HSPA+ Technology Introduction

Application Note

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High Speed Downlink Packet Access (HSDPA) and High Speed Uplink Packet Access (HSUPA) optimize UMTS for packet data services in downlink and uplink, respectively. Together, they are referred to as High Speed Packet Access (HSPA). Within 3GPP release 7 and 8, further improvements to HSPA have been specified in the context of HSPA+ or HSPA evolution. This application note introduces key features of HSPA+ and outlines the changes to the radio interface.

ROHDE&SCHWARZ

Application Note

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1 Introduction

Currently, UMTS High Speed Downlink Packet Access (HSDPA) and High Speed Uplink Packet Access (HSUPA) networks worldwide are being deployed in order to increase data rate and capacity for downlink and uplink packet data. While HSDPA was introduced as a release 5 feature in 3GPP (3rd Generation Partnership Project), HSUPA is an important feature of 3GPP release 6. The combination of HSDPA and HSUPA is often referred to as HSPA (High Speed Packet Access).
However, even with the introduction of HSPA, evolution of UMTS has not reached its end. **HSPA+** will bring significant enhancements in 3GPP release 7 and 8. The objective is to enhance performance of HSPA based radio networks in terms of spectrum efficiency, peak data rate and latency, and to exploit the full potential of WCDMA operation. Important features of HSPA+ are:

3GPP Release 7

- downlink MIMO (Multiple Input Multiple Output),
- higher order modulation for uplink (16QAM) and downlink (64QAM),
- improved layer 2 support for high downlink data rates,
- enhanced CELL_FACH state (downlink),
- continuous packet connectivity (CPC).
- enhanced fractional DPCH (F-DPCH)

3GPP Release 8

- combination of MIMO and 64QAM
- CS over HSPA
- Dual Cell HSDPA
- improved layer 2 support for high uplink data rates
- enhanced CELL_FACH state (uplink)
- HS-DSCH DRX reception in CELL_FACH
- HSPA VoIP to WCDMA/GSM CS continuity
- Serving cell change enhancements

This application note introduces HSPA+ technology and provides an overview of the different features in both 3GPP release 7 and 8. Focus is on radio protocols. **Chapter 2 – 6** outline the 3GPP Rel7 features and **Chapter 7 – 14** describe the 3GPP Rel8 features, respectively. **Chapter 15** illustrates the current measurement possibilities for HSPA+ using R&S measurement equipment. **Chapters 16-18** provide additional information including literature references and ordering information.

This application note assumes basic knowledge of UMTS and HSPA radio protocols.

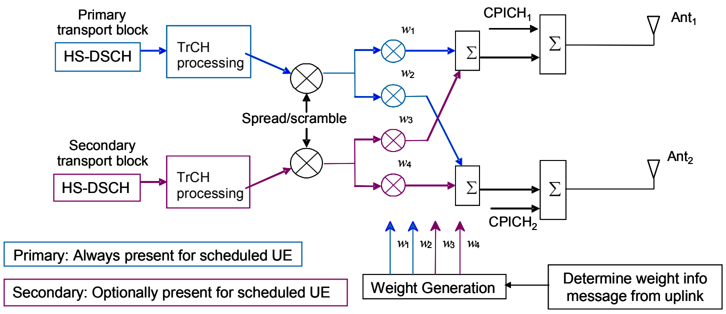
2 Downlink MIMO for HSPA+

2.1 MIMO in general

The term MIMO (Multiple Input Multiple Output) is widely used to refer to multi antenna technology. In general, the term MIMO refers to a system having multiple input signals and multiple output signals. In practice, MIMO means the use of multiple antennas at transmitter and receiver side in order to exploit the spatial dimension of the radio channel. MIMO systems significantly enhance the performance of data transmission. Note that different types of performance gains can be discriminated. On the one hand side, diversity gains can be exploited to increase the quality of data transmission. On the other hand side, spatial multiplexing gains can be exploited to increase the throughput of data transmission. A general MIMO introduction can be found in [1].

2.2 MIMO in HSPA+

Downlink MIMO has been introduced in the context of HSPA+ to increase throughput and data rate. Baseline is a 2x2 MIMO system, i.e. two transmit antennas at the base station side, and two receive antennas at the UE side. MIMO for HSPA+ allows (theoretical) downlink peak data rates of 28 Mbps. Note that HSPA+ does not support uplink MIMO.
The process of introducing MIMO in HSPA+ took a long time in 3GPP. A large number of different approaches was evaluated and extensive performance studies were carried out. Finally, a consensus was reached to extend the closed loop transmit diversity scheme of 3GPP release 99 WCDMA (Wideband Code Division Multiple Access) to a full MIMO approach including spatial multiplexing. The approach is called D-TxAA which means Double Transmit Antenna Array. It is only applicable for the High Speed Downlink Shared Channel, the HS-DSCH. Figure 1 shows the basic principle of the 2x2 approach.



$w_2 \in \left\{ \frac{1+j}{2} \quad \frac{1-j}{2} \quad \frac{-1+j}{2} \quad \frac{-1-j}{2} \right\}$ $\quad w_3 = w_1 = 1/\sqrt{2}$ $\quad w_4 = -w_2$

Figure 1: MIMO for HSPA+ [2]

With D-TxAA, two independent data streams (transport blocks to be more precise) can be transmitted simultaneously over the radio channel over the same WCDMA channelization codes. The two data streams are indicated with blue and red colour in Figure 1. Each transport block is processed and channel coded separately. After spreading and scrambling, **precoding** based on weight factors is applied to optimize the signal for transmission over the mobile radio channel. Four precoding weights w_1-w_4 are available. The first stream is multiplied with w_1 and w_2, the second stream is multiplied with w_3 and w_4. The weights can take the following values:

$$w_3 = w_1 = 1/\sqrt{2}$$

$$w_4 = -w_2$$

$$w_2 \in \left\{ \frac{1+j}{2}, \; \frac{1-j}{2}, \; \frac{-1+j}{2}, \; \frac{-1-j}{2} \right\}$$

Note that w_1 is always fixed, and only w_2 can be selected by the base station. Weights w_3 and w_4 are automatically derived from w_1 and w_2, because they have to be orthogonal. The base station selects the optimum weight factors based on proposals reported by the UE in uplink. This feedback reporting is described in more detail below. After multiplication with the weight factors, the two data streams are summed up before transmission on each antenna, so that each antenna transmits a part of each stream. Note that the two different transport blocks can have a different modulation and coding scheme depending on data rate requirements and radio channel condition.
The UE has to be able to do channel estimation for the radio channels seen from each transmit antenna, respectively. Thus, the transmit antennas have to transmit a different pilot signal. One of the antennas will transmit the antenna 1 modulation pattern of P-CPICH (Primary Common Pilot Channel). The other antenna will transmit either the antenna 2 modulation pattern of P-CPICH, or the antenna 1 modulation pattern of S-CPICH. The modulation patterns for the common pilot channel are defined in [3].
Also the UE receiver has to know the precoding weights that were applied at the transmitter. Therefore, the base station signals to the UE the precoding weight w_2 via the **HS-SCCH (High Speed Shared Control Channel)**. The 2 bit precoding weight indication is used on HS-SCCH to signal one out of four possible w2 values. The other weights applied on HS-DSCH can then be derived from w_2. The precoding weight adjustment is done at the sub-frame border.
D-TxAA requires a **feedback signaling** from the UE to assist the base station in taking the right decision in terms of modulation and coding scheme and precoding weight selection. The UE has to determine the preferred primary precoding vector for transport block 1 consisting of w_1 and w_2. Since w_1 is fixed, the feedback message only consists of a proposed value for w_2. This feedback is called **precoding control information (PCI)**. The UE also recommends whether one or two streams can be supported in the current channel situation. In case dual stream transmission is possible, the secondary precoding vector consisting of weights w_3 and w_4 is inferred in the base station, because it has to be orthogonal to the first precoding vector with w_1 and w_2. Thus, the UE does not have to report it explicitly. The UE also indicates the optimum modulation and coding scheme for each stream. This report is called **channel quality indicator (CQI)**.

Based on the composite PCI/CQI reports, the base station scheduler decides whether to schedule one or two data streams to the UE and what packet sizes (transport block sizes) and modulation schemes to use for each stream.
Note that in case only one stream can be supported due to radio channel conditions, the approach is basically to fall back to the conventional closed loop transmit diversity scheme as of 3GPP release 99, cmp. [2].

2.3 MIMO UE capabilities

MIMO is a UE capability, i.e. not all UEs will have to support it. New UE categories with MIMO support have been introduced, see Table 1:

- **Categories 15 and 16:**
  - Support of MIMO with modulation schemes QPSK and 16QAM
  - No support of 64QAM
  - Maximum data rate of category 16 is 28 Mbps
- **Categories 17 and 18:**
  - Support of MIMO with modulation schemes QPSK and 16QAM
  - Support of 64QAM, but not simultaneously with MIMO
  - Maximum data rate of category 18 is 28 Mbps

Additional UE categories with simultaneous MIMO and 64QAM support are specified in 3GPP release 8.

Table 1: New release 7 UE categories 15-18 with MIMO support

HS DSCH category	MIMO support	Modulation	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	Maximum data rate per stream [Mbps]
…	…	…	…	…	…	…
Category 11	No	QPSK	5	2	3630	~ 1.8
Category 12			5	1	3630	~ 0.9
Category 13		QPSK / 16QAM / 64QAM	15	1	35280	~ 17.64
Category 14			15	1	42192	~ 21.10
Category 15	Yes	QPSK / 16QAM	15	1	23370	~ 11.66
Category 16			15	1	27952	~ 13.98
Category 17	No	QPSK / 16QAM / 64QAM	15	1	35280	~ 17.64
	Yes	QPSK / 16QAM	15	1	23370	~ 11.66
Category 18	No	QPSK / 16QAM / 64QAM	15	1	42192	~ 21.10
	Yes	QPSK / 16QAM	15	1	27952	~ 13.98

2.4 MIMO downlink control channel support

In order to support MIMO operation, changes to the HSDPA downlink control channel have become necessary, i.e. the HS-SCCH.
There is a new **HS-SCCH type 3** for MIMO operation defined. If **one transport block** is transmitted, the following information is transmitted by HS-SCCH type 3 (changes to regular HS-SCCH marked in blue italics):

- Channelization-code-set information (7 bits)
- Modulation scheme + *number of transport blocks info (3 bits)*
- *Precoding weight information (2 bits)*
- Transport-block size information (6 bits)
- Hybrid-ARQ process information (*4 bits*)
- Redundancy/constellation version (*2 bits*)
- UE identity (16 bits)

If **two transport blocks** are transmitted, the following information is transmitted by HS-SCCH type 3:

- Channelization-code-set information (7 bits)
- Modulation scheme + *number of transport blocks info (3 bits)*
- *Precoding weight info for the primary transport block (2 bits)*
- Transport-block size info for primary transport block (6 bits)
- *Transport-block size info for secondary transport block (6 bits)*
- Hybrid-ARQ process information (*4 bits*)
- Redundancy/constellation version for prim. transport block (*2 bits*)
- *Redundancy/constellation version for sec. transport block (2 bits)*
- UE identity (16 bits)

The number of transport blocks transmitted and the modulation scheme information are jointly coded as shown in Table 2.

Table 2: Interpretation of "Modulation scheme and number of transport blocks" sent on HS-SCCH

Modulation scheme and number of transport blocks info (3 bits)	Modulation for primary transport block	Modulation for secondary transport block	Number of transport blocks
111	16QAM	16QAM	2
110	16QAM	QPSK	2
100	16QAM	n/a	1
011	QPSK	QPSK	2
000	QPSK	n/a	1

The "Precoding weight info for the primary transport block" contains the information on weight factor w_2 as described above. Weight factors w_1, w_3, and w_4 are derived accordingly.

Redundancy versions for the primary transport block and for the secondary transport block are signalled. Four redundancy version values are possible (unlike HSDPA in 3GPP release 5 where eight values for the redundancy version could be signalled). Also the signalling of the **HARQ processes** differs from HSDPA in 3GPP release 5. In 3GPP release 5, up to eight HARQ processes can be signalled. A minimum of six HARQ processes needs to be configured to achieve continuous data transmission. Similarly, in MIMO with dual stream transmission, a minimum of twelve HARQ processes would be needed to achieve continuous data transmission. Each HARQ process has independent acknowledgements and retransmissions. In theory, HARQ processes on both streams could run completely independently from one another. This would however increase the signalling overhead quite significantly (to 8 bits), since each possible combination of HARQ processes would need to be addressed.
To save signalling overhead, a restriction is introduced: HARQ processes are only signalled for the primary transport block within 4 bits, the HARQ process for the secondary transport block is derived from that according to a fixed rule [4]. Thus, there is a one-to-one mapping between the HARQ process used for the primary transport block and the HARQ process used for the secondary transport block. The relation is shown in Table 3 for the example of 12 HARQ processes configured:

Table 3: Combinations of HARQ process numbers for dual stream transmission (example)

HARQ process number on primary stream	0	1	2	3	4	5	6	7	8	9	10	11
HARQ process number on secondary stream	6	7	8	9	10	11	0	1	2	3	4	5

Note that only an even number of HARQ processes is allowed to be configured with MIMO operation.

2.5 MIMO uplink control channel support

Also the uplink control channel for HSDPA operation is affected by MIMO, i.e. the HS-DPCCH (High Speed Dedicated Physical Control Channel). In addition to CQI reporting as already defined from 3GPP release 5 onwards, PCI reporting for precoding feedback needs to be introduced as described above. Channel coding is done separately for the composite precoding control indication (PCI) / channel quality indication (CQI) and for HARQ-ACK (acknowledgement or negative acknowledgement information). Figure 2 shows the principle.

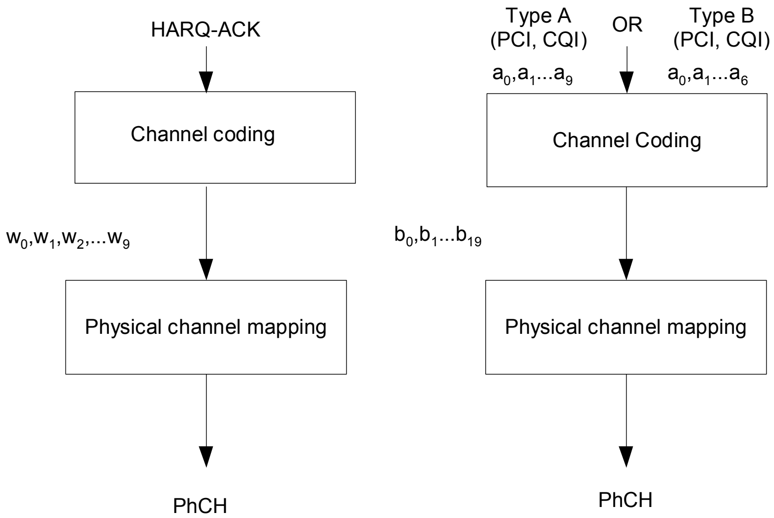


Figure 2: Channel coding for HS-DPCCH

The 10 bits of the HARQ-ACK messages are interpreted as shown in Table 4. ACK/NACK information is provided for the primary and for the secondary transport block.

Table 4: Interpretation of HARQ-ACK in MIMO operation

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
HARQ-ACK in response to a single scheduled transport block											
ACK		1	1	1	1	1	1	1	1	1	1
NACK		0	0	0	0	0	0	0	0	0	0
HARQ-ACK in response to two scheduled transport blocks											
Response to primary transport block	**Response to secondary transport block**										
ACK	**ACK**	1	0	1	0	1	1	1	1	0	1
ACK	**NACK**	1	1	0	1	0	1	0	1	1	1
NACK	**ACK**	0	1	1	1	1	0	1	0	1	1
NACK	**NACK**	1	0	0	1	0	0	1	0	0	0
PRE/POST indication											
PRE		0	0	1	0	0	1	0	0	1	0
POST		0	1	0	0	1	0	0	1	0	0

In MIMO case, two types of CQI reports need to be supported:

- **type A CQI reports** can indicate the supported transport format(s) for the number of transport block(s) that the UE prefers. Single and dual stream transmission are supported. The UE assumes that the precoding is done according to the proposed PCI value.
- **type B CQI reports** are used for single stream transmission according to what has been defined from 3GPP release 5 onwards. The UE assumes that the precoding is done according to the proposed PCI value.

For type A CQI reports, the UE selects the appropriate CQI_1 and CQI_2 values for each transport block in dual stream transmission, or the appropriate CQI_S value in single stream transmission, and then creates the CQI value to report on HS-DPCCH. For dual stream transmission, new CQI tables are required in [2] for correct interpretation of transport formats based on CQI_1 and CQI_2, see Table 5 and Table 6.

$$CQI = \begin{cases} 15 \text{ x } CQI_1 + CQI_2 + 31 & \text{when 2 transport blocks are preferred by the UE} \\ CQI_S & \text{when 1 transport block is preferred by the UE} \end{cases}$$

Table 5: CQI mapping table for UE category 15/17 in case of dual transport block type A CQI reports

CQI1 or CQI2	Transport Block Size	Number of HS-PDSCH	Transport Block Size	Equivalent AWGN SINR difference Δ	NIR	Xrvpb or Xrvsb
0	4581	15	QPSK	-3.00	28800	0
1	4581	15	QPSK	-1.00		
2	5101	15	QPSK	0		
3	6673	15	QPSK	0		
4	8574	15	QPSK	0		
5	10255	15	QPSK	0		
6	11835	15	QPSK	0		
7	14936	15	16QAM	0		
8	17548	15	16QAM	0		
9	20617	15	16QAM	0		
10	23370	15	16QAM	0		
11	23370	15	16QAM	1.50		
12	23370	15	16QAM	2.50		
13	23370	15	16QAM	4.00		
14	23370	15	16QAM	5.00		

Table 6: CQI mapping table for UE category 16/18 in case of dual transport block type A CQI reports

CQI1 or CQI2	Transport Block Size	Number of HS-PDSCH	Transport Block Size	Equivalent AWGN SINR difference Δ	NIR	X_{rvpb} or X_{rvsb}
0	4581	15	QPSK	-3.00	28800	0
1	4581	15	QPSK	-1.00		
2	5101	15	QPSK	0		
3	6673	15	QPSK	0		
4	8574	15	QPSK	0		
5	10255	15	QPSK	0		
6	11835	15	QPSK	0		
7	14936	15	16QAM	0		
8	17548	15	16QAM	0		
9	20617	15	16QAM	0		
10	23370	15	16QAM	0		
11	25558	15	16QAM	0		
12	26969	15	16QAM	0		
13	27456	15	16QAM	0		
14	27952	15	16QAM	0		

Whether the UE has to report type A or type B CQI reports is determined by higher layers. The percentage of required type A reports compared to the total number of CQI reports can be configured.

The parameter Δ indicates by how much the equivalent AWGN symbol SINR (Signal to Interference plus Noise Ratio) for a specific transport block would be different from the one required to meet the target block error rate performance.
NIR stands for the virtual incremental redundancy buffer size the UE shall assume for CQI calculation, and X_{rvpb} and X_{rvsb} stand for the redundancy versions for primary and secondary transport block.
The PCI value is created in the UE according to the preferred precoding weight w_2 according to Table 7.

Table 7: Mapping of preferred precoding weight to PCI values

w_2^{pref}	**PCI value**
$\frac{1+j}{2}$	0
$\frac{1-j}{2}$	1
$\frac{-1+j}{2}$	2
$\frac{-1-j}{2}$	3

The PCI value shall be transmitted together with the CQI value as a composite PCI/CQI value. The composite PCI/CQI report is created as follows:

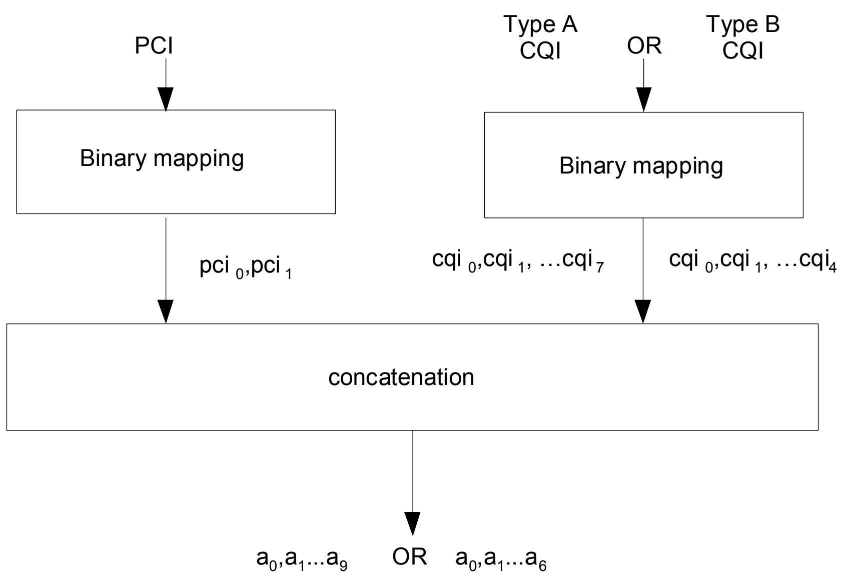


Figure 3: Composite PCI/CQI information

3 Higher Order Modulation

3.1 64QAM in downlink

With the possibility to use 64QAM in downlink, HSPA+ can achieve downlink data rates of 21 Mbps. 64QAM is a UE capability, i.e. not all UEs will be able to support it. New UE categories have been introduced (categories 13 and 14, and categories 17 and 18) to provide support of 64 QAM in addition to 16QAM and QPSK.

- **Categories 13 and 14:**
  - Support of 64QAM
  - No support of MIMO
  - Maximum data rate of category 14 is 21 Mbps
- **Categories 17 and 18:**
  - Support of 64QAM and MIMO, but not simultaneously
  - Maximum data rate of category 18 is 28 Mbps when MIMO is used and 21 Mbps when 64QAM is used
  - See Table 8 for details on these categories.

Additional UE categories with simultaneous MIMO and 64QAM support are specified in 3GPP release 8.

Table 8: UE categories with 64QAM support

HS DSCH category	Modulation	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	Maximum data rate [Mbps]
…	…	…	…	…	…
Category 9	QPSK / 16QAM	15	1	20251	~ 10.13
Category 10		15	1	27952	~ 13.98
Category 11	QPSK	5	2	3630	~ 1.8
Category 12		5	1	3630	~ 0.9
Category 13	QPSK / 16QAM / 64QAM	15	1	35280	~ 17.64
Category 14		15	1	42192	~ 21.10

As in HSDPA of 3GPP release 5, the selection of the modulation scheme is done in the base station scheduler for each new transmission interval. The decision is communicated to the UE via HS-SCCH. A new slot format for the HS-DSCH is introduced which reflects the higher data rate possible with 64QAM, see Table 9.

Table 9: HS-DSCH slot formats

Slot format #i	Channel Bit Rate [kbps]	Channel Symbol Rate [ksps]	SF	Bits / HS-DSCH subframe	Bits / Slot	N_{data}
0 (QPSK)	480	240	16	960	320	320
1 (16QAM)	960	240	16	1920	640	640
2 (64QAM)	1440	240	16	2880	960	960

The coding of the control information on HS-SCCH has to be adapted in order to signal usage of 64QAM to the UE. Therefore, the interpretation of the bits on HS-SCCH has been changed, more precisely the seven bits that have been used so far exclusively to signal channelization code set (ccs) for HS-DSCH. The seventh bit is now used to indicate whether 64QAM is used.
The network informs the UE via higher layer signalling whether 64QAM usage is possible, and thus whether the new HS-SCCH format has to be used or not.
Unlike HSDPA in 3GPP release 5, a 64QAM configured UE shall monitor all (up to four) HS-SCCHs also in the subframe following transmission on HS-DSCH to that UE.
As for 16QAM in 3GPP release 5, constellation re-arrangement is possible for 64QAM. The base station may decide to change the constellation mapping from one transmission time interval to the next in order to average the error probability. Four different constellation versions are available for 64QAM. The signalling of the constellation version on HS-SCCH is combined with the signalling of redundancy versions (RV) as in 3GPP release 5.
Another change is required to the channel quality reporting procedure. New CQI tables have to be added in [2] so that the UE is able to propose the usage of transport formats including 64QAM.

3.1.1 64QAM Fixed Reference Channel: H-Set 8

In order to support 64QAM testing, a new fixed reference channel has been introduced. H-Set 8 is specified as reference test channel for HSDPA test cases in [5]. H-Set 8 parameterization and coding chain is shown in Figure 4. It is based on 15 codes with 64QAM modulation. Six Hybrid ARQ processes are used, and HS-DSCH is continuously transmitted.

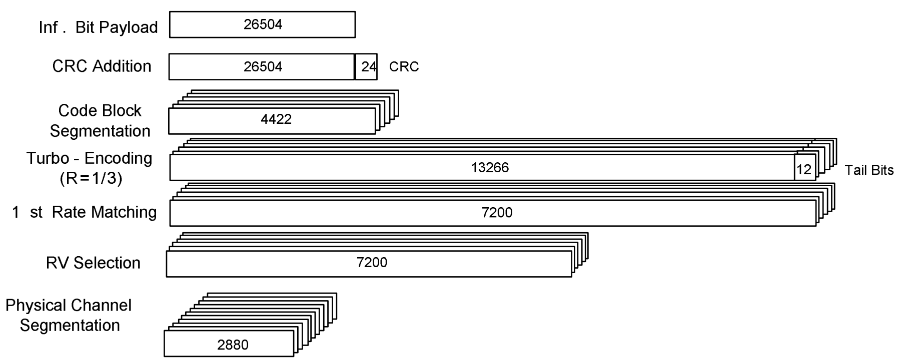


Figure 4: H-Set 8 parameterization

3.2 16QAM in uplink

With the possibility to use 16QAM on E-DCH (Enhanced Dedicated Channel) in uplink, HSPA+ can achieve uplink peak data rates of 11.5 Mbps. A new uplink UE category 7 has been introduced which supports 16QAM in addition to BSPK, see Table 10.

Table 10: FDD E-DCH physical layer categories

E-DCH category	Maximum number of E-DCH codes transmitted	Minimum spreading factor	Support for 10 ms and 2 ms TTI EDCH	Maximum number of bits of an E-DCH transport block transmitted within a 10 ms E-DCH TTI	Maximum number of bits of an E-DCH transport block transmitted within a 2 ms E-DCH TTI	Maximum data rate [Mbps]
Category 1	1	4	10ms	7110	-	~ 0.71
Category 2	2	4	10ms / 2ms	14484	2798	~ 1.45 ~ 1.40
Category 3	2	4	10ms	14484	-	~ 1.45
Category 4	2	2	10ms / 2ms	20000	5772	~ 2.00 ~ 2.89
Category 5	2	2	10ms	20000	-	~ 2.00
Category 6	4	2	10ms / 2ms	20000	11484	~ 2.00 ~ 5.74
Category 7	4	2	10ms / 2ms	20000	22996	~ 2.00 ~ 11.50
NOTE: When 4 codes are transmitted in parallel, two codes shall be transmitted with SF2 and two with SF4						

Uplink transmission in HSPA+ is based on IQ multiplexing of E-DPDCH (Enhanced Dedicated Physical Data Channel) physical channels as in HSUPA of 3GPP release 6. In fact, the 16QAM constellation is made up of two orthogonal 4PAM (pulse amplitude modulation) constellations. In case of 4PAM modulation, a set of two consecutive binary symbols n_k, n_{k+1} is converted to a real valued sequence following the mapping described in Table 11.

Table 11: Mapping of E-DPDCH with 4PAM modulation

n_k, n_{k+1}	Mapped real value
00	0.4472
01	1.3416
10	-0.4472
11	-1.3416

This results in the following symbol mapping (Figure 5):

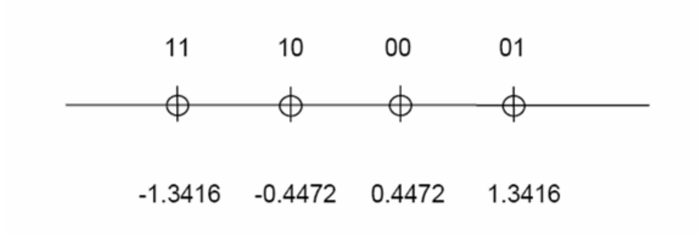


Figure 5: 4PAM symbol mapping

An E-DPDCH may use BPSK or 4PAM modulation symbols. The new E-DPDCH slot formats 8 and 9 are shown in Table 12. M is the number of bits per modulation symbol i.e. M=1 for BPSK and M=2 for 4PAM. 2 Bits / symbol are available for spreading factor SF2 and SF4. The resulting maximum uplink data rate of 11.5 Mbps is achieved by combining two E-DPDCHs with SF2 and two E-DPDCHs with SF4.

Table 12: E-DPDCH slot formats

Slot format #i	Channel Bit Rate [kbps]	Bits/Symbol M	SF	Bits / Frame	Bits / Subframe	N_{data}
0	15	1	256	150	30	10
1	30	1	128	300	60	20
2	60	1	64	600	120	40
3	120	1	32	1200	240	80
4	240	1	16	2400	480	160
5	480	1	8	4800	960	320
6	960	1	4	9600	1920	640
7	1920	1	2	19200	3840	1280
8	1920	2	4	19200	3840	1280
9	3840	2	2	38400	7680	2560

16QAM introduction also affects the transport format selection as well as uplink power setting and gain factor calculation. Bigger transport block sizes and higher grants become possible due to the higher order modulation scheme. Table 13 and Figure 6 provide details of the fixed reference channel FRC8 used for base station receiver test.

Table 13: Fixed Reference Channel (FRC8) – 16QAM parameters

Parameter	Unit	Value
Modulation		16QAM
Maximum. Inf. Bit Rate	Kbps	8109.0
TTI	Ms	2
Number of HARQ Processes	Processes	8
Information Bit Payload (NINF)	Bits	16218
Binary Channel Bits per TTI (NBIN) (3840 / SF x TTI sum for all channels)	Bits	23040
Coding Rate (NINF/ NBIN)		0.704
Physical Channel Codes	SF for each physical channel	{2,2,4,4}

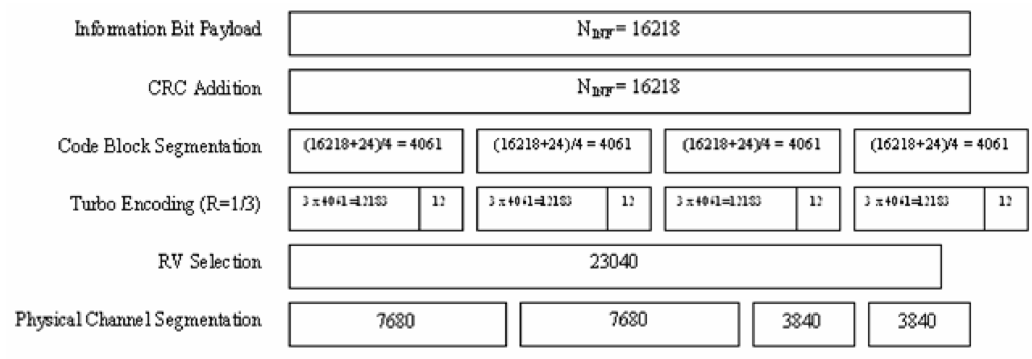


Figure 6: Fixed Reference Channel (FRC8) – 16QAM parameters

4 Continuous Packet Connectivity (CPC)

Continuous Packet Connectivity (CPC) comprises a bundle of features that aim to optimize the support of packet data users in a HSPA network. With increased acceptance of packet data services, a large number of users has to be supported in a cell. These users would ideally stay connected over a long time span, even though they may only occasionally have active periods of data transmission, similarly to a DSL type of connection. Thus, the connections of the packet data users must be maintained, and frequent connection termination and re-establishment must be avoided in order to minimize the latency as perceived by the users.
Maintaining the connection of a high number of packet data users in a cell means that the control channels of these users in downlink and uplink need to be supported. Uplink control channels are important to maintain synchronisation. However, the uplink control channels contribute to the overall uplink noise rise. This includes both the Uplink Dedicated Physical Control Channel (DPCCH) and the High Speed Dedicated Physical Control Channel (HS-DPCCH). Thus, one aim of CPC is to reduce the uplink control channel overhead for both DPCCH and HS-DPCCH.
It is also worthwhile to reduce the downlink control channel overhead, which is caused by the High Speed Shared Control Channel (HS-SCCH), because continuous monitoring of the HS-SCCH increases UE battery consumption.
Thus, in the context of CPC different features have been introduced to reduce the uplink and downlink control channel overhead. Some of the features can also be introduced independently. In the following, the different features are introduced.

4.1 Uplink Discontinuous Transmission (DTX)

Uplink discontinuous transmission shall reduce the uplink control channel overhead. It allows the UE to stop transmission of uplink DPCCH in case there is no transmission activity on E-DCH or HS-DPCCH. This is sometimes also called uplink DPCCH gating. Uplink DPCCH is not transmitted continuously any more, but it is transmitted from time to time according to a known activity pattern. This regular activity is needed in order to maintain synchronisation and power control loop. Note that gating is only active if there is no uplink data transmission on E-DCH or HS-DPCCH transmission ongoing. In case E-DCH or HS-DPCCH are used, the uplink DPCCH is always transmitted in parallel.
To allow more flexibility, two uplink DPCCH activity patterns can be defined per UE:

- UE DTX cycle 1
- UE DTX cycle 2

UE DTX cycle 2 is used whenever there is no uplink data transmission activity. UE DTX cycle 1 is used temporarily depending on the duration of E-DCH inactivity. After a certain threshold of inactivity, UE changes from cycle 1 to 2. UE DTX cycle 2 therefore allows to transmit the uplink DPCCH less frequently. The use of UE DTX cycles 1 and 2 is shown in the example of Figure 7 in comparison to Release 6 operation. After the last uplink transmission on E-DCH, the UE waits for the duration of the parameter "Inactivity threshold for UE DTX cycle 2" and then switches from UE DTX cycle 1 to the longer UE DTX cycle 2.

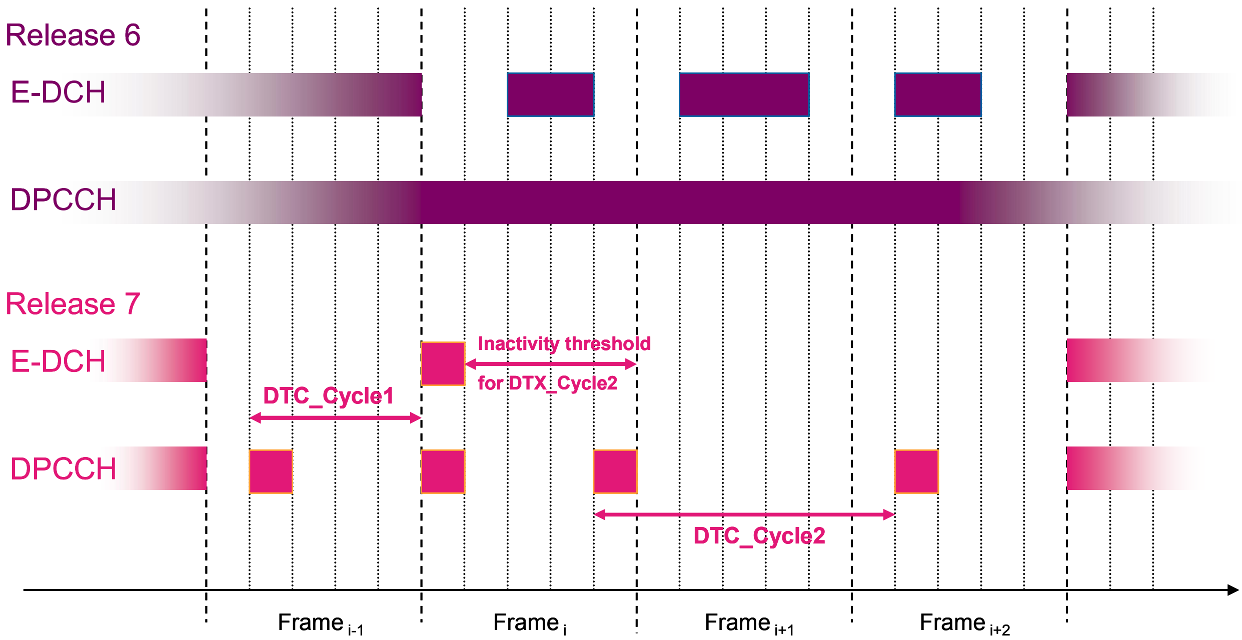


Figure 7: Uplink DTX example, 2 ms TTI (pre-/postambles not shown), [2]

The length of the uplink DPCCH transmission can be configured by higher layers. The parameters UE DPCCH burst 1 and UE DPCCH burst 2 indicate the length of the uplink DPCCH transmission (in subframes) for cycle 1 and 2.
To aid synchronization, the UE starts already two slots before uplink data or HS-DPCCH transmission with the DPCCH transmission (preamble), and continues one slot longer with it (postamble). If there hasn't been any uplink data or HS-DPCCH transmission for a longer time, then the preamble can be configured to be even longer than two slots.
A summary of all relevant parameters for configuring the UE DTX operation can be found in Table 14. These parameters can be configured by higher layers.

Table 14: Parameters relevant for DTX operation

Parameter	**Possible values**	**Meaning**
UE DTX cycle 1	1, 5, 10, 20 subframes for 10 ms TTI	DPCCH activity patttern, i.e. how often UE has to transmit uplink DPCCH when UE DTX cycle 1 is active
UE DTX cycle 2	1, 4, 5, 8, 10, 16, 20 subframes for 2 ms TTI	DPCCH activity patttern, i.e. how often UE has to transmit uplink DPCCH when UE DTX cycle 2 is active
UE DPCCH burst 1	5, 10, 20, 40, 80, 160 subframes for 10 ms TTI	Length of DPCCH transmission when UE DTX cycle 1 is active
UE DPCCH burst 2	4, 5, 8, 10, 16, 20, 32, 40, 64, 80, 128, 160 subframes for 2 ms TTI	Length of DPCCH transmission when UE DTX cycle 2 is active

Parameter	Possible values	Meaning
Inactivity Threshold for UE DTX cycle 2	1, 2, 5 subframes	When to activate the UE DTX cycle 2 after the last uplink data transmission
UE DTX long preamble length	1, 2, 5 subframes	Uplink preamble length
CQI DTX Timer	1, 2, 4, 8, 16, 32, 64, 128, 256 TTIs	Number of subframes after an HS-DSCH reception during which the CQI reports have higher priority than the DTX pattern and are transmitted according to the regular CQI pattern
Enabling Delay	2, 4, 15 slots (default 2)	Time the UE waits until enabling a new timing pattern for DRX/DTX operation
UE DTX DRX Offset	(0, 1, 2, 4, 8, 16, 32, 64, 128, 256, 512, Infinity) subframes	Additional UE specific offset of DRX and DTX cycles (compared to other UEs)

UE will move to DTX mode when higher layers have provided the configuration parameters and "Enabling Delay" radio frames have passed. Deactivation and consecutive activation of DTX mode is possible based on layer 1 orders transmitted on HS-SCCH, see chapter 4.5 below. Additional savings in uplink overhead can be achieved by reducing the amount of reporting for the Channel Quality Indications (CQI). Usually, CQI is regularly transmitted on HS-DPCCH in uplink in order to inform the base station about the downlink channel quality situation experienced by a particular UE. This information helps the base station to do the right decisions on scheduling and adapt the downlink modulation and coding scheme. In case of no downlink data transmission, CQI reporting can thus be reduced because this information is not necessarily needed in the base station. During and directly after a downlink data transmission, CQI is reported regularly, as defined in 3GPP release 5. After a specific timer has passed (CQI DTX Timer as configured by higher layers, see Table 14), the UE only provides CQI reports if they coincide with an uplink DPCCH transmission according to the uplink DPCCH activity pattern.

4.2 E-DCH Tx start time restrictions

This features makes it possible for the base station to restrict the starting points of the uplink transmission on E-DCH for a particular UE. This means that the UE can transmit only on pre-defined time instants. To achieve this, a MAC DTX cycle and a MAC inactivity threshold are introduced which can be configured by higher layers, see Table 15.

Table 15: Parameters relevant for E-DCH Tx start time restrictions

MAC DTX cycle	5, 10, 20 subframes for 10 ms TTI 1, 4, 5, 8, 10, 16, 20 subframes for 2 ms TTI	pattern of time instances where the start of uplink E-DCH transmission after inactivity is allowed
MAC Inactivity Threshold	1, 2, 4, 8, 16, 32, 64, 128, 256, 512, Infinity TTIs	E-DCH inactivity time after which the UE can start E-DCH transmission only at given times

4.3 Downlink Discontinuous Reception (DRX)

In HSDPA of 3GPP release 5, the UE has to monitor the HS-SCCH continuously in order to watch out for possible downlink data allocations. In HSPA+, the network can limit the number of subframes where the UE has to monitor the HS-SCCH in order to reduce UE battery consumption. The DRX operation is controlled by the parameter UE_DRX_cycle which is configured by higher layers and can take values of 4, 5, 8, 10, 16, or 20 subframes. For example, if UE_DRX_cycle is 5 subframes, the UE only monitors the HS-SCCH on every 5th subframe.

The DRX also affects the monitoring of E-RGCH and E-AGCH downlink control channels, which control the uplink data transmission of the UE. Rules are defined when to monitor these channels. In general, when UE uplink data transmission is ongoing or has just stopped, the UE has to monitor these channels. If there is no uplink data for transmission available and the last transmission is a defined time threshold away, then the UE can stop monitoring the grant channels.

However, the UE's DRX behaviour can be fine tuned and configured by a lot of higher layer parameters, see Table 16.

Note that downlink DRX operation is only possible when also uplink DTX operation is activated. Deactivation and consecutive activation of DRX mode is possible based on layer 1 orders transmitted on HS-SCCH, see chapter 4.5.

Table 16: **Parameters relevant for DRX operation**

Parameter	Possible values	Meaning
UE DRX cycle	4, 5, 8, 10, 16, 20 subframes	HS-SCCH reception pattern, i.e. how often UE has to monitor HS-SCCH
Inactivity threshold for UE DRX cycle	0, 1, 2, 4, 8, 16, 32, 64, 128, 256, 512 subframes	Number of subframes after downlink activity where UE has to continuously monitor HS-SCCH
Inactivity Threshold for UE Grant Monitoring	1, 2, 4, 8, 16, 32, 64, 128, 256 E-DCH TTIs	Number of subframes after uplink activity when UE has to continue to monitor E-AGCH/E-RGCH
UE DRX Grant Monitoring	TRUE/FALSE	whether the UE is required to monitor E-AGCH/E-RGCH when they overlap with the start of an HS-SCCH reception as defined in the HS-SCCH reception pattern
Enabling Delay	0, 1, 2, 4, 8, 16, 32, 64, 128 radio frames	Time threshold the UE waits until enabling a new timing pattern for DRX/DTX operation
UE DTX DRX Offset	0…159 subframes	Additional offset of DRX and DTX cycles (UE specific)

4.4 HS-SCCH less operation

HS-SCCH less operation is a special HSDPA mode of operation which reduces the HS-SCCH overhead and reduces UE battery consumption. It changes the conventional structure of HSDPA data reception. In HSDPA as defined from 3GPP release 5 onwards, UE is supposed to read continuously on HS-SCCH where data allocations are being signalled. The UE is being addressed via a UE specific identity (16 bit H-RNTI / HSDPA Radio Network Temporary Identifier) on HS-SCCH. As soon as the UE detects relevant control information on HS-SCCH it switches to the associated HS-PDSCH resources and receives the data packet. This scheme is fundamentally changed in HS-SCCH less operation. The principle is illustrated in Figure 8. Note that HS-SCCH less operation is optimized for services with relatively small packets, e.g. VoIP. The base station can decide for each packet again whether to apply HS-SCCH less operation or not, i.e. conventional operation is always possible.

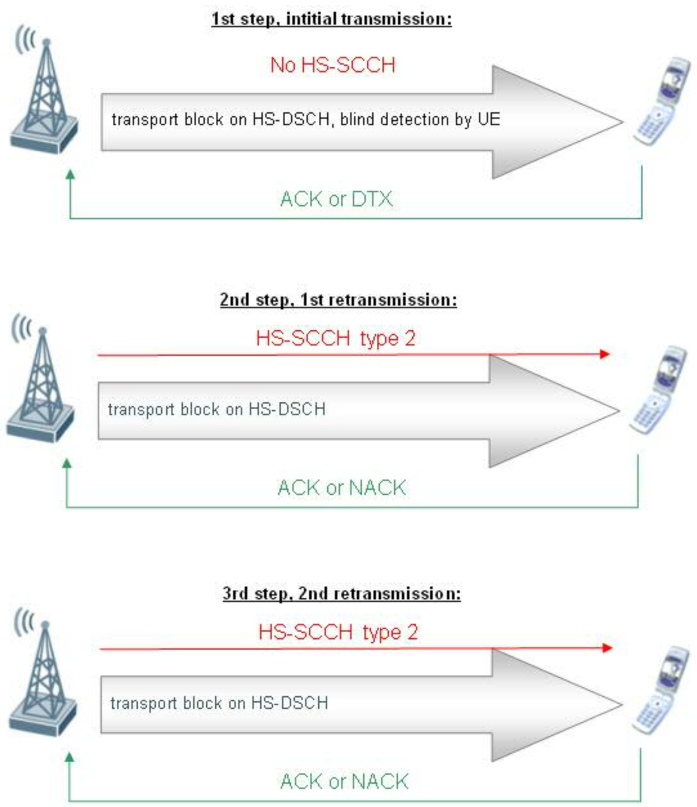


Figure 8: HS-SCCH less operation

1st step, initial transmission of data packet:

The first transmission of a data packet on HS-DSCH is done without an associated HS-SCCH. The first transmission always uses QPSK and redundancy version X_{rv} = 0. Only four pre-defined transport formats can be used so the UE can blindly detect the correct format. The four possible transport formats are configured by higher layers. Only pre-defined channelisation codes can be used for this operation mode and are configured per UE by higher layers.

The parameter *HS-PDSCH code index* provides the index of the first HS-PDSCH code to use. For each of the transport formats, it is configured whether one or two channelisation codes are required.
In order to allow detection of the packets on HS-DSCH, the HS-DSCH CRC (Cyclic Redundancy Check) becomes UE specific based on the 16 bit H-RNTI. This is called CRC attachment method 2 (CRC attachment method 1 is conventional as of 3GPP release 5).
In case of successful reception of the packet, the UE will send an ACK on HS-DPCCH. If the packet was not received correctly, the UE will send nothing.

2nd and 3rd step, retransmission of data packet:

If the packet is not received in the initial transmission, the base station may retransmit it. The number of retransmissions is limited to two in HS-SCCH less operation.

In contrast to the intial transmission, the retransmissions are using HS-SCCH signalling. However, the coding of the HS-SCCH deviates from release 5, since the bits on HS-SCCH are re-interpreted. This is called HS-SCCH type 2. The conventional HS-SCCH as of 3GPP release 5 is now called HS-SCCH type 1. See
Figure 9 for a comparison of the two formats.

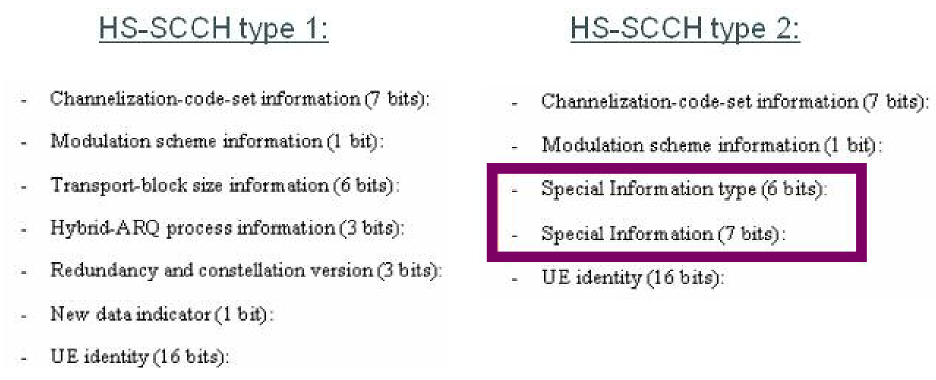


Figure 9: Comparison of HS-SCCH type 1 and 2

The Special Information type on HS-SCCH type 2 must be set to 111110 to indicate HS-SCCH less operation. The 7 bits Special information then contains:

- 2 bit transport block size information (one of the four possible transport block sizes as configured by higher layers)
- 3 bit pointer to the previous transmission of the same transport block (to allow soft combining with the initial transmission)
- 1 bit indicator for the second or third transmission
- 1 bit reserved.

QPSK is also used for the retransmissions. The redundancy version X_{rv} for the second and third transmissions shall be equal to 3 and 4, respectively. For the retransmissions, also HS-DSCH CRC attachment method 2 is used. ACK or NACK are reported by the UE for the retransmitted packets. If the packet is not positively acknowledged by the UA after the maximum number of two retransmissions, higher layer mechanism have to react.

4.5 HS-SCCH orders

HS-SCCH orders are fast commands sent on HS-SCCH. They tell the UE whether to enable or disable discontinuous downlink reception, discontinuous uplink DPCCH transmission or HS-SCCH less operation. No HS-PDSCH is associated with HS-SCCH orders. On HS-SCCH type 1 the channelisation code and modulation information is set to the fixed pattern '1110000' (see Figure 9) and on HS-SCCH type 3 the channelisation code, modulation and precoding weight information is set to the fixed pattern '111000000000' (see chapter 2.4). The subsequent transport block size information is then set to the fixed pattern '111101'. The combination of these fixed patterns indicate an HS-SCCH order.
Then, the remaining information bits (originally used for HARQ process and redundancy/constellation information) are comprised of a 3 bit *order type* and a 3 bit *order info*. If *order type* = '000', then *order info* addresses DRX (first bit), DTX (second bit) and HS-SCCH less operation (third bit), whereas a "1" activates the feature and a "0" deactivates the feature.

4.6 New Uplink DPCCH slot format

A new uplink DPCCH slot format is introduced in order to further reduce uplink control channel overhead. The general structure of uplink DPDCH and DPCCH is shown in Figure 10, and the parameters for the new uplink DPCCH slot format 4 are given in Table 17. It contains only six pilot bits and four TPC (Transmit Power Control) bits in order to reduce DPCCH transmit power. FBI (Feedback Information) and TFCI (Transport Format Combination Indicator) bits are not sent.

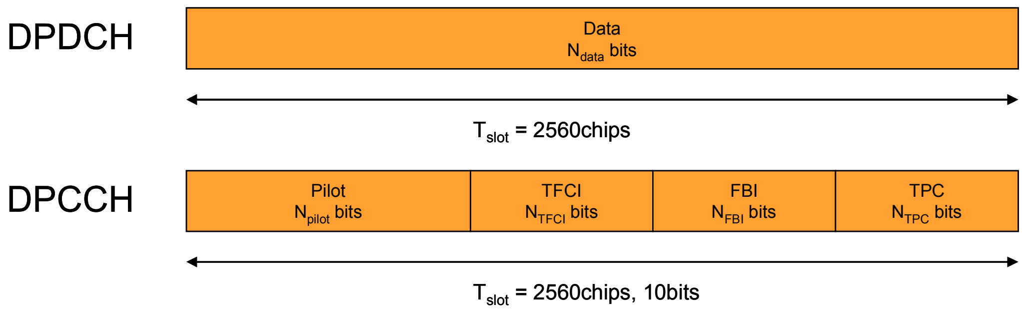


Figure 10: Uplink DPDCH/DPCCH slot format (one slot shown)

Table 17: Uplink DPCCH slot formats

Slot format #i	Channel Bit Rate [kbps]	Channel Symbol Rate [ksps]	SF	N_{pilot}	N_{TPC}	N_{TFCI}	N_{FBI}	Transmitted slots per radio frame
0	15	15	256	6	2	2	0	15
0A	15	15	256	5	2	3	0	10 – 14
0B	15	15	256	4	2	4	0	8 – 9
1	15	15	256	8	2	0	0	8 – 15

Slot format #i	Channel Bit Rate [kbps]	Channel Symbol Rate [ksps]	SF	N_{pilot}	N_{TPC}	N_{TFCI}	N_{FBI}	Transmitted slots per radio frame
2	15	15	256	5	2	2	1	15
2A	15	15	256	4	2	3	1	10 – 14
2B	15	15	256	3	2	4	1	8 – 9
3	15	15	256	7	2	0	1	8 – 15
4	15	15	256	6	4	0	0	8 – 15

4.7 Enhanced Fractional DPCH (F-DPCH)

In Rel6 specification an improvement to support data-only services (streaming, interactive or background service) has been included called Fractional DPCH (F-DPCH).
When a user wants to have data-only service there is still a need from the system perspective to set up a dedicated physical channel in the DL. In general this downlink dedicated channel will be mainly used to carry RRC signalling and the data traffic will go through the HSDPA channel. However RRC signalling has a minimum data rate since transmission of RRC signalling is rather infrequent, i.e. the physical channel carrying this signalling will be DTX'ed most of the time except for TPC and pilot bits transmission. As the signalling is also allowed to be carried on the HS-DSCH transport channel, the dedicated physical channel may be setup in the downlink to carry only layer 1 signalling. The F-DPCH concept implements code sharing between data-only HSDPA users to carry power control information and thus reduces the code limitation problem. In Rel6 TPC bits are allocated at a fixed position within the slot (see Figure 11). In principle up to 10 TPC streams for 10 different UEs can be supported. However a timing requirement is specified as follows: "UTRAN starts the transmission of the downlink DPCCH/DPDCH or F-DPCH for each new radio link at a frame timing such that the frame timing received at the UE will be within T0 ± 148 chips prior to the frame timing of the uplink DPCCH/DPDCH at the UE."

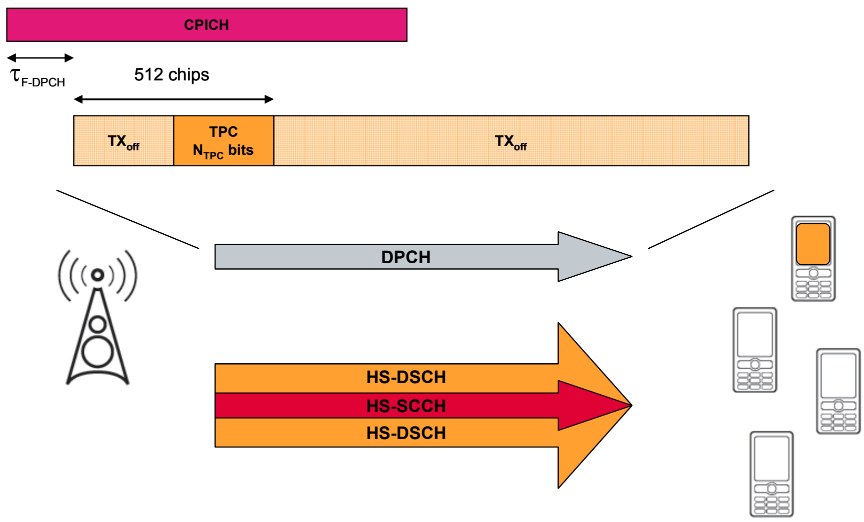


Figure 11: Rel6 Frame structure for F-DPCH

Due to the timing requirement and considering soft handover scenarios the capacity of the F-DPCH goes down to ~3-4 users per channel. With Continuous Packet Connectivity, the number of UEs in Cell_DCH can increase significantly, which may require the use of multiple F-DPCHs to support the traffic. In order to increase the F-DPCH capacity the timing restriction for all F-DPCH received by a given UE has been removed in 3GPP release 7. Therefore it is specifically allowed to have different TPC timing offsets from different cells (see [3]), whereas this offset is signalled in form of a specific slot format from the RNC (Table 18).

Table 18: F-DPCH fields

Slot format #i	Channel Bit Rate [kbps]	Channel Symbol Rate [ksps]	SF	N_{OFF1}	N_{TPC}	N_{OFF2}
0	3	1.5	256	2	2	16
1	3	1.5	256	4	2	14
2	3	1.5	256	6	2	12
3	3	1.5	256	8	2	10
4	3	1.5	256	10	2	8
5	3	1.5	256	12	2	6
6	3	1.5	256	14	2	4
7	3	1.5	256	16	2	2
8	3	1.5	256	18	2	0
9	3	1.5	256	0	2	18

Note that in some cases (depending on the actual DPCH offset and F-DPCH slot format selection) this enhancement results in an additional one slot power control loop delay. However simulations results demonstrated that the impact of this additional delay on the uplink system capacity is small and acceptable given the expected benefits in terms of downlink capacity.

5 Improved Layer 2 for High Data Rates (DL)

Modifications to layer 2 have become necessary in order to support the high data rates enabled by features like MIMO or higher order modulation. This includes enhancements to both Medium Access Control (MAC) and Radio Link Control (RLC) protocols.

5.1 New MAC-ehs protocol entity

A new Medium Access Control entity MAC-ehs is introduced which is optimized for HSPA+. MAC-ehs can be used alternatively to MAC-hs. It is configured by higher layers which of the two entities is handling the data transmitted on HS-DSCH and the management of the physical resources allocated to HS-DSCH. Figure 12 shows the UTRAN side MAC architecture including the new MAC-ehs [6].

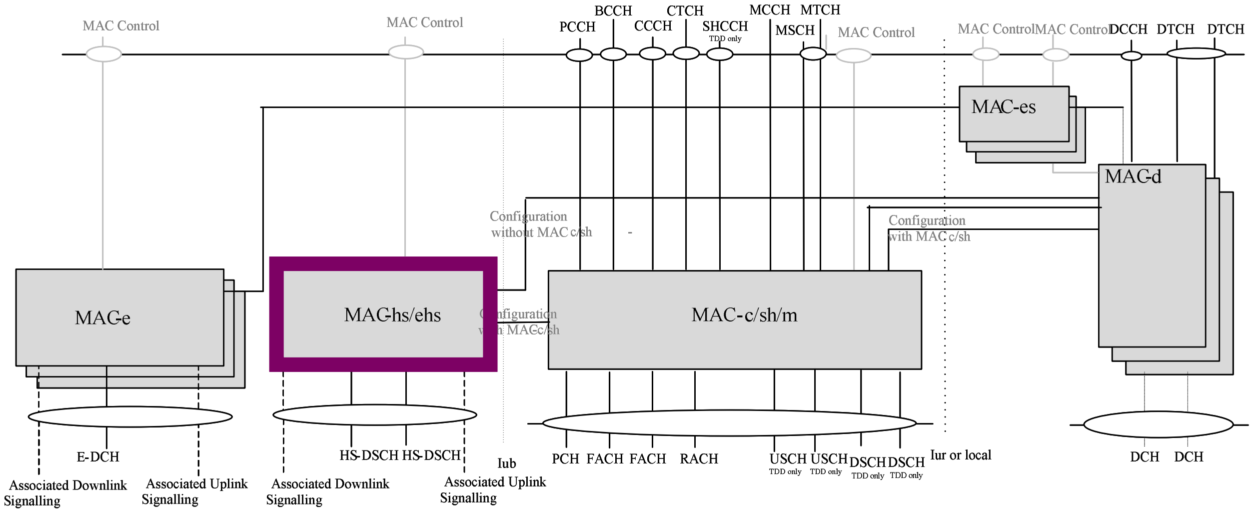


Figure 12: UTRAN side MAC architecture with MAC-ehs

Basically, MAC-ehs allows the support of flexible RLC PDU (Protocol Data Unit) sizes as well as MAC segmentation/reassembly. Furthermore, unlike MAC-hs for HSDPA, MAC-ehs allows to multiplex data from several priority queues within one transmission time interval of 2 ms. Figure 13 shows the details of the MAC-ehs on UTRAN side.

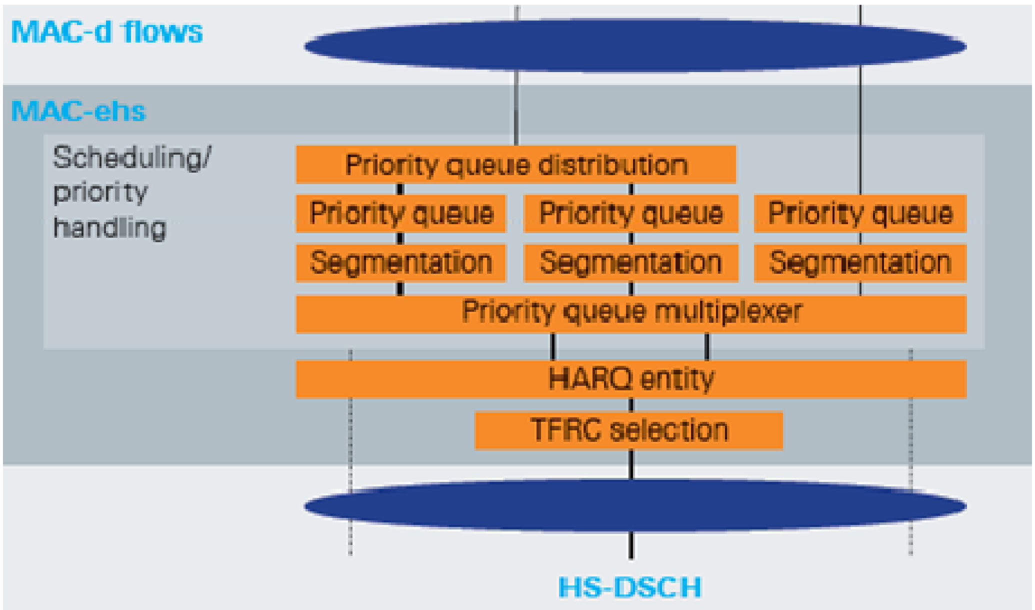


Figure 13: UTRAN side MAC-ehs details

The scheduling/priority handling function is responsible for the scheduling decisions. For each transmission time interval of 2 ms, it is decided whether single or dual stream (MIMO) transmission is used. New transmissions or retransmissions are sent according to the ACK/NACK uplink feedback, and new transmissions can be initiated at any time. In CELL_FACH, CELL_PCH, and URA_PCH state, the MAC-ehs can additionally perform retransmissions on HS-DSCH without relying on uplink signalling. This is explained in the chapter 6 Enhanced CELL_FACH State (DL) below. Logical channels can be multiplexed onto priority queues.

Reordering on receiver side is based on priority queues. Transmission sequence numbers (TSN) are assigned within each reordering queue to enable reordering. On the receiver side, the MAC-ehs SDU (Service Data Unit) or segment of it is assigned to the correct priority queue based on the logical channel identifier. A MAC-ehs SDU is either a MAC-c PDU (see chapter 6) or MAC-d PDU. The MAC-ehs SDUs included in a MAC-ehs PDU can have different size and different priority and can belong to different MAC-d flows.

Higher layers are configuring the MAC-ehs protocol.

5.2 MAC-ehs Protocol Data Unit (PDU)

In order to take the new MAC-ehs protocol functionality into account, a MAC-ehs PDU format with specific MAC header is introduced, see Figure 14. Per transmission time interval, one MAC-ehs PDU can be transmitted (two in the MIMO case).

A MAC-ehs PDU consists of one MAC-ehs header and one or more reordering PDUs. Each reordering PDU consists of one or more MAC-ehs SDUs or segments of MAC-ehs SDUs belonging to the same priority / reordering queue. MAC-ehs SDUs from up to 3 priority queues can be multiplexed within a transmission time interval.

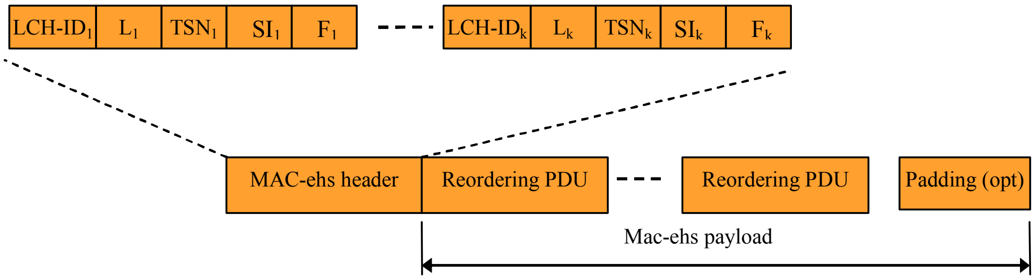


Figure 14: MAC-ehs PDU

For each MAC-ehs SDU or segment of it the MAC-ehs header carries a *logical channel identifier* field (LCH-ID, 4 bits) and a *length field* (L, 11 bits). The *logical channel identifier* provides explicit identification of the logical channel for the MAC-ehs SDU or segment and also of the priority queue for reordering. The mapping of the LCH-ID to the priority / reordering queue is provided by upper layers. The *length field* provides the length of the SDU or segment of it in octets. Each header extension thus corresponds to one MAC-ehs SDU or segment of MAC-ehs SDU.
For each reordering PDU, the header contains a *transmission sequence number* field (TSN, 6 bits) for reordering purposes, and a *segmentation indication* field (SI, 2 bits). The *SI* field indicates whether the reordering PDU contains segments or full MAC-ehs SDUs. The presence of the *TSN* and *SI* fields is based on the *logical channel identifier*, i.e. the UE detects based on the received LCH-ID if the next MAC-ehs SDU or segment belongs to the same reordering queue, and knows that there is no *TSN* or *SI* field for that SDU. The *TSN1* and *SI1* fields are always present. The MAC-ehs header is octet aligned.

5.3 Enhancements to RLC

The use of MIMO and higher order modulation will significantly increase the peak data rates of HSDPA at the physical layer. However the RLC peak data rate is limited by the RLC PDU size, the RTT and the RLC window size. In Release 6 the RLC PDU sizes are fixed, i.e. 320 or 640 bit. In consequence the maximum data rate is reduced due to the RLC overhead inefficiency. In order to optimize HSPA+ operation, RLC has been enhanced to support flexible downlink RLC PDU sizes for acknowledged mode (AM) operation (26 different PDU sizes are available). When flexible PDU size usage has configured by higher layers, the data PDU size is selected according to the payload size unless the SDU size exceeds the configured maximum size in which case segmentation is performed.
Figure 15 illustrates the principle of flexible downlink RLC PDU sizes comparing 3GPP release 5 and 3GPP release 7 mode of operation.

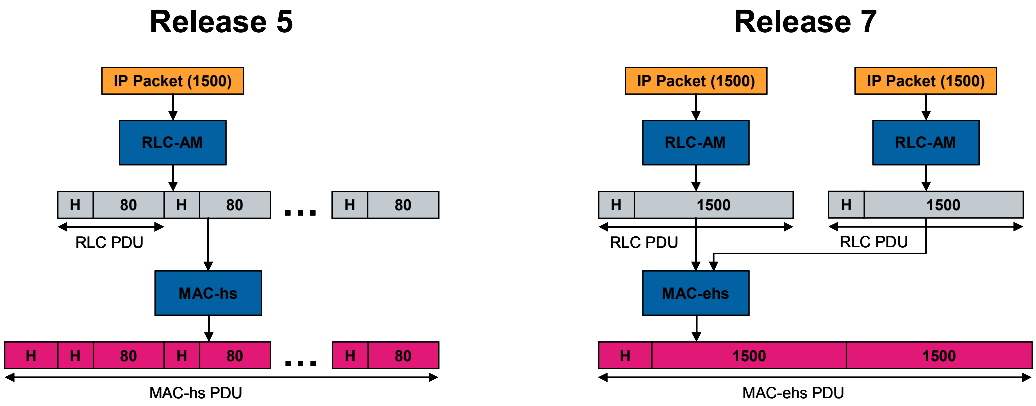


Figure 15: Flexible RLC PDU size operation

6 Enhanced CELL_FACH State (DL)

From release 99 onwards, four different protocol states have been defined for UEs in RRC connected mode (see Figure 16):

- CELL_DCH state
- CELL_FACH state
- CELL_PCH state
- URA_PCH state

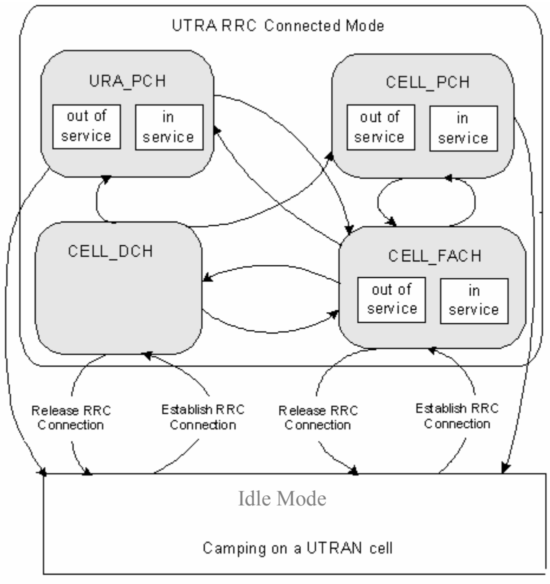


Figure 16: RRC States and State Transitions [7]

They are characterized by the channels the UE may receive or transmit and the tasks the UE has to carry out. As of 3GPP release 99, the logical channels DCCH (Dedicated Control Channel) and DTCH (Dedicated Traffic Channel) are only available in CELL_DCH and CELL_FACH states. Usage of HSDPA and HSUPA as defined in 3GPP release 5 and release 6, respectively, has only been possible in CELL_DCH state so far.
The work on “Enhanced CELL_FACH state” for HSPA+ in 3GPP release 7 extends the usage of HSDPA to CELL_FACH state, URA_PCH state, and CELL_PCH state. In that respect the title of the work item is misleading, because it does not only affect CELL_FACH state.
CELL_FACH state of 3GPP release 99 utilizes FACH (Forward Access Channel) mapped on S-CCPCH (Secondary Common Control Physical Channel) for transmission of small downlink data packets. Due to its limited control channel overhead, CELL_FACH state is optimum for “always on” type of services which introduce frequent but small packets to be transmitted to the UE.

Being able to use the HS-DSCH on HS-PDSCH in CELL_FACH state has a lot of benefits. It further increases the available data rate in CELL_FACH. Furthermore, because of the reduced transmission time interval of 2 ms, HS-DSCH allows to reduce signalling delays of downlink control messages. Also state transition to CELL_DCH state can be accelerated.
Figure 17 illustrates the mapping of logical channels on transport and physical channels in case of CELL_FACH state. The mapping as of release 7 onwards is shown using red arrows, the mapping as of release 5 is included for comparison using shaded arrows.

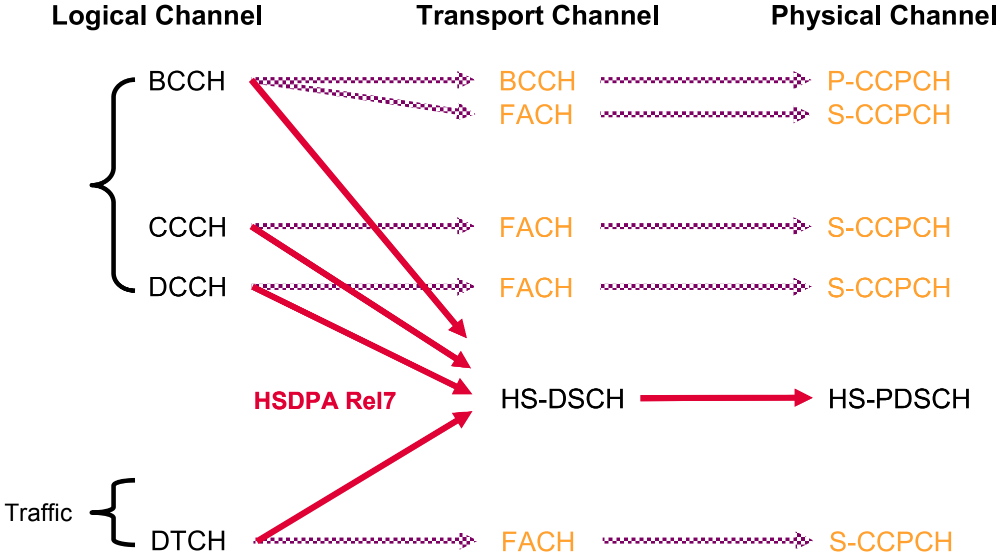


Figure 17: Mapping of logical channels on transport and physical channels in CELL_FACH state

Furthermore, the benefits of transmitting on HS-DSCH is also available for CELL_PCH and URA_PCH states which reduces signalling delays.
Table 19 provides an overview on the logical channels that may be transmitted on HS-DSCH in the different states.

Table 19: Support of logical channel transmission on HS-DSCH

	CELL_FACH	CELL_PCH	URA_PCH
DCCH/DTCH	X	X	-
BCCH	X	X	-
PCCH	-	X	X
CCCH	X	-	-

The major differences to conventional HSDPA operation as of 3GPP release 5 / 6 can be summarized as follows for operation of HS-DSCH in CELL_FACH, CELL_PCH and URA_PCH states:

– Lack of associated dedicated channels

- Lack of uplink feedback signalling on HS-DPCCH (i.e. neither ACK/NACK nor CQI signalling is available); retransmissions are performed without ACK/NACK
- Use of MAC-ehs
- New mapping of logical channels on HS-DSCH, see Table 18
- New paging mechanism in CELL_PCH and URA_PCH state (also used for reception of other logical channels besides PCCH)
- System information change indication on HS-DSCH possible in CELL_FACH and CELL_PCH states
- New measurement reporting mechanism for HSDPA operation based on measured results in RACH

6.1 Enhanced paging procedure with HS-DSCH

An enhanced paging procedure is introduced for HSPA+ in 3GPP release 7 in order to leverage HS-DSCH usage for paging and reduce latency.
Operation of HS-DSCH in CELL_PCH and URA_PCH states is defined as follows. It relates to reception of paging messages on PCCH in CELL_PCH and URA_PCH states, but the basic mechanism is also re-used for reception of other logical channels in CELL_PCH and URA_PCH states.
The enhanced paging procedure is still based on paging occasions and monitoring of PICH (Paging Indicator Channel) as defined from 3GPP release 99 onwards. PICH will be used to alert the UE in CELL_PCH/URA_PCH that a PCCH paging message or another logical channel is going to be transmitted on the HS-DSCH.
The UE can find a list of PICHs in *HS-DSCH paging system information* (see Table 20) in system information block types 5/5bis, and will select a specific PICH according to a pre-defined rule based on U-RNTI (UTRAN Radio Network Temporary Identifier). The UE then monitors this selected PICH in DRX operation. Basically, the PICH is shared between conventional paging and HSDPA purposes. The PICH channels listed in HS-DSCH paging system information may actually point to the same physical channel as legacy ones.

Table 20: HS-DSCH paging system information [7]

Information Element/Group name	**Need**	**Type**	**Semantics description**
DL Scrambling Code	MD	Secondary scrambling code	DL Scrambling code to be applied for HS-DSCH and HS-SCCH. Default is same scrambling code as for the primary CPICH.
PICH for HSDPA supported paging list	MP		
>HSDPA associated PICH info	MP	PICH info	

Information Element/Group name	Need	Type	Semantics description
>HS-PDSCH Channelisation Code	MP	Integer (0..15)	HS-PDSCH channel, associated with the PICH for HS-SCCH less PAGING TYPE 1 message transmission.
Number of PCCH transmissions	MP	Integer (1..5)	number of subframes used to transmit the PAGING TYPE 1.
Transport Block Size List	MP		
>Transport Block Size Index	MP	Integer (1..32)	Index of value range 1 to 32 of the MAC-ehs transport block size as described in appendix A of [15]

The PICH is associated with HS-SCCH subframes which are again associated with HS-PDSCH(s). If the UE is being addressed via a paging indicator set in a PICH frame, the UE switches to the associated HS-SCCHs and HS-PDSCHs. Figure 18 illustrates the timing between a PICH frame and its set of five associated HS-SCCH subframes. The first subframe of the associated HS-SCCH starts τ_{PICH} chips = 7680 chips (i.e. one subframe of three timeslots) after the transmitted PICH frame.

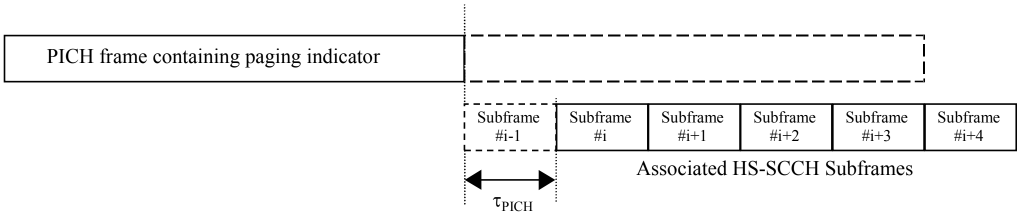


Figure 18: Timing relation between PICH frame and associated HS-SCCH subframes

Both HS-SCCH and HS-SCCH less operation is possible. Whether the UE has to read the HS-SCCH or whether it attempts to blindly decode the information on HS-PDSCH in HS-SCCH less operation mode is depending on whether the UE has been configured by the network with a dedicated H-RNTI (HS-DSCH Radio Network Temporary Identifier).
When HS-SCCH is used, after receiving notification on the PICH, the UE receives the four associated HS-SCCH channelisation codes on five subframes for its H-RNTI to check if it has been scheduled. HS-SCCH type 1 format is used. If the UE's H-RNTI is not received in these five subframes the UE resumes DRX operation. Note that in this mode of operation, the base station has the choice to do retransmissions of the same message within the five associated HS-SCCH subframes (up to four retransmissions).
For HS-SCCH less operation, the network directly associates each PICH with a HS-PDSCH channelisation code. This information is provided by *HS-DSCH paging system information*. After notification on PICH, the UE directly switches to the associated HS-PDSCH and attempts to blindly decode the message. The network informs the UE about the maximum number of contiguous retransmissions (up to five) on HS-DSCH, and about the two possible transport block sizes. QPSK modulation is used on HS-PDSCH. The redundancy versions for the retransmissions are fixed.

6.2 User data on HS-DSCH in Enhanced CELL_FACH state

User data transfer on HS-DSCH is possible in CELL_FACH state. This is based on regular HS-SCCH type 1 and associated HS-DSCH reception. In CELL_FACH state, the UE performs continuous reception of the HS-SCCH (except on predefined measurement occasion frames where the UE has to perform measurements).
The configuration of HS-DSCH in CELL_FACH state is provided in *HS-DSCH common system information* via system information block type 5 / 5bis (see Table 21). This information is also used when the UE is entering connected mode from idle mode by sending an *RRC connection request* message.

Table 21: HS-DSCH common system information [7]

Information Element/Group name	**Need**	**Multi**	**Type**
CCCH mapping info	MP		Common RB mapping info
SRB1 mapping info	MD		Common RB mapping info
Common MAC-ehs reordering queue list	MP		Common MAC-ehs reordering queue list
HS-SCCH system info	MP		HS-SCCH system info
HARQ system Info	MP		HARQ Info
Common H-RNTI Information	MP	1 to <maxCommonHRNTI>	
>Common H-RNTI	MP		H-RNTI
BCCH specific H-RNTI	MP		H-RNTI

The UE will start listening to the HS-SCCH(s) indicated in *HS-DSCH common system information*, based on a common H-RNTI. A list of common H-RNTIs is provided by *HS-DSCH common system information*, and the common H-RNTI to use is selected by the UE based on a pre-defined rule containing U-RNTI. After detecting the HS-SCCH with common H-RNTI, the UE starts reception of the corresponding HS-PDSCH(s) containing CCCH logical channel.
When the UE has been configured with a H-RNTI, it is being addressed via this identifier on HS-SCCH in CELL_FACH state. The enhanced Layer 2 architecture is used for the data transfer, i.e. flexible RLC PDU size and MAC-ehs segmentation.
Additionally, as can be seen from Table 19, 3GPP release 7 also introduces the direct data transmission in CELL_PCH state for UEs with a dedicated H-RNTI configured. The option of transmitting data to users in CELL_PCH provides effective means of supporting background traffic like presence updates and broadcast news for always connected UEs. Data can be delivered without cell update delay, and also using less signalling overhead (no paging over S-CCPCH required).

The mechanism is based on monitoring paging occasions on PICH similarly to the paging mechanism outlined above in this chapter. UEs in CELL_PCH state with a dedicated H-RNTI configured will receive the HS-SCCH after detecting the PICH, according to the association in Figure 18. If the UE is being addressed on H-RNTI, it will initiate sending a downlink quality measurement report on RACH (and move to CELL_FACH state for this purpose).

6.3 BCCH reception in Enhanced CELL_FACH state

System information and system information change indication messages can be sent on S-CCPCH in CELL_FACH state. To avoid that a UE has to simultaneously receive HS-DSCH and S-CCPCH in order to learn about modifications of system information, support of BCCH transmission via HS-DSCH has been introduced. Users in CELL_FACH state may have been configured with a dedicated H-RNTI and are able to receive dedicated data on HS-DSCH. Other users are only receiving data on common channels based on a common H-RNTI, as outlined above in this chapter. Both users with and without dedicated H-RNTI must be able to receive BCCH data. In order to avoid that BCCH data has to be transmitted using the H-RNTIs of all UEs in CELL_FACH, causing high load, a BCCH specific H-RNTI has been introduced to notify all UEs in CELL_FACH that BCCH information is transmitted.
The BCCH specific H-RNTI is provided by *HS-DSCH common system information*. BCCH is then received by listening to the first indexed HS-SCCH code listed in *HS-DSCH common system information*. As soon as UE is being addressed by the BCCH specific H-RNTI on this HS-SCCH, the UE will switch to the associated HS-PDSCH and receive BCCH containing the *system information change indication* message with *BCCH modification info*.
This mechanism is valid for CELL_FACH state and for CELL_PCH state in case UE is configured with a dedicated H-RNTI. The base station will avoid mixing BCCH modification info and any other CELL_FACH data within the same transmission time interval.

6.4 Measurement reporting procedure

Link Adaptation by adapting the modulation and coding scheme is one of the key features of HSDPA operation. However, in enhanced CELL_FACH state, no downlink channel quality (CQI) reports are available due to the lack of HS-DPCCH feedback channel. Hence the link adaptation mechanism needs modification to work in enhanced CELL_FACH state.
Instead of using HS-DPCCH, the UE will include measurements of downlink quality (i.e. CPICH measurements) within measured results on RACH in uplink RRC messages (see Figure 19). After reception in the network, these measurements are then forwarded from radio network controller to base station via I_{ub} interface and can be used as input for selecting the optimum modulation and coding scheme.

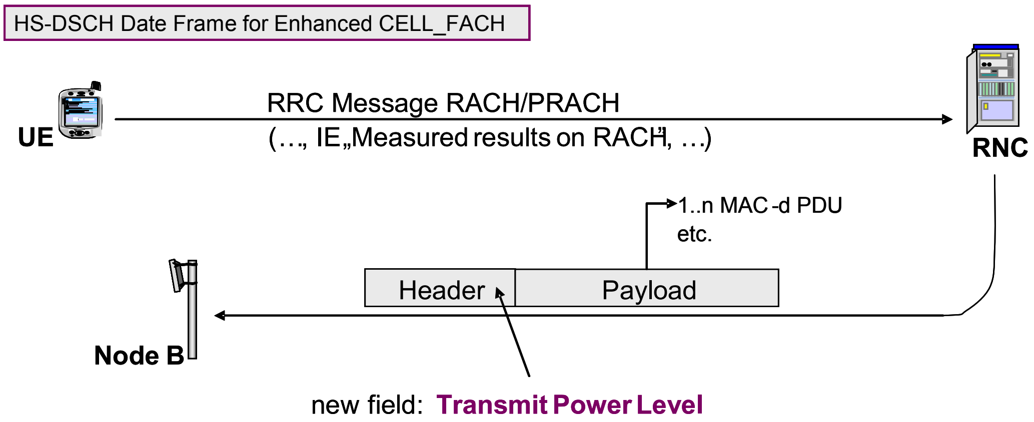


Figure 19: Measurement reporting procedure in Enhanced CELL_FACH

Measurement reporting is performed when moving from CELL_PCH state to CELL_FACH state so that the base station has valid information about downlink channel quality available. This information also helps to adapt the number of retransmissions on HS-DSCH in CELL_FACH state (due to the lack of HS-DPCCH no ACK/NACK feedback is available).

6.5 UE capabilities

As mentioned above, the UE is required to be able to receive HS-DSCH in contiguous subframes in CELL_PCH, URA_PCH and CELL_FACH states. Therefore, certain UE capabilities agreed for 3GPP release 5 are no longer possible in 3GPP release 7 when UE supports Enhanced CELL_FACH state. This is true for UE Categories 1 to 4 and Category 11. They do not support the required Inter TTI distance of 1 and thus do not support HS-DSCH reception in CELL_FACH, CELL_PCH or URA_PCH states.

7 Combination of MIMO and 64QAM

In 3GPP release 7 the UE can indicate support for both MIMO and 64QAM however it is not required to run both features simultaneously. In 3GPP release 8 the combination of 64QAM and MIMO is introduced in order to further increase user throughput in scenarios where users can benefit from favourable radio conditions such as in well tuned outdoor systems, indoor system solutions or isolated cell scenarios. The maximum possible UE data rate combining both features is increased to about 42Mbps.

7.1 MIMO/64QAM UE capabilities

MIMO in combination with 64QAM is an UE capability, i.e. not all UEs will have to support it. New UE categories have been introduced, see Table 22:

- **Categories 19 and 20:**
  - Support of MIMO with modulation schemes QPSK, 16QAM and 64QAM
  - Maximum data rate of category 19 is 35.28 Mbps
  - Maximum data rate of category 20 is 42.40 Mbps

Table 22: New release 8 UE categories 19/20 with simultaneous MIMO and 64QAM support

HS DSCH category	MIMO support	Modulation	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	Maximum data rate per stream [Mbps]
…	…	…	…	…	…	…
Category 17	No	QPSK / 16QAM / 64QAM	15	1	35280	~ 17.64
	Yes	QPSK / 16QAM	15	1	23370	~ 11.66
Category 18	No	QPSK / 16QAM / 64QAM	15	1	42192	~ 21.10
	Yes	QPSK / 16QAM	15	1	27952	~ 13.98
Category 19	Yes	QPSK / 16QAM / 64QAM	15	1	35280	~ 17.64
Category 20			15	1	42192	~ 21.20

7.2 HS-SCCH information field mapping for 64QAM MIMO

In order to notify the UE of 64QAM in case of MIMO the HS-SCCH type 3 signalling scheme is extended. The number of transport blocks transmitted on the associated HS-PDSCH(s) and the modulation scheme information are jointly coded as shown in Table 23 (additions – see also Table 2 – are marked in blue). However the 3 bits of the information field *modulation and number of transport blocks info* are not enough to signal all possible combinations. Therefore an extra bit is needed for modulation information which is taken from channelization-code-set (CCS) information, i.e. in case $X_{ms,1}$, $X_{ms,2}$, $X_{ms,3}$ equals "101" $X_{ccs,7}$ is used as an extra bit in modulation scheme information.

- $X_{ccs,7}$ = 0 if the modulation for the secondary transport block is QPSK, and
- $X_{ccs,7}$ = 1 if the number of transport blocks = 1.

Table 23: Interpretation of "Modulation scheme and number of transport blocks" sent on HS-SCCH

Modulation scheme and number of transport blocks info (3 bits)	Modulation for primary transport block	Modulation for secondary transport block	Number of transport blocks
111	16QAM	16QAM	2
110	16QAM	QPSK	2
101	**64QAM**	**Indicated by Xccs,7**	**Indicated by Xccs,7**
100	16QAM	n/a	1
011	QPSK	QPSK	2
010	**64QAM**	**64QAM**	**2**
001	**64QAM**	**16QAM**	**2**
000	QPSK	n/a	1

For each of the primary transport blocks and a secondary transport block if two transport blocks are transmitted on the associated HS-PDSCH(s), the redundancy version (RV) parameters r, s and constellation version parameter b are coded jointly. This joint coding is done in the same way as for MIMO with 16QAM modulation (see [4] for details).

7.3 New CQI tables for combination of 64QAM and MIMO

The CQI reporting scheme for MIMO is described in chapter 2.5. The reporting scheme is maintained. However for use of 64QAM in case of dual stream transmission, i.e. in case of the type A CQI reports, new CQI mapping tables are introduced (see Table 24 and Table 25).

Table 24: CQI mapping table for UE category 19 in case of dual transport block type A CQI reports

CQI_1 or CQI_2	Transport Block Size	Number of HS-PDSCH	Transport Block Size	Equivalent AWGN SINR difference Δ	NIR	Xrvpb or Xrvsb
0	4592	15	QPSK	-3.00	43200	0
1	4592	15	QPSK	-1.00		
2	5296	15	QPSK	0		
3	7312	15	QPSK	0		
4	9392	15	QPSK	0		
5	11032	15	QPSK	0		
6	14952	15	16QAM	0		
7	17880	15	16QAM	0		
8	21384	15	16QAM	0		
9	24232	15	16QAM	0		
10	27960	15	64QAM	0		
11	32264	15	64QAM	0		
12	32264	15	64QAM	2		
13	32264	15	64QAM	4		
14	32264	15	64QAM	6		

Table 25: CQI mapping table for UE category 20 in case of dual transport block type A CQI reports

CQI_1 or CQI_2	Transport Block Size	Number of HS-PDSCH	Transport Block Size	Equivalent AWGN SINR difference Δ	NIR	Xrvpb or Xrvsb
0	4592	15	QPSK	-3.00	43200	0
1	4592	15	QPSK	-1.00		
2	5296	15	QPSK	0		
3	7312	15	QPSK	0		
4	9392	15	QPSK	0		
5	11032	15	QPSK	0		
6	14952	15	16QAM	0		
7	17880	15	16QAM	0		
8	21384	15	16QAM	0		
9	24232	15	16QAM	0		
10	27960	15	64QAM	0		
11	32264	15	64QAM	0		
12	36568	15	64QAM	0		
13	39984	15	64QAM	0		
14	42192	15	64QAM	0		

8 CS over HSPA

Basically, CS voice over HSPA takes the mobile circuit voice service, using the circuit core switches in the network and tunnels it over an underlying IP bearer. So the application is not VoIP, but circuit telephony while the wireless transport is IP. The feature supports both adaptive multi rate (AMR) and AMR wide band (WB) operation. The reasons to consider running CS speech over HSPA are:

- The use of DCH in a cell can be minimised and thus more power and code resources are available for HSPA use.
- The setting up of the CS call when using HSPA for SRB is accelerated.
- The availability of the benefits of the features from Continuous Connectivity for Packet Data Users, including DTX/DRX for devices in order to save battery and reduce interference.
- Faster set-up of PS services in parallel to CS speech as HSPA is readily on.

8.1 Jitter Buffer Management

In contrast to traditional CS voice service CS over HSPA transmission faces additional delays on the air interface resulting from scheduling and layer 1 retransmissions. Note however that the overall delay is smaller compared to the Voice over IP (VoIP) case, since in the core network the I_u CS interface is used in contrast to IP backbone. The main solution is to introduce a Jitter Buffer Management (JBM) on each receiver end (RNC and UE), which allows to compensate varying delays on the air interface at the expense of an acceptable absolute delay. The same principle solution applies to VoIP. The JBM is also responsible to detect silent periods, i.e. when no data is sent via the air interface (DTX) as well as when data is lost on the air interface.
In order to cope with silent periods and lost data the de-jitter buffer needs additional information, i.e. a time stamp information and means to understand in sequence delivery, e.g. a sequence number. If only the sequence number is known the receiver does not know about the time gap which occurred on the air interface resulting into possible stretched-out or compressed words or syllables. If only the time stamp is known the receiver can construct the timeline accurately, however it is impossible to know which frames were dropped over the air. In consequence the receiver does not know whether to do erasure processing or comfort noise generation.
The maximum delay experienced in either downlink or uplink is the crucial parameter for CS over HSPA. There is always a trade of between capacity and speech quality which is finally decided by the operator policy. However it is beneficial to limit the maximum delay to not degrade speech quality due to too long E2E delay.
In downlink a discard timer is used in the MAC (see Figure 20) which is signalled from RNC to NodeB. The NodeB will discard AMR packets after the discard timer is expired. Therefore for uplink transmission the RNC can set scheduling parameters for the UE and manage its own receiving de-jitter buffer such that the overall delay matches the discard timer.

In downlink the RNC is again setting scheduling parameters, however the de-jitter buffer is managed by the UE. Without knowing the maximum jitter delay the UE will need to use its maximum de-jitter buffer size and thus will always add maximum delay in the overall E2E delay budget. With a maximum DL jitter delay information and a time stamp information in PDCP, the UE will be able to manage its de-jitter buffer more efficiently resulting into improved speech quality. In consequence an information element *Max CS delay* is signalled to the UE, which is configured by the RNC and ranges from 20ms to 200ms.

8.2 PDCP solution and RLC Mode of operation

Figure 20 illustrates the solution specified in 3GPP release 8 compared to legacy CS operation. The RLC is used in unacknowledged mode due to the nature of the voice service. Note that class A, B and C bits are not separated into different streams, i.e. unequal error protection (UEP) is not applied.

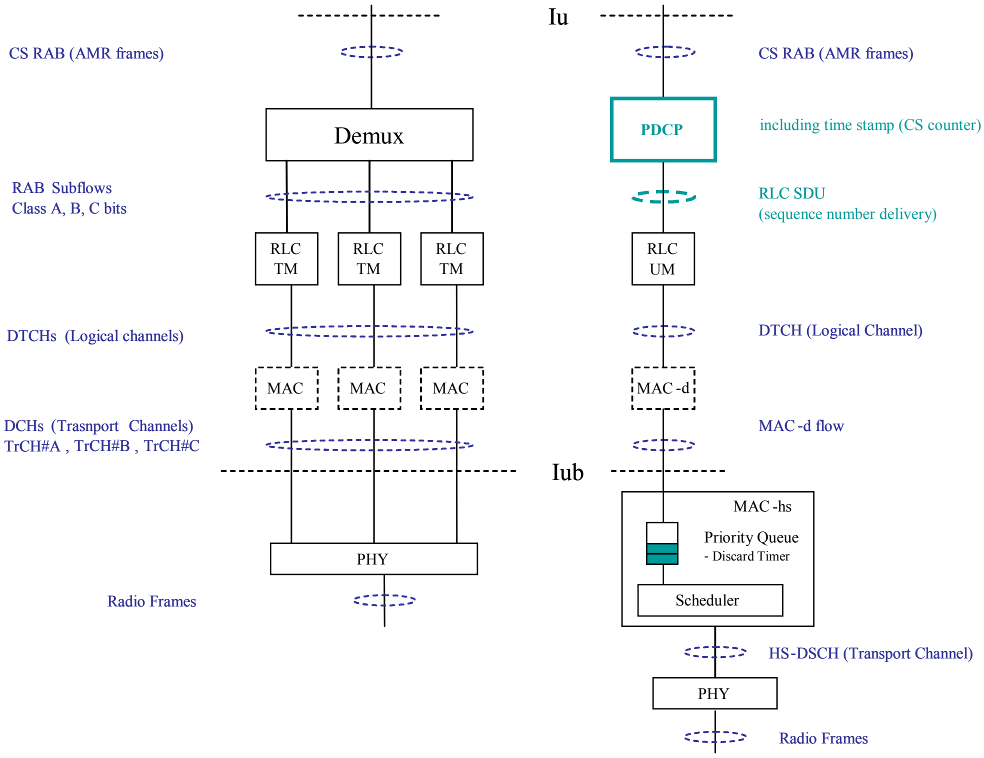


Figure 20: Downlink U-plane multiplexing: Legacy vs.CS over HSPA scheme

The main modifications are introduced in the PDCP layer. Also the PDCP layer is not any longer defined for the PS domain only. Figure 21 provides the basic PDCP structure.

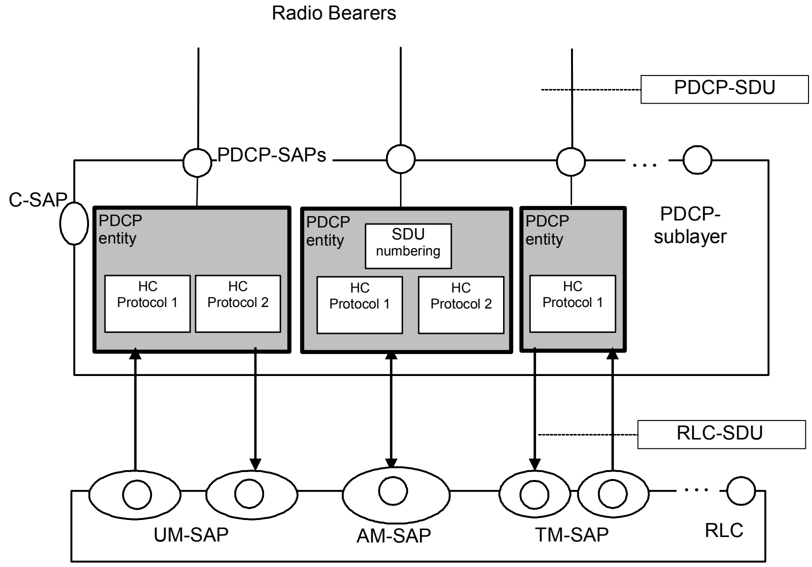


Figure 21: PDCP structure

Every CS domain voice RAB is associated with one RB, which in turn is associated with one PDCP entity. Each PDCP entity is associated with two UM RLC entities as CS voice RBs are always bi-directional. The PDCP entity serving CS service does not use header compression. In order to support CS service over PDCP a new PDU type and a new PDCP Data AMR PDU are defined (see Table 26). The AMR classes are always encoded in the order of class A, B and C, where the first bit of data follows immediately after the *CS counter* field and any padding for octet alignment is inserted at the end of the data field.

Table 26: PDCP AMR Data PDU format

PDU Type	CS Counter
Data	

The time stamp information is incorporated as *CS counter* information (5 bits). The *CS counter* field value indicates the timing of AMR or AMR-WB frames. The value of the *CS counter* is set to the first to fifth LSBs of the *connection frame number* (CFN) at which the packet has been received from higher layers. Therefore the *CS counter* provides the required timing information.
The RLC PDU in unacknowledged mode (see Figure 22) already contains a *sequence number (SN)*. Within 3GPP release 8 it is explicitly enabled delivering *SN* to upper layers through the service access point (UM-SAP), if SN Delivery is configured by higher layers.
In summary *CS counter* and the *sequence number* allow appropriate reaction of the JBM to manage CS over HSPA.

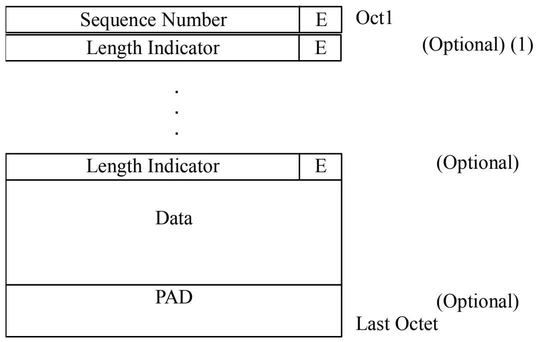


Figure 22: Unacknowledged Mode Data (UMD) PDU

8.3 AMR rate control on RRC layer

Adaptive multi rate transmission allows variation of the coding rate according to current propagation conditions and also to trade off capacity/coverage against speech quality depending on operator policy. Although rate changes are not anticipated frequently, e.g. only during busy hour operation during the day, means to control the AMR rate at call set-up and to modify the AMR rate during the call have been incorporated in the RRC layer. AMR allows 7 codec rates to be used ranging from 4.75kbps to 12.2kbps. The AMR WB speech allows 9 codec rates to be used ranging from 6.6kbps to 23.85kbps. A new information element *UL AMR rate* is introduced in the *RAB information for setup*, which allows controlling the rate at call set-up. During the established connection the rate may be modified by the new TrCH information element *UL AMR rate* in the *transport format combination control message*, sent by UTRAN to the UE in order to control the uplink transport format combination within the allowed transport format combination set. With the above messages if the network changes the AMR mode and wants to limit the UL AMR rate, two messages are needed, because reconfiguring AMR <-> AMR-WB is only possible by *radio bearer setup message* and limiting UL AMR rate is possible only by *transport format combination control* message. Therefore a final optimization is introduced adding the same information element *UL AMR rate* in *RAB information to reconfigure* message.

8.4 CS over HSPA UE capability

CS over HSPA is a UE capability, i.e. it is an optional release 8 feature. The UE indicates its *Support for CS voice over HSPA* to the network, which defines whether the UE is able to route CS voice (AMR and AMR WB) data over HS-DSCH and E-DCH transport channels. If the UE supports CS voice over HS-DSCH and E-DCH, then it needs to support HSDPA/HSUPA in CELL_DCH state, CPC DTX (see chapter 4) and MAC-ehs (see chapter 5).

9 Dual Cell HSDPA

Within 3GPP Rel7 the peak user throughout was significantly enhanced (MIMO, Higher Order Modulation). In order to fulfil the desire for even better and more consistent user experience across the cell the deployment of a second HSDPA carrier creates an opportunity for network resource pooling as a way to enhance the user experience, in particular when the radio conditions are such that existing techniques (e.g. MIMO) can not be used.
The following restrictions apply in case of dual cell HSDPA operation:

- The dual cell transmission only applies to HSDPA physical channels
- The two cells belong to the same Node-B and are on adjacent carriers
- The two cells do not use MIMO to serve UEs configured for dual cell operation
- The two cells operate in the same frequency band

From a system capacity point of view and in order not to prevent load balancing between the two uplink carriers, it is important that the uplink carrier for a dual-cell HSDPA UE is not strictly tied by the standard to one of the two downlink carriers (Figure 23). Therefore it is possible to distribute the users in the uplink on both carriers at least semi-statically using the inter-frequency handover procedure.

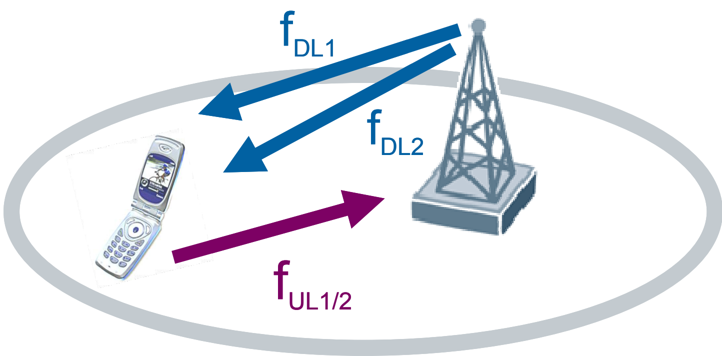


Figure 23: Dual Cell HSDPA operation

Simulative investigations within 3GPP indicated that by applying Dual Cell HSPA transmission, significantly higher data rates are achievable for users experiencing low and moderate SNR. Furthermore, due to scheduling gains, the system capacity is also expected to be increased compared to system where the carriers are used independently.
Note that DTX/DRX operation (see chapter 4.1and 4.3) is possible in case of Dual Cell HSDPA whereas DTX/DRX is (de-)activated on the serving cell and secondary serving cell simultaneously. HS-SCCH less operation (see chapter 4.4) is only possible on the serving cell.

9.1 Downlink HS-PDSCH/HS-SCCH and Uplink HS-DPCCH transmission

In contrast to MIMO HS-SCCH is transmitted on each downlink carrier characterizing the actual data transmission on the associated HS-PDSCH, i.e. there is no single HS-SCCH for “dual stream” transmission as in MIMO. In case of Dual Cell HSDPA the UE is configured with a secondary serving HS-DSCH cell. With one HS-SCCH in each of the two cells scheduling flexibility to have different transport formats depending on CQI feedback on each carrier is maintained. In consequence the downlink scheme is principally not changed compared to release 5 operation.
The maximum size of the HS-SCCH set in a secondary serving HS-DSCH cell is 4 (as in release 5) and the maximum number of HS-SCCHs monitored by the UE across both cells is 6. The UE shall be able to receive up to one HS-DSCH or HS-SCCH order from the serving HS-DSCH cell and up to one HS-DSCH or HS-SCCH order from a secondary serving HS-DSCH cell simultaneously. HS-SCCH-less operation shall not be used in a secondary serving HS-DSCH cell.
Since two HS-PDSCH are sent on adjacent carrier frequencies both streams need to be acknowledged via HS-DPCCH. The solution uses the same principle mechanism as for acknowledgment of two data stream operation in MIMO mode (see chapter 2.5, Table 4). The bits w_k of the HS-DPCCH need to be interpreted differently depending on whether the UE detects a single transport block on the serving HS-DSCH cell, a single transport block on the secondary serving HS-DSCH cell or a single transport block on each of the serving and secondary serving HS-DSCH cell. The 10 bits of the HARQ-ACK messages are interpreted as shown in Table 27.

Table 27: Interpretation of HARQ-ACK in Dual Cell HSDPA operation

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
HARQ-ACK when UE detects a single scheduled transport block on the serving HS-DSCH cell											
ACK		1	1	1	1	1	1	1	1	1	1
NACK		0	0	0	0	0	0	0	0	0	0
HARQ-ACK when UE detects a single scheduled transport block on the secondary serving HS-DSCH cell											
ACK		1	1	1	1	1	0	0	0	0	0
NACK		0	0	0	0	0	1	1	1	1	1
HARQ-ACK when UE detects a single scheduled transport block on each of the serving and secondary serving HS-DSCH cells											
Response to transport block from serving HS-DSCH cell	Response to transport block from secondary serving HS-DSCH cell										
ACK	ACK	1	0	1	0	1	0	1	0	1	0
ACK	NACK	1	1	0	0	1	1	0	0	1	1
NACK	ACK	0	0	1	1	0	0	1	1	0	0
NACK	NACK	0	1	0	1	0	1	0	1	0	1

It is important to understand that the maximum number of simultaneously-configured uplink dedicated channels is specified in [8] according to Table 28. The actual number of configured DPDCHs, denoted $N_{max\text{-}dpdch}$, is equal to the largest number of DPDCHs from all the TFCs in the TFCS.

Table 28: Maximum number of simultaneously-configured uplink dedicated channels

	DPDCH	HS-DPCCH	E-DPDCH	E-DPCCH
Case 1	6	1	-	-
Case 2	1	1	2	1
Case 3	-	1	4	1

HS-DPCCH is mapped to the I branch in case $N_{max\text{-}dpdch}$ is 2, 4 or 6, and to the Q branch otherwise ($N_{max\text{-}dpdch}$ = 0, 1, 3 or 5). This is unchanged compared to release 5 operation. Note that current UE implementations support either $N_{max\text{-}dpdch}$ = 0 or 1 only.

Figure 24 exemplify the different cases as described above, i.e. illustrating the I/Q mapping applying four E-DCH codes ($N_{max\text{-}dpdch}$ = 0) and two E-DCH codes ($N_{max\text{-}dpdch}$ = 1).

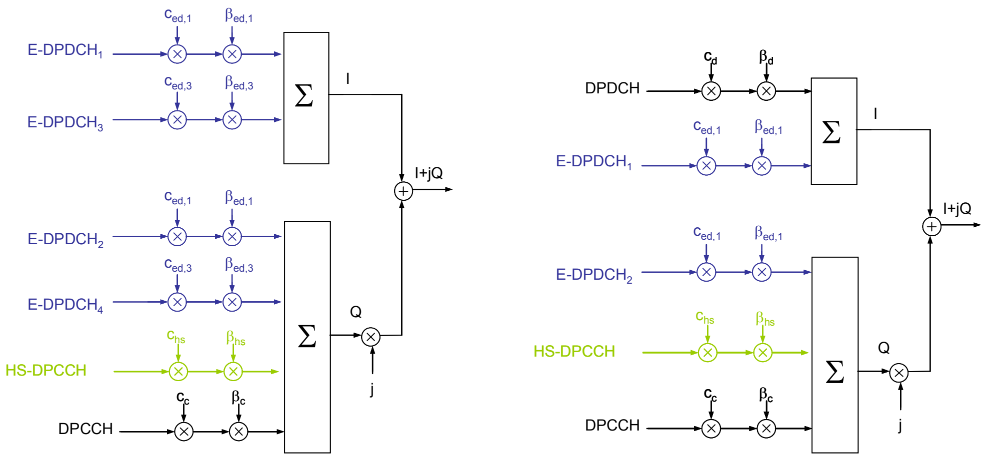


Figure 24: Physical Channel mapping in case of four EDPDCH codes and two EDPDCH codes

For a secondary serving HS-DSCH cell, the nominal radio frame timing for CPICH and timing reference are the same as the radio frame timing for CPICH and timing reference for the serving HS-DSCH cell.

9.2 Activation of Dual Cell HSDPA via HS-SCCH orders

In order to signal (de-)activation of dual cell HSPA operation to the UE the HS-SCCH order mechanism as already used for discontinuous transmission / reception and HS-SCCH less operation (see chapter 4.5) is reused. HS-SCCH orders are fast commands sent on HS-SCCH. For Dual Cell HSPA the 3 bit *order type* field is set to ‘001’ (instead of ‘000’) and the last bit of the subsequent 3 bits *order info* field is then used for activation (bit set to ‘1’) and deactivation (bit set to ‘0’), respectively. The remaining and unused 2 bits in the *order info* field are reserved for future use.

9.3 Dual Cell HSDPA Fixed Reference Channel H-Set 12

In order to support Dual Cell HSDPA testing, a new fixed reference channel has been introduced. H-Set 12 is specified as reference test channel for HSDPA test cases in [5]. H-Set 12 parameterization and coding chain is shown in Table 29 and Figure 25. It is based on one code with QPSK modulation. Six Hybrid ARQ processes are used, and HS-DSCH is continuously transmitted.

Table 29: Parameters for fixed reference channel H-Set 12 (QPSK)

Parameter	**Unit**	**Value**
Nominal Avg. Inf. Bit Rate	kbps	60
Inter-TTI Distance	TTI's	1
Number of HARQ Processes	Processes	6
Information Bit Payload (N_{INF})	Bits	120
Number Code Blocks	Blocks	1
Binary Channel Bits Per TTI	Bits	960
Total Available SML's in UE	SML's	19200
Number of SML's per HARQ Proc.	SML's	3200
Coding Rate		0.15
Number of Physical Channel Codes	Codes	1
Modulation		QPSK

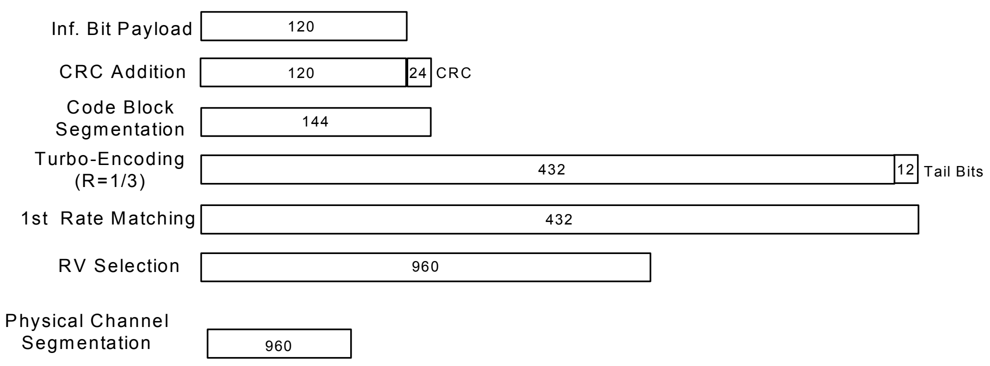


Figure 25: Coding rate for fixed reference channel H-Set 12 (QPSK)

10 Improved Layer 2 for High Data Rates (UL)

Modifications to layer 2 have become necessary in order to support the high data rates from the physical layer which result from the introduction of 16QAM modulation in 3GPP release 7.

10.1 New MAC-i/is protocol entity

A new Medium Access Control entity MAC-is/i is introduced which is optimized for HSPA+ [6]. MAC-is/i can be used alternatively to MAC-es/e. It is configured by higher layers which of the two entities is handling the data transmitted on E-DCH and the management of the physical resources allocated to E-DCH. Figure 26 shows the UE side MAC architecture including the new MAC-is/i.

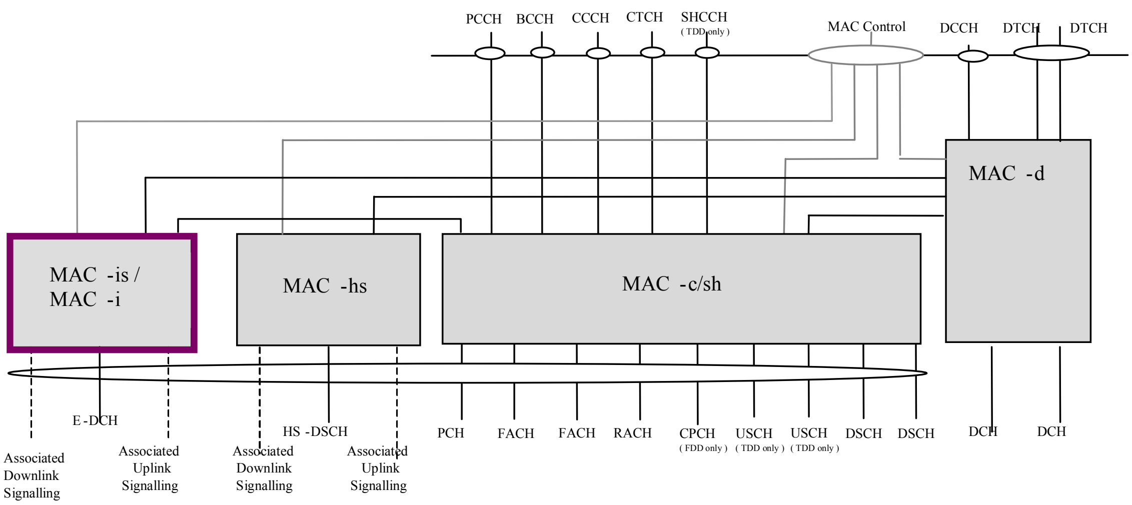


Figure 26: UE side MAC architecture with MAC-i and MAC-is

In the same way as in downlink MAC-is/i basically allows the support of flexible RLC PDU sizes and segmentation/reassembly. Figure 27 shows the details of the MAC is/i on the UE side.
Reordering on receiver side is based on priority queues. *Transmission sequence numbers* (TSN) are assigned within each reordering queue to enable reordering. On the receiver side, the MAC-is/i SDU or segment of it is assigned to the correct priority queue based on the *logical channel identifier*.
MAC-is/i SDUs can be segmented and have to be reassembled on receiver side. The MAC-is/i SDUs included in a MAC-is/i PDU can have different size and different priority and can belong to different MAC-d flows. Higher layers are configuring the MAC-is/i protocol.

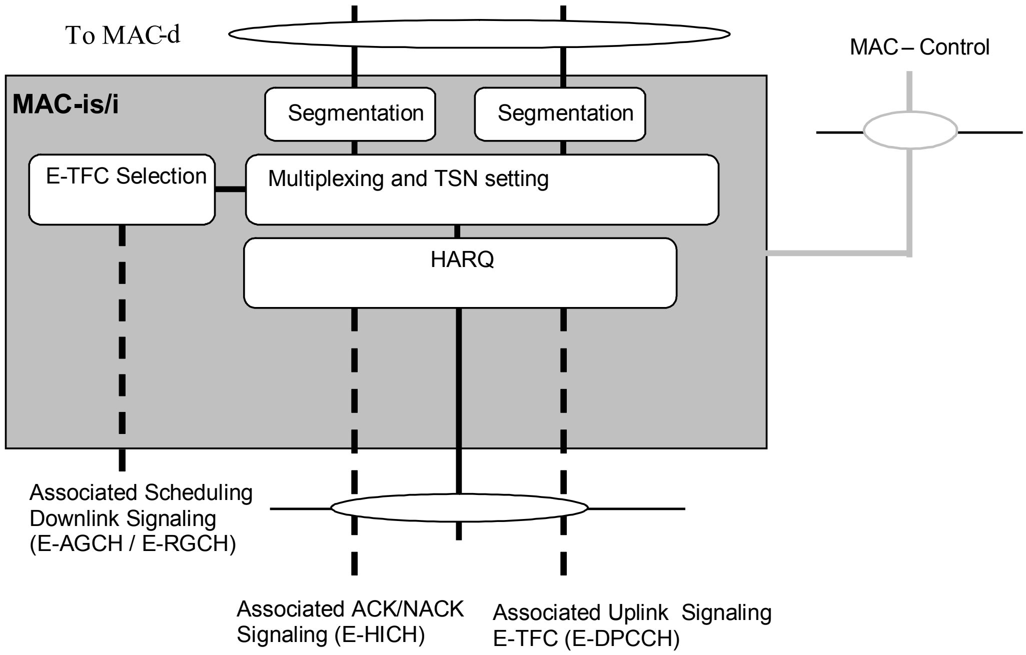


Figure 27: UE side MAC-is/i details

10.2 MAC-is/i Protocol Data Unit (PDU)

In order to support the new MAC-is/i functionality, a new PDU format is introduced, see Figure 28 and Figure 29. A MAC PDU for E-DCH consists of one MAC-i header and one or more MAC-is PDUs, whereas each MAC-is PDU consists of one or more MAC-is SDUs belonging to the same logical channel. Each MAC-is SDU equals a complete or a segment of a MAC-d PDU.
A LCH-ID (*logical channel identity*) is associated with each MAC-d PDU. In the MAC-i header, the LCH-ID field (4 bits) identifies the logical channel and MAC-d flow. The L (*length*) field indicates the size of the MAC SDU. The *TSN* field (6 bits) provides the *transmission sequence number* on the E-DCH for reordering purposes. The *SS* field provides indication whether MAC-is SDU of the MAC-is PDU is a complete MAC-d PDU or which is the first/last segment of a MAC-d PDU. The MAC-i PDU is forwarded to a Hybrid ARQ entity, which then forwards the MAC-i PDU to layer 1 for transmission in one TTI. I.e. multiple MAC-is PDUs from multiple logical channels are possible, but only one MAC-i PDU can be transmitted in a TTI.

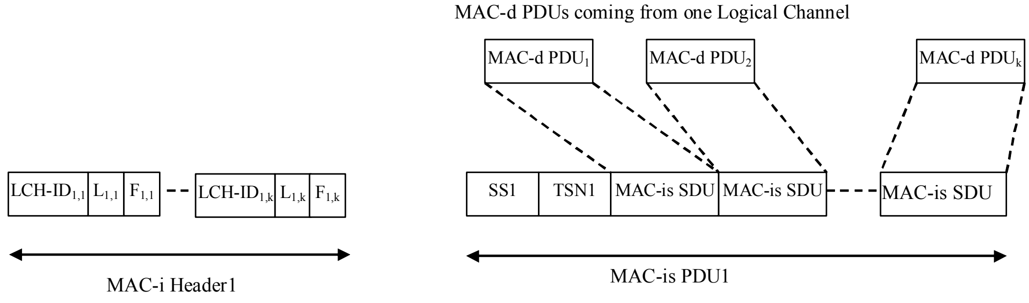


Figure 28: MAC-is PDU

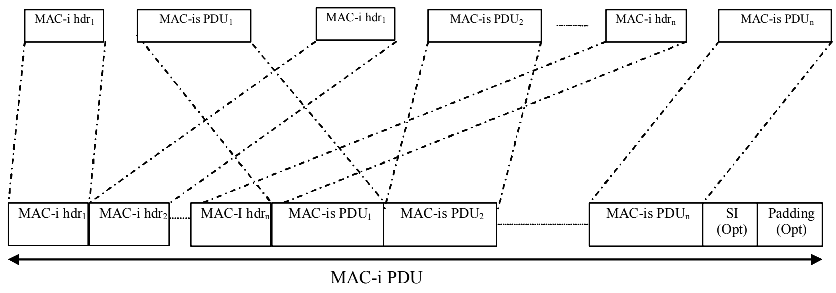


Figure 29: MAC-i PDU

10.3 Enhancements to RLC

In the same way as in downlink (see chapter 5.3) use of flexible instead of fixed PDU sizes is introduced in uplink. The maximum size is configured by higher layers and may vary from 16 to 5000 bits (in steps of 8bits). When flexible PDU size usage has been configured by higher layers, the data PDU size is selected according to the payload size unless the SDU size exceeds the configured maximum size in which case segmentation is performed.

11 Enhanced Uplink for CELL_FACH State

Work to reduce uplink and downlink signalling delays, to overcome the limitations of release 99 common transport channels, was continued in release 7 with Enhanced CELL_FACH state in FDD downlink (see section 6). However the benefits of this enhancement are limited by the poor uplink counterpart.
Considerations how common channels can be made more efficient to address cases where the usage of CELL_DCH state is not preferred by the network are motivated by high interest on "always on"- type of services like active PoC, Push email and VPN connections expected to be used via UTRAN, which introduce relatively frequent but small packets to be transmitted between UE and server. For example sending an HTTP request takes roughly 500 bytes and it has been observed that this requires over ten random accesses to transmit a complete HTTP request which is too much to be in any way practical, i.e. a transition to CELL_DCH is needed. However moving the UE to the CELL_DCH state before sending any uplink messages introduces significant delay before the actual data transmission can start.
In consequence HSUPA access in CELL_FACH state is introduced in 3GPP release 8 in order to increase the available uplink peak data rate in CELL_FACH state. Additionally the objective is to reduce latency in the IDLE mode, CELL_FACH, CELL_PCH and URA_PCH state as well as reducing state transition delay from CELL_FACH, CELL_PCH and URA_PCH to CELL_DCH state.

11.1 New E-DCH transport channel and contention resolution

In order to support enhanced uplink in CELL_FACH a new common transport channel E-DCH is specified (E-DCH is already in use as a dedicated transport channel from release 6 onwards). This common transport channel is used for uplink transmission and it is shared between UEs by allocation of individual codes from a common pool of codes assigned for the channel. There is a collision risk associated with the channel which can however be resolved if a E-RNTI is allocated to the UE. As for dedicated E-DCH the common E-DCH is inner loop power controlled, allows link adaptation and HARQ operation and is always associated with a DPCCH and one or more physical channels.
For UEs in CELL_FACH state or Idle mode, the Node B determines whether the UE id (E-RNTI) is included (its inclusion is signalled with a reserved LCH-ID value see chapter 11.4). If the Node B receives a MAC-i PDU with an E-RNTI included in the MAC-i header, then the Node B is aware of the user using a common E-DCH resource. By sending a received E-RNTI on the E-AGCH, the Node B grants the common E-DCH resource explicitly to the UE with this UE id, resolving any potential collision. A UE adds its E-RNTI in all MAC-i PDUs at its side until the UE receives an E-AGCH with its E-RNTI (through an E-RNTI-specific CRC attachment).
If no E-RNTI is included in any MAC-i header, then only CCCH data can be transmitted and consequently collision resolution can not be performed.

Common E-DCH resources are under direct control of the Node B and are shared by UEs in CELL_FACH and IDLE mode. The RNC is not involved in the assignment of these resources to UEs. Since only one cell is involved in the resource allocation, soft handover is not possible.

11.2 Enhanced random access

The only common physical channel available in the uplink is the physical random access channel (PRACH). From release 8 onwards this channel can be used to carry E-DCH. Figure 30 illustrates the mapping of logical channels on transport channels and further on physical channels comparing release 99 (shaded) and release 8 (red) mode of operation.

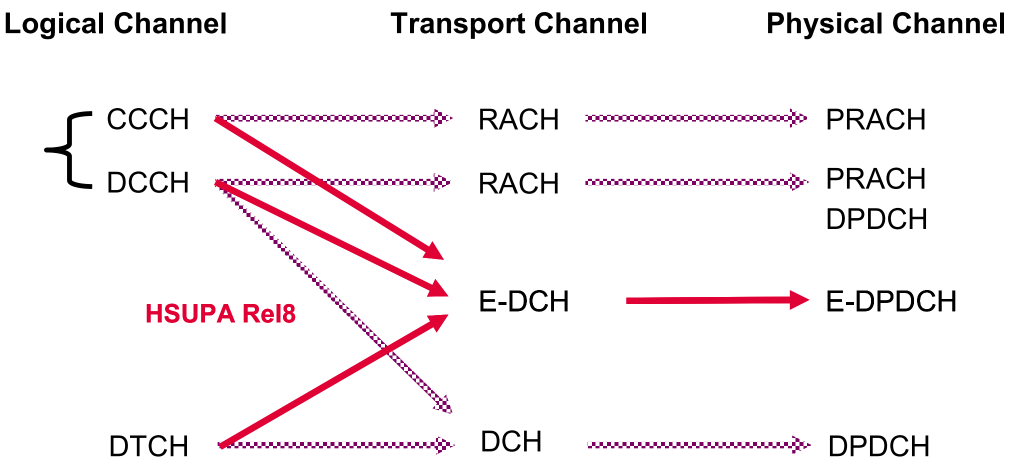


Figure 30: Mapping of logical channels on transport and physical channels for enhanced uplink in CEL_FACH state

The preamble power ramping concept is maintained, i.e. the UE sends preambles using power ramping until the NodeB acknowledges reception via the Acquisition Indicator Channel (AICH). However the AICH has been significantly enhanced allowing to acknowledge the resource request in combination with a E-DCH resource allocation from the NodeB.

In release 7 the UE chooses an access slot for initial RACH transmission using a set of allowed sequences and sub-channels per access service class as signalled by higher layers. There are 15 access slots per two frames (20ms) available. The NodeB eventually acknowledges the RACH access via the AICH in the related downlink access slot and the UE continues transmitting the message part of the RACH.

In release 8 the preamble "space" is shared between traditional RACH access and E-DCH transmission in CELL_FACH state. Before starting the RACH procedure for enhanced Uplink in CELL_FACH state the UE again receives sequence and – different from traditional RACH - sub channel information from higher layers (RRC) per access service class.

I.e. the meaning of acquisition indicators depends on whether a UE sends an access preamble signature corresponding to a PRACH message or corresponding to an E-DCH transmission.
Furthermore, if a UE sends an access preamble signature corresponding to an E-DCH transmission, the meaning of the NodeB response in the acquisition indicator depends on whether Extended Acquisition Indicator (EAI) is configured in the cell or not.
Extended Acquisition Indicators (EAI) represent a set of values corresponding to a set of E-DCH resource configurations. The UE performs power ramping the same way as in traditional RACH as long as no positive or negative acknowledgement is received on the AICH from the NodeB. If the NodeB positively acknowledges the request from the UE and if EAI is configured in the cell, the UE receives one out of 16 EAI signature patterns *s'* in the AICH. The signature in combination with the ACK (EAI=1) or NACK (EAI=-1) represents a resource allocation according to Table 30. X is the Default E-DCH resource index and Y is the total number of E-DCH resources configured in the cell for Enhanced Uplink in CELL_FACH [3].

Table 30: EAI and resource configuration mapping

$EAI_{s'}$	Signature s'	E-DCH Resource configuration index
+1	0	NACK
-1		(X + 1) mod Y
+1	1	(X + 2) mod Y
-1		(X + 3) mod Y
+1	2	(X + 4) mod Y
-1		(X + 5) mod Y
+1	3	(X + 6) mod Y
-1		(X + 7) mod Y
+1	4	(X + 8) mod Y
-1		(X + 9) mod Y
+1	5	(X + 10) mod Y
-1		(X + 11) mod Y
+1	6	(X + 12) mod Y
-1		(X + 13) mod Y
+1	7	(X + 14) mod Y
-1		(X + 15) mod Y
+1	8	(X + 16) mod Y
-1		(X + 17) mod Y
+1	9	(X + 18) mod Y
-1		(X + 19) mod Y
+1	10	(X + 20) mod Y
-1		(X + 21) mod Y
+1	11	(X + 22) mod Y
-1		(X + 23) mod Y
+1	12	(X + 24) mod Y
-1		(X + 25) mod Y
+1	13	(X + 26) mod Y
-1		(X + 27) mod Y
+1	14	(X + 28) mod Y
-1		(X + 29) mod Y
+1	15	(X + 30) mod Y
-1		(X + 31) mod Y

Figure 31 illustrates the timing relation between preambles, access slots, acquisition indication and F-DPCH/DPCCH transmission at seen from the UE.

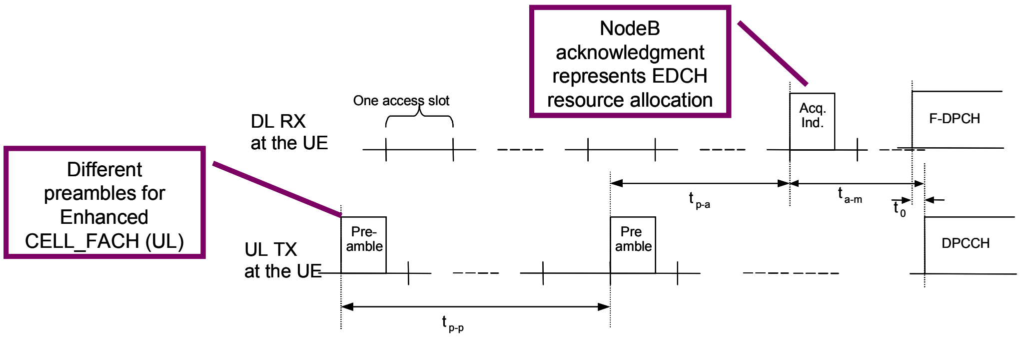


Figure 31: UL/DL timing relation for Enhanced Uplink in CELL_FACH as seen at the UE [3]

$t_{F\text{-}DPCH}$ = [(5120 * AICH access slot # with the AI) + 10240 + 256 * S_{offset}] mod 38400
$t_{a\text{-}m}$ = 10240 + 256 * S_{offset} + t_0 chips, where
S_{offset} = a symbol offset, configured by higher layers, {0,…,9}.
t_0 = 1024 chips defining the DL to UL frame timing difference.

11.3 Modified synchronisation procedure

In the NodeB each radio link set can be in three different states: initial state, out-of-sync state and in-sync state. Transitions between the different states is shown in Figure 32 below. Note that in case of Enhanced Uplink for CELL_FACH State there is only one link in the set. As described in Figure 31 above the UE starts transmission at the defined time and executes a post verification procedure confirming the establishment of the downlink physical channel.

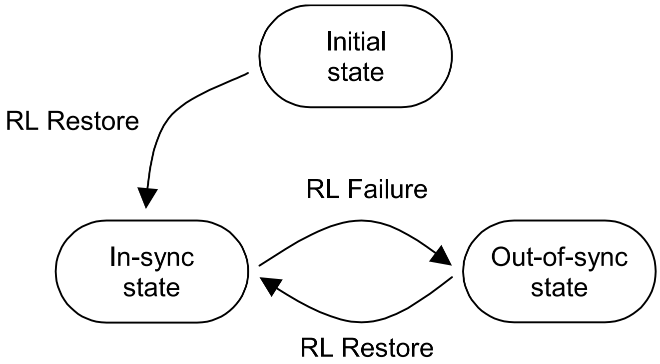


Figure 32: Node B radio link set states and transitions [2]

During the first 40 ms period of the first phase of the downlink synchronisation procedure the UE shall control its transmitter according to a downlink F-DPCH quality criterion. If during this first 40ms the quality criteria is below the threshold Q_{in}, the UE need to shut down its transmitter. There are specific test cases in [5] verifying F-DPCH reception performance. These test cases implicitly define the threshold Q_{in}. The uplink link failure / restore is under the control of the NodeB.

11.4 UE MAC modifications

In FDD, the MAC sublayer is in charge of controlling the timing of Enhanced Uplink transmissions in CELL_FACH state and idle mode on transmission time interval level (the timing on access slot level is controlled by L1, see chapter 11.1 above). After common EDCH resource allocation the transmission, retransmission and collision resolution is under control of MAC. Retransmissions in case of erroneously received MAC-is PDUs are under control of higher layers, i.e. RLC, or RRC for CCCH.
Being in CELL_FACH state the UE may map logical channels of dedicated type to common transport channels. In this case MAC-d may alternatively to using MAC-c (for RACH) submit the data to MAC-is/i (for E-DCH) as can be seen from the connection between the functional entities in Figure 26. Enhanced functionality and new functions are added to MAC-is/i as illustrated in Figure 33. The multiplexing and TSN setting entity becomes responsible to also multiplex MAC-c PDUs into a single MAC-is PDU. The new entity **CRC attachment** adds a 8bit CRC check sum to the MAC-is SDU before this data (MAC-c PDU and CRC checksum) is segmented.

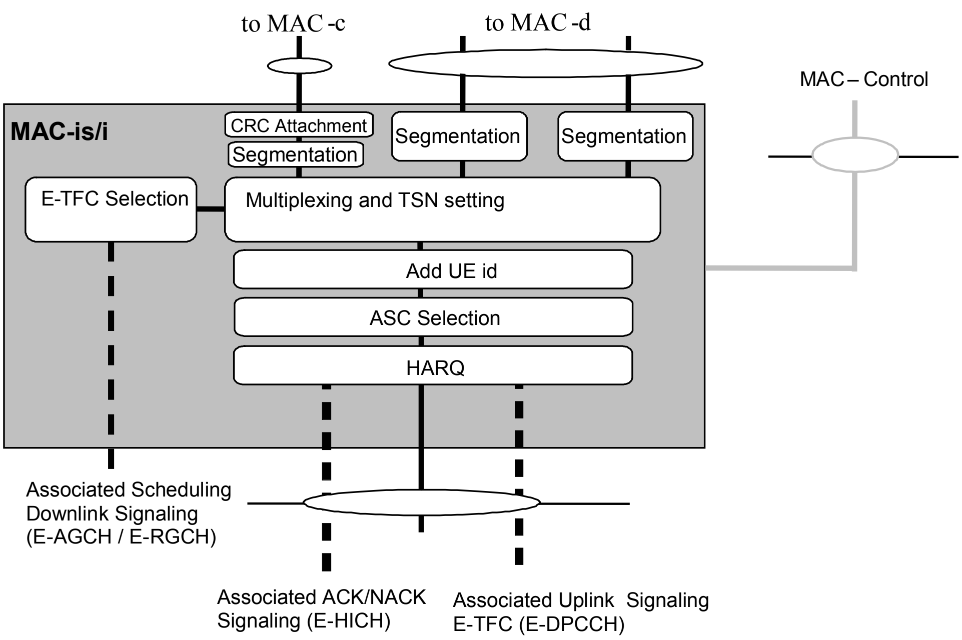


Figure 33: UE side MAC architecture / MAC-i/is details

As mentioned above the contention resolution is possible by adding E-RNTI. This is executed in the new **Add UE ID** entity. In CELL_FACH for DCCH / DTCH transmission the E-RNTI is added in the MAC-i PDU until the UE receives an E-AGCH with its E-RNTI (through an E-RNTI-specific CRC attachment). E-RNTI is naturally not added in case of CCCH data transmission.

Finally the new entity **Access Service Class (ASC) Selection** applies the appropriate back-off parameter(s) associated with the given Access Service Class (ASC) at the start of the Enhanced Uplink in CELL_FACH state. When sending an RRC *connection request* message, RRC will determine the ASC; in all other cases MAC-is/i selects the ASC.
The physical resources for Enhanced Uplink in CELL_FACH state and idle mode (i.e. access slots and preamble signatures) may be divided between different Access Service Classes in order to provide different priorities of the usage of the Enhanced Uplink in CELL_FACH state and Idle mode.

11.5 UTRAN MAC modifications

Within UTRAN and for DTCH/DCCH transmission in CELL_FACH state using E-DCH the architecture is unchanged, i.e. MAC-i is located in the NodeB and MAC-is is located in the SRNC for each UE. However in case of CCCH transmission MAC-is is located in the CRNC and there is only one MAC-i for each common E-DCH resource within the NodeB.
On NodeB level a new entity **Read UE-id** is added which determines the E-RNTI in case of DTCH/DCCH transmission (see Figure 34: UTRAN side MAC architecture / MAC-i details
). The NodeB detects whether or not E-RNTI is included from *LCH-ID* field in MAC-i header (see Figure 35 and Table 31). Using the E-RNTI **E-DCH control** becomes responsible for collision resolution and common E-DCH resource release by transmitting appropriate scheduling grants.

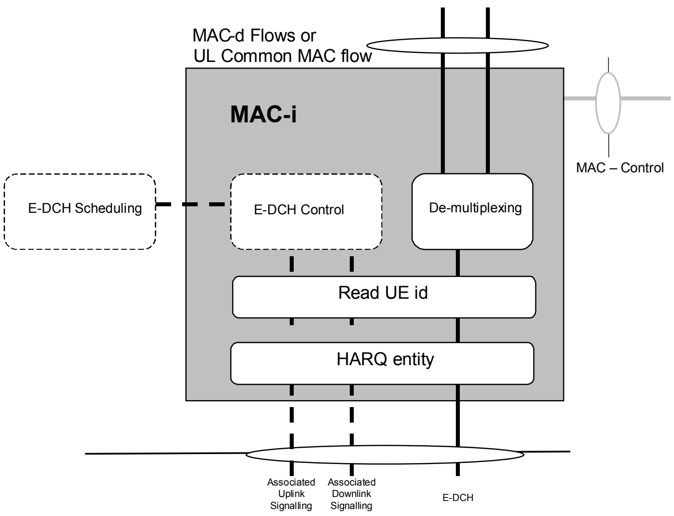


Figure 34: UTRAN side MAC architecture / MAC-i details

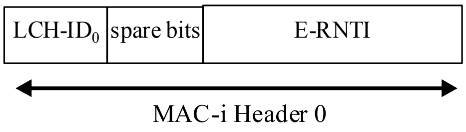


Figure 35: MAC-i header part for E-RNTI transmission

Table 31: Structure of the LCH-ID field

LCH-ID Field	Designation
0000	Logical channel 1
0001	Logical channel 2
…	…
1101	Logical channel 14
1110	Identification of CCCH (SRB0)
1111	Identification of E-RNTI being included.

Within the MAC-is (SRNC/CRNC) disassembly, reordering and reassembly stays the same as in release 7, however for CCCH transmission the reassembly functions reassembles segmented MAC-c PDUs (not MAC-d PDUs) and delivers those to the new **CRC error correction** entity (see Figure 36). In case of incorrect CRC check sums, MAC-is discards the relevant PDUs.

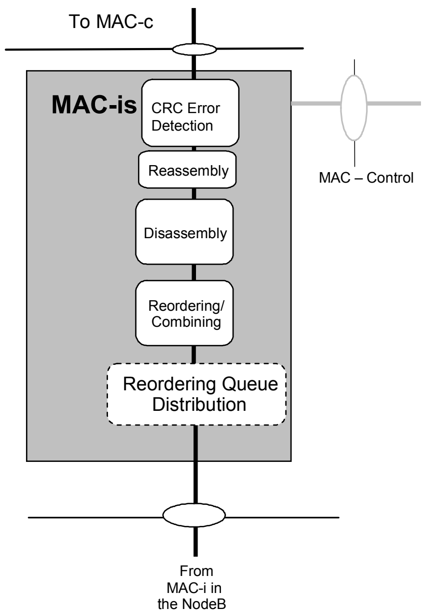


Figure 36: UTRAN side MAC architecture / MAC-is details (for CCCH transmission)

12 HS-DSCH DRX reception in CELL_FACH

The release 7 Work Item CPC achieved enhancing the efficiency of the radio links when not actively transmitting data in either direction. The release 7 efficiency enhancement can be seen both in the capacity of the system as well in the battery consumption of the UE.
The support for frequent transmission of small packets due to IP applications keeping their connection alive by periodically sending a message to the network is targeted by the Enhanced CELL_FACH feature, where such packets lead to the UE moving to CELL_FACH state and later being explicitly moved back to the CELL/URA_PCH state. However there was little consideration of the actual continuous reception activity in CELL_FACH when the packet exchange is rather infrequent. This causes unnecessary receiver activity before the UE can be moved away form the CELL_FACH state, which leads to reduced UE battery life. In addition, the signalling load is also further increased if the UE is kept in CELL_FACH for shorter periods. Therefore, minimising the signalling needed to move the UE from CELL_FACH state is another area of possible improvement.

12.1 DRX Operation in CELL_FACH state

In CELL_FACH state, the UE continuously receives the HS-SCCH (expect measurement occasion frames) in order to detect data allocation. In order to improve battery consumption in case of infrequent small packet data services discontinuous reception is enabled for the UE by the UTRAN by the following methods:

- Moving the UE to CELL/URA_PCH state by means of dedicated RRC reconfiguration procedure
- Configuring the UE with a *DRX Cycle* configuration for usage in CELL_FACH state

The UTRAN provides an *inactivity time*, a *DRX cycle length* and a *RX burst length* which is stored by the UE. Note that the HS-DSCH DRX operation in CELL_FACH state is only possible when the UE has a dedicated H-RNTI configured.
The operation is initialized when the *inactivity timer* expires. The *inactivity timer* is triggered whenever no data transmission activities are ongoing. Once the *inactivity timer* has expired, the UE is allowed to not receive HS-DSCH for a given time within the period of the configured *DRX Cycle*. The UE however needs to receive HS-DSCH for the *RX burst length* of the *DRX Cycle* configured. This operation is illustrated in Figure 37. The UE stops the DRX operation and continuously receives HS-DSCH, if data transmission activity on E-DCH is initiated.

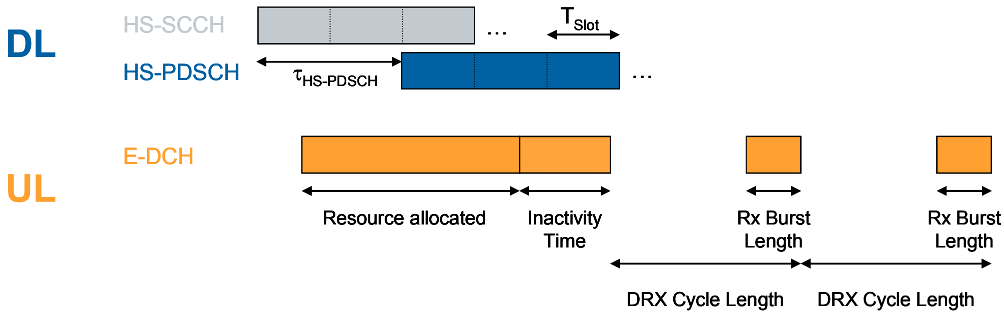


Figure 37: HS-DSCH DRX operation in CELL_FACH state

13 HSPA VoIP to WCDMA/GSM CS Continuity

Support for VoIP service will not be ubiquitous over an entire operator's network. In consequence there is the objective to introduce enhancements that allow efficient support for UTRA VoIP WCDMA/GSM continuity, i.e. a procedure that allows a connected mode UE to switch from a VoIP call to a WCDMA or GSM CS call. A "Single Radio Voice Call Continuity (SRVCC)" mechanism has been specified in 3GPP which facilitates session transfer of the voice component within a PS bearer to the CS domain (see Figure 38). For transferring the VoIP component to the CS domain, the IMS multimedia telephony sessions needs to be anchored in the IMS.
The SGSN receives the handover request from UTRAN (HSPA) with the indication that this is for SRVCC handling, and then triggers the SRVCC procedure with the MSC Server. The MSC Server then initiates the session transfer procedure to IMS and coordinates it with the CS handover procedure to the target cell. Finally the MSC Server sends a PS-CS handover response message to SGSN, which includes the necessary CS HO command information for the UE to access the UTRAN/GERAN.

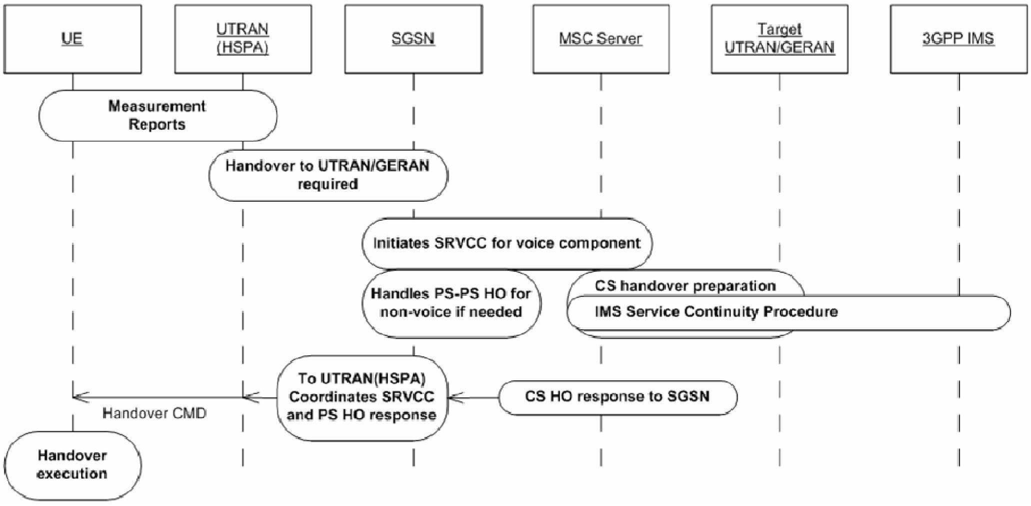


Figure 38: Overall high level concepts for SRVCC from UTRAN (HSPA) to UTRAN/GERAN

13.1 RRC protocol modifications

The main modification to the RRC protocol is the addition of a *SR-VCC Info* information element and a *RAB info to replace* information element.
The *NONCE* information element/group name within *SR-VCC Info* is a bit string that allows the UE to calculate the ciphering key (CK) and integrity key (IK) necessary to run the voice service in the CS domain. This information element is not included if ciphering is not active for PS domain prior to the reception of *SR-VCC Info*.
The *RAB info to replace* includes the information element/group name *RAB identity* and *CN domain identity* which allow the UE to identify the radio access bearer to be replaced as part of the handover procedure.

14 Serving Cell Change Enhancements

HSPA related features have originally been proposed, optimized and deployed primarily for data delivery. A number of features have been introduced in 3GPP Release 6 (F-DPCH), Release 7 (CPC) and Release 8 (CS over HSPA) to enable efficient support of real time services, in particular voice services, over the HSPA related channels. However serving cell change (i.e. mobility) reliability is a critical metric when considering mapping of voice bearers over HS-DSCH. 3GPP conducted a study item on HS-PDSCH serving cell change enhancements, which concluded that the success rate of the serving cell change procedure is compromised in some difficult scenarios. The specified solution in 3GPP Release 8 improves the reliability of cell changes when running a real time service over HSPA.

14.1 Serving HS-DSCH cell change with target cell pre-configuration

Target cell pre-configuration adds robustness to the serving HS-DSCH cell change procedure by allowing the network to send the serving HS-DSCH cell change command not only in the serving cell, but also in the target cell using the HS-SCCH. The use of target cell pre-configuration is configured by the network during the active set update procedure

The initial procedure for HS-DSCH cell change stays the same, i.e. the UE transmits a measurement report containing intra-frequency measurement results requesting the addition of a new cell into the active set and the SRNC establishes the new radio link in the target Node B for the dedicated physical channels and transmits an *active set update* message to the UE. The *active set update* message includes the necessary information for establishment of the dedicated physical channels in the added radio link. If SRNC decides to preconfigure the target cell, the *active set update* message will also include the HS serving cell related configuration (e.g. H-RNTI, HS-SCCH configuration, etc.) of the new cell.

In a second step, the UE transmits a measurement report to request the change of the HS-DSCH serving cell to a target cell. This measurement report may include a calculated *Activation time* of the requested cell change, that the UE has calculated using an offset signalled in the *active set update* message before. The main enhancement in 3GPP Release 8 is that the UE then starts monitoring one HS-SCCH channel in the target cell in addition to the four HS-SCCH channels in the source cell (see Figure 39). I.e. if the message to initiate the serving HS-DSCH cell change is not correctly received in the serving cell, the UE will upon receiving the HS-SCCH in the target cell execute serving HS-DSCH cell change.

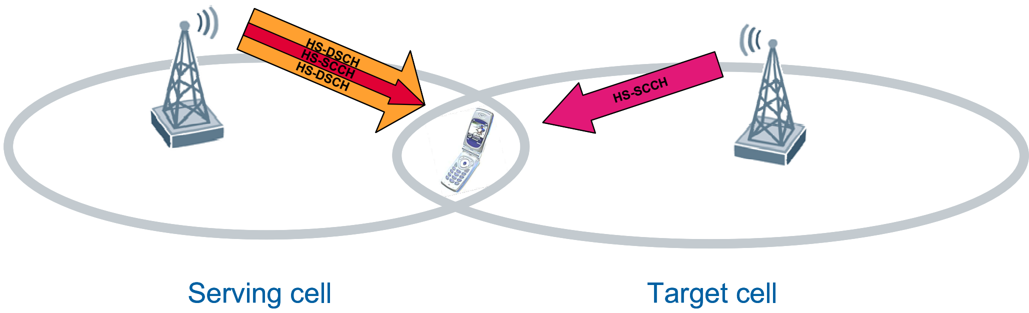


Figure 39: Enhanced serving HS-DSCH cell change procedure

14.2 HS-SCCH order in target cell

In order to identify a HS-SCCH in the target cell as an HS-SCCH cell change order the same principal identification method is used as for recognizing a HS-SCCH as an HS-SCCH order to switch on/off CPC features (see chapter 4.5). I.e. pre-defined bit patterns allow to detect a stand alone HS-SCCH order. If additionally the HS-SCCH order is transmitted from a non-serving cell and the *info order* bits $x_{ord,1}$, $x_{ord,2}$, $x_{ord,3}$ = '000', then the UE recognizes the specific HS-SCCH as an "HS-DSCH serving cell change order". The UE needs to be ready to receive the full configured HS-SCCH set in the target cell within 40 ms from the end of the TTI containing the HS-SCCH order.

15 Testing HSPA+ with R&S measurement equipment

15.1 Signal Generation

The R&S®SMU-K59 option for the R&S®SMU200A, R&S®SMATE200A, R&S®SMJ100A, R&S®SMBV100A and R&S®AMU200A signal generator allows the internal generation of standard-conform HSPA+ signals as well as the generation of multicarrier and multisegment signals in line with 3GPP Releases 7. Additionally R&S WinIQSIM2™ software provides a convenient way of creating any standard conform waveform with all the included standards using the arbitrary waveform generators functionality. WinIQSIM2™ HSPA+ support is realized using software option K259 on the respective signal generator. The supported features include correct MIMO coding, new HSPA+ specific channel parameters as well as channel coding (H-Sets). This enables the test engineer to thoroughly investigate the performance of HSPA+ receivers, no matter whether the physical layer tests are to be performed at the component level (power amplifiers, filters, etc.) or on complete receivers in base stations or mobile phones. Signals for demanding diversity and MIMO tests are intuitively generated. The K59/K259 options support HSPA+ downlink and uplink signal generation. The feature set supports

- 64QAM (Downlink)
- MIMO
- Continuous Packet Connectivity (CPC)
- 16QAM (Uplink)

15.1.1 64QAM (DL) signal generation

In order to support 64QAM testing, a fixed reference channel has been introduced. H-Set 8 is specified as reference test channel for HSDPA test cases. The H-Set 8 parameterization and coding chain is based on 15 codes with 64QAM modulation. Six Hybrid ARQ processes are used, and HS-DSCH is continuously transmitted. Figure 40 illustrates the possibility to select 64QAM downlink signals in channel type setting of the R&S®SMU200A. Additionally K59 supports the new orthogonal channel noise (OCNS) mode which was defined for 64QAM operation.
Note that user defined H-Set configuration is possible, i.e. either H-Set 8 can be used or individual parameter settings may be configured effectively creating a user defined H-Set.
Additionally K59 also supports Test Model 6 in accordance with [10]. Test Model 6 defines a certain number of channels (including 8 HS-PDSCH using 64QAM) at specified power levels which is used to test code domain error requirements of a base station supporting 64QAM modulation in downlink.

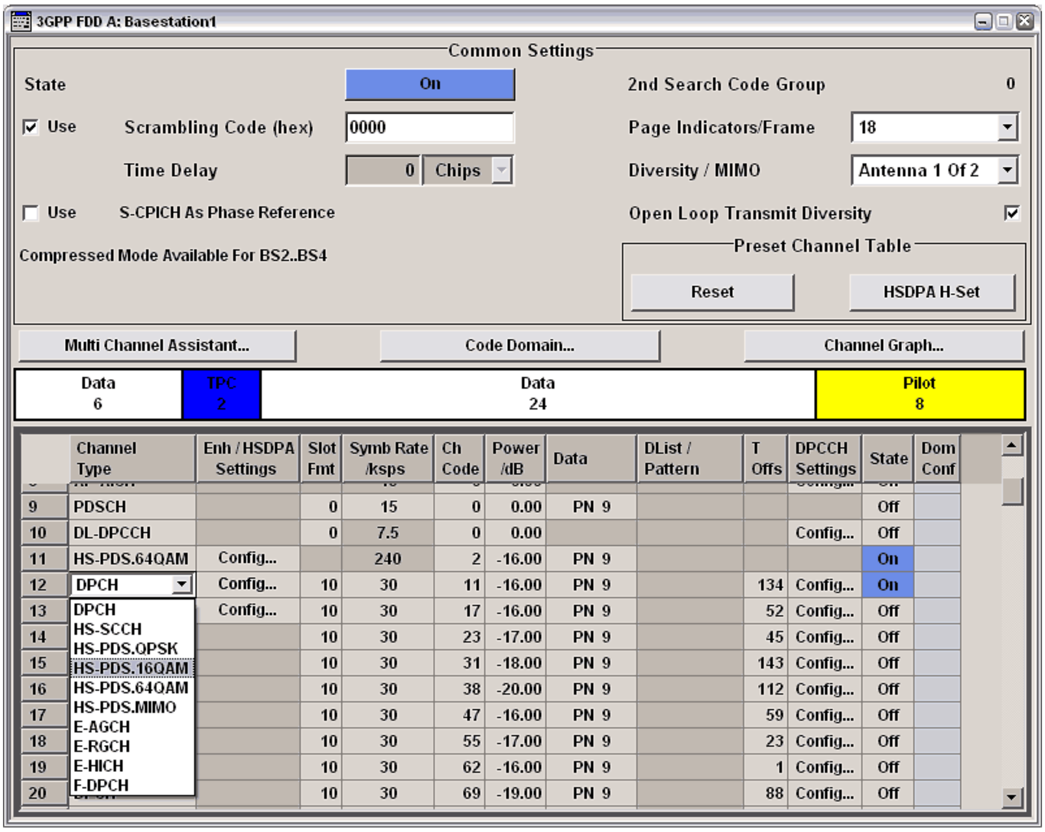


Figure 40: R&S SMU200A support for 64QAM operation

15.1.2 16QAM (UL) signal generation

In order to support 16QAM testing (4PAM modulation on I and Q), a fixed reference channel has been introduced. FRC8 is specified as reference test channel for HSUPA test cases at the base station receiver. Figure 41 shows the signal generator user interface providing the 16QAM signal by four EDPDCH codes, two of which using spreading factor 2 and two of which using spreading factor 4 in accordance with 3GPP specifications.
Again it is possible to set individual parameters according to the specific testing needs.

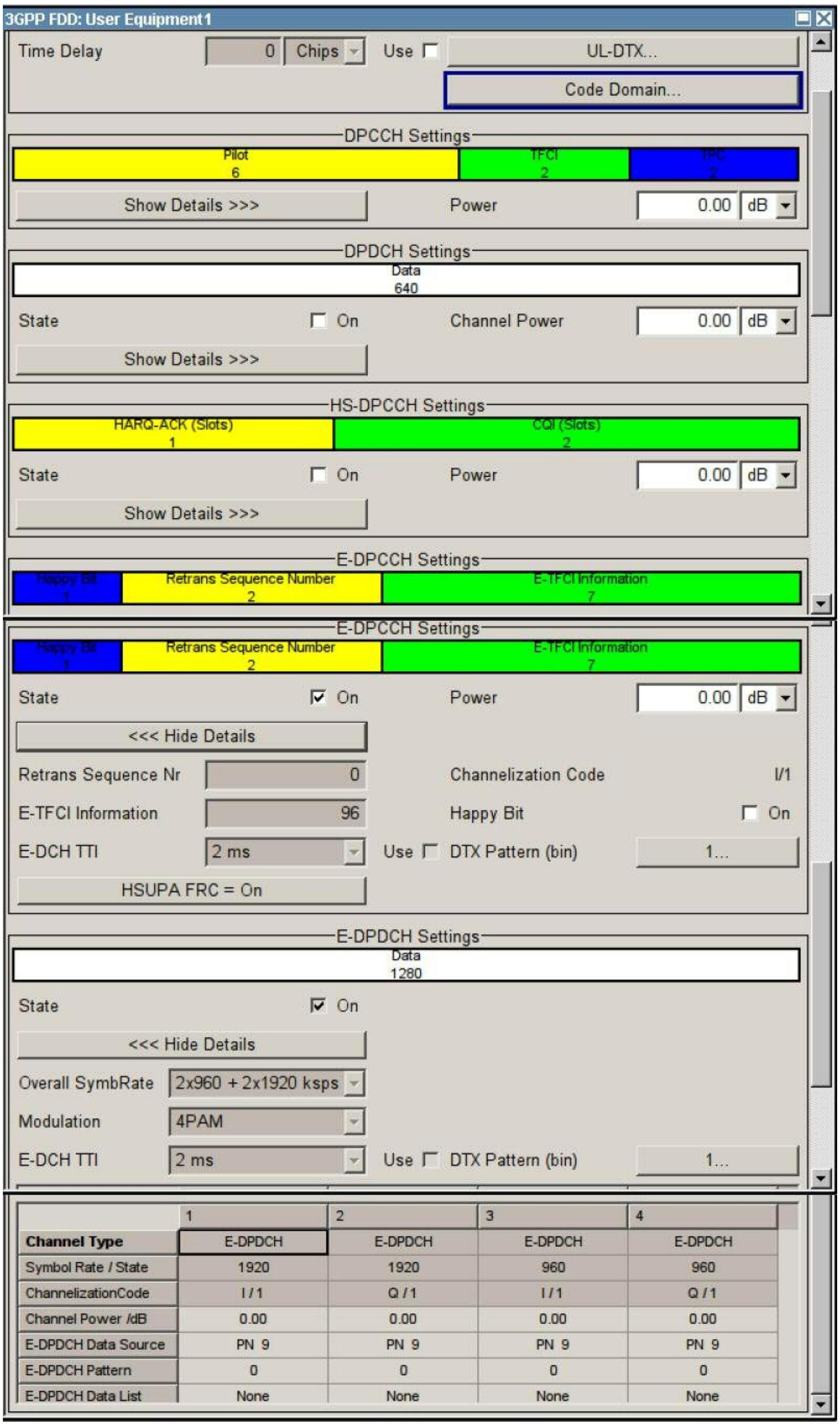


Figure 41: 16QAM UL signal generation

15.1.3 MIMO operation

In order to support MIMO operation, changes to the HSDPA downlink control channel have become necessary, i.e. the HS-SCCH. There is a new HS-SCCH Type 3 for MIMO operation (see Figure 42). HS-SCCH Type 3 includes precoding weights signalling as specified by 3GPP. H-Set 9 is specified as reference test channel for HSDPA test cases. The H-Set 9 parameterization and coding chain is based on 15 codes with two different modulations, 16QAM and QPSK, for both primary and secondary transport blocks respectively. Six HARQ processes are used, and HS-DSCH is continuously transmitted. Again an user defined H-Set configuration is possible as well. MIMO as of 3GPP release 7 offers dynamic switching between dual stream and single stream data transmission. Single stream effectively represents a fallback solution to Tx diversity mode in case propagation conditions do not allow MIMO transmission. The parameter “Stream 2 Active Pattern” (see Figure 42) allows generating a user defined sequence for single and dual stream transmission.
Note that the combination of MIMO and 64QAM as specified in 3GPP release 8 is possible using the HSPA+ functionality on the R&S SMU200A generator as modulation schemes on both streams can be configured individually.

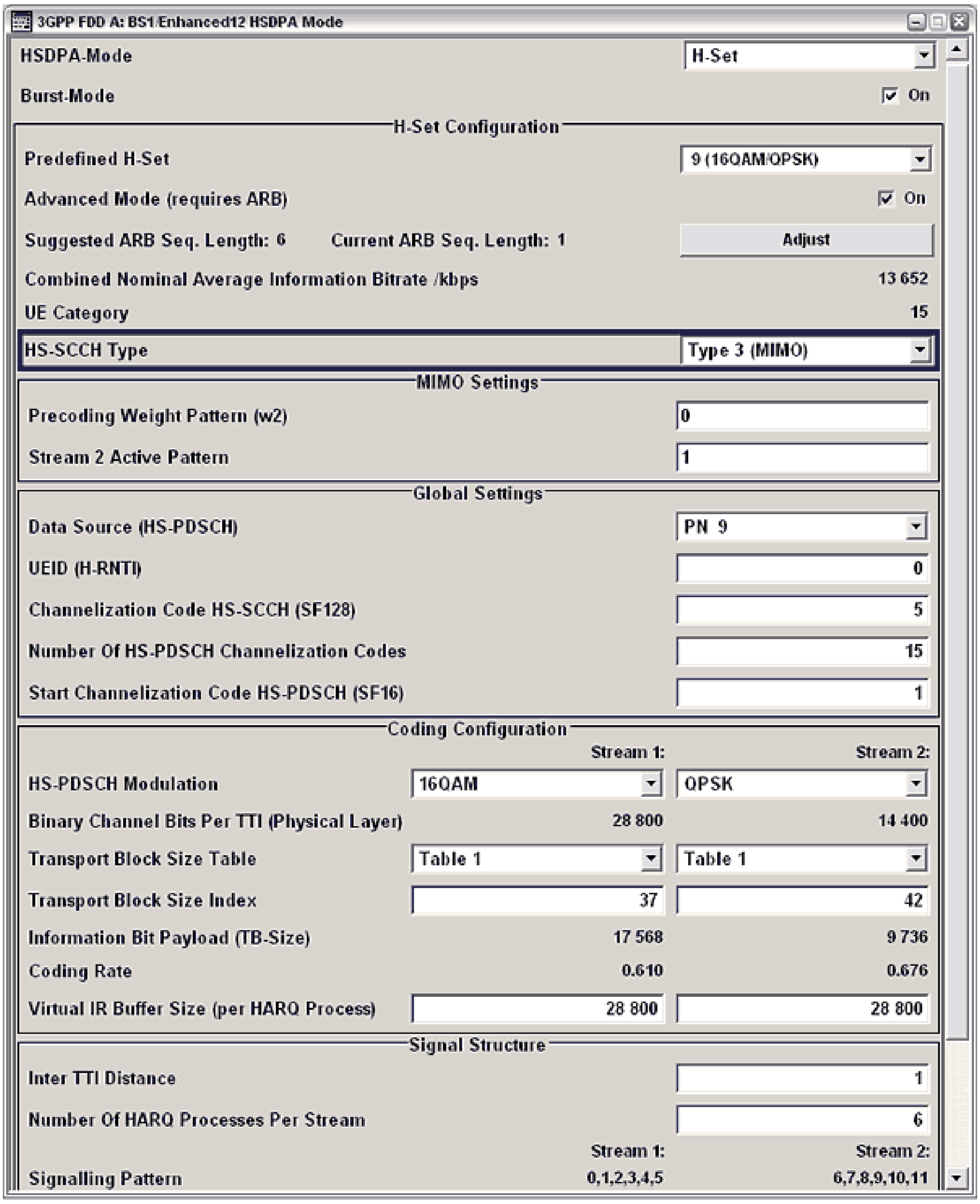


Figure 42: R&S®SMU200A support for MIMO operation

The Rohde & Schwarz R&S®SMU200A Vector Signal Generator can be equipped with two signal generators and a four-channel fading simulator. This would require adding hardware options B14 and B15 and the software option K74 which allows testing of 2x2 MIMO receivers using one box. With this solution, you operate the entire functionality from one convenient user interface, without having to calibrate or synchronize your setup. The fader makes it possible to e.g. simulate the extended ITU fading profiles with correlation between the channels. The same fading and baseband functionality is available with the R&S®AMU200A baseband signal generator and fading simulator. Figure 43 illustrates the user interface operating a HSPA+ 2x2 MIMO signal including multipath fading.

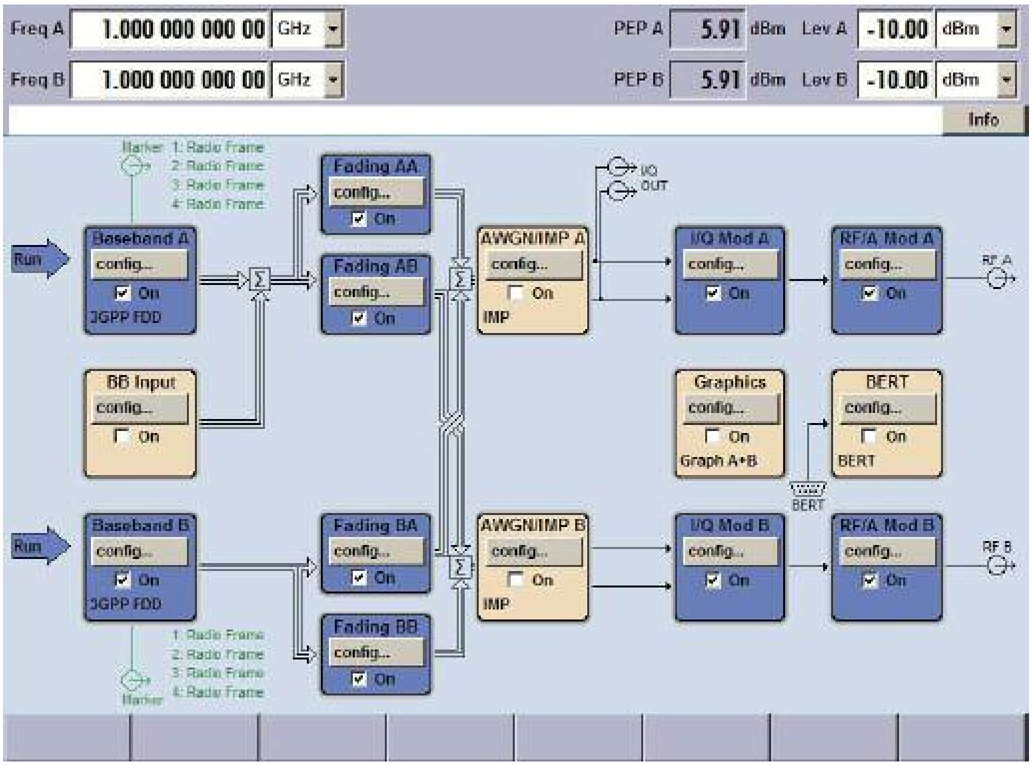


Figure 43: R&S®SMU200A user interface generating a 2x2 MIMO signal including multipath fading

15.1.4 CPC (HS-SCCH less operation)

CPC functionality has been added specifically supporting the HS-SCCH less operation mode, i.e. physical channel settings in HS-SCCH and HS-DPCCH for “HS-SCCH-less operation” (incl. HS-SCCH Type 2) can be selected. H-Set 7 is specified as reference test channel for HSDPA test cases. The H-Set 7 consists of one HS-PDSCH and its parameterization and coding chain is based on one code with QPSK modulation and one HARQ process. Also for CPC an user defined H-Set configuration is possible.

15.1.5 HARQ simulation

Hybrid Automatic Repeat Request is a mechanism to allow the receiver (NodeB) to request packets to be resend by the sender (UE) if these packets could not be received error free in the first place. Incorrectly received coded data blocks may be stored at the receiver and when the retransmitted block is received, the two blocks may be combined. While it is possible that independently decoded, two given transmissions are not possible to decode error-free, it may happen that the combination of the previously erroneously received transmissions gives enough information to correctly decode.

In order to test this complex mechanism at the device under test (NodeB) the R&S signal generator R&S®SMU200A, R&S®SMJ100A, R&S®SMATE200A and R&S®AMU200A offer a TTL input connector that allows the receiver feedback to be taken into account as illustrated in Figure 44. Based on the received feedback the generator decides in real time to transmit new data or to retransmit the last packet.

Figure 44: HARQ Feedback operation

This HARQ feedback mode is offered in addition to the well known “Constant ACK” and “Constant NACK” configuration possibility, see Figure 45. In “Constant ACK” mode the generator assumes that the device under test is always able to correctly decode the packets, i.e. this mode is useful to conduct maximal throughput tests. In “Constant NACK” mode the generator assumes always that the device under test did not received the data correctly whereas in this mode certain redundancy versions for subsequent retransmissions can be configured. This mode of operation is used to verify the soft combining capabilities of the device under test.

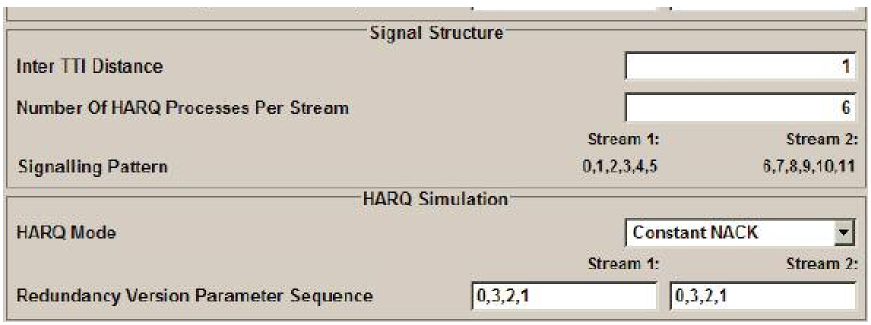


Figure 45: Constant ACK and Constant NACK mode

15.2 Signal Analysis

15.2.1 64QAM downlink and 16QAM uplink analysis

This chapter illustrates how to add HSPA+ measurement functions to the R&S®FSU, R&S®FSQ, R&S®FSG, R&S®FSP and R&S®FSV analyzer families in line with the 3GPP specifications for the FDD mode. Measurements can be performed on systems as well as on individual components such as amplifiers which may have to meet more stringent requirements. All measurements can be remote controlled. The results and demodulated data bits can be transferred via Ethernet LAN (100 Mbps) or via the IEEE bus – an ideal solution in production.

R&S offers a dedicated firmware option to analyse HSPA+ signals for R&S®FSU, R&S®FSQ, R&S®FSG and R&S®FSP. The released version FS K74+ and FS K73+ offer 64QAM downlink analysis and 16QAM uplink analysis, respectively. This includes automatic detection of signals including the new relative code domain error measurement.

R&S®FS-K74+ and R&S®FS-73+ run on top of the existing options for WCDMA, HSDPA and HSUPA signal analysis. The R&S®FS-K72 application firmware provides the basic functionality needed for WCDMA base station testing. This firmware can be extended to encompass HSPA (high speed packet access) for base station testing using R&S®FS-K74 and to encompass user equipment testing using R&S®FS-K73. For R&S®FSV the R&S®FSV-K72 and R&S®FSV-K73 application firmware already includes HSPA+ analysis possibilities as described below, i.e. for R&S®FSV the additional FS K74+ and/or FS K73+ option are not required.

Figure 46 provides an example measurement for a code domain power measurement on a 64QAM downlink signal with 32 active channels. Active and inactive channels are marked in different colours. Inactive channels (noise, interference) are displayed with the highest spreading factor. The summary table (see Figure 47) shows the main parameters of the total signal at a glance, e.g. total power, frequency error and error of chip rate, as well as the parameters of the marked code channel such as modulation type (64QAM), timing offset, code power and relative code domain error. The relative code domain error was newly added within 3GPP release 7. Three different measurements are stipulated in the 3GPP specifications for determining the modulation quality:

- EVM (error vector magnitude)
- Peak code domain error
- Relative code domain error

The code domain power measurement offers an in-depth analysis for a WCDMA signal with several active channels. The composite EVM measurement returns a modulation error value for the total signal, whereas the symbol EVM function yields the individual vector errors of the active channels.

To obtain the peak code domain error (PCDE), the vector error between the measured signal and the ideal reference signal is determined and projected to the codes of a specific spreading factor. With R&S®FS-K72, the spreading factor for the PCDE measurement can be selected by the user.

R&S®FS-K74+/K73+ and R&S®FSV-K72/K73 provides relative code domain error (RCDE) measurements, i.e. it determines the ratio of the mean power of the error vector projection onto a selectable code to the code's mean power in the composite reference waveform.

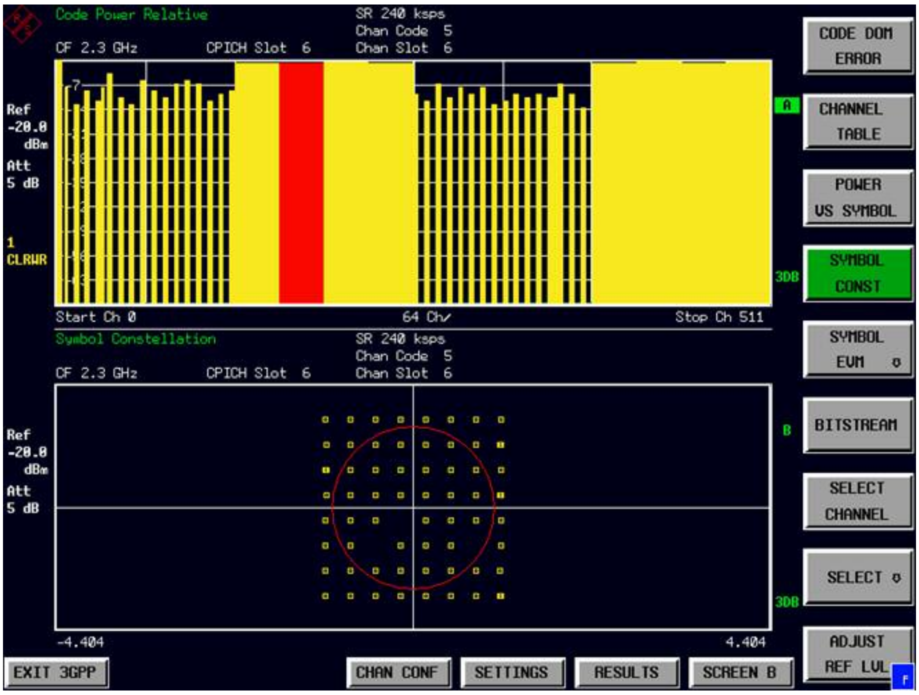


Figure 46: Code domain power measurement on a 64QAM signal with 32 active channels

GLOBAL RESULTS FOR FRAME 0:		Carrier Freq Error	-5.47 mHz
Total Power	-24.62 dBm	Trigger to Frame	331.421914 µs
Chip Rate Error	0.83 ppm	Avg Pow Ina Chan	-89.96 dB
IQ Offset / Imb	0.00 / 0.00 %	Pk CDE (15 ksps)	-80.15 dB
Composite EVM	0.09 %	Avg RCDE (64QAM)	-60.73 dB
Rho	1.00000	No of Active Chan	44
CHANNEL RESULTS		RCDE	-60.67 dB
Symbol Rate	240.00 ksps	Timing Offset	0 Chips
Channel Code	5	Channel Slot No	6
No of Pilot Bits	0	Modulation Type	64QAM
Channel Power Rel	-1.00 dB	Channel Power Abs	-36.65 dBm
Symbol EVM	0.09 % rms	Symbol EVM	0.36 % Pk

Figure 47: Result summary table

Accordingly Figure 48 illustrates a code domain power measurement of a 16QAM uplink signal displaying in addition the constellation diagram.

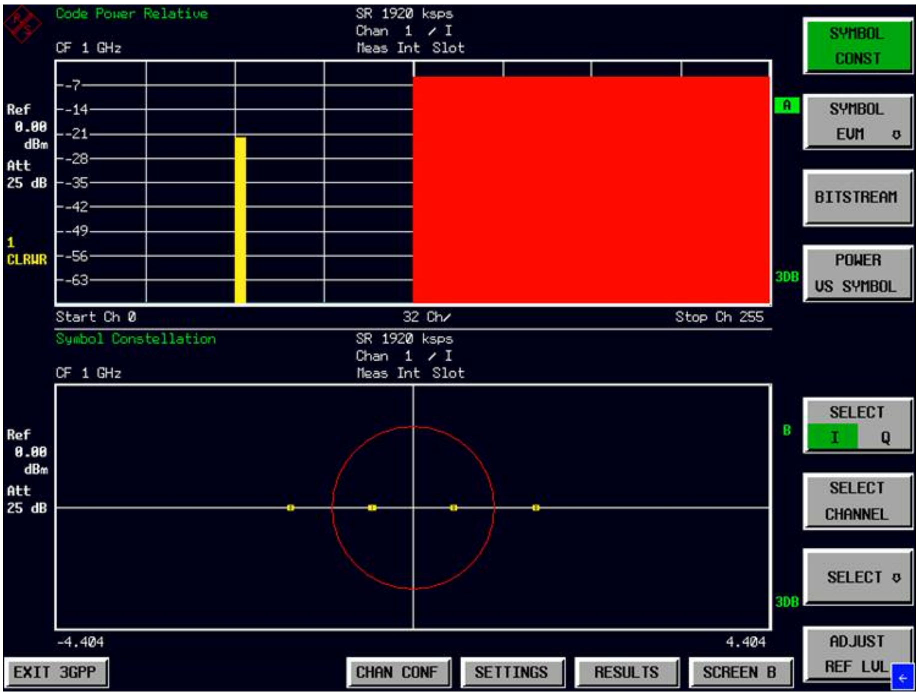


Figure 48: Code domain power measurement on a 16QAM signal

15.2.2 MIMO time alignment measurement

One important requirement for the NodeB transmitting HSPA+ MIMO signals is to achieve a specified time wise synchronicity of the MIMO signal via the two transmit antennas.
In 3GPP TS 25.104 [9] the specification text reads:
In Tx Diversity and MIMO transmission, signals are transmitted from two antennas. These signals shall be aligned. The time alignment error in Tx Diversity and MIMO transmission is specified as the delay between the signals from the two diversity antennas at the antenna ports.
The time alignment error in Tx Diversity or MIMO transmission shall not exceed ¼ Tc.

In consequence the absolute requirement is approximately 65µs, which can easily be measured with an R&S®FSU, R&S®FSQ, R&S®FSG and R&S®FSP using the HSPA+ software options R&S®FS-K74+ as illustrated in Figure 49.

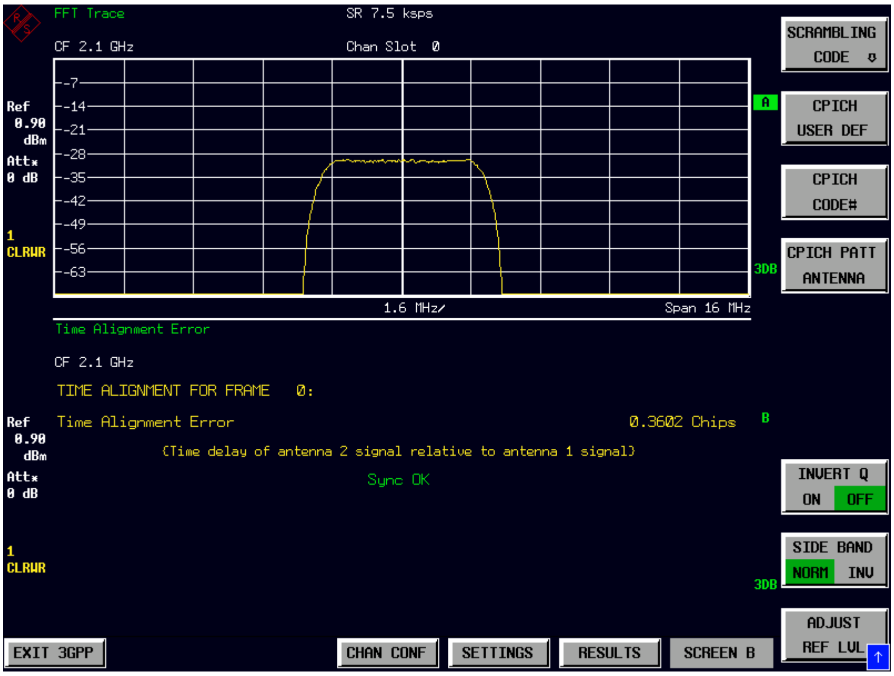


Figure 49: Time alignment error measurement of a MIMO signal

15.3 Protocol Test

Equipped with powerful hardware and various interfaces to wireless devices, the R&S®CMW500 can be used throughout all phases of HSPA+ device development – from the initial module test up to the integration of software and chipset, as well as for conformance and performance tests of the protocol stack of 3GPP standard compliant wireless devices, see Figure 50.

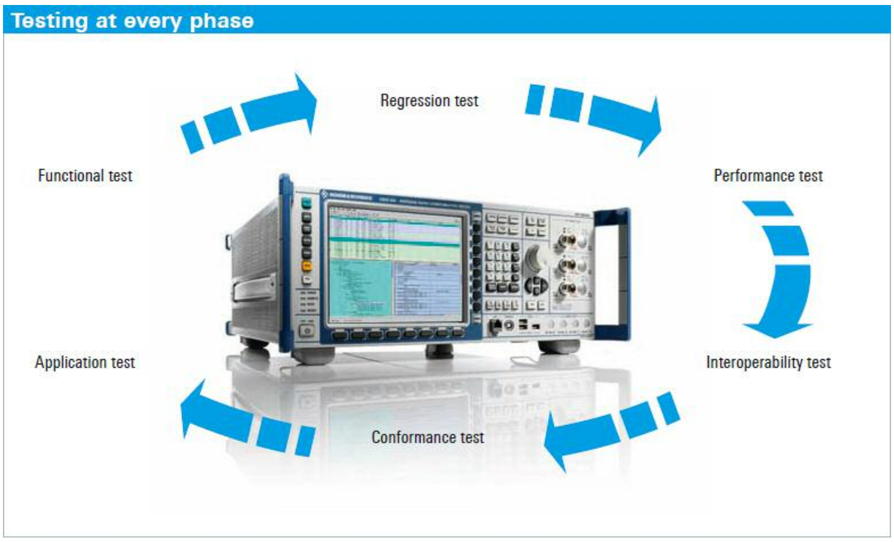


Figure 50: Consistent hardware and software concept for all device development phases

The R&S®CMW500 protocol tester provides developers of UE protocol stacks with a specification-conforming reference implementation of the air interface. The comprehensive functions of the programming interfaces and the highly detailed representation in the analysis tools can be used to quickly detect discrepancies in the DUT protocol stack. The widely used MLAPI interface provides the C++ programming interface to the protocol tester allowing to run pre-defined example- or reference scenarios as well as to develop and modify own scnearios. In consequence test case creation is significantly simplified and accelerated. The very same tool chain as known from the well established R&S®CRTU-W protocol tester environment is available and can be reused. The Message Composer allows to compose send and receive constraints, whereas the Message Analyzer provides all means to analyze results and export constraints. The TestSuite Explorer defines configurations and manages suites, the Project Explorer defines sequences, executes and manages the results. Finally MS Visual Studio is available to develop and build your test scenarios and the Automation Manager allows full automation while executing all the test cases and scenarios with minimum or no human interaction. The workflow is illustrated in Figure 51.

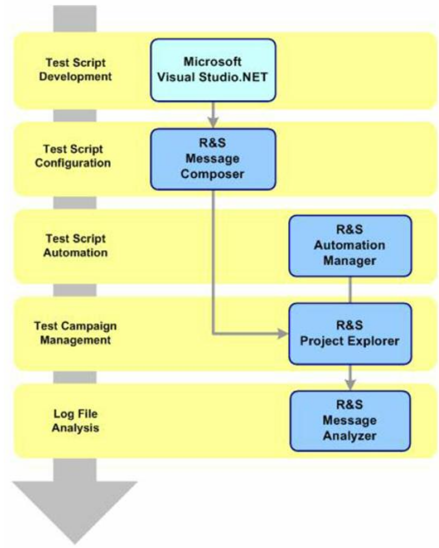


Figure 51: Test case development workflow

15.3.1 HSPA+ E2E throughput test (64QAM and improved layer 2)

The initial HSPA+ features implemented on the R&S®CMW500 3GPP Rel7 (HSPA+) protocol tester are 64QAM (see section 3.1) and improved layer2 (see section 5). Beside message analysis the main test requirement using the two features is to determine the throughput capabilities of the device under test (DUT) ideally allowing an E2E application to run a specific service of interest. The above illustrated tool chain and the 64QAM / improved layer2 functionality implemented offers an ideal environment to access the performance of the DUT including E2E testing.
As shown in Figure 52 three example scenarios (RS_075, RS_076 and RS_077) are available to test initial HSPA+ functionality. Using RS_76 the R&S®CMW500 protocol tester generates internal arbitrary data after setting up the appropriate 64QAM radio bearer with the DUT.

After successful start of the test case the throughput can be evaluated by e.g. starting the RLC throughput monitor (see Figure 53). Using the logging capabilities of the protocol tester and the message analyzer a detailed investigation of the message flow is possible, i.e. loss of performance due to incorrect behavior and/or protocol errors can easily be identified.
In addition to the throughput performance on RLC level it is essential to identify the E2E capabilities of the device under test. This is required to understand the performance of a specific service on IP level. The example scenario RS_077 may be used in this case. Similar to RS_076 a 64QAM radio bearer is set-up, however in this case no internal data is generated. IP data has to be provided from a suitable application, e.g. IPerf and/or a certain media player. The application needs to use an appropriate IP address configuration. After start of the test case and the used IP application the performance may again be evaluated on RLC layer using the RLC throughput monitor. Additionally IPerf and/or an alternative bitmeter application will allow to access the achieved data rate on IP layer (see Figure 54).

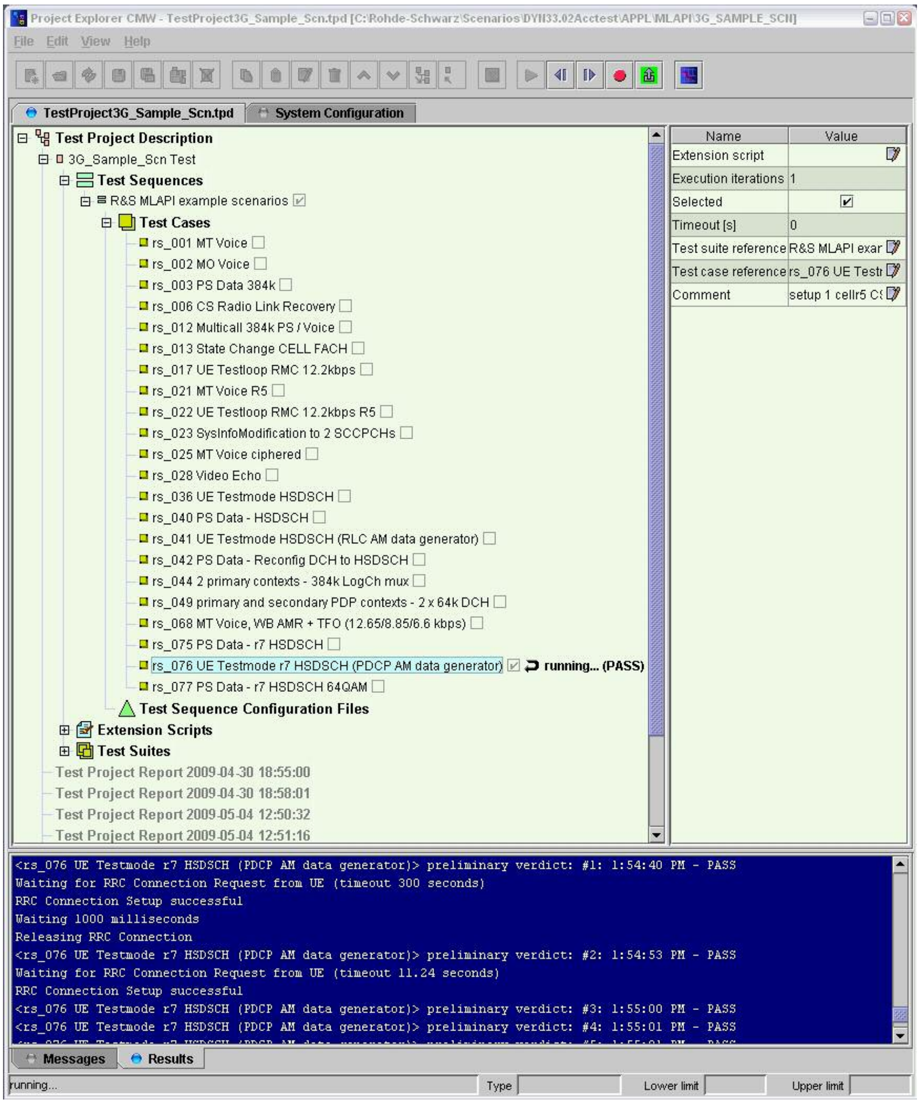


Figure 52: Project Explorer running example test case RS_076 for HSPA+ testing

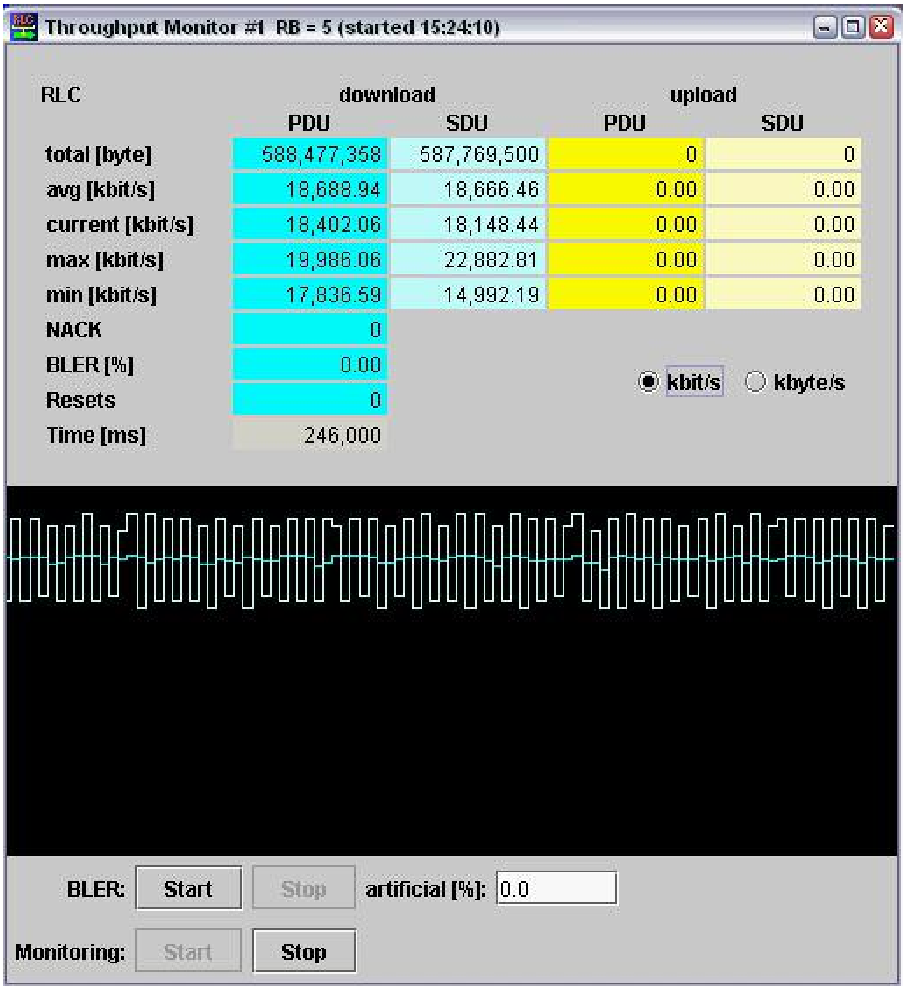


Figure 53: RLC throughput monitor

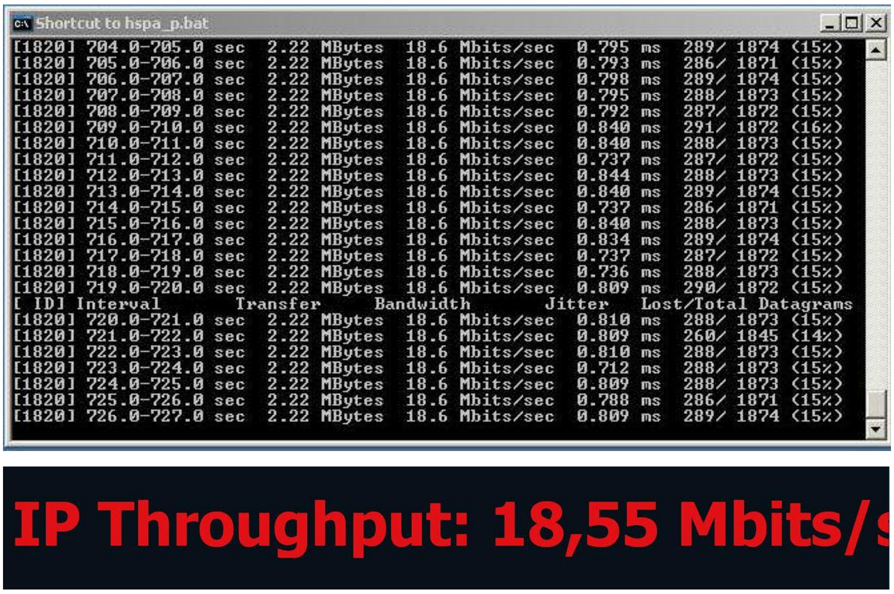


Figure 54: IPerf screenshot and Bitmeter screenshot

15.3.2 Running HSPA+ MLAPI scenarios and parallel UL measurements

Since the R&S®CMW500 is equipped with powerful hardware and is additionally providing a very modular software concept it is possible to use the very same hardware for both protocol testing (message analysis) and radio communication testing (RF testing like EVM, power, spectrum emission mask, etc).
It is even possible to install both protocol testing and RF testing software options and consequently run RF measurements in parallel to a MLAPI test scenario started in the protocol environment. The R&S®CMW500 radio communication tester performing RF measurements offers a multi evaluation mode as illustrated in Figure 55. The overview screen provides all measured results and scalar values for the essential measurements UE power, error vector magnitude (EVM) root mean square (RMS) power, carrier frequency error and occupied bandwidth (OBW). As measurements results are based on the same set of data, the individual results relate to each other which eases trouble shooting and debugging.
This is in particular useful testing the 64QAM and improved layer2 feature out of the HSPA+ feature set, since it allows to analyze the throughput and at the same time monitor whether basic Tx operation of the DUT is still working according to 3GPP specified limits.

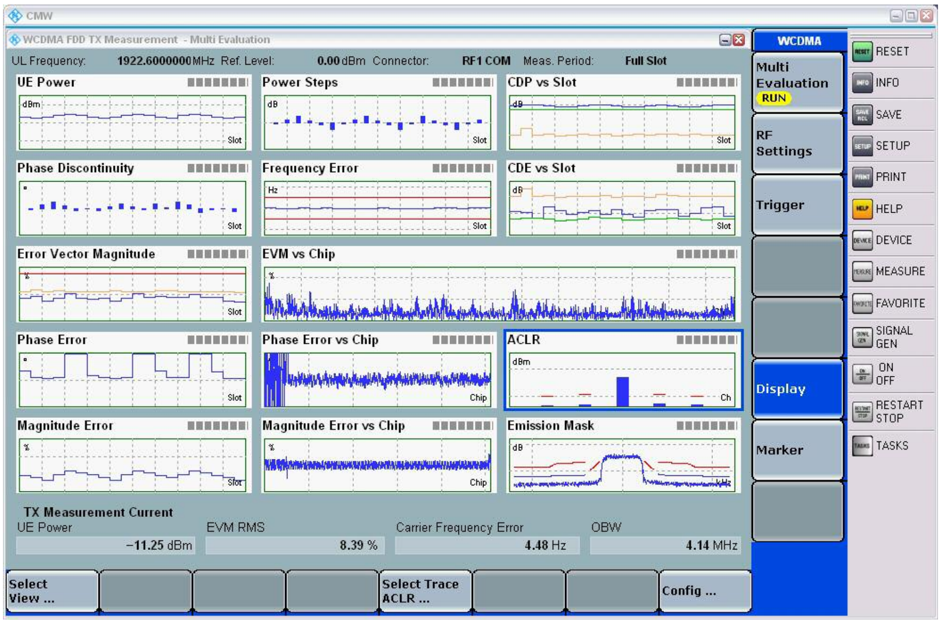


Figure 55: Multi evaluation mode of RF uplink measurements

The overview display in multi evaluation mode can be adapted to the individual testing needs. For example it may be needed to closely monitor only two measurement results or just one measurement results comparing maximum and average values. As illustrated in Figure 56 the overview display can be freely configured.

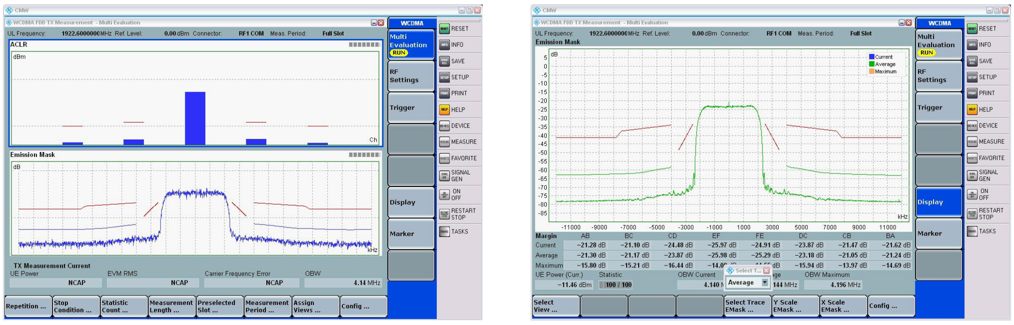


Figure 56: Configurable multi evaluation mode and single result display

16 Literature

[1] R&S application note 1MA102; Introduction to MIMO systems
[2] 3GPP TS 25.214; Physical Layer Procedures (FDD), Release 8
[3] 3GPP TS 25.211; Physical channels and mapping of transport channels onto physical channels (FDD), Release 8
[4] 3GPP TS 25.212; Multiplexing and Channel Coding (FDD), Release 8
[5] 3GPP TS 25.101; User Equipment (UE) radio transmission and reception (FDD), Release 8
[6] 3GPP TS 25.321; Medium Access Control (MAC) protocol specification, Release 8
[7] 3GPP TS 25.331; Radio Resource Control (RRC) protocol specification, Release 8
[8] 3GPP TS 25.213; Spreading and Modulation, Release 8
[9] 3GPP TS 25.104; Base Station (BS) radio transmission and reception (FDD), Release 8
[10] 3GPP TS 25.141; Base Station (BS) conformance testing (FDD), Release 8

17 Additional Information

This application note is updated from time to time. Please visit the website 1MA121 to download the latest version.

Please send any comments or suggestions about this application note to TM-Applications@rohde-schwarz.com.

18 Ordering Information

Vector Signal Generator

R&S®SMU200A		1141.2005.02
R&S®SMU-B102	Frequency range 100 KHz to 2.2GHz for 1st RF Path	1141.8503.02
R&S®SMU-B103	Frequency range 100 KHz to 3GHz for 1st RF Path	1141.8603.02
R&S®SMU-B104	Frequency range 100 KHz to 4GHz for 1st RF Path	1141.8703.02
R&S®SMU-B106	Frequency range 100 KHz to 6 GHz for 1st RF Path	1141.8803.02
R&S®SMU-B202	Frequency range 100 KHz to 2.2 GHz for 2nd RF Path	1141.9400.02
R&S®SMU-B203	Frequency range 100 KHz to 3 GHz for 2nd RF Path	1141.9500.02
R&S®SMU-B9	Baseband Generator with digital modulation (realtime) and ARB (128 M Samples)	1161.0766.02
R&S®SMU-B10	Baseband Generator with digital modulation (realtime) and ARB (64MSamples)	1141.7007.02
R&S®SMU-B11	Baseband Generator with digital modulation (realtime) and ARB (16MSamples)	1159.8411.02
R&S®SMU-B13	Baseband Main Module	1141.8003.02
R&S®SMU-K43	3GPP FDD Enhanced MS/BS Tests incl. HSDPA	1160.9660.02
R&S®SMU-K243	3GPP Enhanced MS/BS Tests incl. HSDPA for WinIQSIM2	1408.5718.02
R&S®SMU-K45	Digital Standard 3GPP FDD HSUPA	1161.0666.02
R&S®SMU-K245	Digital Standard 3GPP FDD HSUPA for WinIQSIM2	1408.5918.02
R&S®SMU-K59	Digital Standard HSPA+	1415.0001.02
R&S®SMU-K259	Digital Standard HSPA+ for WinIQSIM2	1415.0101.02
R&S®SMU-B14	Fading simulator	1160.1800.02
R&S®SMU-B15	Fading simulator extension	1160.2288.02
R&S®SMU-K74	2x2 MIMO Fading	1408.7762.02
R&S®SMBV100A		1407.6004.02
R&S®SMBV-B103	Frequency range 9 KHz to 3.2GHz for	1407.9603.02
R&S®SMBV-B106	Frequency range 9 KHz to 6GHz for	1407.9703.02

R&S®SMBV-B10	Baseband generator with digital modulation (realtime) and ARB (32 MSamples), 120 MHz RF bandwidth	1407.8607.02
R&S®SMBV-B50	Baseband Generator with digital modulation (realtime) and ARB (32MSamples), 120 MHz RF bandwidth	1407.8907.02
R&S®SMBV-B51	Baseband Generator with digital modulation (realtime) and ARB (32MSamples), 60 MHz RF bandwidth	1407.9003.02
R&S®SMBV-B55	Memory Extension, extends memory to 256 MSamples	1407.9203.02
R&S®SMBV-K43	3GPP FDD Enhanced MS/BS Tests incl. HSDPA	1415.8054.02
R&S®SMBV-K243	3GPP Enhanced MS/BS Tests incl. HSDPA for WinIQSIM2	1415.8254.02
R&S®SMBV-K45	Digital Standard 3GPP FDD HSUPA	1415.8077.02
R&S®SMBV-K245	Digital Standard 3GPP FDD HSUPA for WinIQSIM2	1415.8277.02
R&S®SMBV-K59	Digital Standard HSPA+	1415.8219.02
R&S®SMBV-K259	Digital Standard HSPA+ for WinIQSIM2	1415.8377.02
R&S®SMJ100A		1403.4507.02
R&S®SMJ-B103	Frequency range 100 kHz - 3 GHz	1403.8502.02
R&S®SMJ-B106	Frequency range 100 kHz - 6 GHz	1403.8702.02
R&S®SMJ-B9	Baseband generator with digital modulation (realtime) and ARB (128 MSamples)	1404.1501.02
R&S®SMJ-B10	Baseband Generator with digital modulation (realtime) and ARB (64 MSamples)	1403.8902.02
R&S®SMJ-B11	Baseband Generator with digital modulation (realtime) and ARB (16MSamples)	1403.9009.02
R&S®SMJ-B13	Baseband Main Module	1403.9109.02
R&S®SMJ-K43	3GPP FDD Enhanced MS/BS Tests incl. HSDPA	1404.0505.02
R&S®SMJ-K243	3GPP Enhanced MS/BS Tests incl. HSDPA for WinIQSIM2	1409.0710.02
R&S®SMJ-K45	Digital Standard 3GPP FDD HSUPA	1409.1816.02
R&S®SMJ-K245	Digital Standard 3GPP FDD HSUPA for WinIQSIM2	1409.0910.02
R&S®SMJ-K59	Digital Standard HSPA+	1415.1508.02
R&S®SMJ-K259	Digital Standard HSPA+ for WinIQSIM2	1415.1608.02
R&S®SMATE200A		1400.7005.02
R&S®SMATE-B103	Frequency range 100 KHz to 3 GHz for	1401.1000.02

	1st RF Path	
R&S®SMATE-B106	Frequency range 100 KHz to 6 GHz for 1st RF Path	1401.1200.02
R&S®SMATE-B203	Frequency range 100 KHz to 3 GHz for 2nd RF Path	1401.1400.02
R&S®SMATE-B206	Frequency range 100 kHz - 6 GHz for 2nd RF path	1401.1600.02
R&S®SMATE-B9	Baseband Generator with digital modulation (real time) and ARB (128 M samples)	1404.7500.02
R&S®SMATE-B10	Baseband Generator with digital modulation (realtime) and ARB (64MSamples)	1401.2707.02
R&S®SMATE-B11	Baseband Generator with digital modulation (realtime) and ARB (16MSamples)	1401.2807.02
R&S®SMATE-B13	Baseband Main Module	1401.2907.02
R&S®SMATE-K43	3GPP FDD Enhanced MS/BS Tests incl. HSDPA	1404.5307.02
R&S®SMATE-45	Digital Standard 3GPP FDD HSUPA	1404.7300.02
R&S®SMATE-59	Digital Standard HSPA+	1415.1320.02
R&S®AMU200A	Baseband signal generator, base unit	1402.4090.02
R&S®AMU-B9	Baseband generator with digital modulation (realtime) and ARB (128 MSamples)	1402.8809.02
R&S®AMU-B10	Baseband generator with dig. modulation (realtime) and ARB (64 MSamples)	1402.5300.02
R&S®AMU-B11	Baseband generator with dig. modulation (realtime) and ARB (16 MSamples)	1402.5400.02
R&S®AMU-B13	Baseband main module	1402.5500.02
R&S®AMU-K43	3GPP FDD Enhanced MS/BS Tests incl. HSDPA	1402.6306.02
R&S®AMU-K243	3GPP Enhanced MS/BS Tests incl. HSDPA for WinIQSIM2	1402.7802.02
R&S®AMU-K45	Digital Standard 3GPP FDD HSUPA	1402.8909.02
R&S®AMU-K245	Digital Standard 3GPP FDD HSUPA for WinIQSIM2	1402.8009.02
R&S®AMU-K59	Digital Standard HSPA+	1403.0053.02
R&S®AMU-K259	Digital Standard HSPA+ for WinIQSIM2	1403.0153.02
R&S®AMU-B14	Fading Simulator	1402.5600.02
R&S®AMU-B15	Fading Simulator extension	1402.5700.02
R&S®AMU-K74	2x2 MIMO Fading	1402.9857.02
R&S®AFQ100A	IQ modulation generator base unit	1401.3003.02

R&S®AFQ-B10	Waveform memory 256 Msamples	1401.5106.02
R&S®AFQ-B11	Waveform memory 1Gsamples	1401.5206.02
R&S®AFQ-K243	3GPP FDD Enhanced MS/BS Tests incl. HSDPA, WinIQSIM2 required	1401.6402.02
R&S®AFQ-K245	Digital Standard 3GPP FDD HSUPA, WinIQSIM2 required	1401.6504.02
R&S®AFQ-K259	Digital Standard HSPA+, WinIQSIM2 required	1401.5658.02

Signal Analyzer

R&S®FSQ3	20 Hz to 3.6 GHz	1155.5001.03
R&S®FSQ8	20 Hz to 8 GHz	1155.5001.08
R&S®FSQ26	20 Hz to 26.5 GHz	1155.5001.26
R&S®FSQ40	20 Hz to 40 GHz	1155.5001.40
R&S®FSU3	20 Hz to 3.6 GHz	1166.1660.03
R&S®FSU8	20 Hz to 8 GHz	1166.1660.08
R&S®FSU26	20 Hz to 26.5 GHz	1166.1660.26
R&S®FSU40	20 Hz to 40 GHz	1166.1660.40
R&S®FSU50	20 Hz to 50 GHz	1166.1660.50
R&S®FSG8	9 kHz to 8 GHz	1309.0002.08
R&S®FSG13	9 kHz to 13.6 GHz	1309.0002.13
R&S®FSP3	9 kHz to 3 GHz	1164.4391.03
R&S®FSP7	9 kHz to 7 GHz	1164.4391.07
R&S®FSP13	9 kHz to 13.6 GHz	1164.4391.13
R&S®FSP30	9 kHz to 30 GHz	1164.4391.30
R&S®FSP40	9 kHz to 40 GHz	1164.4391.40
R&S®FSV3	9 kHz to 3.6 GHz	1307.9002K03
R&S®FSV7	9 kHz to 7 GHz	1307.9002K07
R&S®FS-K72	WCDMA 3GPP Application Firmware BTS	1154.7000.02
R&S®FSV-K72	3 GPP BS (DL)-Analyse inkl. HSDPA	1310.8503.02
R&S®FS-K73	WCDMA 3GPP Application Firmware UE	1154.7252.02
R&S®FSV-K73	3 GPP UE (UL)-Analyse inkl. HSUPA	1310.8555.02

R&S®FS-K74	3GPP HSDPA Base Transceiver Station (BTS) Application Firmware	1300.7156.02
R&S®FS-K74+	HSPA+ Application Firmware	1309.9180.02

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3GPP	3rd Generation Partnership Project
ACK	Acknowledgement
ACS	Access Service Class
AM	Acknowledged Mode
AMR	Adaptive Multi-Rate
AMR-WB	AMR Wide-Band
Ant	Antenna
ARQ	Automatic Repeat Request
ASC	Access Service Class
BCCH	Broadcast Control Channel
CCCH	Common Control Channel
CPC	Continuous Packet Connectivity
CPICH	Common Pilot Channel
CQI	Channel Quality Indicator
CRC	Cyclic Redundancy Check
DCCH	Dedicated Control Channel
DL	Downlink
DPCCH	Dedicated Physical Control Channel
DPDCH	Dedicated Physical Data Channel
DRX	Discontinuous Reception
DTCH	Dedicated Traffic Channel
DTX	Discontinuous Transmission
D-TxAA	Double Transmit Antenna Array
E2E	End to End
E-AGCH	E-DCH Absolute Grant Channel
E-DCH	Enhanced Dedicated Channel
E-DPDCH	Enhanced Dedicated Physical Data Channel
E-RGCH	E-DCH Relative Grant Channel
EVM	Error Vector Magnitude
FACH	Forward Access Channel
FBI	Feedback Information
F-DPCH	Fractional Dedicated Physical Channel
FDD	Frequency Division Duplex
HARQ	Hybrid Automatic Repeat Request
H-RNTI	HS-DSCH Radio Network Temporary Identifier
HSDPA	High Speed Downlink Packet Access
HS-DPCCH	High Speed Dedicated Physical Control Channel
HS-DSCH	High Speed Downlink Shared Channel
HSPA	High Speed Packet Access
HS-PDSCH	High Speed Physical Downlink Shared Channel
HS-SCCH	High Speed Shared Control Channel
HSUPA	High Speed Uplink Packet Access
JBM	Jitter Buffer Management
IP	Internet Protocol
LCH	Logical Channel
LSB	Least Significant Bit
MAC	Medium Access Control
MIMO	Multiple Input Multiple Output
NACK	Negative Acknowledgement
PAM	Pulse Amplitude Modulation
PCCH	Paging Control Channel
PCH	Paging Channel
PCI	Precoding Control Indication
P-CPICH	Primary Common Pilot Channel
PHY	Physical Layer
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
PCH	Paging Channel
PDU	Protocol Data Unit
PICH	Paging Indicator Channel
PRACH	Physical RACH
RACH	Random Access Channel
RAN	Radio Access Network
RAT	Radio Access Technology
RB	Radio Bearer
RF	Radio Frequency
RLC	Radio Link Control
RMS	Root Mean Square
RRC	Radio Resource Control
RV	Redundancy Version
S-CCPCH	Secondary Common Control Physical Channel
S-CPICH	Secondary Common Pilot Channel
SDU	Service Data Unit
SF	Spreading Factor
SI	Segmentation indication
SRVCC	Single Radio Voice Call Continuity

TDD Time Division Duplex
TFC Transport Format Combination
TFCI Transport Format Combination Indicator
TFCS Transport Format Combination Set
TPC Transmit Power Control
TrCH Transport Channel
TS Technical Specification
TSN Transmission Sequence Number
TTI Transmission Time Interval
UE User Equipment
UEP Unequal Error Protection
UL Uplink
UMTS Universal Mobile Telecommunications System
URA UMTS Registration Area
U-RNTI UTRAN Radio Network Temporary Identifier
UTRA UMTS Terrestrial Radio Access
UTRAN UMTS Terrestrial Radio Access Network
VoIP Voice over IP
WCDMA Wideband Code Division Multiple Access A

About Rohde & Schwarz

Rohde & Schwarz is an independent group of companies specializing in electronics. It is a leading supplier of solutions in the fields of test and measurement, broadcasting, radiomonitoring and radiolocation, as well as secure communications. Established 75 years ago, Rohde & Schwarz has a global presence and a dedicated service network in over 70 countries. Company headquarters are in Munich, Germany.

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