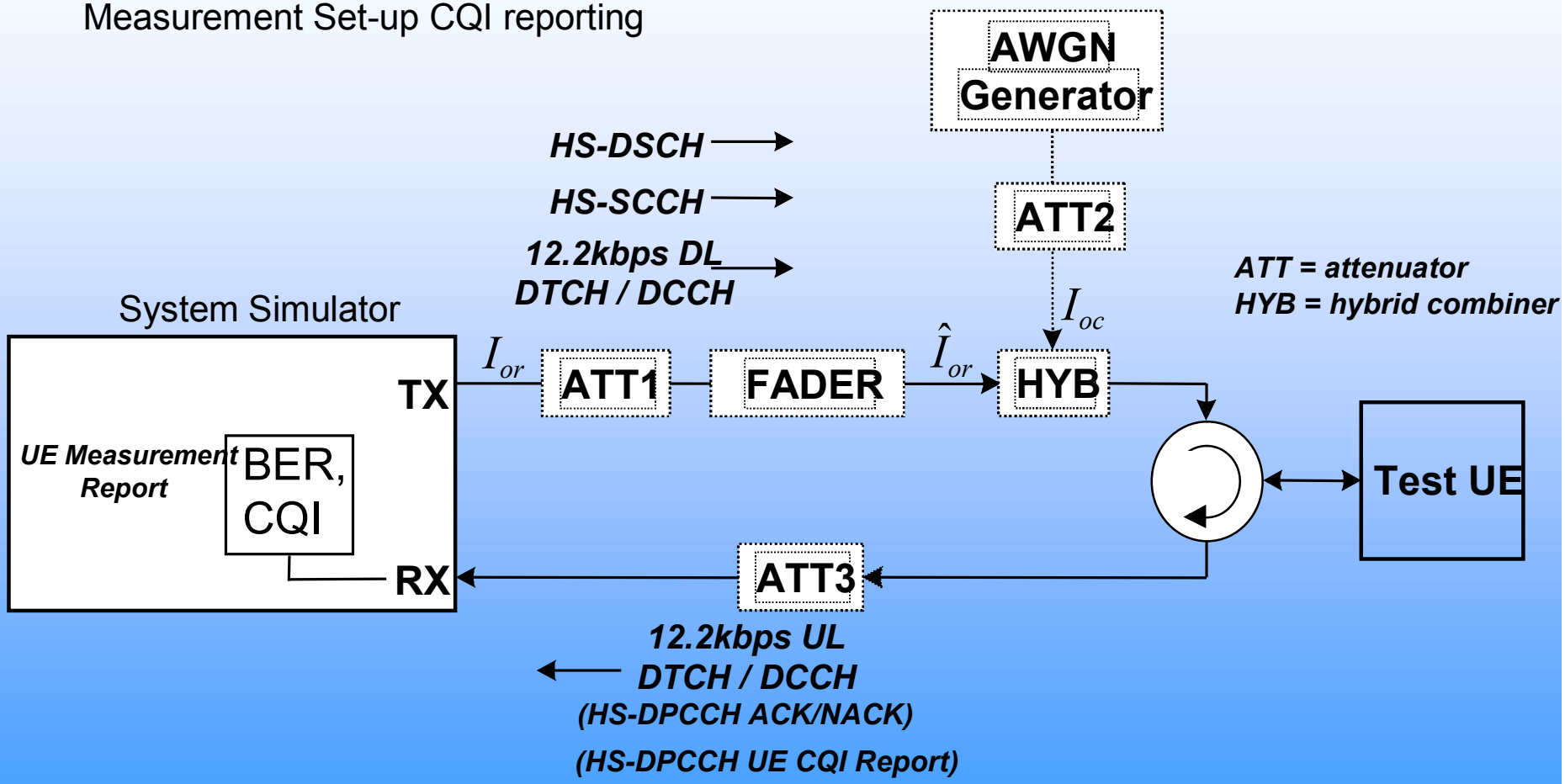
Measurement Set-up FRC*, HS-SCCH performance



*FRC: Fixed Rate Channel

ROHDE & SCHWARZ

Measurement Set-up CQI reporting



HSDPA – UE Testing -RF-

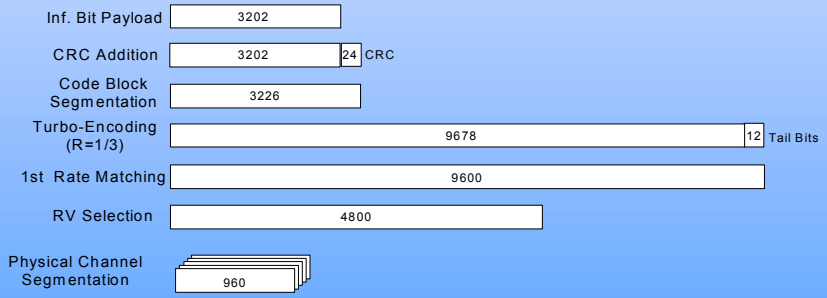
HS-DSCH category	Corresponding requirement
Category 1	H-Set 1
Category 2	H-Set 1
Category 3	H-Set 2
Category 4	H-Set 2
Category 5	H-Set 3
Category 6	H-Set 3
Category 11	H-Set 4
Category 12	H-Set 5

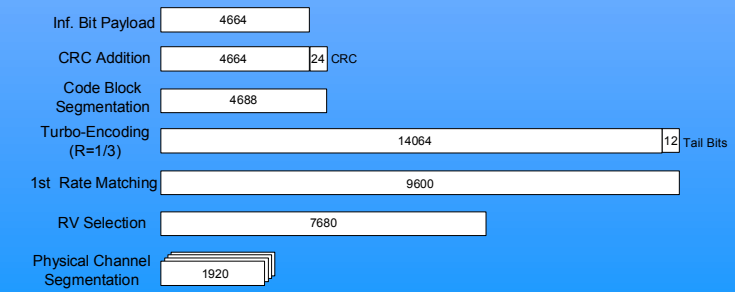
Test Number	Propagation Conditions	Reference value		
		(dB)	= 0 dB	= 10 dB
1	PA3	-6	65	309
		-3	N/A	423
2	PB3	-6	23	181
		-3	138	287
3	VA30	-6	22	190
		-3	142	295
4	VA120	-6	13	181
		-3	140	275

* Notes: 1) The reference value R is for the Fixed Reference Channel (FRC) H-Set 1
2) For Fixed Reference Channel (FRC) H-Set 2 the reference values for R should be scaled (multiplied by 1.5 and rounding to the nearest integer t-put in kbps, where values of i+1/2 are rounded up to i+1, i integer)
3) For Fixed Reference Channel (FRC) H-Set 3 the reference values for R should be scaled (multiplied by 3 and rounding to the nearest integer t-put in kbps, where values of i+1/2 are rounded up to i+1, i integer)

HSDPA – UE Testing -RF-

HS-DSCH category	Corresponding requirement
Category 1	H-Set 1
Category 2	H-Set 1
Category 3	H-Set 2
Category 4	H-Set 2
Category 5	H-Set 3
Category 6	H-Set 3
Category 11	H-Set 4
Category 12	H-Set 5





Parameter	Unit	Value	
Nominal Avg. Inf. Bit Rate	kbps	534	777
Inter-TTI Distance	TTI's	3	3
Number of HARQ Processes	Proce sses	2	2
Information Bit Payload	Bits	3202	4664
Number Code Blocks	Blocks	1	1
Binary Channel Bits Per TTI	Bits	4800	7680
Total Available SML's in UE	SML's	19200	19200
Number of SML's per HARQ Proc.	SML's	9600	9600
Coding Rate		0.67	0.61
Number of Physical Channel Codes	Codes	5	4
Modulation		QPSK	16QA M

HSDPA – UE Testing -Protocol-

34.108 Spec does not exist for Release 5 yet.

Thus no HSDPA coverage (release 5 feature, see above).Currently intensive discussions at 3GPP working groups.

Radio bearer:

1) Interactive or background / UL:64 DL: [max bit rate depending on UE category] / PS RAB + UL:3.4 DL:3.4 kbps SRBs for DCCH

2) Interactive or background / UL:384 DL: [max bit rate depending on UE category] / PS RAB + UL:3.4 DL:3.4 kbps SRBs for DCCH

34.123 No HSDPA protocol tests are defined in the test specification

34.109 Definition of test loops (Applicability of R99 functionality has to be considered)

HSDPA – UE Testing -Protocol-

ROHDE & SCHWARZ

Higher layer	RAB/Signalling RB	**RAB**
RLC	Logical channel type	DTCH
	RLC mode	AM
	Payload sizes, bit	320 (alt. 640)
	Max data rate, bps	depends on UE category NOTE1
	AMD PDU header, bit	16
MAC	MAC-d flow ID	0
	MAC-d header, bit	0
	MAC multiplexing	N/A
	MAC-d PDU size, bit	336 (alt. 656)
	MAC-hs header fixed part, bit	21
	MAC-hs Queue ID	1
Layer 1	TrCH type	HS-DSCH
	TTI	2 ms
	Coding type	TC
	CRC, bit	24

UE HS-DSCH Physical Layer category 6:

HS-PDSCH	Number of processes	6, (alt. 8)
	Process memory size	Split equally among all processes
	Max Data Rate	3.65Mbps, (alt. 3.65Mbps)

Physical Layer testing

- No specific physical layer test cases are considered as those areas are considered implicitly tested by upper layer test cases (Layer 2, Layer 3 and Radio Bearer test cases).
- ´

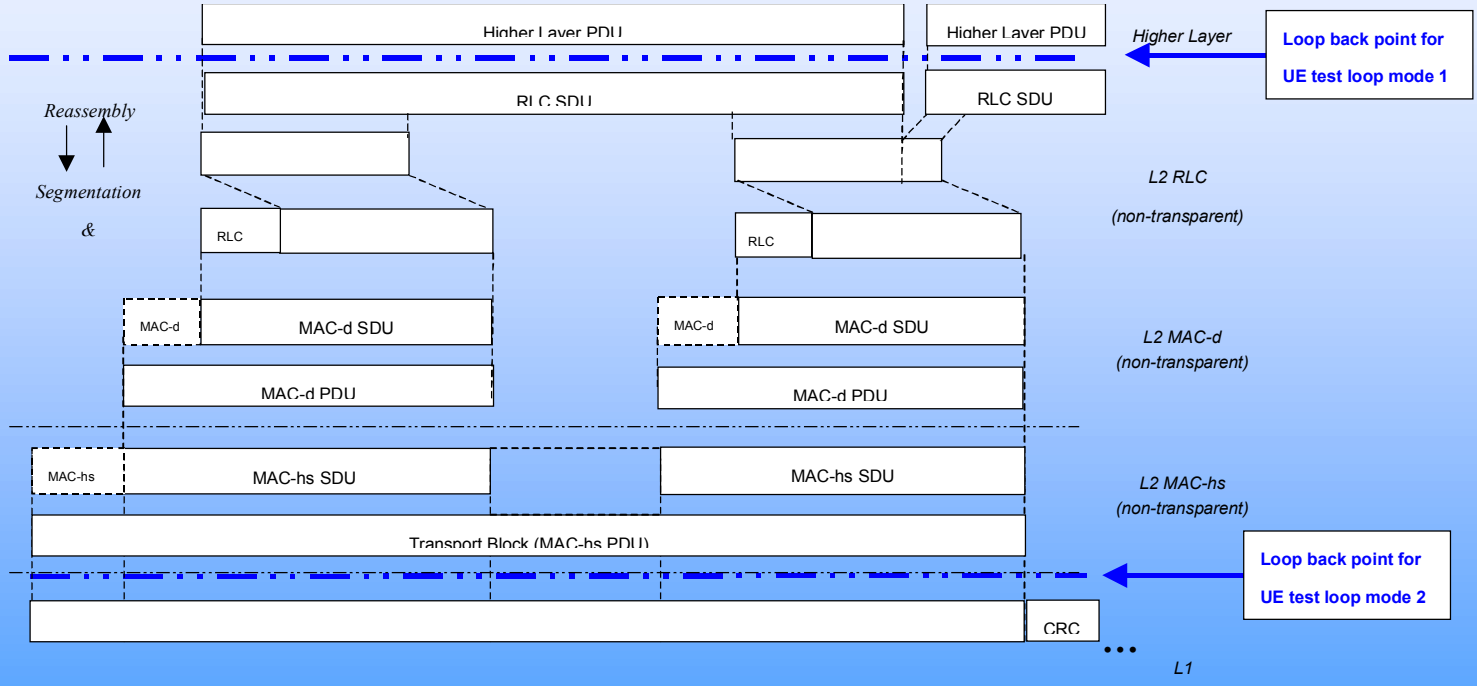
Layer 2 testing

- Radio bearer testing for HS-DSCH is considered to partly cover HS-DSCH Layer 2 testing. Additional Layer 2 testing areas which is identified requiring specific testing are:
- MAC-hs reordering and stall avoidance
- Priority queue handling
- MAC-hs PDU header handling
- MAC-hs retransmissions

RRC testing

- Radio Bearer Establishment procedure. Start and stop of HS-DSCH reception
- Physical Channel Reconfiguration procedure.
  - Start and stop of HS-DSCH reception
  - Serving HS-DSCH cell change with MAC-hs reset
- Active Set Update procedure in soft handover: Radio link addition and serving HS-DSCH cell change

HSDPA – UE Testing -Protocol-



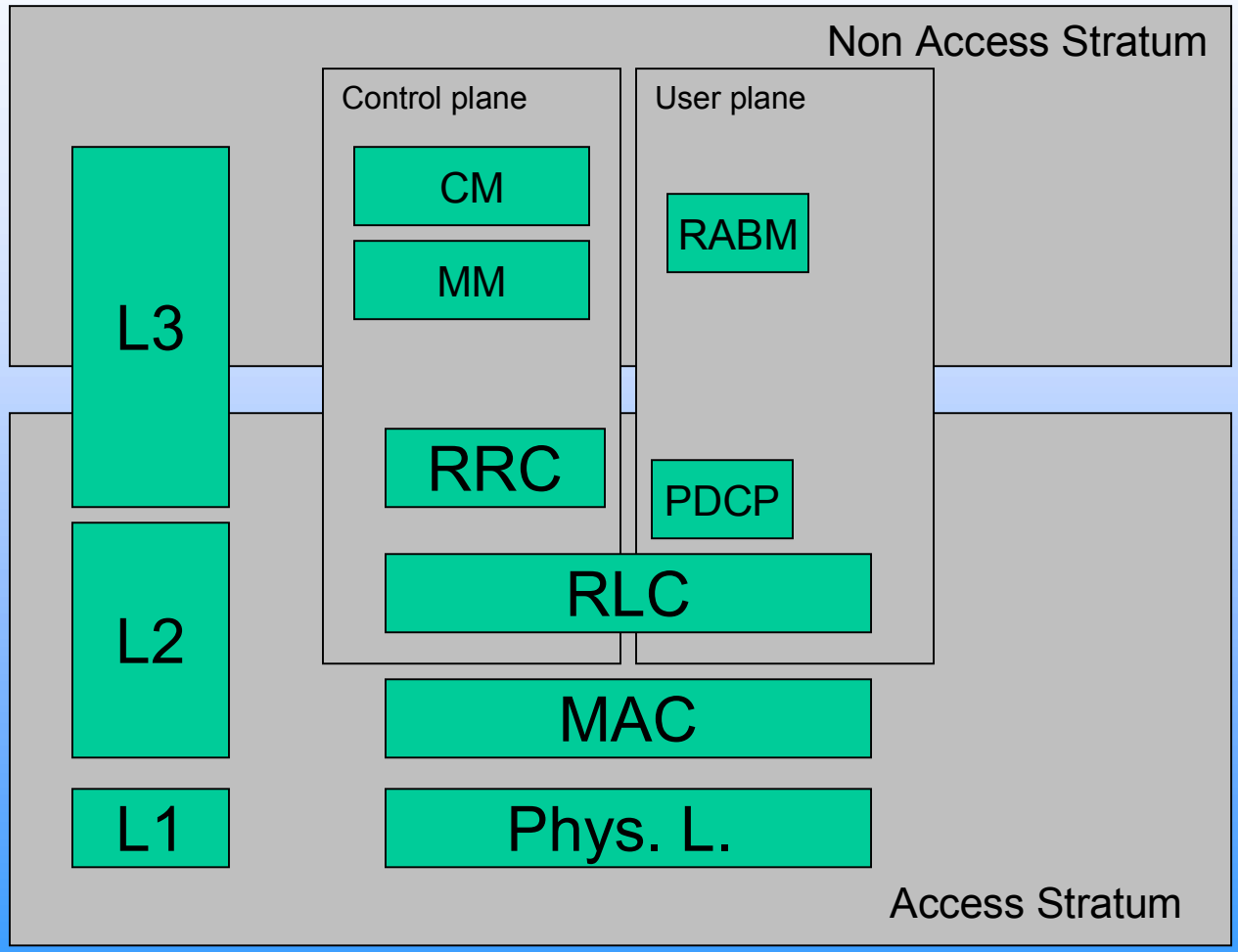
ROHDE&SCHWARZ

HSDPA – Node B Testing

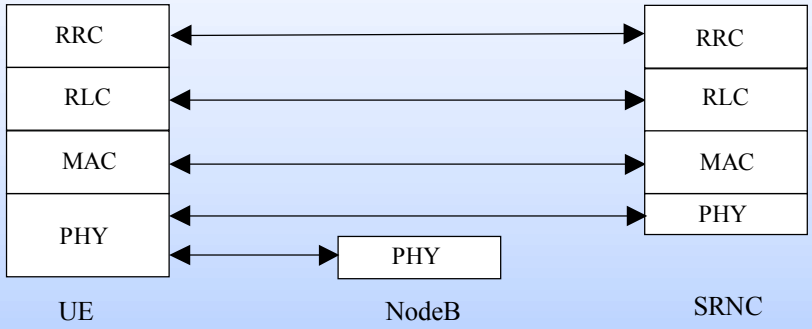
Error Vector Magnitude:
The Error Vector Magnitude is a measure of the difference between the reference waveform and the measured waveform. This difference is called the error vector. Both waveforms pass through a matched Root Raised Cosine filter with bandwidth 3.84 MHz and roll-off a =0.22. Both waveforms are then further modified by selecting the frequency, absolute phase, absolute amplitude and chip clock timing so as to minimise the error vector. The EVM result is defined as the square root of the ratio of the mean error vector power to the mean reference power expressed as a %. The measurement interval is one timeslot as defined by the C-PICH (when present) otherwise the measurement interval is one timeslot starting with the beginning of the SCH._ The requirement is valid over the total power dynamic range as specified in subclause 6.4.3.

Minimum requirement
The Error Vector Magnitude shall not be worse than 17.5 % when the base station is transmitting a composite signal using only QPSK modulation.
The Error Vector Magnitude shall not be worse than 12.5 % when the base station is transmitting a composite signal that includes 16QAM modulation.

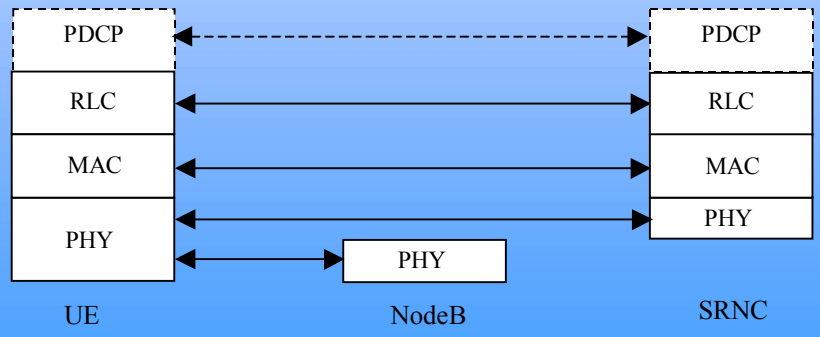
UMTS – OSI structure



Protocol termination for dedicated connection

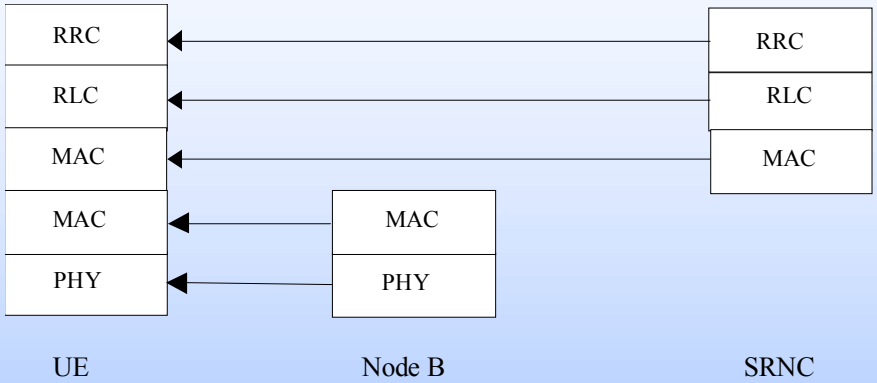


Protocol termination for dedicated control

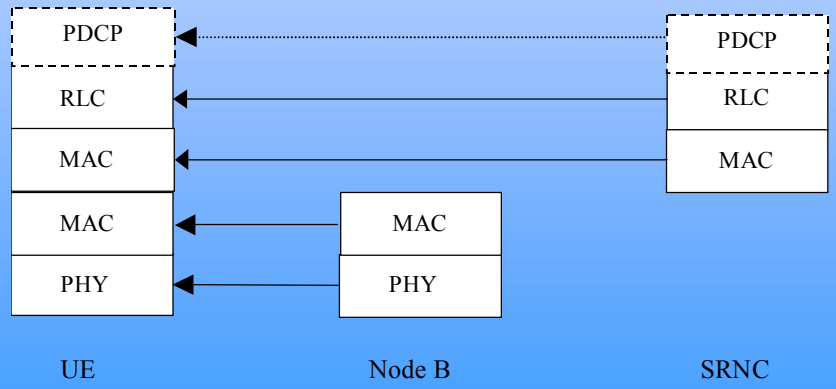


Protocol termination for dedicated traffic

Protocol termination for HSDPA

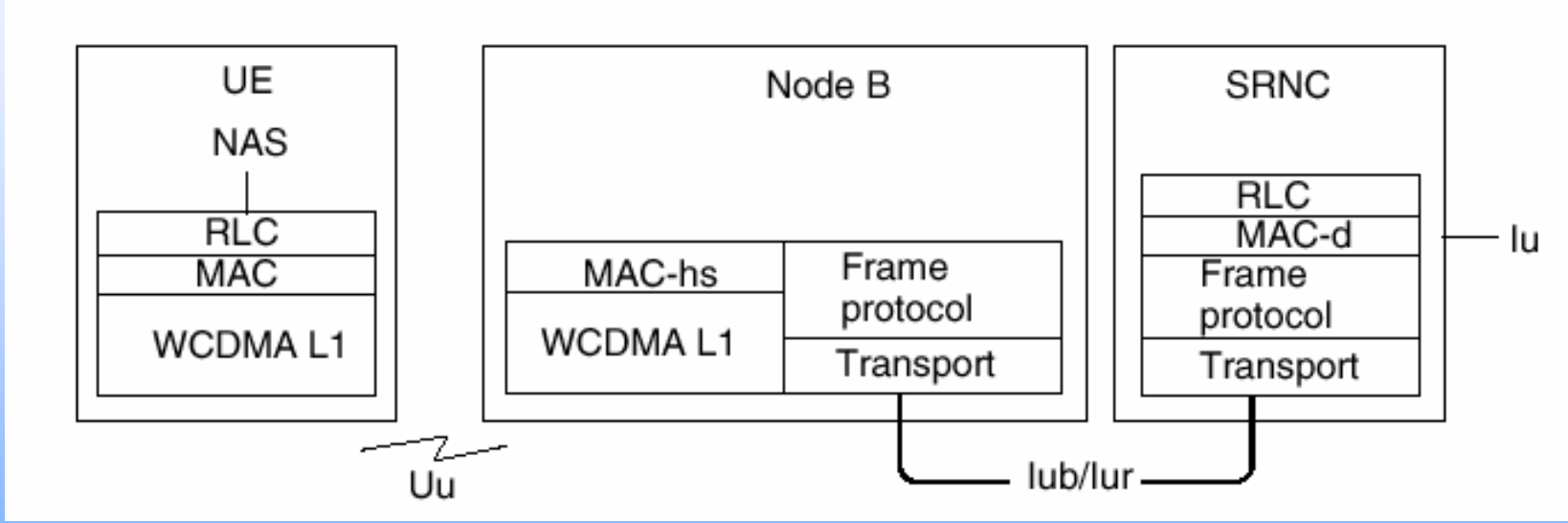


Protocol termination for control plane

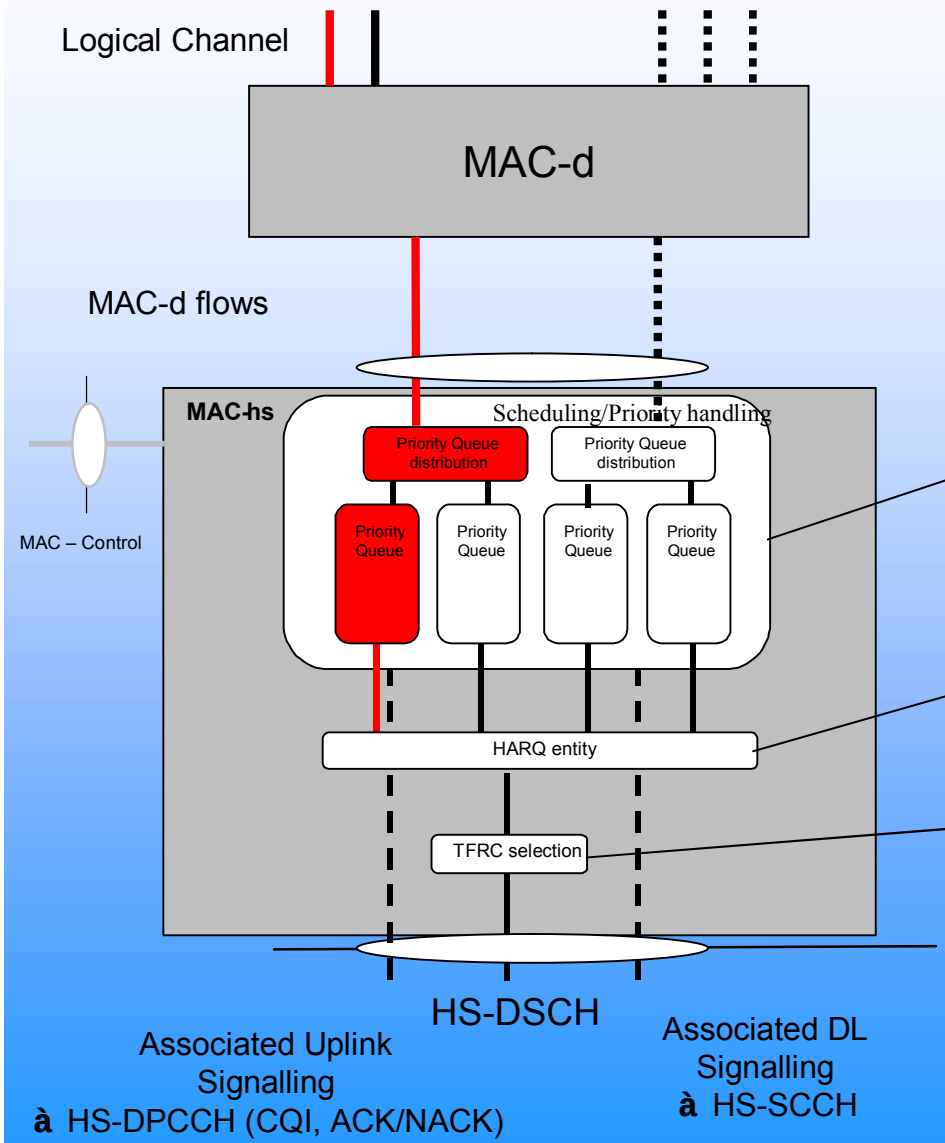


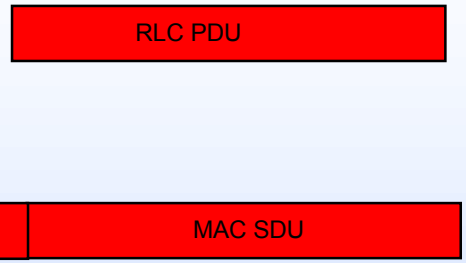
Protocol termination for user plane

HSDPA Architecture



MAC-hs Node B

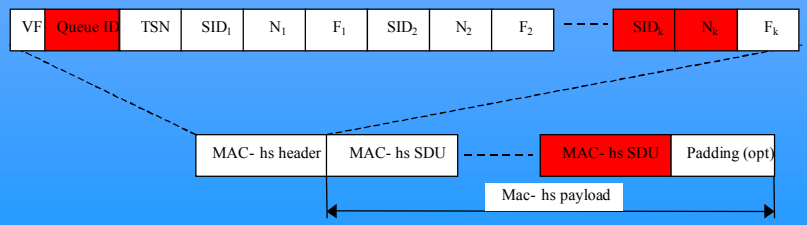




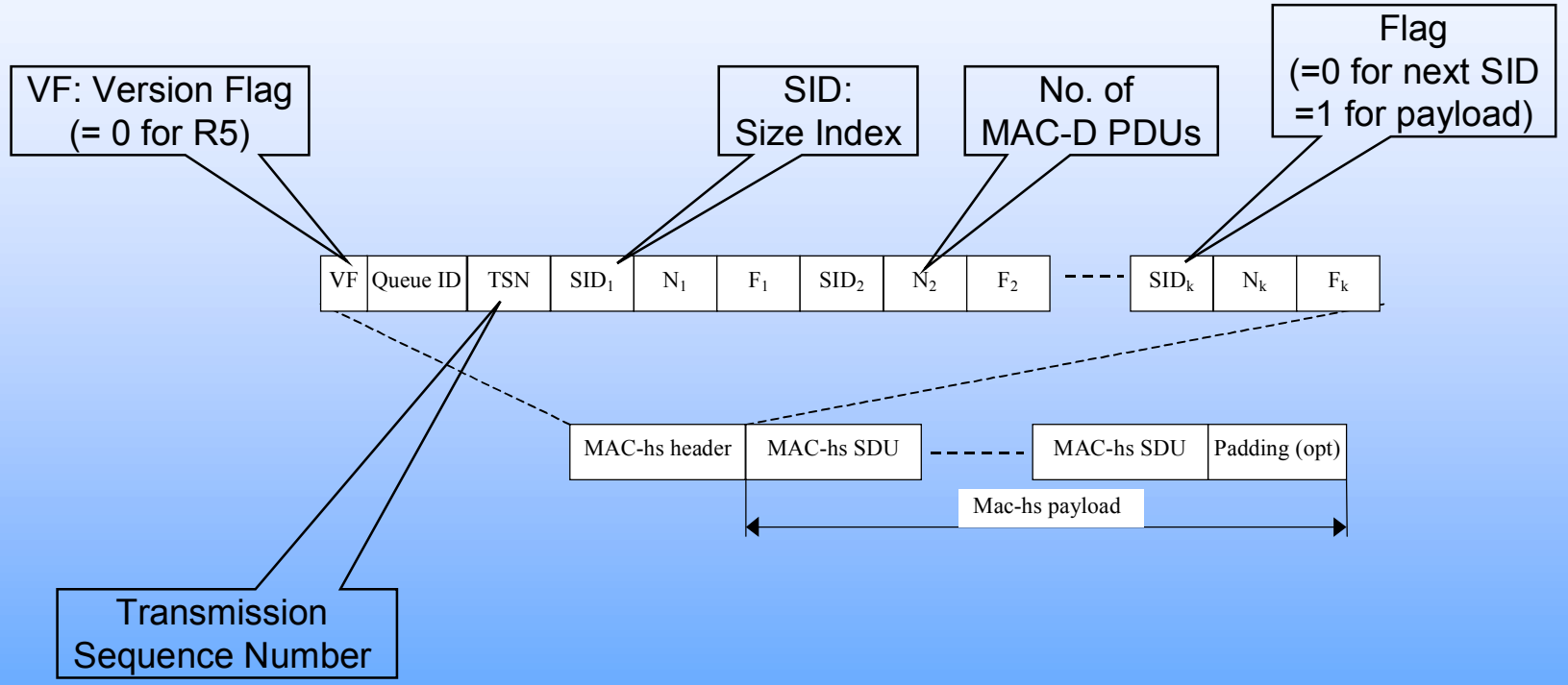
Scheduling:
- CQI analysis
- Priority handling

- Re-ordering Queue selection
- HARQ process
- RV selection

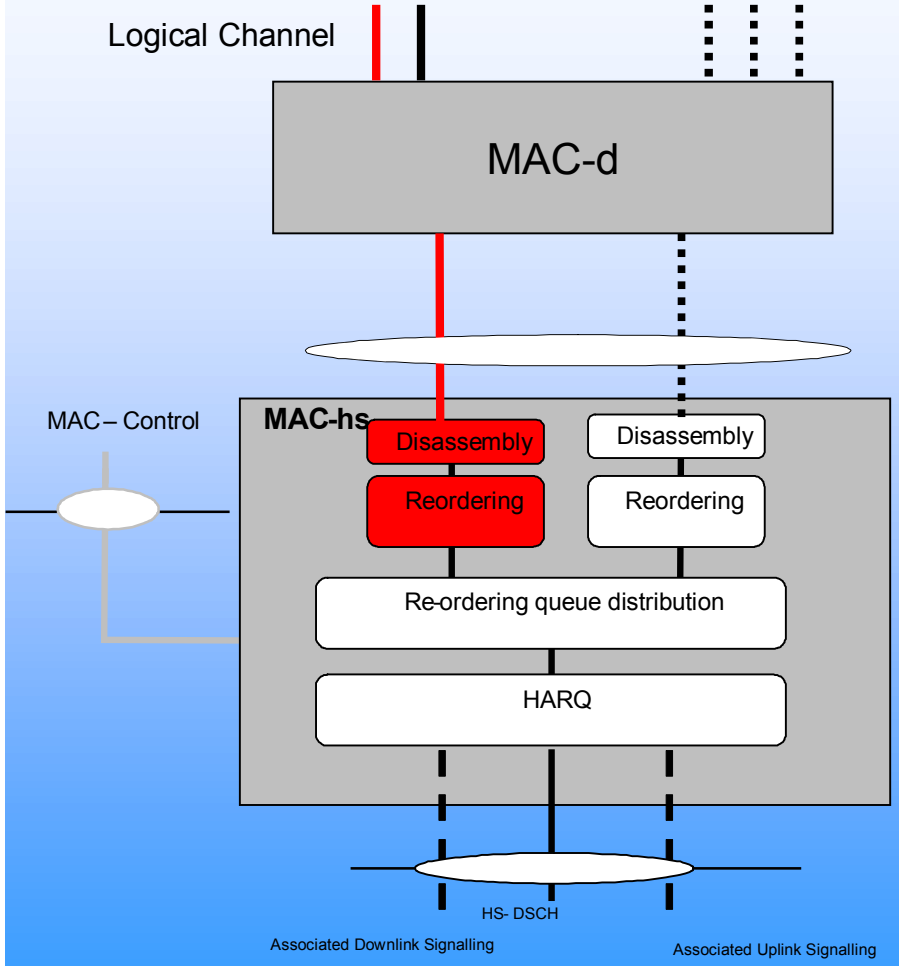
- TFRC selection:
- Transportblock size
- Number of physical channels



HSDPA Data Unit

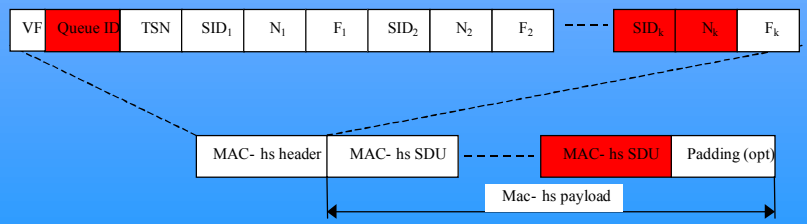


MAC-hs UE


Logical Channel
MAC-d
MAC – Control
MAC-hs
Disassembly
Disassembly
Reordering
Reordering
Re-ordering queue distribution
HARQ
HS- DSCH
Associated Downlink Signalling
Associated Uplink Signalling


RLC PDU


C/T
MAC SDU


VF
Queue ID
TSN
SID1
N1
F1
SID2
N2
F2
SIDk
Nk
Fk
MAC- hs header
MAC- hs SDU
MAC- hs SDU
Padding (opt)
Mac- hs payload