HSPA+ Technology Introduction

White Paper

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, 8, 9 and 10, further improvements to HSPA have been specified in the context of HSPA+ or HSPA evolution. This white paper introduces key features of HSPA+ and outlines the changes to the radio interface.

HSPA+ Technology Introduction

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1 Introduction

UMTS High Speed Downlink Packet Access (HSDPA) and High Speed Uplink Packet Access (HSUPA) networks worldwide are operated 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+** brings significant enhancements in 3GPP Release 7, 8, 9 and 10. 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 listed below and their dependency is illustrated in Figure 0:

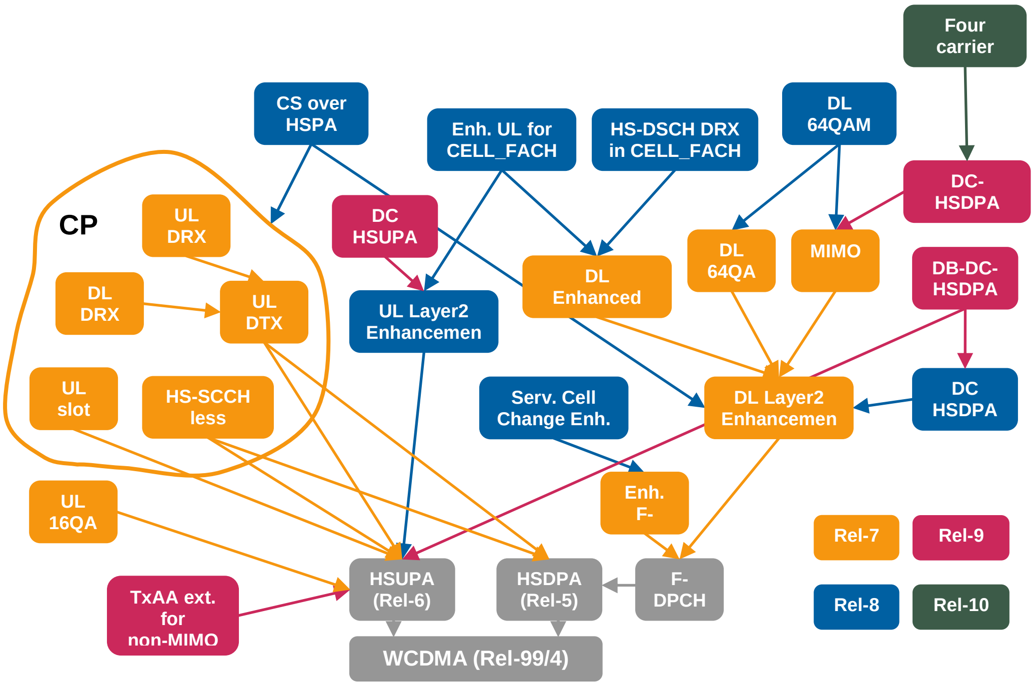


Figure 0: HSPA+ features and dependencies

3GPP Release 7

- Downlink MIMO (Multiple Input Multiple Output),
- Higher order modulation for uplink (16QAM) and downlink (64QAM),
- Continuous packet connectivity (CPC).
- Enhanced fractional DPCH (F-DPCH)
- Improved layer 2 support for high downlink data rates,
- Enhanced CELL_FACH state (downlink),

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

3GPP Release 9

- Dual cell HSUPA
- Dual band HSDPA
- Dual Cell HSDPA + MIMO
- 2ms TTI uplink range extensions
- TxAA extensions

3GPP Release 10

- Four carrier HSDPA

This application note introduces the HSPA+ technology and provides an overview of the different features in each 3GPP Release. Each feature is described and specifically test and measurement requirements are explained. Focus is on radio protocols.

Chapter 2 outlines the 3GPP Release 7 features, **Chapter 3** describes the 3GPP Release 8 features, and **Chapter 4** and **Chapter 5** complete the technology description with 3GPP Release 9 and 10 features. For each feature the test requirements for both base station and user equipment are illustrated. Furthermore the certification aspects on the terminal side are explained, i.e. each sub chapter elaborates those test requirements defined by the Global Certification Forum (GCF). **Chapters 6 - 8** provide additional information including an overview of the specified frequency bands and literature references.

This white paper assumes basic knowledge of UMTS and HSPA radio protocols.

2 HSPA+ Release 7

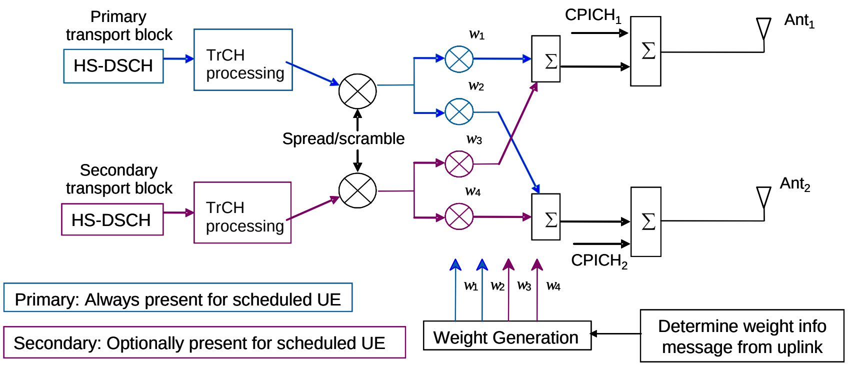
2.1 Downlink MIMO for HSPA+

2.1.1 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].

2.1.2 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.



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

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:

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

$$w_4 = -w_2$$

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

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 signalling** 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, see [2].

2.1.3 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 1.

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

Table 1: Interpretation of "Modulation scheme and number of transport blocks" sent on HS-SCCH

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 2 for the example of 12 HARQ processes configured:

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

Table 2: Combinations of HARQ process numbers for dual stream transmission (example)

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

2.1.4 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.

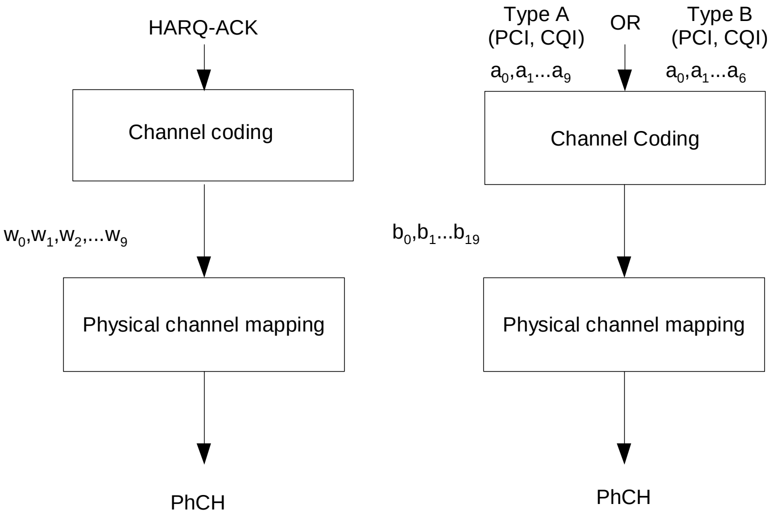


Figure 2: Channel coding for HS-DPCCH

The 10 bits of the HARQ-ACK messages are interpreted as shown in Table 3. ACK/NACK information is provided for the primary and for the secondary transport block.

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

Table 3: Interpretation of HARQ-ACK in MIMO operation

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 4 and Table 5.

$$\mathrm{CQI} = \begin{cases} 15 \text{ x } \mathrm{CQI}_1 + \mathrm{CQI}_2 + 31 & \text{when 2 transport blocks are preferred by the UE} \\ \mathrm{CQI}_S & \text{when 1 transport block is preferred by the UE} \end{cases}$$

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 4: 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	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		

CQI1 or CQI2	Transport Block Size	Number of HS-PDSCH	Transport Block Size	Equivalent AWGN SINR difference Δ	NIR	X_{rvpb} or X_{rvsb}
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		

Table 5: CQI mapping table for UE category 16/18 in case of dual transport block type A CQI reports

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 6.

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

Table 6: Mapping of preferred precoding weight to PCI values

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:

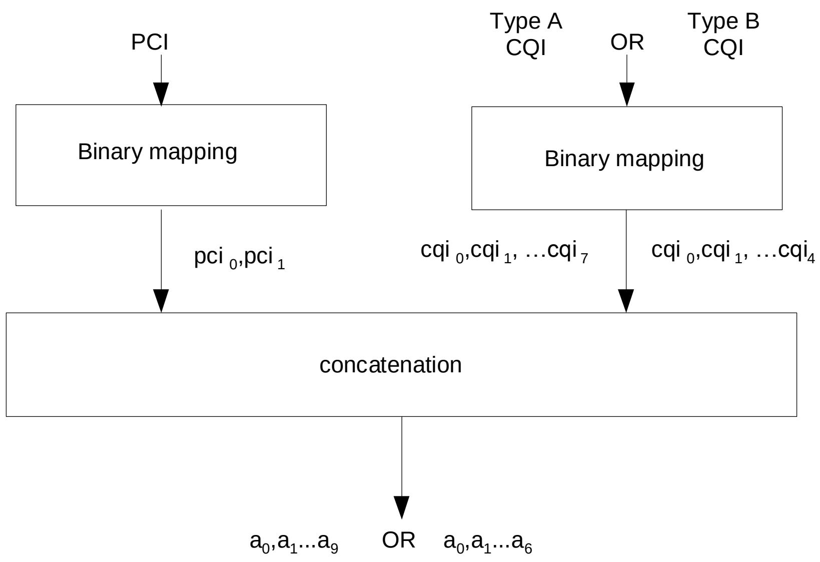


Figure 3: Composite PCI/CQI information

2.1.5 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 7:

- **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.

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 [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	~ 23.37
Category 16			15	1	27952	~ 28

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 [Mbps]
Category 17	No	QPSK / 16QAM / 64QAM	15	1	35280	~ 17.64
	Yes	QPSK / 16QAM	15	1	23370	~ 23.37
Category 18	No	QPSK / 16QAM / 64QAM	15	1	42192	~ 21.10
	Yes	QPSK / 16QAM	15	1	27952	~ 28

Table 7: New Release 7 UE categories 15-18 with MIMO support [11]

2.1.6 MIMO test and measurement requirements

2.1.6.1 NodeB test and measurement requirements

NodeB test requirements for MIMO are specified in [9] and the corresponding test methods are detailed in [10].
Regarding MIMO transmitter tests, it is sufficient to measure the signal at any one of the transmitter antenna connectors, with the remaining antenna connector(s) being terminated. There is however one specific requirement added due to MIMO operation. The time alignment error in MIMO transmission is specified as the delay between the signals from the two diversity antennas at the antenna ports. The time alignment error in MIMO transmission shall not exceed ¼ $T_c \approx 65$ns.

2.1.6.2 UE test and measurement requirements

UE test requirements for MIMO are specified in [5] and the corresponding test methods are detailed in [12] for RF conformance and in [13] for protocol conformance, respectively.
MIMO performance, as MIMO is a fairly complex feature, needs to be thoroughly verified. Consequently a number of new test requirements have been added. First of all the MIMO throughput performance is tested using a new fixed reference channel (FRC) H-Set 9 as illustrated in Table 8, Figure 4 and Figure 5. Each of the two (primary and secondary) data streams use 15 codes and 6 HARQ processes.

Parameter	Unit	Value	
Transport block		Primary	Secondary
Combined Nominal Avg. Inf. Bit Rate		13652	
Nominal Avg. Inf. Bit Rate	kbps	8784	4868
Inter-TTI Distance	TTI's	1	1
Number of HARQ Processes	Process	6	6

	es		
Information Bit Payload (N_{INF})	Bits	17568	9736
Number Code Blocks	Blocks	4	2
Binary Channel Bits Per TTI	Bits	28800	14400
Total available SML's in UE	Bits	345600	
Number of SML's per HARQ Proc.	SML's	28800	28800
Coding Rate		0.61	0.68
Number of Physical Channel Codes	Codes	15	15
Modulation		16QAM	QPSK

Table 8: Fixed Reference Channel H-Set 9

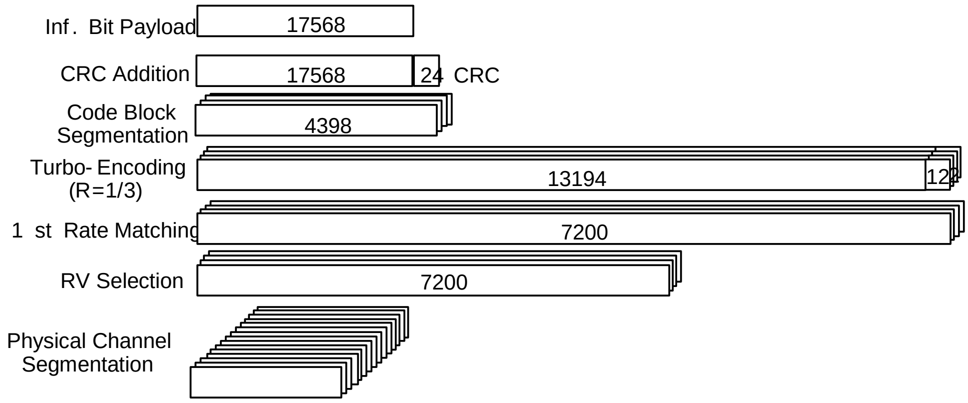


Figure 4: Coding rate for Fixed Reference Channel H-Set 9 Primary Transport Block

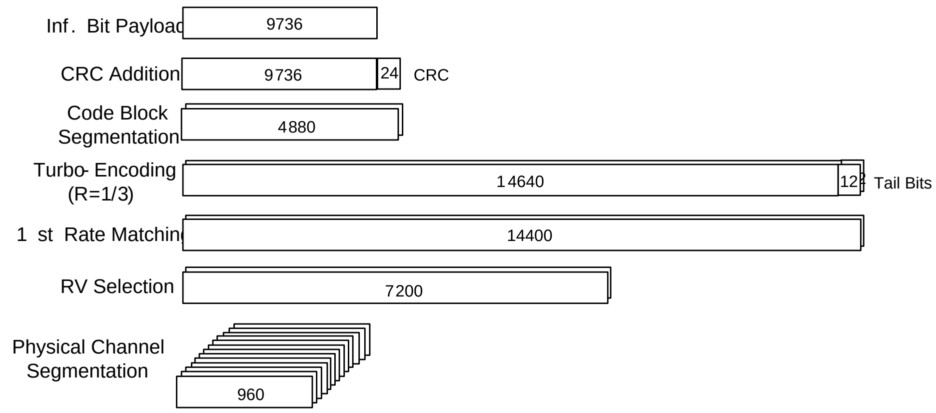


Figure 5: Coding rate for Fixed Reference Channel H-Set 9 Secondary Transport Block

Furthermore the minimum performance requirements of CQI reporting in single and dual stream fading conditions are tested reusing the same method as already specified for HSDPA operation as of 3GPP Release 5 and onwards. I.e. the reporting accuracy of CQI under MIMO conditions is determined by the BLER performance of two streams of transport blocks. The two streams are using the transport formats indicated by the respective stream specific reported CQI median over all CQI reports for each stream that were reported together with PCI reports by the UE that match the precoding matrix embedded in the propagation channel. For single and dual stream fading conditions different test setups are required.
In case of single stream conditions the two signals applied to the two RX inputs at the device under test have the same power but a different phase depending on the simulated speed in the fading scenario according to Figure 11 and Table 9. Note that α_2 is not used in this case.

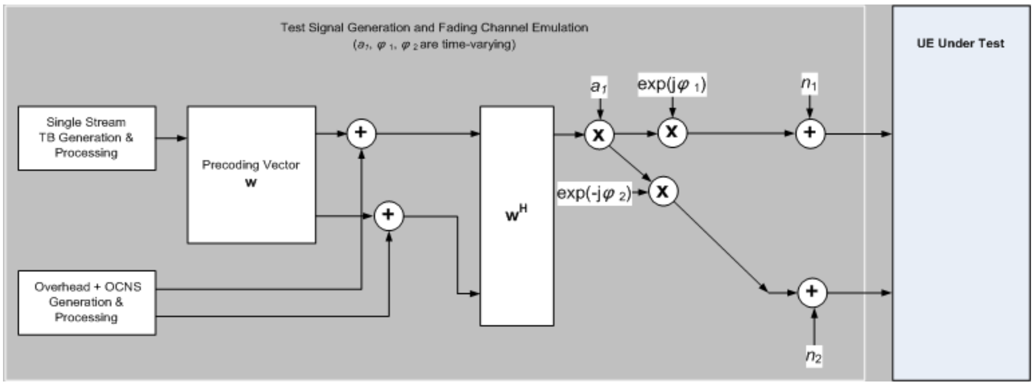


Figure 6: Test setup under MIMO Single Stream Fading Conditions

Speed for Band I, II, III, IV, IX and X: 3km/h Speed for Band V, VI, VIII and XIX: 7.1km/h Speed for Band VII: 2.3km/h Speed for Band XI, XXI: 4.1km/h Speed for Band XII, XIII and XIV 8 km/h	
Relative Mean Power [dB]	(Amplitude, phase) symbols
0	(a_1 , φ_1)
0	(a_2 , φ_2)

Table 9: MIMO Single Stream Conditions

In case of dual stream conditions two different scenarios are specified. One scenario applies different power levels and different phases for the different input signals connected to the receiver ports of the device under test according to Figure 7 and Table 10. The other scenario applies static orthogonal conditions according to .

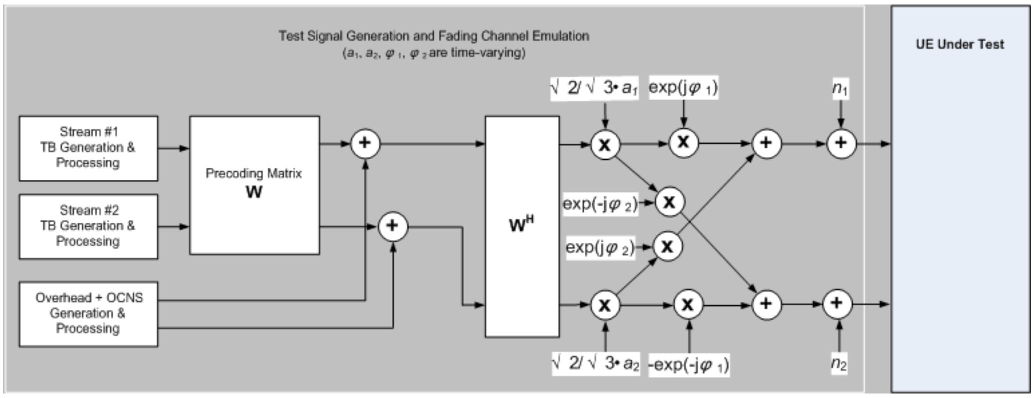


Figure 7: Test setup under MIMO Dual Stream Fading Conditions

Speed for Band I, II, III, IV, IX and X: 3km/h Speed for Band V, VI, VIII and XIX: 7.1km/h Speed for Band VII: 2.3km/h Speed for Band XI, XXI: 4.1km/h Speed for Band XII, XIII and XIV: 8 km/h		
Relative Delay [ns]	Relative Mean Power [dB]	(Amplitude, phase) symbols
0	0	(a_1 , φ_1)
0	-3	(a_2 , φ_2)

Table 10: MIMO Dual Stream Conditions

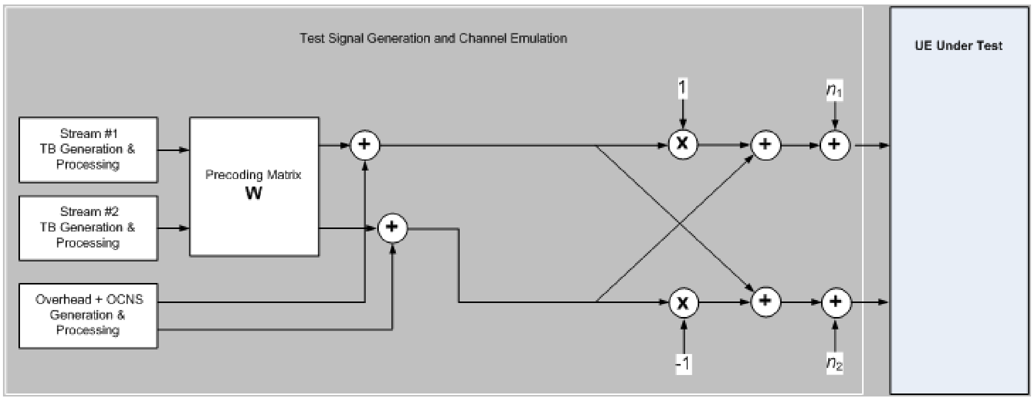


Figure 8: Test setup under MIMO Dual Stream Static Orthogonal Conditions

Finally the HS-SCCH detection performance needs to be tested. The method used is the same as for earlier 3GPP Releases, i.e. a specific resource allocation is signaled on the HS-SCCH to the UE and DTX is observed in the corresponding HS-DPCCH ACK/NACK field in uplink. The probability for DTX is not allowed to exceed a specified limit. In case of MIMO HS-SCCH type 3 signaling is used and the probability for DTX as described above shall not exceed 0.01 in a specified scenario using vehicular and pedestrian (3 km/h) propagation conditions.

2.1.6.3 GCF requirements for MIMO

The purpose of the work item GCF-WI-067 is to define the test cases selected to cover the essential core functionality and performance requirements for the 3GPP MIMO feature. GCF has identified two protocol test cases and four RF test cases to be verified in order to achieve GCF certification for a MIMO capable UE (see Table 11 and Table 12).

Subject Area	TS	TC	TC title	Priority
RB	34.123-1	14.6.1d	Interactive or background / UL:64 DL: [max bit rate depending on UE category] with Flexible RLC and MAC-ehs PS RAB + UL:3.4 DL:3.4 kbps SRBs for DCCH / DL: QPSK, 16QAM and MIMO	1
RB	34.123-1	14.6.6c	Streaming / unknown / UL:128 DL: [guaranteed 128, max bit rate depending on UE category] with Fixed RLC and MAC-ehs / PS RAB + Interactive or background / UL:128 DL: [max bit rate depending on UE category] with Flexible RLC and MAC-ehs / PS RAB + UL:3.4 DL:3.4 kbps SRBs for DCCH / DL: QPSK, 16QAM and MIMO	1

Table 11: GCF MIMO Protocol Test Cases

Subject Area	TS	TC	TC title	Priority
RF	34.121-1	9.2.4A	MIMO Performance – Fixed Reference Channel (FRC) H-Set 9	1
RF	34.121-1	9.3.7A	Reporting of Channel Quality Indicator - MIMO Single Stream Conditions	1
RF	34.121-1	9.3.7B	Reporting of Channel Quality Indicator - MIMO Dual Stream Conditions	1
RF	34.121-1	9.4.3	HS-SCCH Detection Performance - HS-SCCH Type 3 Performance	1

Table 12: GCF MIMO RF Test Cases

Note that GCF decided to open an additional work item for certification of MIMO capable UEs. GCF WI-118 covers HSPA MIMO enhancements for the 3GPP Release 7 MIMO protocol testing for single (UTRA FDD) and dual (UTRA FDD/GSM/GPRS) mode terminals. These additional requirements will complement existing MIMO test cases and help to ensure adequate test coverage within GCF. The additional four protocol test cases cover radio bearer / physical channel reconfigurations and active set update scenarios as shown in Table 13.

TS	TC	TC title	Priority
34.123-1	8.2.2.62	Radio Bearer Reconfiguration for transition from CELL_DCH to CELL_DCH: Success (activation and deactivation of MIMO)	1
34.123-1	8.2.6.54a	Physical Channel Reconfiguration for transition from CELL_DCH to CELL_DCH: Failure (Timing re-initialized hard handover, Serving E-DCH and HS-DSCH cell change with MIMO activated,	1

		physical channel failure and reversion to old channel)	
34.123-1	8.2.6.63	Physical Channel Reconfiguration from CELL_DCH to CELL_DCH: Success (Timing re-initialised hard handover to another frequency, Serving HS-DSCH cell change with MIMO enabled)	1
34.123-1	8.3.4.14	Active Set Update in Soft Handover: Radio Link addition/removal and serving HS-DSCH / E-DCH cell change with activation/deactivation of MIMO	1

Table 13: GCF MIMO additional Protocol Test Cases

2.2 Higher Order Modulation - 64QAM 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.
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 14.

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

Table 14: HS-DSCH slot formats

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 affecting the channel quality reporting procedure. New CQI tables were added in [2] such that the UE is able to propose the usage of transport formats including 64QAM.

2.2.1 64QAM (DL) UE capabilities

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 15 for details on these categories.

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

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

Table 15: UE categories with 64QAM support [11]

2.2.2 64QAM (DL) test and measurement requirements

2.2.2.1 NodeB test and measurement requirements

NodeB test requirements for 64QAM (DL) are specified in [9] and the corresponding test methods are detailed in [10].
If the NodeB uses 64QAM modulation in downlink the modulation accuracy has to be verified. From earlier 3GPP Releases 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. PCDE requirements for 16QAM modulation are specified in [9] and needed to be verified for HSDPA operation up to 3GPP Release 5. In 3GPP Release 7 a relative code domain error (RCDE) measurement is introduced. The RCDE for every active code is defined as the ratio of the mean power of the error projection onto that code, to the mean power of the active code in the composite reference waveform. The ratio is expressed in dB and the measurement interval is one frame. The measured RCDE shall not exceed -21dB at a spreading factor of 16.

2.2.2.2 UE test and measurement requirements

UE test requirements for 64QAM (DL) reception are specified in [5] and the corresponding test methods are detailed in [12] for RF conformance and in [13] for protocol conformance, respectively. In order to support 64QAM testing at the UE side, 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 9. It is based on 15 codes with 64QAM modulation. Six Hybrid ARQ processes are used, and HS-DSCH is continuously transmitted. H-Set 8 is used for verification of a minimum throughput limit at a maximum input level. The equivalent test case already exists for 16QAM reception. Additionally the CQI reporting test cases are enhanced to include also 64QAM operation, whereas the test method from earlier 3GPP Releases on 16QAM CQI reporting performance is kept.

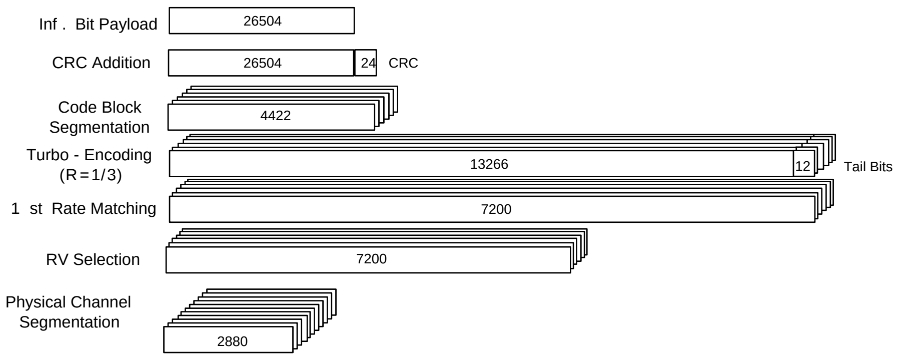


Figure 9: H-Set 8 parameterization

The HS-SCCH detection performance test cases are not extended as one can assume that the UE reception performance is independent from the bit content signalled on HS-SCCH.

2.2.2.3 GCF requirements for 64QAM (DL)

The purpose of the work item GCF-WI-069 is to define the test cases selected to cover the essential core functionality and performance requirements for the 3GPP 64QAM (DL) feature. GCF has identified three protocol test cases and four RF test cases to be verified in order to achieve GCF certification for a 64QAM (DL) capable UE (see Table 16 and Table 17).

Subject Area	TS	TC	TC title	Priority
MAC-hs	34.123-1	7.1.5a.5.3	MAC-ehs transport block size selection / 64QAM	1
RB	34.123-1	14.6.1c	Interactive or background / UL:64 DL: [max bit rate depending on UE category] with Flexible RLC and MAC-ehs PS RAB + UL:3.4 DL:3.4 kbps SRBs for DCCH / DL: 64QAM	1
RB	34.123-1	14.6.6b	Streaming / unknown / UL:128 DL: [guaranteed 128, max bit rate depending on UE category] with Fixed RLC and MAC-ehs / PS RAB + Interactive or background / UL:128 DL: [max bit rate	1

Subject Area	TS	TC	TC title	Priority
			depending on UE category] with Flexible RLC and MAC-ehs / PS RAB + UL:3.4 DL:3.4 kbps SRBs for DCCH / DL: 64QAM	

Table 16: GCF protocol test cases for 64QAM (DL)

Subject Area	TS	TC	TC title	Priority
FDD Receiver Characteristics	34.121-1	6.3B	Maximum Input Level for HS-PDSCH Reception (64QAM)	1
HSDPA (FDD) Single Link Performance	34.121-1	9.2.1H	Single Link Performance - Enhanced Performance Requirements Type 2 - 64QAM, Fixed Reference Channel (FRC) H-Set 8	2
HSDPA (FDD) Single Link Performance	34.121-1	9.2.1I	Single Link Performance - Enhanced Performance Requirements Type 3 - 64QAM, Fixed Reference Channel (FRC) H-Set 8	2
HSDPA (FDD) Single Link Performance	34.121-1	9.3.1A	Reporting of Channel Quality Indicator - Single Link Performance - AWGN Propagation Conditions, 64QAM	2

Table 17: GCF RF test cases for 64QAM (DL)

Note that GCF decided to open an additional work item for 64QAM Enhancements, GCF WI-114. These additional requirements will complement existing 3GPP Release 7 64QAM test cases and help to ensure adequate test coverage within GCF. The additional three protocol test cases cover radio bearer / physical channel reconfigurations and active set update scenarios as shown in Table 18.

TS	TC	TC title	Priority
34.123-1	8.2.2.63	Radio Bearer Reconfiguration from CELL_DCH to CELL_DCH: Success (activation and de-activation of 64QAM)	1
34.123-1	8.2.6.62	Physical Channel Reconfiguration from CELL_DCH to CELL_DCH: Success (activation and de-activation of 64QAM)	1
34.123-1	8.3.4.13	Active set update in soft handover: Radio Link addition/removal and serving HS-DSCH / E-DCH cell change, with activation/deactivation of 64QAM	1

Table 18: GCF additional protocol test cases for 64QAM (DL) enhancements

2.3 Higher Order Modulation - 16QAM 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.
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 19.

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

Table 19: Mapping of E-DPDCH with 4PAM modulation

This results in the following symbol mapping (Figure 10):

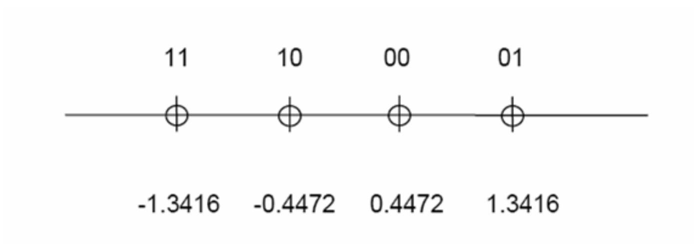


Figure 10: 4PAM symbol mapping

An E-DPDCH may use BPSK or 4PAM modulation symbols. The new E-DPDCH slot formats 8 and 9 are shown in Table 20. 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.

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

Slot format #i	Channel Bit Rate [kbps]	Bits/Symbol M	SF	Bits / Frame	Bits / Subframe	N_{data}
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

Table 20: E-DPDCH slot formats

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.

2.3.1 16QAM (UL) UE capability

A new uplink UE category 7 has been introduced which supports 16QAM in addition to BSPK, see Table 21.

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						

Table 21: FDD E-DCH physical layer categories [11]

2.3.2 16QAM (UL) test and measurement requirements

2.3.2.1 NodeB test and measurement requirements

NodeB test requirements for 16QAM (UL) are specified in [9] and the corresponding test methods are detailed in [10]. New receiver performance requirements are added. Table 22 and Figure 11 provide details of the new fixed reference channel FRC8 used for base station receiver test in case of 16QAM modulation.

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}

Table 22: Fixed Reference Channel (FRC8) – 16QAM parameters

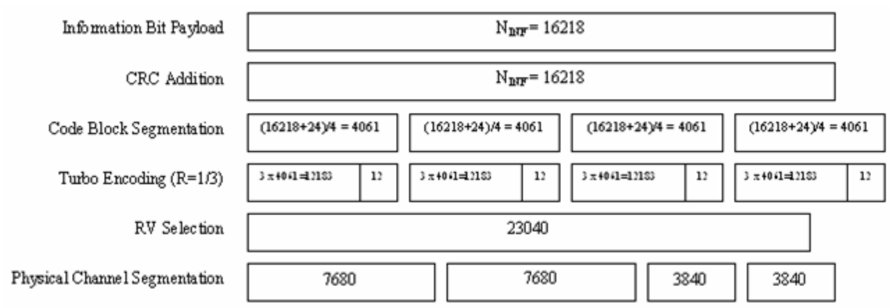


Figure 11: Fixed Reference Channel (FRC8) – 16QAM parameters

2.3.2.2 UE test and measurement requirements

UE test requirements for 16QAM (UL) transmission are specified in [5] and the corresponding test methods are detailed in [12] for RF conformance and in [13] for protocol conformance, respectively.

In the same as with introduction of 64QAM in downlink (for the NodeB), the uplink modulation accuracy needs to be improved when 16QAM in addition to QPSK modulation is used by the terminal. As of 3GPP Release 6 the UE needs to achieve a EVM of 17.5% for QPSK modulation. If the UE supports 16QAM modulation in uplink it needs to satisfy one or both of the two following requirements. The EVM shall be less than 14%. Additionally a Relative Code Domain Error (RCDR) is specified. RCDE for every non-zero beta code in the domain is defined as the ratio of the mean power of the projection onto that non-zero beta code, to the mean power of the non-zero beta code in the composite reference waveform. This ratio is expressed in dB. The measurement interval is one timeslot except when the mean power between slots is expected to change whereupon the measurement interval is reduced by 25 µs at each end of the slot. The RCDE is affected by both the spreading factor and beta value of the various code channels in the domain. Therefore the RCDE requirement is specified depending on the parameter Effective Code Domain Power (ECDP), which captures both affects in one single parameter. ECDP is defined as:

$$ECDP_k = (\text{Nominal CDP ratio})_k + 10*\log10(SF_k/256)$$

The UE needs to satisfy the RCDE requirements in Table 23 and Table 24 in case 16QAM is not used on any of the UL code channels and in case 16QAM is used on any of the UL code channels, respectively.

ECDP dB	Relative Code Domain Error dB
-21 < ECDP	≤ -16
-30 ≤ ECDP ≤ -21	≤ -37 – ECDP
ECDP < -30	No requirement

Table 23: Relative Code Domain Error minimum requirement (non 16QAM usage)

ECDP dB	Relative Code Domain Error dB
-22 < ECDP	≤ -18
-30 ≤ ECDP ≤ -22	≤ -40 – ECDP
ECDP < -30	No requirement

Table 24: Relative Code Domain Error minimum requirement (16QAM usage)

In addition an average requirement over all used codes needs to be evaluated. The Nominal CDP Ratio-weighted average of the Relative Code Domain Errors means the sum $\sum_k 10^{(\text{Nominal CDP ratio})_k/10} \cdot 10^{(\text{Relative Code Domain Error})_k/10}$ over all code k that uses 16QAM. For this specific requirement the ECDP value is determined as the minimum of the individual ECDP values corresponding to the codes using 16QAM. Table 25 provides the requirement on the average relative code domain error.

ECDP dB	Average Relative Code Domain Error dB
-25.5 < ECDP	≤ -18
-30 ≤ ECDP ≤ -25.5	≤ -43.5 – ECDP
ECDP < -30	No requirement

Table 25: Average relative Code Domain Error minimum requirement (16QAM usage)

Finally a relative carrier leakage power requirement needs to be satisfied. If 16QAM modulation is used on any of the uplink code channels, the relative carrier leakage power (IQ origin offset power) shall not exceed the values specified in Table 26.

UE Transmitted Mean Power	Relative Carrier Leakage Power (dB)
P ≥ -30 dBm	< -17

Table 26: Relative Carrier Leakage Power (16QAM usage)

2.3.2.3 GCF requirements for 16QAM (UL)

The purpose of the work item GCF-WI-112 is to define the test cases selected to cover the essential core functionality and performance requirements for the 3GPP 16QAM (UL) feature. GCF has identified five protocol test cases and three RF test cases to be verified in order to achieve GCF certification for a 16QAM (UL) capable UE (see Table 27 and Table 28).

TS	TC	TC title	Priority
34.123-1	7.1.6.3.2a	MAC-es/e transport block size selection/UL 16QAM	1
34.123-1	8.2.6.64	Physical channel reconfigurations for transition from CELL_DCH to CELL_DCH (activation and de-activation of UL 16QAM): Success	1
34.123-1	8.3.4.12	Active set update in soft handover: Radio Link addition/removal (stop and start of UL 16QAM)	1
34.123-1	14.7.1a	Streaming or interactive or background / UL: [max bit rate depending on UE category and TTI] DL: [max bit rate depending on UE category] / PS RAB + UL:3.4 DL:3.4 kbps SRBs for DCCH on DCH/ UL 16QAM	1
34.123-1	14.7.6a	Conversational / unknown or speech / UL:[max bit rate depending on UE category and TTI] DL: [max bit rate depending on UE category] kbps / PS RAB + Streaming or Interactive or background / UL: [max bit rate depending on UE category and TTI] DL: [max bit rate depending on UE category] / PS RAB + UL:[max bit rate depending on UE category and TTI] DL: :[max bit rate depending on UE category] SRBs for DCCH on E-DCH and HS-DSCH/ UL 16QAM	1

Table 27: GCF protocol test cases for 16QAM (UL)

TS	TC	TC title	Priority
34.121-1	5.2E	UE Relative Code Domain Power Accuracy for HS-DPCCH and E-DCH with 16QAM	1
34.121-1	5.13.1AAA	EVM and IQ origin offset for HS-DPCCH and E-DCH with 16 QAM	1
34.121-1	5.13.2C	Relative Code Domain Error for HS-DPCCH and E-DCH with 16QAM	1

Table 28: GCF RF test cases for 16QAM (UL)

2.4 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.

2.4.1 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 synchronization 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 12 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.

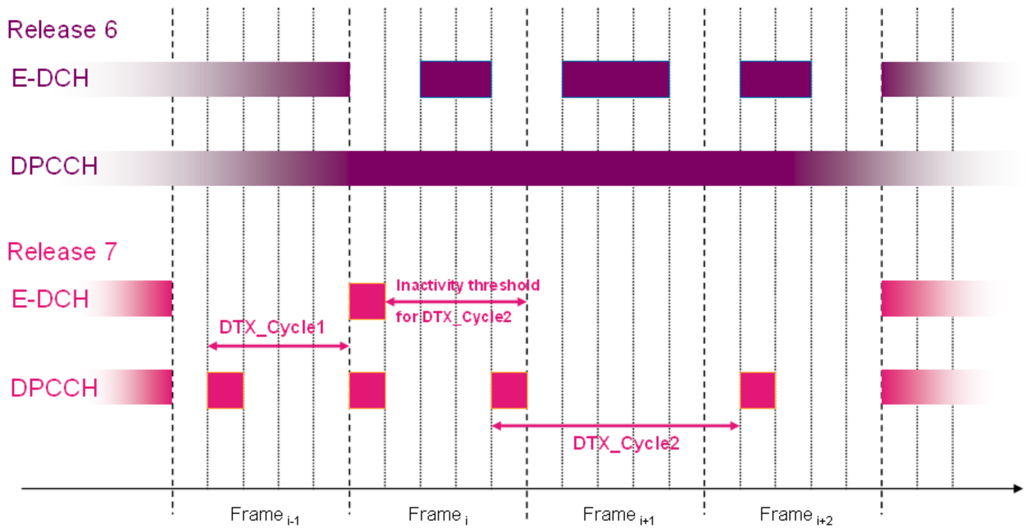


Figure 12: Uplink DTX example, 2 ms TTI (pre-/postambles not shown), [2]

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 29. These parameters can be configured by higher layers.

Parameter	Possible values	Meaning
UE DTX cycle 1	1, 5, 10, 20 subframes for 10ms TTI 1, 4, 5, 8, 10, 16, 20 subframes for 2ms 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	5, 10, 20, 40, 80, 160 subframes for 10ms TTI 4, 5, 8, 10, 16, 20, 32, 40, 64, 80, 128, 160 subframes for 2ms 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	1, 2, 5 subframes	Length of DPCCH transmission when UE DTX cycle 1 is active
UE DPCCH burst 2	1, 2, 5 subframes	Length of DPCCH transmission when UE DTX cycle 2 is active
Inactivity Threshold for UE DTX cycle 2	1, 4, 8, 16, 32, 64, 128, 256 units of E-DCH TTI	When to activate the UE DTX cycle 2 after the last uplink data transmission
UE DTX long preamble length	4, 15 slots	Uplink preamble length

Parameter	Possible values	Meaning
CQI DTX Timer	0, 1, 2, 4, 8, 16, 32, 64, 128, 256, 512, Infinity subframes	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	0, 1, 2, 4, 8, 16, 32, 64, 128 radio frmes	Time the UE waits until enabling a new timing pattern for DRX/DTX operation
UE DTX DRX Offset	0.. 159 subframes	Additional UE specific offset of DRX and DTX cycles (compared to other UEs)

Table 29: Parameters relevant for DTX operation

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 2.4.5 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 29), the UE only provides CQI reports if they coincide with an uplink DPCCH transmission according to the uplink DPCCH activity pattern.

2.4.2 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 30.

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 E-DCH TTIs	E-DCH inactivity time after which the UE can start E-DCH transmission only at given times

Table 30: Parameters relevant for E-DCH Tx start time restrictions

2.4.3 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 behavior can be fine tuned and configured by a lot of higher layer parameters, see Table 31.
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 2.4.5.

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)

Table 31: **Parameters relevant for DRX operation**

2.4.4 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 signaled. 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 13. 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.

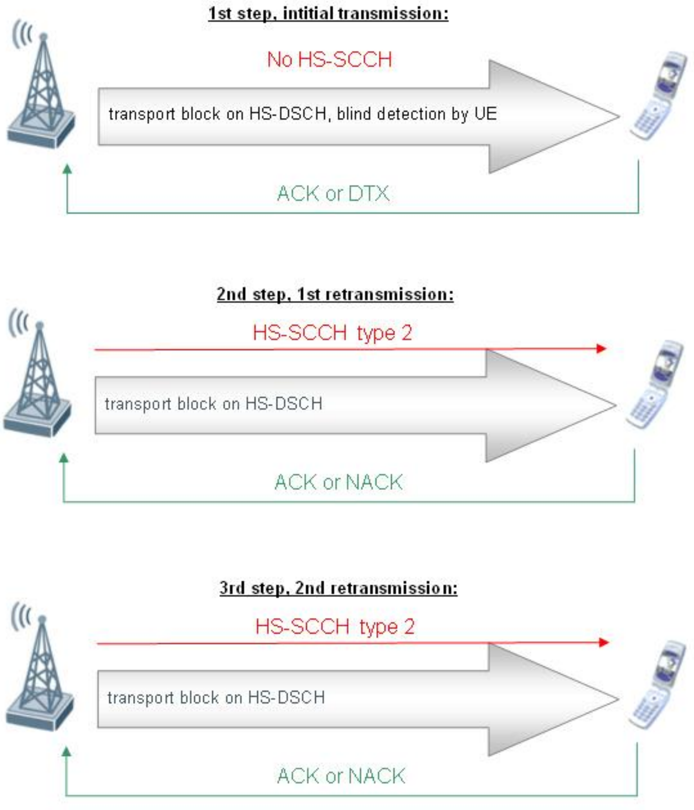


Figure 13: HS-SCCH less operation

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 channelization 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 channelization 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 initial transmission, the retransmissions are using HS-SCCH signaling. 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 14 for a comparison of the two formats.

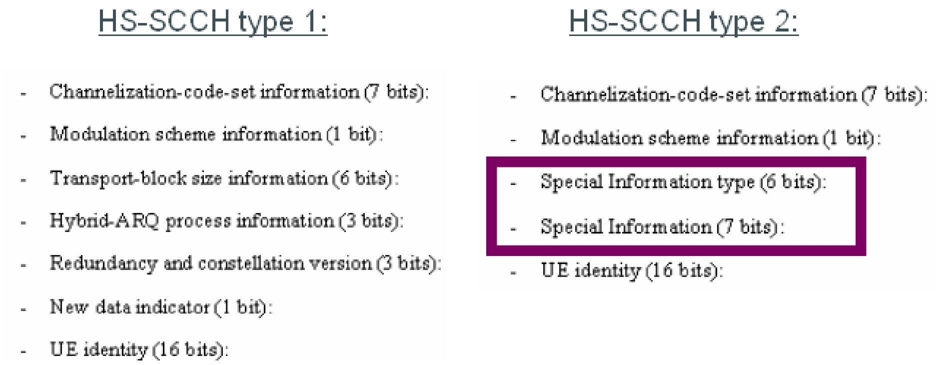


Figure 14: Comparison of HS-SCCH type 1 and 2

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.

2.4.5 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 channelization code and modulation information is set to the fixed pattern ‘1110000’ (see Figure 14) and on HS-SCCH type 3 the channelization code, modulation and precoding weight information is set to the fixed pattern ‘111000000000’ (see chapter 2.1.3). 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.

2.4.6 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 15, and the parameters for the new uplink DPCCH slot format 4 are given in Table 32. 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.

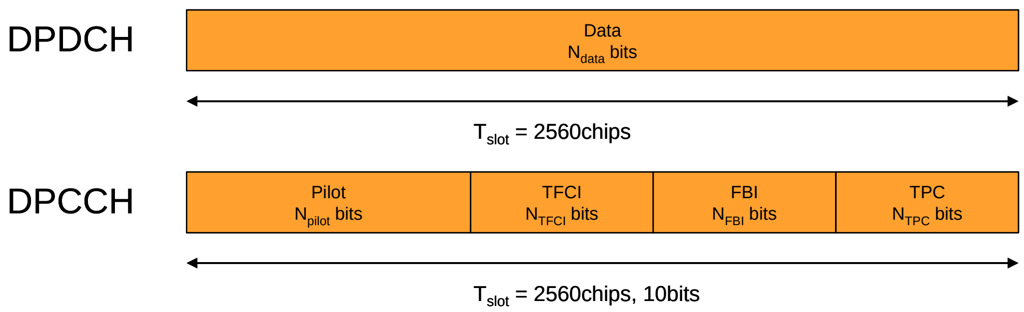


Figure 15: Uplink DPDCH/DPCCH slot format (one slot shown)

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
2	15	15	256	5	2	2	1	15
2A	15	15	256	4	2	3	1	10 – 14

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
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

Table 32: Uplink DPCCH slot formats

2.4.7 CPC test and measurement requirements

2.4.7.1 NodeB test and measurement requirements

NodeB test requirements are specified in [9] and the corresponding test methods are detailed in [10], however there is no impact on those specifications due to the CPC feature, since CPC does not affect the RF performance of the NodeB.

2.4.7.2 UE test and measurement requirements

UE test requirements for CPC transmission/reception are specified in [5] and the corresponding test methods are detailed in [12] for RF conformance and in [13] for protocol conformance, respectively.
Regarding verification of RF transmitter performance the transmit off power requirement is enhanced to also cover the discontinuous uplink DPCCH case, i.e. the transmit OFF power requirement of less than -56 dBm needs to be fulfilled during periods when the uplink DPCCH is gated. The off power observation period is defined as the RRC filtered mean power in a duration of at least one timeslot excluding any transient periods (see Figure 16).

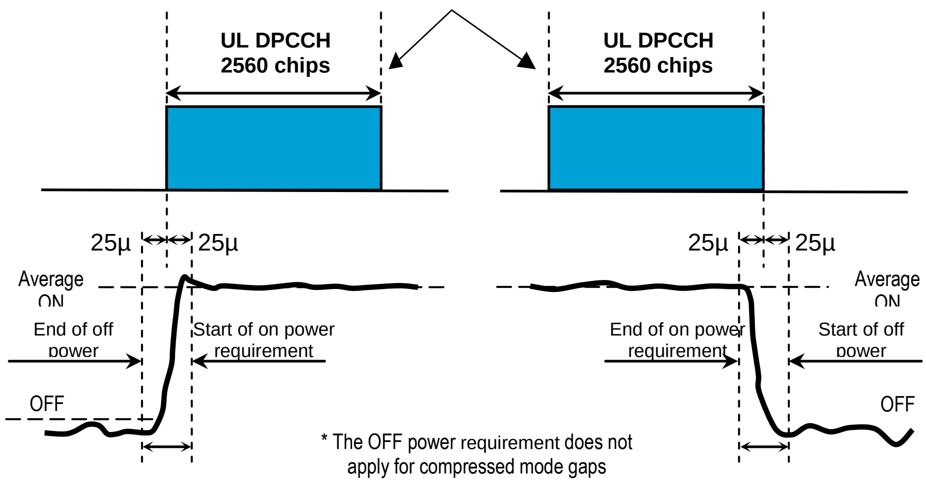


Figure 16: Transmit ON/OFF template for discontinuous uplink DPCCH transmission

Furthermore specific transmit power difference tolerances are specified in case of uplink discontinuous transmission according to Table 33.

Last TPC_cmd	Transmitter power step tolerance after discontinuous UL DPCCH transmission gap					
	1 dB step size		2 dB step size		3 dB step size	
	Lower	Upper	Lower	Upper	Lower	Upper
+ 1	-2 dB	+4 dB	-1 dB	+5 dB	0 dB	+6 dB
0	-3 dB	+3 dB	-3 dB	+3 dB	-3 dB	+3 dB
-1	-4 dB	+2 dB	-5 dB	+1 dB	-6 dB	0 dB

Table 33: Transmitter power difference tolerance after a gap of up to 10 sub-frames due to discontinuous uplink DPCCH transmission

The TPC_cmd value shown in Table 33 corresponds to the last TPC_cmd value received before the transmission gap and applied by the UE after the transmission gap when discontinuous uplink DPCCH transmission is activated.
Finally a dedicated performance requirement was added in [5], which covers the power control during uplink discontinuous DPCCH transmission. This test verifies that the UE follows only those TPC commands that correspond to the UL DPCCH slots which are transmitted. Before the start of the tests, the UE transmit power is initialized to -15 dBm. After transmission gaps due to discontinuous uplink DPCCH transmission the uplink transmitter power difference needs to be within the range as defined in Table 34. The transmit power difference is defined as the difference between the power of the last slot transmitted before the gap and the power of first slot transmitted after the gap.

Parameter	Unit	Test 1	
		Lower	Upper
UE output power difference tolerance	dB	-2	+4

Table 34: Test requirements for UE UL power control operation with discontinuous UL DPCCH transmission

2.4.7.3 GCF requirements for CPC

The purpose of the work item GCF-WI-070 is to define the test cases selected to cover the essential core functionality and performance requirements for the 3GPP CPC feature. GCF has identified 27 protocol test cases and two RF test cases to be verified in order to achieve GCF certification for CPC capable UE (see Table 35 and Table 36). Note that all CPC RF test cases are only priority 2 and do only cover the HS-SCCH less feature within in the CPC feature family.

Subject Area	TS	TC	TC title	Priority
MAC	34.123-1	7.1.5b.1	HARQ procedure for HS-SCCH less operation	2
MAC	34.123-1	7.1.6.2.11	MAC-es/e correct handling of absolute and relative grants in discontinuous downlink reception operation	1
MAC	34.123-1	7.1.6.3.3	Impact on E-TFCI selection on MAC at UE for UL DRX at Node B/ MAC Inactivity Threshold>1	1

Subject Area	TS	TC	TC title	Priority
MAC	34.123-1	7.1.6.3.4	Impact on E-TFCI selection on MAC at UE for UL DRX at Node B/ MAC Inactivity Threshold=1	1
RRC	34.123-1	8.1.2.19	RRC Connection Establishment for transition from Idle Mode to CELL_DCH: Success (start of discontinuous uplink transmission and downlink reception)	1
RRC	34.123-1	8.2.1.38	Radio Bearer Establishment for transition from CELL_DCH to CELL_DCH: Success (start of discontinuous uplink transmission)	1
RRC	34.123-1	8.2.1.39	Radio Bearer Establishment for transition from CELL_DCH to CELL_DCH: Success (start of HS-SCCH less operation)	2
RRC	34.123-1	8.2.1.40	Radio Bearer Establishment for transition from CELL_DCH to CELL_DCH: Success (hard handover to another frequency, start of discontinuous uplink transmission)	1
RRC	34.123-1	8.2.2.51	Radio Bearer Reconfiguration from CELL_DCH to CELL_DCH: Success (With active discontinuous uplink transmission)	1
RRC	34.123-1	8.2.2.52	Radio Bearer Reconfiguration for transition from CELL_FACH to CELL_DCH and CELL_DCH to CELL_FACH: Success (start and stop of discontinuous uplink transmission)	1
RRC	34.123-1	8.2.2.53	Radio Bearer Reconfiguration for transition from CELL_DCH to CELL_DCH: Success (hard handover to another frequency, start and stop of discontinuous uplink transmission)	1
RRC	34.123-1	8.2.2.54	Radio Bearer Reconfiguration for transition from CELL_FACH to CELL_DCH and CELL_DCH to CELL_FACH: Success (frequency modification, start and stop of discontinuous uplink transmission)	1
RRC	34.123-1	8.2.2.55	Radio Bearer Reconfiguration for transition from CELL_DCH to CELL_DCH: Success (Start and stop of discontinuous uplink transmission)	1
RRC	34.123-1	8.2.2.56	Radio Bearer Reconfiguration for transition from CELL_DCH to CELL_PCH: Success (stop of discontinuous uplink transmission)	1
RRC	34.123-1	8.2.3.37	Radio Bearer Release for transition from CELL_DCH to CELL_DCH: Success (frequency modification, stop of discontinuous uplink transmission)	1
RRC	34.123-1	8.2.6.55	Physical channel reconfiguration for transition from CELL_DCH to CELL_DCH: Success (Start of discontinuous uplink transmission and downlink reception)	1
RRC	34.123-1	8.2.6.56	Physical channel reconfiguration for transition from CELL_DCH to CELL_DCH: Success (Start	2

Subject Area	TS	TC	TC title	Priority
			of HS-SCCH less operation)	
RRC	34.123-1	8.2.6.57	Physical Channel Reconfiguration for transition from CELL_DCH to URA_PCH: Success (frequency modification, stop of discontinuous uplink transmission)	1
RRC	34.123-1	8.2.6.58	Physical Channel Reconfiguration for transition from CELL_DCH to CELL_DCH: Success (serving E-DCH cell change with discontinuous uplink transmission)	1
RRC	34.123-1	8.2.6.59	Physical channel reconfiguration for transition from CELL_DCH to CELL_DCH: Success (Timing re-initialized hard handover to another frequency, Serving E-DCH cell change with discontinuous uplink transmission)	1
RRC	34.123-1	8.2.6.60	Physical Channel Reconfiguration for transition from CELL_DCH to CELL_DCH: Failure (Timing re-initialized hard handover, Serving E-DCH cell change with discontinuous uplink transmission, physical channel failure and reversion to old channel)	1
RRC	34.123-1	8.2.6.61	Physical channel reconfiguration for transition from CELL_DCH to CELL_DCH: Success (CQI reporting reduction)	1
RRC	34.123-1	8.3.1.44	Cell Update: Transition from CELL_PCH to CELL_DCH: Success (frequency modification, start of discontinuous uplink transmission)	1
RRC	34.123-1	8.3.1.45	Cell Update: Radio Link Failure, with active discontinuous uplink transmission	1
RRC	34.123-1	8.3.1.46	Cell Update: Transition from URA_PCH to CELL_DCH: Success (start of discontinuous uplink transmission)	1
RRC	34.123-1	8.3.4.11	Active set update in soft handover: Radio Link addition/removal and serving HS-DSCH / E-DCH cell change, with discontinuous uplink transmission	1
RRC	34.123-1	8.3.11.15	Inter-RAT Cell Change Order from UTRAN to GPRS/CELL_DCH/Success (stop of discontinuous uplink transmission)	1

Table 35: GCF protocol test cases for CPC

Subject Area	TS	TC	TC title	Priority
L1 Perf	34.121-1	9.5.1	HS-SCCH-less demodulation of HS-DSCH	2
L1 Perf	34.121-1	9.5.1A	HS-SCCH-less demodulation of HS-DSCH - Enhanced Performance Requirements Type 1	2

Table 36: GCF RF test cases for CPC

2.5 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 signaling and the data traffic will go through the HSDPA channel. However RRC signaling has a minimum data rate since transmission of RRC signaling is rather infrequent, i.e. the physical channel carrying this signaling will be DTX'ed most of the time except for TPC and pilot bits transmission. As the signaling 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 signaling. 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 Release 6 TPC bits are allocated at a fixed position within the slot (see Figure 17). 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."

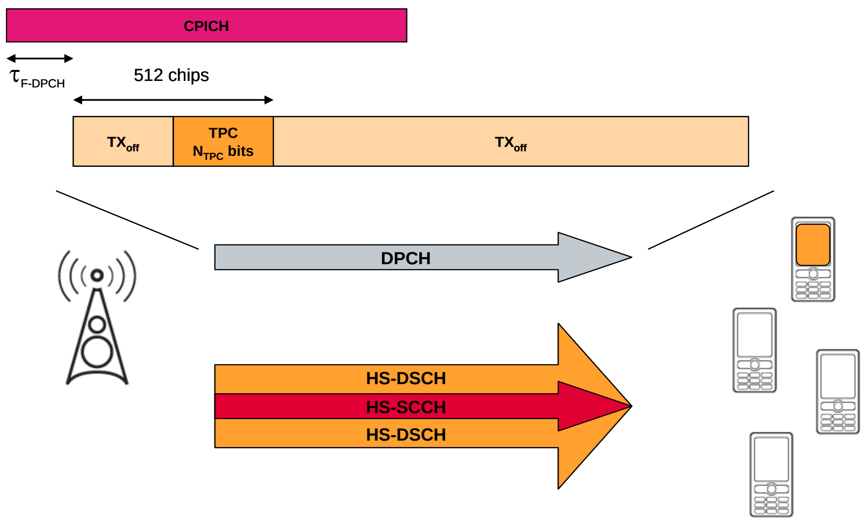


Figure 17: Rel6 Frame structure for F-DPCH

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 signaled in form of a specific slot format from the RNC (Table 37).

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

Table 37: F-DPCH fields

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.

2.5.1 Enhanced F-DPCH test and measurement requirements

2.5.1.1 NodeB test and measurement requirements

NodeB test requirements are specified in [9] and the corresponding test methods are detailed in [10]. However there is no additional impact from the enhancement of the F-DPCH concept. Existing F-DPCH requirements remain as specified in 3GPP Release 6.

2.5.1.2 UE test and measurement requirements

UE test requirements for transmission/reception are specified in [5] and the corresponding test methods are detailed in [12] for RF conformance and in [13] for protocol conformance, respectively. There is only minor impact on the protocol conformance specification reflecting the change of signaling different slot formats to the UE.

2.5.1.3 GCF requirements for enhanced F-DPCH

There are no specific GCF requirements due to the enhanced F-DPCH feature because the basic concept of F-DPCH as per 3GPP Release 6 is maintained to a large extend.

2.6 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.

2.6.1 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 18 shows the UTRAN side MAC architecture including the new MAC-ehs [6].

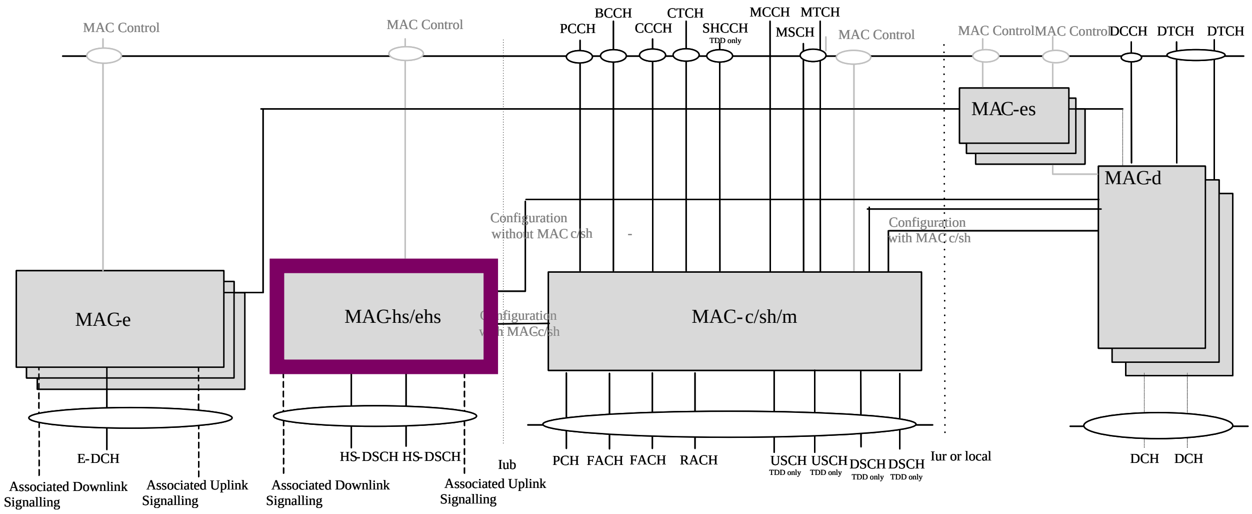


Figure 18: UTRAN side MAC architecture with MAC-ehs

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 19 shows the details of the MAC-ehs on UTRAN side. 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 signaling. This is explained in the chapter 2.7 below. Logical channels can be multiplexed onto priority queues.

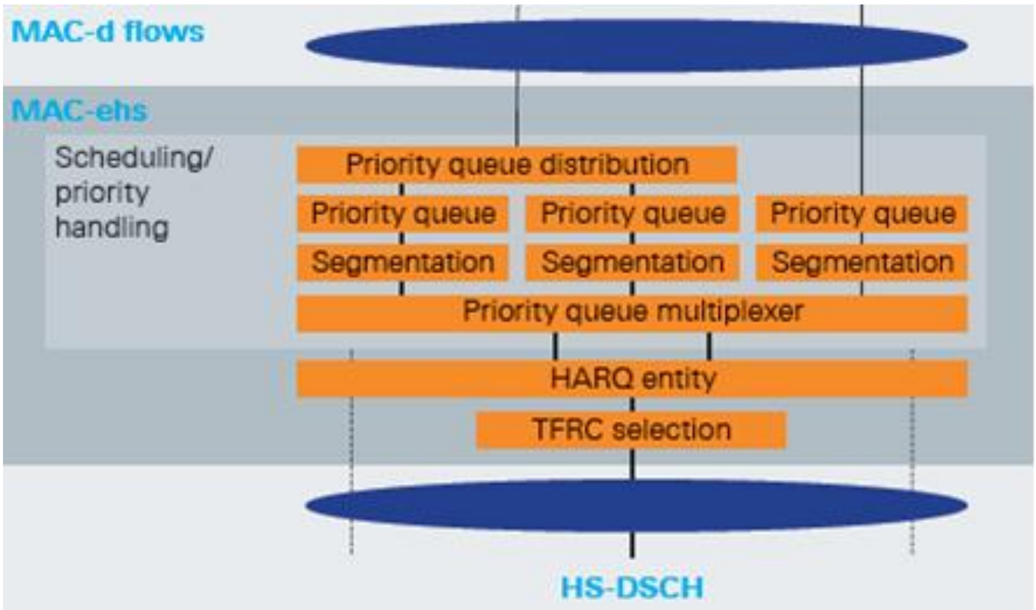


Figure 19: UTRAN side MAC-ehs details

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 2.7) 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.

2.6.2 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 20. 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.

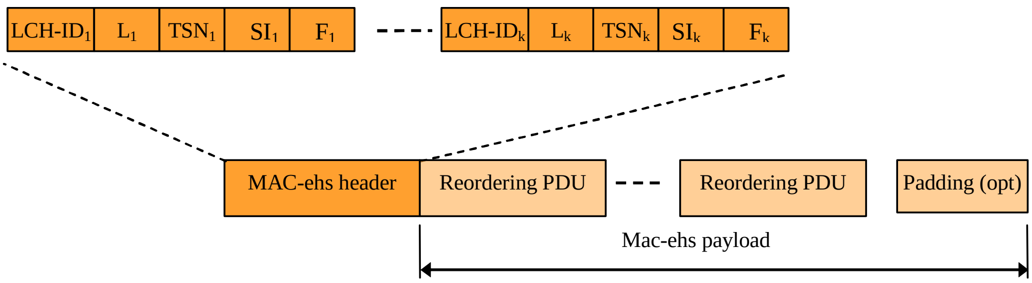


Figure 20: MAC-ehs PDU

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.

2.6.3 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 21 illustrates the principle of flexible downlink RLC PDU sizes comparing 3GPP Release 5 and 3GPP Release 7 mode of operation.

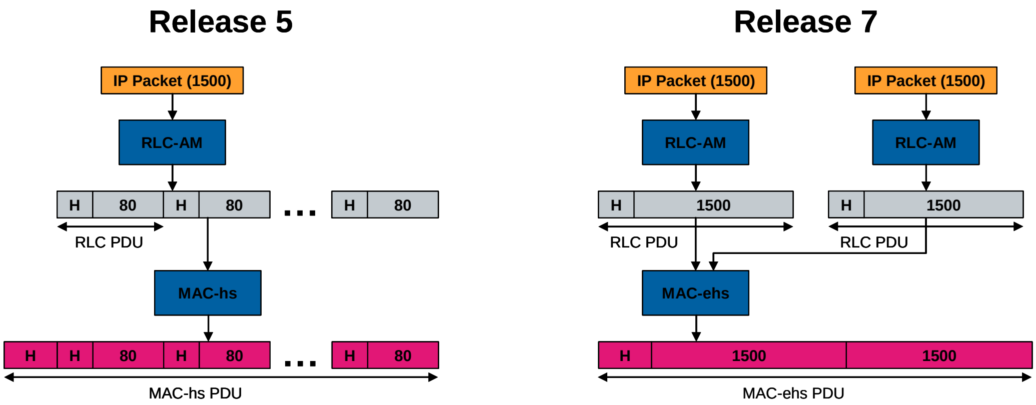


Figure 21: Flexible RLC PDU size operation

2.6.4 Improved Layer 2 (DL) test and measurement requirements

2.6.4.1 NodeB test and measurement requirements

NodeB test requirements are specified in [9] and the corresponding test methods are detailed in [10]. However since improved Layer 2 is a pure protocol feature there are no modifications in these 3GPP specifications resulting from the improved Layer 2 (DL) feature.

2.6.4.2 UE test and measurement requirements

UE test requirements for transmission/reception are specified in [5] and the corresponding test methods are detailed in [12] for RF conformance and in [13] for protocol conformance, respectively. There is no impact on [5], however a number of new protocol test cases were added in [13] to verify the protocol behaviour in case improved Layer 2 (DL) is used.

2.6.4.3 GCF requirements for improved Layer 2 (DL)

The purpose of the work item GCF-WI-068 is to define the test cases selected to cover the essential core functionality and performance requirements for the 3GPP improved Layer 2 (DL) feature. GCF has identified 11 protocol test cases to be verified in order to achieve GCF certification for an improved Layer 2 (DL) capable UE (see Table 38).

Subject Area	TS	TC	TC title	Priority
MAC-ehs	34.123-1	7.1.5a.1	MAC-ehs multiplexing / multiple logical channels on same queue	1
MAC-ehs	34.123-1	7.1.5a.2	MAC-ehs multiplexing / multiple logical channels on multiple queues	1
MAC-ehs	34.123-1	7.1.5a.3	MAC-ehs segmentation / UE handling of partial and full PDUs	1
MAC-ehs	34.123-1	7.1.5a.4	MAC-ehs reordering and stall avoidance	1
MAC-ehs	34.123-1	7.1.5a.5.2	MAC-ehs transport block size selection / QPSK and 16QAM	1
RLC UM	34.123-1	7.2.2.14	Flexible handling of RLC PDU sizes for UM RLC in downlink	1
RLC AM	34.123-1	7.2.3.36	Flexible handling of RLC PDU sizes for AM RLC	1
RRC	34.123-1	8.2.2.57	Radio Bearer Reconfiguration from CELL_DCH to CELL_DCH: Success (with reconfiguration between fixed & flexible RLC)	1
RB	34.123-1	14.6.1b	Interactive or background / UL:64 DL: [max bit rate depending on UE category] with Fixed RLC and MAC-ehs PS RAB + UL:3.4 DL:3.4 kbps SRBs for DCCH / DL: QPSK and 16QAM	1

Subject Area	TS	TC	TC title	Priority
RB	34.123-1	14.6.6a	Streaming / unknown / UL:128 DL: [guaranteed 128, max bit rate depending on UE category] with Fixed RLC and MAC-ehs / PS RAB + Interactive or background / UL:128 DL: [max bit rate depending on UE category] with Flexible RLC and MAC-ehs / PS RAB + UL:3.4 DL:3.4 kbps SRBs for DCCH / DL: QPSK and 16QAM	1
RB	34.123-1	14.7.6b	Conversational / unknown or speech / UL:[max bit rate depending on UE category and TTI] DL: [max bit rate depending on UE category] kbps with Flexible RLC and MAC-ehs / PS RAB + Streaming or Interactive or background / UL: [max bit rate depending on UE category and TTI] DL: [max bit rate depending on UE category] with Fixed RLC and MAC-ehs / PS RAB + UL:[max bit rate depending on UE category and TTI] DL: :[max bit rate depending on UE category] SRBs for DCCH on E-DCH and SRBs with Flexible RLC and MAC-ehs on HS-DSCH / UL: QPSK and DL: QPSK	2

Table 38: GCF protocol test cases for improved Layer 2 (DL)

2.7 Enhanced CELL_FACH State (DL)

From Release 99 onwards, four different protocol states have been defined for UEs in RRC connected mode (see Figure 22):

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

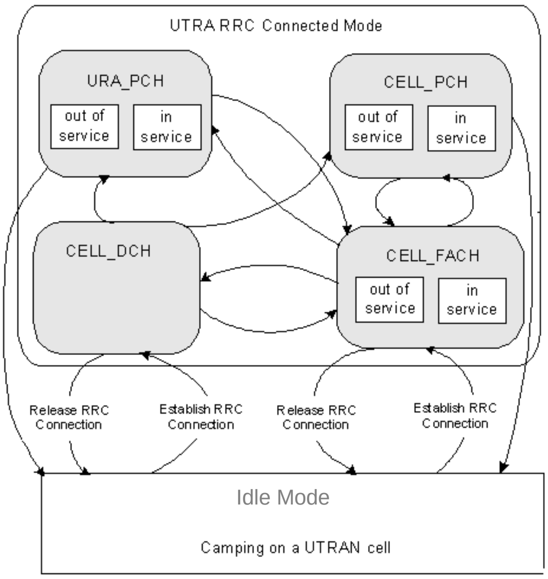


Figure 22: RRC States and State Transitions [7]

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 23 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.

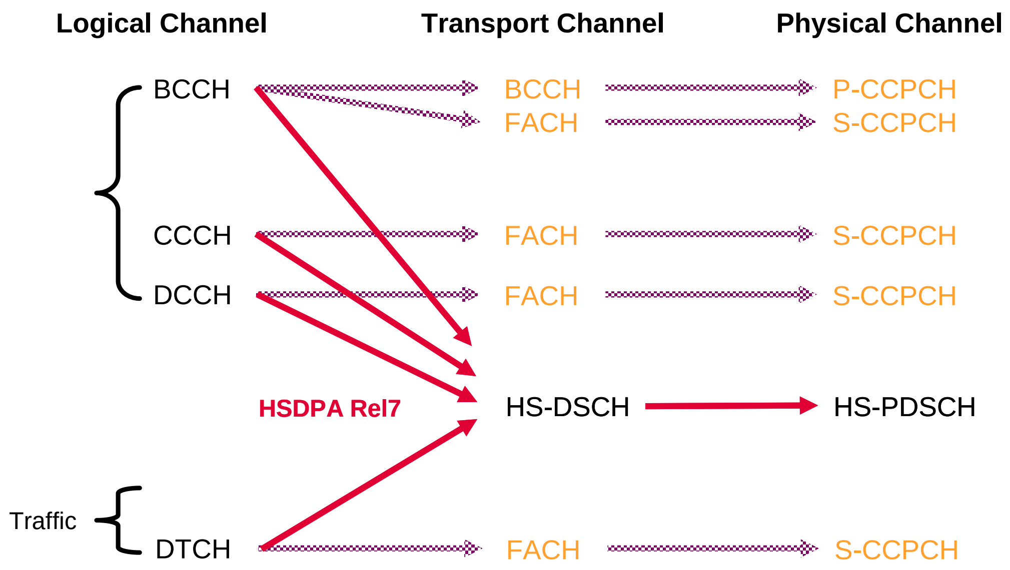


Figure 23: Mapping of logical channels on transport and physical channels in CELL_FACH state

Furthermore, the benefits of transmitting on HS-DSCH is also available for CELL_PCH and URA_PCH states which reduces signalling delays. Table 39 provides an overview on the logical channels that may be transmitted on HS-DSCH in the different states.

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

Table 39: Support of logical channel transmission on HS-DSCH

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 signaling on HS-DPCCH (i.e. neither ACK/NACK nor CQI signaling 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

2.7.1 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 40) 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.

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	
>HS-PDSCH Channelization 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]

Table 40: HS-DSCH paging system information [7]

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 24 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.

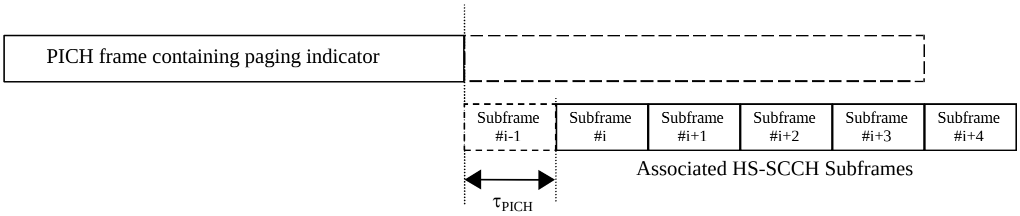


Figure 24: Timing relation between PICH frame and associated HS-SCCH subframes

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 channelization 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 channelization 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.

2.7.2 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 41). This information is also used when the UE is entering connected mode from idle mode by sending an *RRC connection request* message.

Information Element/Group name	Need	Multi	Type
CCCH mapping info	MP		Common RB mapping info
SRB1 mapping info	MD		Common RB mapping info

Information Element/Group name	Need	Multi	Type
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

Table 41: HS-DSCH common system information [7]

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 39, 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 signaling 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 24. 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).

2.7.3 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.

2.7.4 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 25). 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.

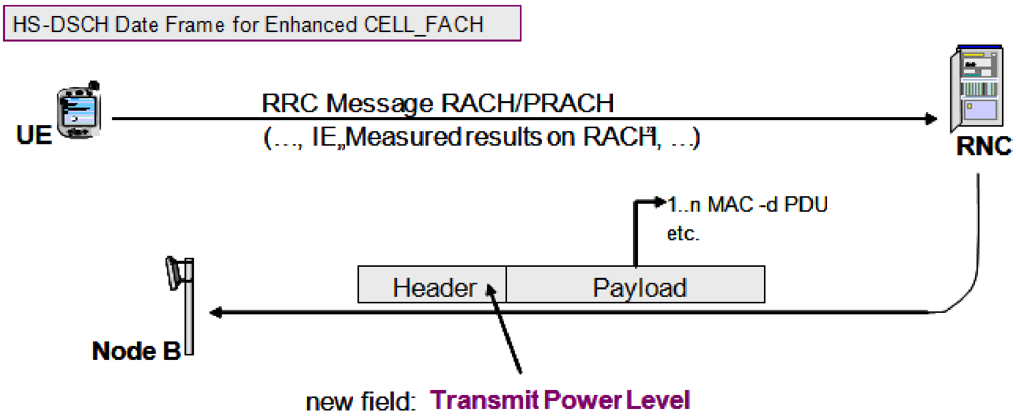


Figure 25: Measurement reporting procedure in Enhanced CELL_FACH

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).

2.7.5 UE capability modifications

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.

2.7.6 Enhanced CELL_FACH test and measurement requirements

2.7.6.1 NodeB test and measurement requirements

NodeB test requirements are specified in [9] and the corresponding test methods are detailed in [10]. However since enhanced CELL_FACH is a pure protocol feature there are no modifications in these 3GPP specifications resulting from the improved Layer 2 (DL) feature.

2.7.6.2 UE test and measurement requirements

UE test requirements for transmission/reception are specified in [5] and the corresponding test methods are detailed in [12] for RF conformance and in [13] for protocol conformance, respectively. The only impact in [5] is the addition of a specific test case to verify HS-DSCH demodulation performance if the UE is in CELL_FACH state. The requirements are specified in terms of a minimum RLC SDU error rate (RLC SDU ER) for the DL reference channel H-Set 3 (QPSK version). The measured RLC SDU ER shall be less than or equal to 0.82 (see Table 42).

Test Number	Propagation Conditions	Reference value	
		HS-PDSCH E_c / I_{or} (Db)	RLC SDU ER $\hat{I}_{or} / I_{oc}$ = 0 Db
1	VA30	-6	0.82

Table 42: Minimum requirement QPSK, Fixed Reference Channel (FRC) H-Set 3

Additionally a number of new protocol test cases were added in [13] to verify the protocol behavior in case enhanced CELL_FACH is used.

2.7.6.3 GCF requirements for enhanced CELL_FACH

The purpose of the work item GCF-WI-110 is to define the test cases selected to cover the essential core functionality and performance requirements for the 3GPP enhanced CELL_FACH feature. GCF has identified nine protocol test cases and two RF test cases to be verified in order to achieve GCF certification for a enhanced CELL_FACH capable UE (see Table 43 and Table 44).

TS	TC	TC title	Priority
34.123-1	7.1.5a.6	UE Identification on HS-PDSCH in CELL_FACH	1
34.123-1	7.1.5a.7	HARQ retransmissions without ACK/NACK signalling in CELL_FACH	1
34.123-1	8.1.1.5a	Paging on HS-DSCH for notification of BCCH modification in CELL_PCH	2
34.123-1	8.1.1.12	Paging for Connection in connected mode (CELL_PCH) without HS-SCCH	2
34.123-1	8.1.2.20	RRC Connection Establishment for transition from Idle Mode to CELL_FACH: Success (Start of HS-DSCH Reception)	1
34.123-1	8.1.10.2	BCCH Mapping on HS-DSCH for Transmitting System Information Change Indication	1
34.123-1	8.2.2.59	Radio Bearer Reconfiguration from Cell FACH (Cell supporting HS-DSCH in Cell FACH) to CELL_FACH(Cell not supporting HS-DSCH in Cell FACH): Success (Cell re-selection)	1
34.123-1	8.2.2.60	Radio Bearer Reconfiguration for transition from CELL_DCH to CELL_FACH and CELL_FACH to CELL_DCH: Success (with ongoing HS-DSCH reception)	1
34.123-1	8.3.1.47	Cell Update: cell reselection in CELL_FACH (Reselection between cell not supporting HS-PDSCH in CELL_FACH and cell supporting HS-PDSCH is CELL_FACH)	1
34.123-1	8.4.1.50	Measurement reporting when moving from CELL_PCH to CELL_FACH	1
34.123-1	14.5.3	Interoperability Radio Bearer tests using enhanced CELL_FACH	1

Table 43: GCF protocol test cases for enhanced CELL_FACH

TS	TC	TC title	Priority
34.121-1	9.6.1	Single link HS-DSCH Demodulation performance in CELL_FACH state	1
34.121-1	9.6.2	Single link HS-SCCH Detection performance in CELL_FACH state	1

Table 44: GCF RF test cases for enhanced CELL_FACH

3 HSPA+ Release 8

3.1 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 favorable 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.

3.1.1 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 signaling 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 45 (additions – see also Table 1 – are marked bold). 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.

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

Table 45: Interpretation of "Modulation scheme and number of transport blocks" sent on HS-SCCH

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).

3.1.2 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 46 and Table 47).

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 46: 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	Transpor t 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		

CQI_1 or CQI_2	Transport Block Size	Number of HS-PDSCH	Transpor t Block Size	Equivalent AWGN SINR difference Δ	NIR	Xrvpb or Xrvsb
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		

Table 47: CQI mapping table for UE category 20 in case of dual transport block type A CQI reports

3.1.3 64QAM and MIMO UE capability

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 48:

- **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 42.20 Mbps

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 [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	~ 35.28
Category 20			15	1	42192	~ 42.20

Table 48: New Release 8 UE categories 19/20 with simultaneous MIMO and 64QAM support [11]

3.1.4 MIMO and 64QAM test and measurement requirements

3.1.4.1 NodeB test and measurement requirements

NodeB test requirements are specified in [9] and the corresponding test methods are detailed in [10]. However there are no new requirements resulting form the combination of 64QAM and MIMO, since each individual feature is already reflected in earlier 3GPP Releases of the test specifications.

3.1.4.2 UE test and measurement requirements

UE test requirements are specified in [5] and the corresponding test methods are detailed in [12] for RF conformance and in [13] for protocol conformance, respectively. In order to support MIMO and 64QAM testing at the UE side, a new fixed reference channel has been introduced. H-Set 11 is specified as reference test channel for HSDPA test cases in [5]. H-Set 11 parameterization and coding chain is shown in Table 49 and illustrated in Figure 26 and Figure 27. It is based on 15 codes with 64QAM modulation. Six Hybrid ARQ processes are used, and HS-DSCH is continuously transmitted. H-Set 11 is used for verification of a minimum throughput limit according to Table 50.

Parameter	Unit	Value	
Transport block		Primary	Secondary
Combined Nominal Avg. Inf. Bit Rate		22074	
Nominal Avg. Inf. Bit Rate	kbps	13300	8774
Inter-TTI Distance	TTI's	1	1
Number of HARQ Processes	Processes	6	6
Information Bit Payload (N_{INF})	Bits	26504	17568
Number Code Blocks	Blocks	6	4
Binary Channel Bits Per TTI	Bits	43200	28800
Total available SML's in UE	Bits	518400	
Number of SML's per HARQ Proc.	SML's	43200	43200
Coding Rate		0.61	0.6
Number of Physical Channel Codes	Codes	15	15
Modulation		64QAM	16QAM

Table 49: Fixed Reference Channel H-Set 11

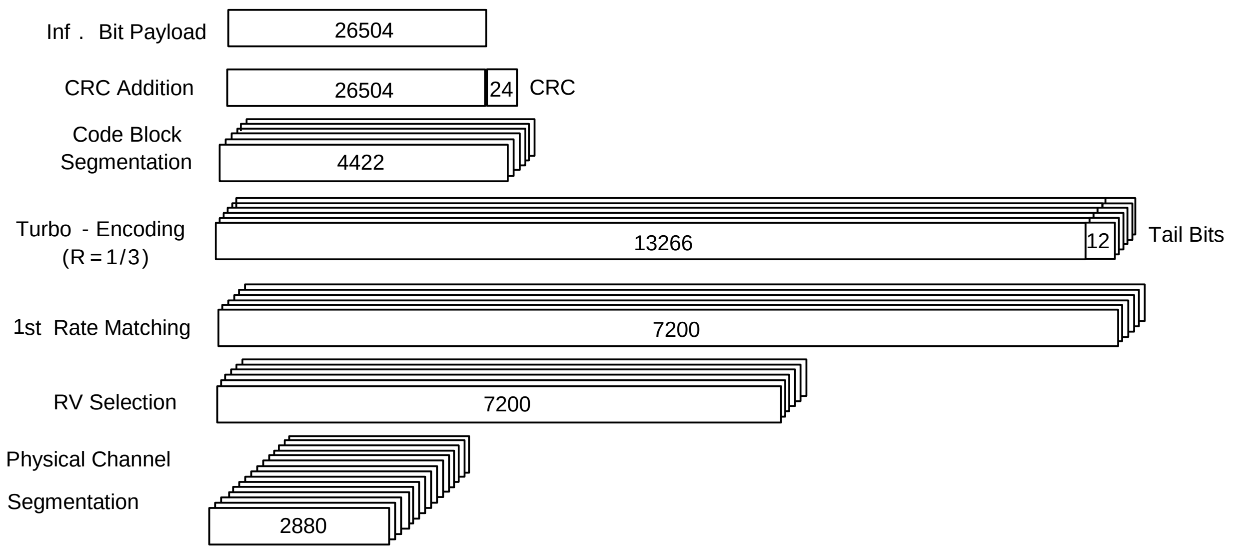


Figure 26: Coding rate for Fixed Reference Channel H-Set 11 Primary Transport Block

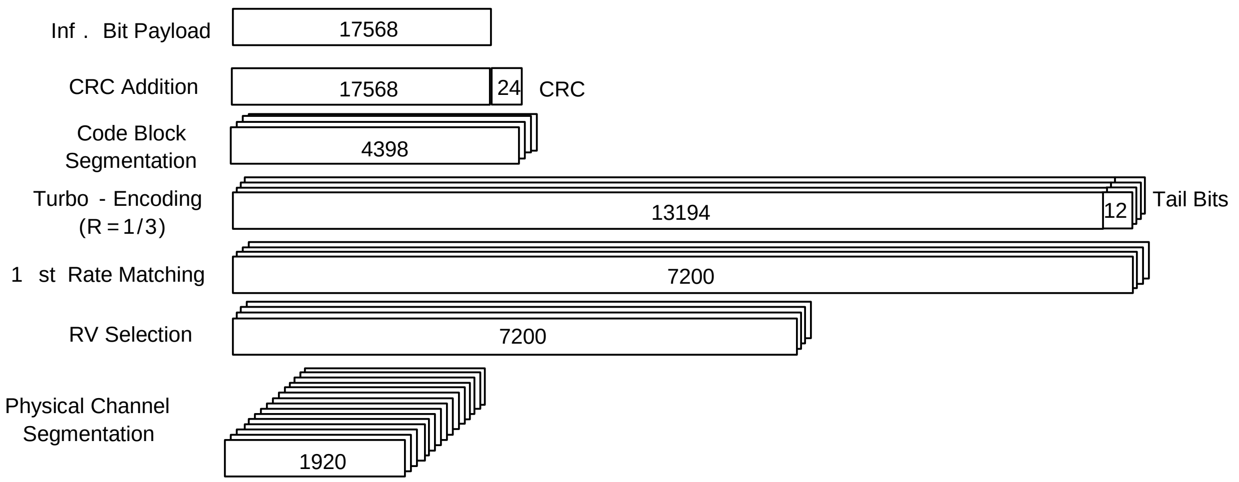


Figure 27: Coding rate for Fixed Reference Channel H-Set 11 Secondary Transport Block

Test Number	Propagation Conditions	Reference value	
		HS-PDSCH $\hat{I}_{or}/I_{oc}$ (dB)	T-put R (kbps) E_c/I_{or} = -1.5 dB
1	PA3	18	9980

Table 50: Minimum requirement MIMO, Fixed Reference Channel (FRC) H-Set 11

3.1.4.3 GCF requirements for MIMO and 64QAM

GCF has not started a work item for certification of MIMO and 64QAM capable UEs yet.

3.2 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 minimized 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.

3.2.1 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 28) which is signaled 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 signaled to the UE, which is configured by the RNC and ranges from 20ms to 200ms.

3.2.2 PDCP solution and RLC Mode of operation

Figure 28 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.

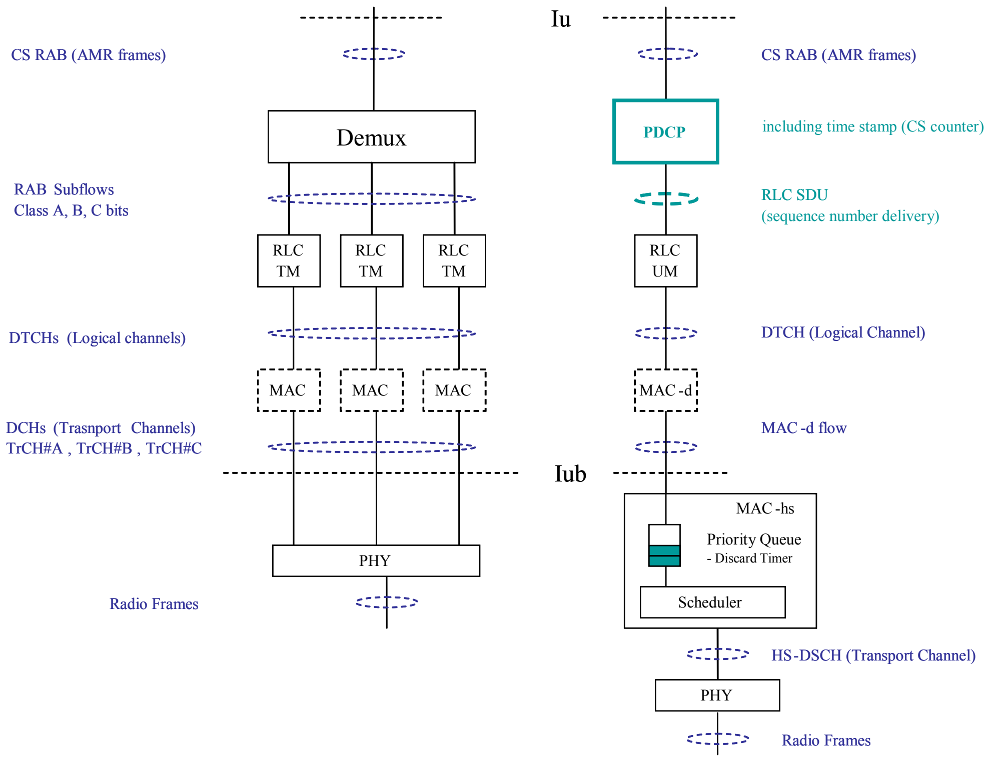


Figure 28: Downlink U-plane multiplexing: Legacy vs. CS over HSPA scheme

The main modifications are introduced in the PDCP layer. Also the PDCP layer is not any longer defined for the PS domain only. Figure 29 provides the basic PDCP structure.

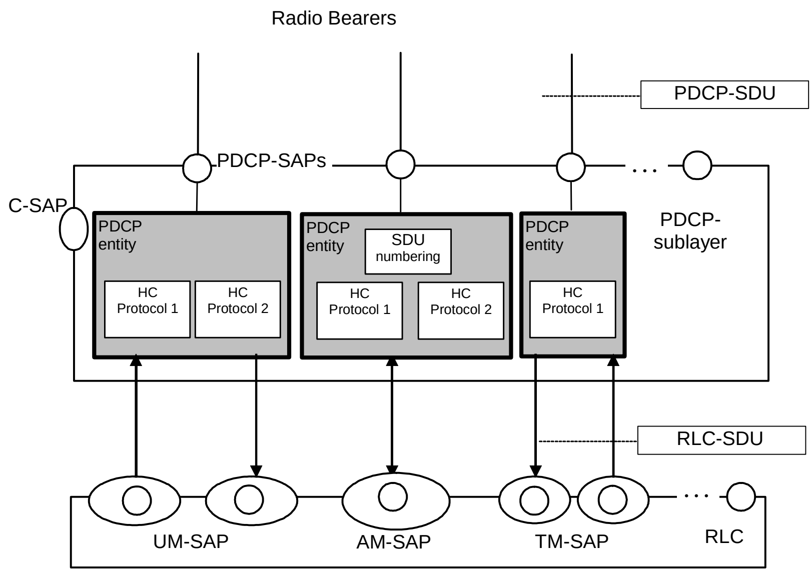


Figure 29: PDCP structure

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 51). 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.

PDU Type	CS Counter
Data	

Table 51: PDCP AMR Data PDU format

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 30) 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.

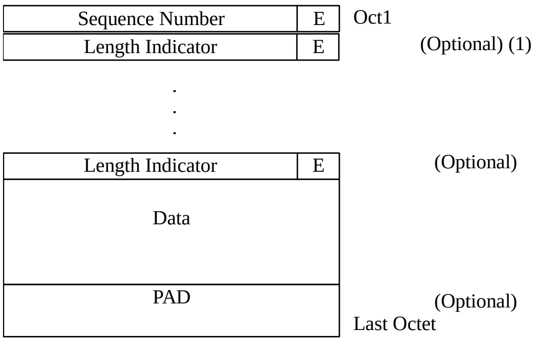


Figure 30: Unacknowledged Mode Data (UMD) PDU

3.2.3 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.

3.2.4 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 2.4) and MAC-ehs (see chapter 2.6).

3.2.5 CS over HSPA test and measurement requirements

3.2.5.1 NodeB test and measurement requirements

NodeB test requirements are specified in [9] and the corresponding test methods are detailed in [10]. However as CS over HSPA is a pure protocol feature there is no impact on the mentioned specifications due to this feature.

3.2.5.2 UE test and measurement requirements

UE test requirements are specified in [5] and the corresponding test methods are detailed in [12] for RF conformance and in [13] for protocol conformance, respectively. As CS over HSPA is a pure protocol feature there is no impact on the UE radio transmission and reception specification in [5] due to this feature. However there a number of new protocol test cases in [13] in order to verify correct protocol behavior when CS over HSPA is used.

3.2.5.3 GCF requirements for CS over HSPA

The purpose of the work item GCF-WI-123 is to define the test cases selected to cover the essential core functionality and performance requirements for the 3GPP CS over HSPA feature. GCF has identified six protocol test cases to be verified in order to achieve GCF certification for a CS over HSPA capable UE (see Table 51).

TS	TC	TC title	Priority
34.123-1	7.3.7.1	PDCP AMR Data PDU testing	1
34.123-1	7.3.7.2	PDCP Unrecoverable Error Detection	1
34.123-1	8.2.2.58	Radio Bearer Reconfiguration for transition from CELL_DCH to CELL_DCH: Success (Reconfigurations between CS voice over DCH and CS voice over HSPA)	1
34.123-1	8.3.1.48	Cell Update: Radio Link Failure, UM RLC Re-establishment	1
34.123-1	14.7.9	Conversational / speech / UL:(12.2, 7.95, 5.9, 4.75) kbps DL: (12.2, 7.95, 5.9, 4.75) kbps / CS RAB on E-DCH and HS-DSCH + UL: [max bit rate depending on UE category and TTI] DL: [max bit rate depending on UE category] SRBs for DCCH on E-DCH and HS-DSCH	1
34.123-1	14.7.10	Conversational / speech / UL:(12.65, 8.85, 6.6) kbps DL: (12.65, 8.85, 6.6) kbps / CS RAB on E-DCH and HS-DSCH + UL: [max bit rate depending on UE category and TTI] DL: [max bit rate depending on UE category] SRBs for DCCH on E-DCH and HS-DSCH	1

Table 51: GCF protocol test cases for CS over HSPA

3.3 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 31). Therefore it is possible to distribute the users in the uplink on both carriers at least semi-statically using the inter-frequency handover procedure.

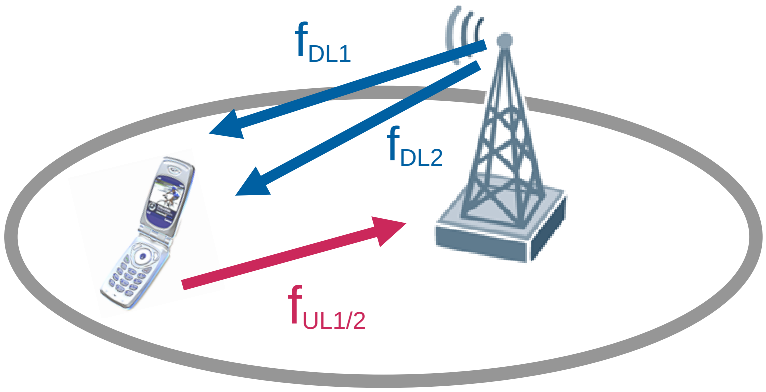


Figure 31: Dual Cell HSDPA operation

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 2.4.1and 0) 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 0) is only possible on the serving cell.

3.3.1 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 2.1.4, Table 3). 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 52.

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

Table 52: Interpretation of HARQ-ACK in Dual Cell HSDPA operation

In a similar way two CQI reports need to be provided on HS-DPCCH in uplink in order to provide channel quality information for each individual downlink frequency. The composite CQI report is constructed from two individual CQI reports that are represented by CQI_1 and CQI_2. CQI_1 corresponds to the serving HS-DSCH cell and CQI_2 corresponds to the secondary serving HS-DSCH cell. The two CQI values are simply concatenated as illustrated in Figure 32 below. Since the available bits after coding the CQI values are limited to 20, a (20,10) code is used for dual cell operation instead of the (20,5) code for HSDPA operation as of Release 5.

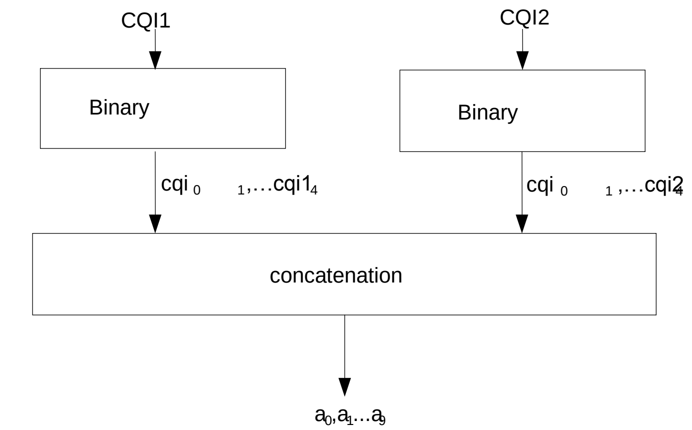


Figure 32: Concatenated CQI values for dual cell HSDPA

It is important to understand that the maximum number of simultaneously-configured uplink dedicated channels is specified in [8] according to Table 53. 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.

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

Table 53: Maximum number of simultaneously-configured uplink dedicated channels

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 33 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).

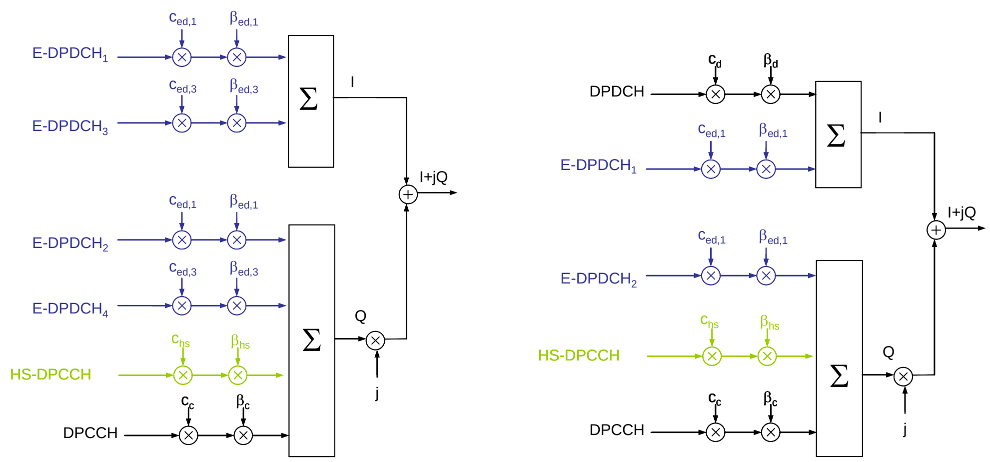


Figure 33: Physical Channel mapping in case of four EDPDCH codes and two EDPDCH codes

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.

3.3.2 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 2.4.5) is reused. HS-SCCH orders are fast commands sent on HS-SCCH. For Dual Cell HSDPA 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.

3.3.3 Dual Cell HSDPA UE capability

As mentioned the support for dual cell HSDPA is optional to the UE. Consequently new UE categories have been specified in [11], see Table 54.

- **Categories 21 - 24:**
  - Support of dual cell with modulation schemes QPSK, 16QAM and 64QAM
  - Maximum data rate of category 21/22 is 28 Mbps
  - Maximum data rate of category 23/24 is 42.40 Mbps

HS DSCH category	Dual Cell support	MIMO support	Modulation	Maximum number of HS DSCH codes received	Min. inter TTI interval	Maximum number of bits of an HS-DSCH transport block received within an HS-DSCH TTI	Maximum data rate [Mbps]
…		…	…	…	…	…	…
Category 19	No	Yes	QPSK / 16QAM / 64QAM	15	1	35280	~ 35.28
Category 20				15	1	42192	~ 42.20
Category 21	Yes	No	QPSK / 16QAM	15	1	23370	~ 23.37
Category 22				15	1	27952	~ 28
Category 23			QPSK / 16QAM / 64QAM	15	1	35280	~ 35.28
Category 24				15	1	42192	~ 42.20

Table 54: New Release 8 UE categories 21-24 supporting dual cell HSDPA operation

3.3.4 Dual Cell HSDPA test and measurement requirements

3.3.4.1 NodeB test and measurement requirements

NodeB test requirements for Dual Cell HSDPA are specified in [9] and the corresponding test methods are detailed in [10]. The only requirement that is affected due to the use of Dual Cell HSDPA feature is the time alignment error requirement. In the same way as for MIMO dual stream transmission also for Dual Cell HSDPA the two adjacent signals need to be synchronized in time to a certain extend. 3GPP distinguished between two cases, i.e. if the two signals are transmitted via one or two antenna connectors at the NodeB. At a single antenna connector the time difference between both signals is not allowed to exceed ¼ T_c. If the signals are present at two different antenna connectors, the time alignment error is not allowed to exceed ½ T_c.

3.3.4.2 UE test and measurement requirements

UE test requirements for dual cell HSDPA transmission/reception are specified in [5] and the corresponding test methods are detailed in [12] for RF conformance and in [13] for protocol conformance, respectively.

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 55 and Figure 34. It is based on one code with QPSK modulation. Six Hybrid ARQ processes are used, and HS-DSCH is continuously transmitted.

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

Table 55: Parameters for fixed reference channel H-Set 12 (QPSK)

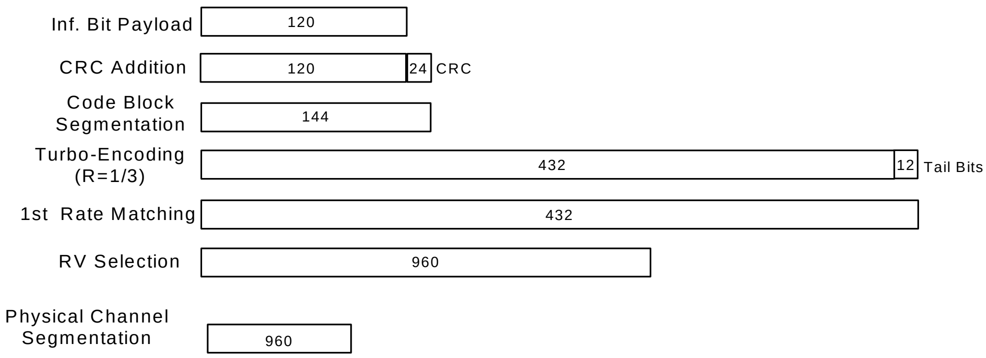


Figure 34: Coding rate for fixed reference channel H-Set 12 (QPSK)

Throughput requirements are not verified for the combined signal on two adjacent carrier frequencies, since it is judged sufficient to verify the performance on each single data stream as already done for traditional 64QAM reception in earlier 3GPP Release specifications. However CQI reporting performance in case of single link (AWGN and fading conditions) and open loop diversity (AWGN and fading conditions) is explicitly tested, i.e. related performance requirements are included in section 9 of [5]. Additionally there a number of new protocol test cases in [13] in order to verify correct protocol behavior when Dual Cell HSDPA is used.

3.3.4.3 GCF requirements for Dual Cell HSDPA

The purpose of the work item GCF-WI-129 is to define the test cases selected to cover the essential core functionality and performance requirements for the 3GPP Dual Cell HSDPA feature. GCF has identified eight protocol test cases and fifteen RF test cases to be verified in order to achieve GCF certification for a Dual Cell capable UE (see Table 56 and Table 57).

TS	TC	TC title	Priority
34.123-1	8.3.4.15	Active set update: Dual Cell (DC) Activation by Serving Cell Change from non DC-HSDPA capable cell to DC-HSDPA capable cell.	1
34.123-1	8.3.4.15a	Active set update: Dual Cell (DC) Activation by Serving Cell Change from non-DC-HSDPA capable cell to DC-HSDPA capable cell, with SRB mapped on E-DCH/DCH	1
34.123-1	8.3.4.16	Active set update: Dual Cell (DC) Activation by Serving Cell Change from DC-HSDPA capable cell to non DC-HSDPA capable cell	1
34.123-1	8.3.4.16a	Active set update: Dual Cell (DC) Activation by Serving Cell Change from DC-HSDPA capable cell to non DC-HSDPA capable cell, with SRB mapped on E-DCH/DCH	1
34.123-1	14.6.1f	Interactive or background / UL:64 DL: [max bit rate depending on UE category] with Flexible RLC and MAC-ehs PS RAB + UL:3.4 DL:3.4 kbps SRBs for DCCH / DL: QPSK, 16QAM and Dual-Cell	1

34.123-1	14.6.1g	Interactive or background / UL:64 DL: [max bit rate depending on UE category] with Flexible RLC and MAC-ehs PS RAB + UL:3.4 DL:3.4 kbps SRBs for DCCH / DL: 64QAM and Dual-Cell	1
34.123-1	14.6.6e	Streaming / unknown / UL:128 DL: [guaranteed 128, max bit rate depending on UE category] with Fixed RLC and MAC-ehs / PS RAB + Interactive or background / UL:128 DL: [max bit rate depending on UE category] with Flexible RLC and MAC-ehs / PS RAB + UL:3.4 DL:3.4 kbps SRBs for DCCH / DL: QPSK, 16QAM and Dual-Cell	1
34.123-1	14.6.6f	Streaming / unknown / UL:128 DL: [guaranteed 128, max bit rate depending on UE category] with Fixed RLC and MAC-ehs / PS RAB + Interactive or background / UL:128 DL: [max bit rate depending on UE category] with Flexible RLC and MAC-ehs / PS RAB + UL:3.4 DL:3.4 kbps SRBs for DCCH / DL: 64QAM and Dual-Cell	1

Table 56: GCF protocol test cases for Dual Cell HSDPA

TS	TC	TC title	Priority
34.121-1	6.2A	Reference sensitivity level for DC-HSDPA	1
34.121-1	6.3C	Maximum Input Level for DC-HSDPA Reception (16QAM)	1
34.121-1	6.3D	Maximum Input Level for DC-HSDPA Reception (64QAM)	1
34.121-1	6.4B	Adjacent Channel Selectivity (ACS) for DC-HSDPA	1
34.121-1	6.5A	Blocking Characteristics for DC-HSDPA	1
34.121-1	6.6A	Spurious Response for DC-HSDPA	1
34.121-1	6.7A	Intermodulation Characteristics for DC-HSDPA	1
34.121-1	9.2.1FA	Demodulation of HS-DSCH (Fixed Reference Channel) – Single Link Performance – Enhanced Performance Requirements Type 2 – QPSK/16QAM, Fixed Reference Channel (FRC) H-Set 6A/3A	1
34.121-1	9.2.1GA	Demodulation of HS-DSCH (Fixed Reference Channel) – Single Link Performance – Enhanced Performance Requirements Type 3 – QPSK/16QAM, Fixed Reference Channel (FRC) H-Set 6A/3A	1
34.121-1	9.2.1HA	Demodulation of HS-DSCH (Fixed Reference Channel) – Single Link Performance – Enhanced Performance Requirements Type 2 – 64QAM, Fixed Reference Channel (FRC) H-Set 8A	1
34.121-1	9.2.1IA	Demodulation of HS-DSCH (Fixed Reference Channel) – Single Link Performance – Enhanced Performance Requirements Type 3 – 64QAM, Fixed Reference Channel (FRC) H-Set 8A	1
34.121-1	9.2.1JA	Demodulation of HS-DSCH (Fixed Reference Channel) – Single Link Performance – Enhanced	1

		Performance Requirements Type 2 – QPSK/16QAM, Fixed Reference Channel (FRC) H-Set 10A	
34.121-1	9.2.1KA	Demodulation of HS-DSCH (Fixed Reference Channel) – Single Link Performance – Enhanced Performance Requirements Type 2 – QPSK/16QAM, Fixed Reference Channel (FRC) H-Set 10A	1
34.121-1	9.2.1LA	Enhanced Performance Requirements Type 3i – QPSK, Fixed Reference Channel (FRC) H-Set 6A	2
34.121-1	9.3.1B	Single Link Performance – AWGN Propagation Conditions, DC-HSDPA requirements	1
34.121-1	9.3.2A	Single Link Performance – Fading Propagation Conditions, DC-HSDPA requirements	1

Table 57: GCF RF test cases for Dual Cell HSDPA

3.4 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.

3.4.1 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 35 shows the UE side MAC architecture including the new MAC-is/i.

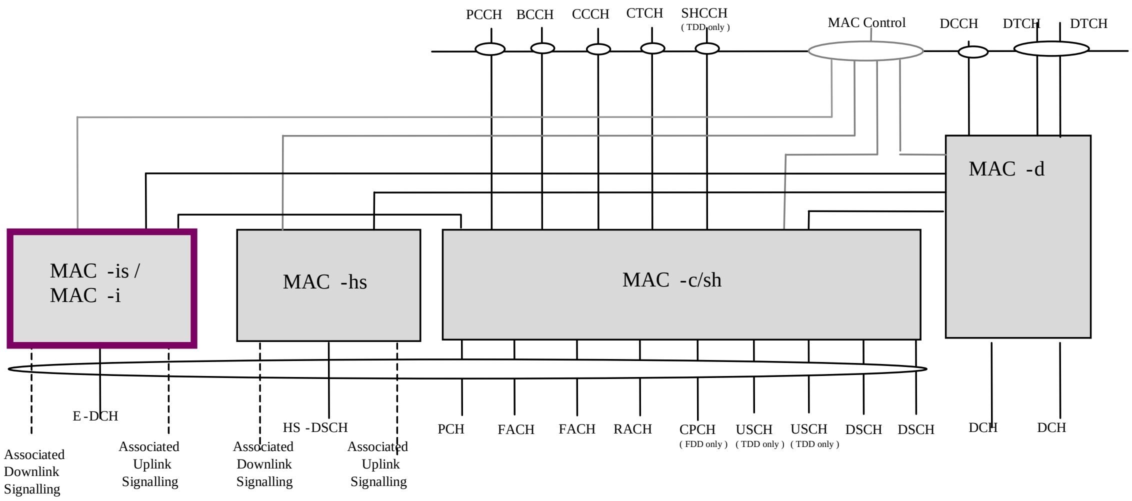


Figure 35: UE side MAC architecture with MAC-i and MAC-is

In the same way as in downlink MAC-is/i basically allows the support of flexible RLC PDU sizes and segmentation/reassembly. Figure 36 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.

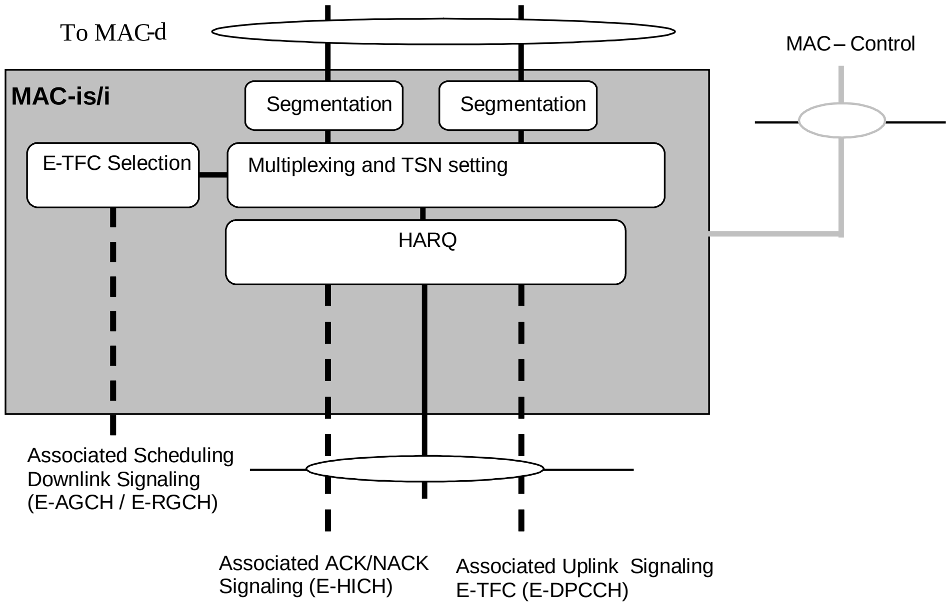


Figure 36: UE side MAC-is/i details

3.4.2 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 37 and Figure 38. 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.

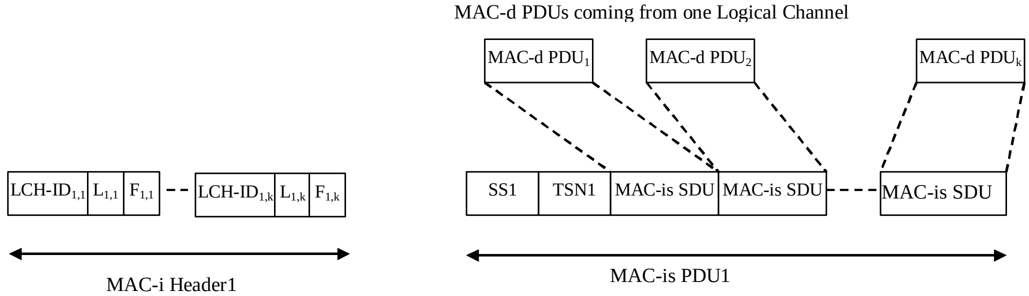


Figure 37: MAC-is PDU

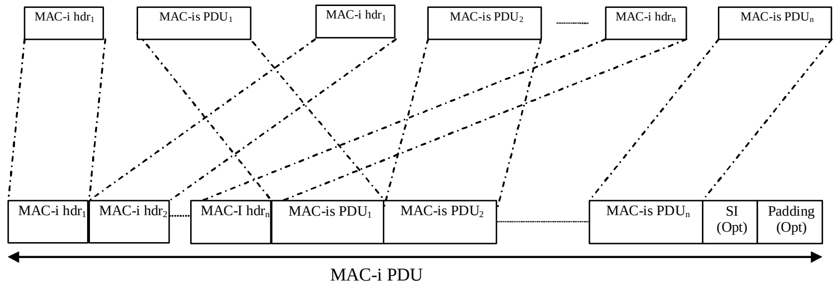


Figure 38: MAC-i PDU

3.4.3 Enhancements to RLC

In the same way as in downlink (see chapter 2.6.3) 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.

3.4.4 Improved Layer 2 (UL) test and measurement requirements

3.4.4.1 NodeB test and measurement requirements

NodeB test requirements are specified in [9] and the corresponding test methods are detailed in [10]. However since improved Layer 2 (UL) is a pure protocol feature there are no modifications in these 3GPP specifications resulting from the improved Layer 2 (UL) feature.

3.4.4.2 UE test and measurement requirements

UE test requirements for improved Layer 2 (UL) transmission/reception are specified in [5] and the corresponding test methods are detailed in [12] for RF conformance and in [13] for protocol conformance, respectively. There is no impact on [5] and [12], because of the protocol nature of this feature. However a number of new protocol test cases were added in [13] to verify the protocol behavior in case improved Layer 2 (UL) is used.

3.4.4.3 GCF requirements for improved Layer 2 (UL)

The purpose of the work item GCF-WI-130 is to define the test cases selected to cover the essential core functionality and performance requirements for the 3GPP improved Layer 2 (UL) feature. GCF has identified eleven protocol test cases to be verified in order to achieve GCF certification for an improved Layer 2 (UL) capable UEs (see Table 58).

TS	TC	TC title	Priority
34.123-1	7.1.7.1	MAC-i/is multiplexing (multiple PDUs from different LC in one TTI)	1
34.123-1	7.1.7.2	MAC-i/is segmentation / Correct Usage of Segmentation Status Field	1
34.123-1	7.1.7.3	Correct settings of MAC-i/is header fields	1
34.123-1	7.1.7.4	MAC-is/i transport block size selection/ UL QPSK	1
34.123-1	7.1.7.5	MAC-is/i transport block size selection/ UL 16QAM	2
34.123-1	7.2.2.15	UM RLC / Flexible handling of RLC PDU sizes for UM RLC in uplink	1
34.123-1	7.2.3.37	RLC PDU Size Adaptation in Uplink	1
34.123-1	7.2.3.38	AM RLC / Flexible handling of RLC PDU sizes for AM RLC in uplink	1
34.123-1	8.2.2.61	Radio Bearer Reconfiguration from CELL_DCH to CELL_DCH: Success (Reconfiguration between fixed and flexible AM RLC, Serving E-DCH cell change between MAC-e/es and MAC-i/is)	1
34.123-1	14.7.3a	Streaming or interactive or background / UL: [max bit rate depending on UE category and TTI] DL: [max bit rate depending on UE category] with Flexible RLC, MAC-ehs and MAC-i/is / PS RAB + UL: [max bit rate depending on UE category and TTI] DL: [max bit rate depending on UE category] SRBs for DCCH on E-DCH and HS-DSCH with MAC-ehs and MAC-i/is	1
34.123-1	14.7.6c	Conversational / unknown or speech / UL:[max bit rate depending on UE category and TTI] DL: [max bit rate depending on UE category] kbps with Flexible RLC, MAC-ehs and MAC-i/is / PS RAB + Streaming or Interactive or background / UL: [max bit rate depending on UE category and TTI] DL: [max bit rate depending on UE category] with Fixed RLC, MAC-ehs and MAC-i/is / PS RAB + UL:[max bit rate depending on UE category and TTI] DL: :[max bit rate depending on UE category] SRBs for DCCH on E-DCH and HS-DSCH with MAC-ehs and MAC-i/is / UL: QPSK and DL: QPSK	1

Table 58: GCF protocol test cases for improved Layer 2 (UL)

3.5 Enhanced Uplink for CELL_FACH State

Work to reduce uplink and downlink signaling 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 2.7). 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.

3.5.1 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 signaled with a reserved LCH-ID value see chapter 3.5.4). 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.

3.5.2 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 39 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.

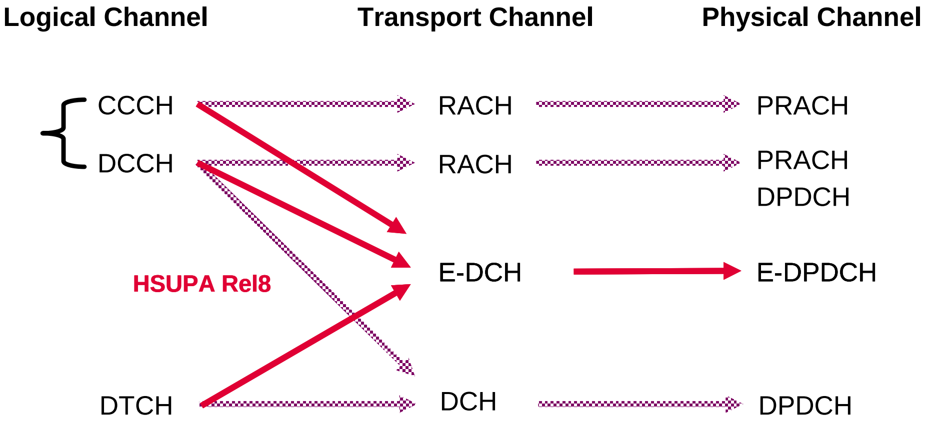


Figure 39: Mapping of logical channels on transport and physical channels for enhanced uplink in CEL_FACH state

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 signaled 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 59. 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].

$EAI_{S'}$	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

Table 59: EAI and resource configuration mapping

Figure 40 illustrates the timing relation between preambles, access slots, acquisition indication and F-DPCH/DPCCH transmission at seen from the UE.

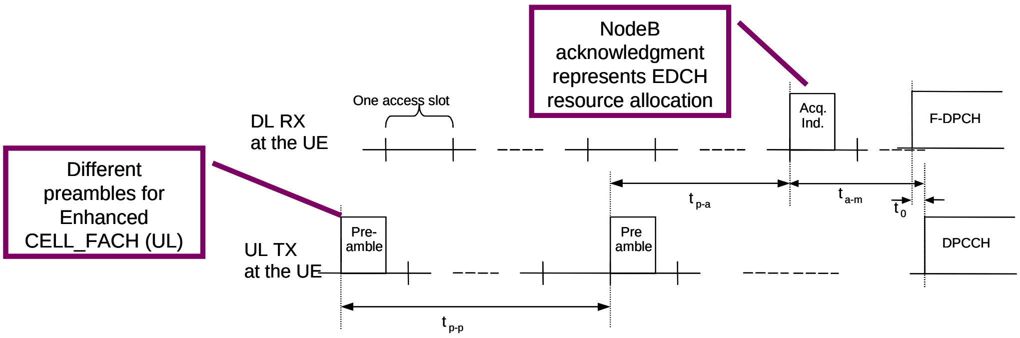


Figure 40: UL/DL timing relation for Enhanced Uplink in CELL_FACH as seen at the UE [3]

$t_{F\text{-}DPCH}$ = [(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.

3.5.3 Modified synchronization 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 41 below. Note that in case of Enhanced Uplink for CELL_FACH State there is only one link in the set. As described in Figure 40 above the UE starts transmission at the defined time and executes a post verification procedure confirming the establishment of the downlink physical channel.

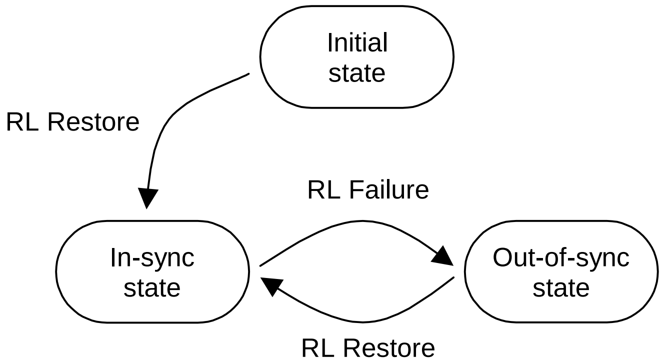


Figure 41: Node B radio link set states and transitions [2]

During the first 40 ms period of the first phase of the downlink synchronization 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.

3.5.4 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 3.5.1 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 35. Enhanced functionality and new functions are added to MAC-is/i as illustrated in Figure 42. 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.

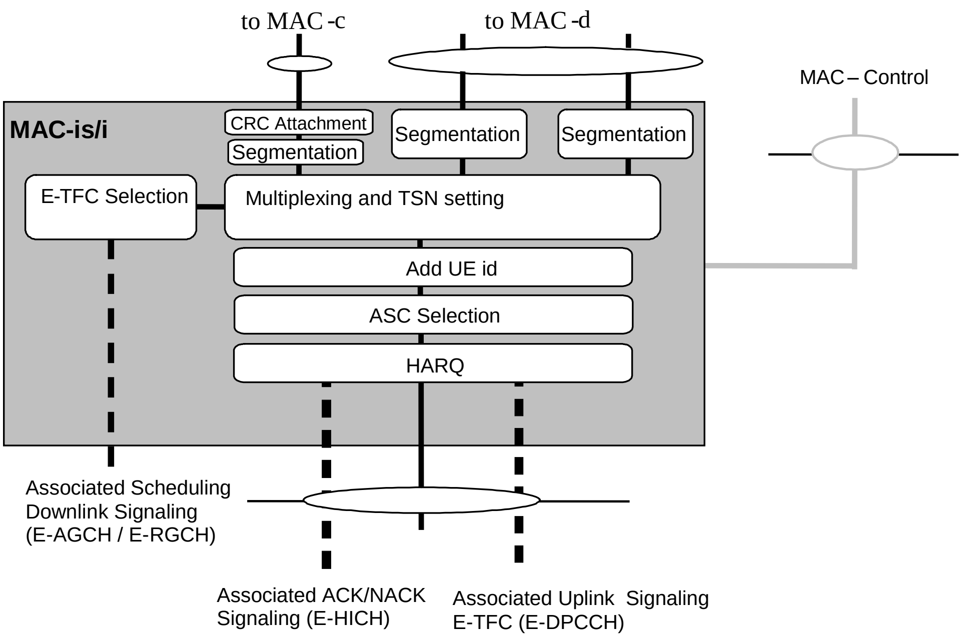


Figure 42: UE side MAC architecture / MAC-i/is details

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.

3.5.5 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 43). The NodeB detects whether or not E-RNTI is included from *LCH-ID* field in MAC-i header (see Figure 44 and Table 60). Using the E-RNTI **E-DCH control** becomes responsible for collision resolution and common E-DCH resource Release by transmitting appropriate scheduling grants.

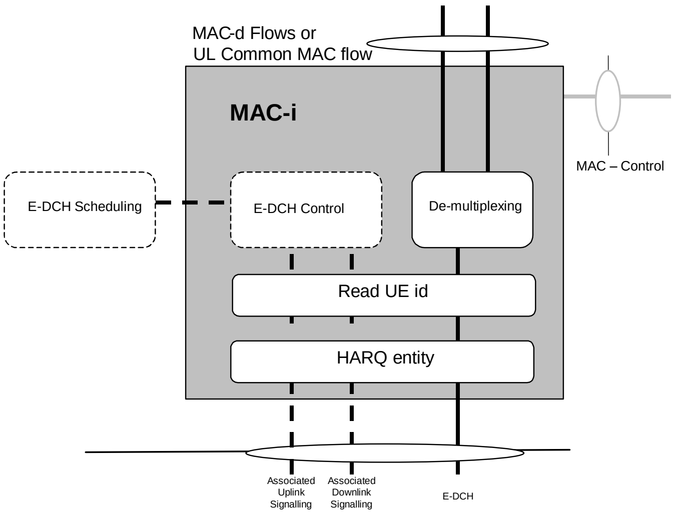


Figure 43: UTRAN side MAC architecture / MAC-i details

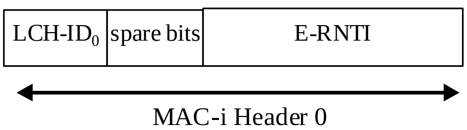


Figure 44: MAC-i header part for E-RNTI transmission

LCH-ID Field	Designation
0000	Logical channel 1
0001	Logical channel 2
…	…

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

Table 60: Structure of the LCH-ID field

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 45). In case of incorrect CRC check sums, MAC-is discards the relevant PDUs.

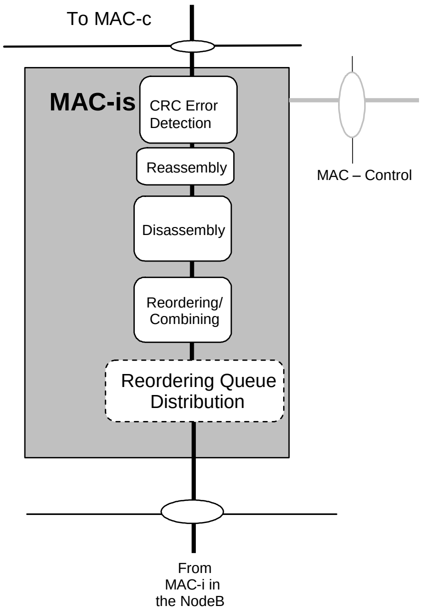


Figure 45: UTRAN side MAC architecture / MAC-is details (for CCCH transmission)

3.5.6 Enhanced Uplink for CELL_FACH state test and measurement requirements

3.5.6.1 NodeB test and measurement requirements

NodeB test requirements are specified in [9] and the corresponding test methods are detailed in [10]. However since the Enhanced Uplink for CELL_FACH state feature is a pure protocol feature there are no resulting modifications in these 3GPP specifications.

3.5.6.2 UE test and measurement requirements

UE test requirements for transmission/reception are specified in [5] and the corresponding test methods are detailed in [12] for RF conformance and in [13] for protocol conformance, respectively. There is no impact on [5], however a number of new protocol test cases were added in [13] to verify the protocol behavior in case the Enhanced Uplink for CELL_FACH state feature is used. Additionally [12] includes a new test case verifying that the UE correctly detects the resource allocation received with the EAI send by the eNodeB.

3.5.6.3 GCF requirements for Enhanced Uplink for CELL_FACH state

The purpose of the work item GCF-WI-131 is to define the test cases selected to cover the essential core functionality and performance requirements for the 3GPP enhanced Uplink for CELL_FACH feature. GCF has identified seventeen protocol test cases and one RF test cases to be verified in order to achieve GCF certification for a enhanced Uplink for CELL_FACH capable UE (see Table 61 and Table 62).

TS	TC	TC title	Priority
34.123-1	7.1.8.1	Release of common E-DCH resource when maximum resource allocation for E-DCH expires or uplink transmission ends for CCCH transmission	1
34.123-1	7.1.8.2	Activation of HS-DPCCH based on the received SIB5/SIB5bis information	1
34.123-1	7.1.8.3	DTCH/DCCH transmission - implicit common E-DCH resource release without receiving E-AGCH	1
34.123-1	7.1.8.4	DTCH/DCCH transmission – explicit common E-DCH resource release by E-AGCH	1
34.123-1	7.1.8.5	RACH procedure with both normal AIs and extended AIs (using E-AICH)	1
34.123-1	7.1.8.6	DTCH/DCCH transmission - Implicit release with E-DCH transmission continuation backoff - Timer Based	1
34.123-1	7.1.8.7	Physical Channel Failure for EUL in CELL-FACH during initial access preamble	1
34.123-1	7.1.8.8	Radio Link Failure for Enhanced UL in CELL-FACH with DTCH/DCCH active	1
34.123-1	8.2.1.42	Radio Bearer Establishment for transition from CELL_FACH (Enhanced UL/DL) to CELL_DCH : Success (with ongoing HS-DSCH reception and E-DCH transmission)	1
34.123-1	8.2.2.65	Radio Bearer Reconfiguration for transition from CELL_DCH to CELL_FACH (Enhanced UL/DL) Success	1
34.123-1	8.2.6.66	Physical Channel Reconfiguration from CELL_PCH to CELL_FACH: Success (autonomous transitions without cell update procedure)	1
34.123-1	8.3.1.49	Cell Update: Intra Frequency cell reselection in Enhanced CELL_FACH with DRX configured	1

34.123-1	8.3.1.49a	Cell Update: Inter Frequency cell reselection in Enhanced CELL_FACH with DRX configured	1
34.123-1	8.3.1.50	Cell Update: Cell reselection in CELL_FACH when common E-DCH resource is released	1
34.123-1	8.4.1.18a	Measurement Control and Report: Traffic volume measurement for transition from Enhanced CELL_FACH state (common E-DCH in UL and HS-DSCH DL) to CELL_DCH state	1
34.123-1	14.7.11	Streaming or interactive or background / UL: [max bit rate depending on UE category and TTI] DL: [max bit rate depending on UE category] / PS RAB + UL: [max bit rate depending on UE category and TTI] DL: [max bit rate depending on UE category] SRBs for DCCH on E-DCH and HS-DSCH for enhanced uplink/downlink in CELL_FACH	1
34.123-1	14.7.11a	Streaming or interactive or background / UL: [max bit rate depending on UE category and TTI] DL: [max bit rate depending on UE category] / PS RAB + UL: [max bit rate depending on UE category and TTI] DL: [max bit rate depending on UE category] SRBs for DCCH on common E-DCH and HS-DSCH for enhanced CELL_FACH with DRX configured	1

Table 61: GCF protocol test cases for enhanced Uplink for CELL_FACH

TS	TC	TC title	Priority
34.121-1	7.12A	Detection of E-DCH Acquisition Indicator (E-AI)	1

Table 62: GCF RF test cases for enhanced Uplink for CELL_FACH

3.6 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 3GPP 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 signaling load is also further increased if the UE is kept in CELL_FACH for shorter periods. Therefore, minimizing the signaling needed to move the UE from CELL_FACH state is another area of possible improvement.

3.6.1 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 46. The UE stops the DRX operation and continuously receives HS-DSCH, if data transmission activity on E-DCH is initiated.

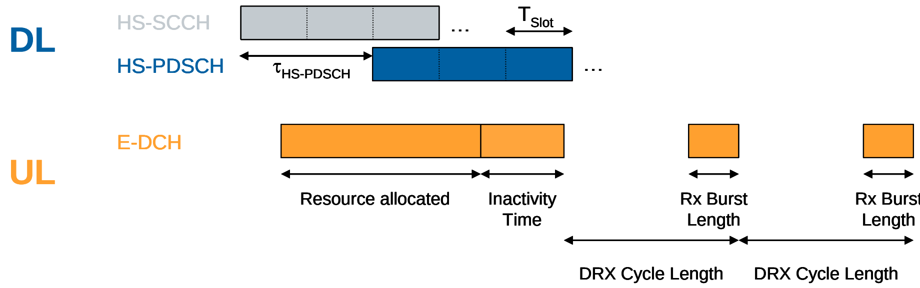


Figure 46: HS-DSCH DRX operation in CELL_FACH state

3.6.2 HS-DSCH DRX reception in CELL_FACH state test and measurement requirements

3.6.2.1 NodeB test and measurement requirements

NodeB test requirements are specified in [9] and the corresponding test methods are detailed in [10]. However since the HS-DSCH DRX reception in CELL_FACH state feature is a pure UE protocol feature there are no resulting modifications in these 3GPP specifications.

3.6.2.2 UE test and measurement requirements

UE test requirements for transmission/reception are specified in [5] and the corresponding test methods are detailed in [12] for RF conformance and in [13] for protocol conformance, respectively. There is no impact on [5], [12] or [13] due to the HS-DSCH DRX reception in CELL_FACH state feature.

3.6.2.3 GCF requirements for HS-DSCH DRX reception in CELL_FACH state

Without impact on the test specifications in 3GPP, GCF will not start any certification activities due to this feature.

3.7 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 (SR-VCC)" mechanism has been specified in 3GPP which facilitates session transfer of the voice component within a PS bearer to the CS domain (see Figure 47). 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 SR-VCC handling, and then triggers the SR-VCC 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.

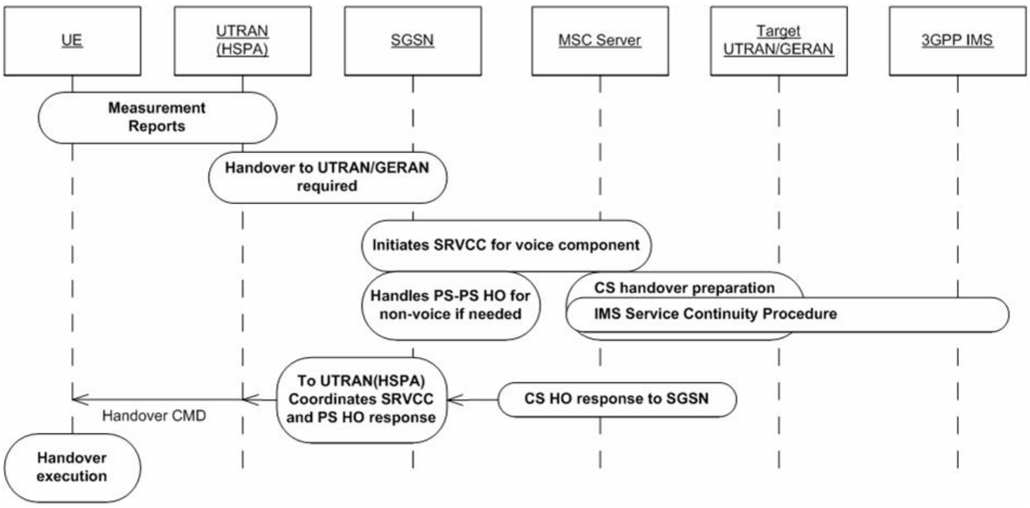


Figure 47: Overall high level concepts for SRVCC from UTRAN (HSPA) to UTRAN/GERAN

3.7.1 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.

3.7.2 HSPA VoIP to WCDMA/GSM CS Continuity test and measurement requirements

3.7.2.1 NodeB test and measurement requirements

NodeB test requirements are specified in [9] and the corresponding test methods are detailed in [10]. However since the HSPA VoIP to WCDMA/GSM CS Continuity feature is a pure radio access network and core network feature there are no resulting modifications in these 3GPP specifications.

3.7.2.2 UE test and measurement requirements

UE test requirements for transmission/reception are specified in [5] and the corresponding test methods are detailed in [12] for RF conformance and in [13] for protocol conformance, respectively. There is no impact on [5], [12] or [13] because of the access network nature of the HSPA VoIP to WCDMA/GSM CS Continuity feature.

3.7.2.3 GCF requirements for HSPA VoIP to WCDMA/GSM CS Continuity

Without impact on the test specifications in 3GPP, GCF will not start any certification activities due to this feature.

3.8 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.

3.8.1 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 48). 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.

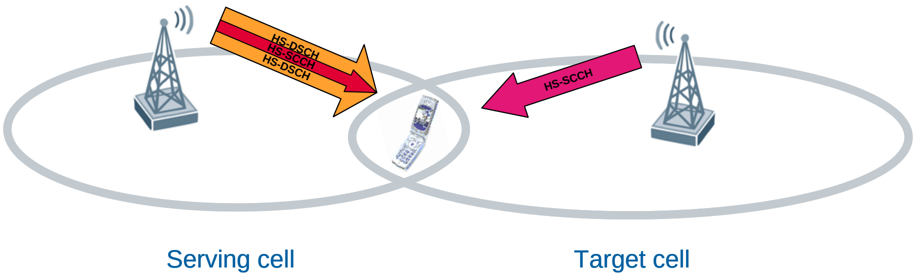


Figure 48: Enhanced serving HS-DSCH cell change procedure

3.8.2 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 2.4.5). 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.

3.8.3 Serving Cell Change Enhancements test and measurement requirements

3.8.3.1 NodeB test and measurement requirements

NodeB test requirements are specified in [9] and the corresponding test methods are detailed in [10]. However since Serving Cell Change Enhancements is mainly to be verified at the UE side, there are no resulting modifications in these 3GPP specifications.

3.8.3.2 UE test and measurement requirements

UE test requirements for transmission/reception are specified in [5] and the corresponding test methods are detailed in [12] for RF conformance and in [13] for protocol conformance, respectively. There is no impact on [5], however a new requirement was added in [14]. As described earlier the enhanced serving HS-DSCH cell change procedure is initiated from UTRAN either with a RRC message that implies a change of the serving HS-DSCH cell or through an HS-SCCH order sent on the target cell. The new requirement covers the latter case as the first case is already included in earlier 3GPP Release test specifications. When the UE receives an HS-SCCH order from the target cell that implies enhanced HS-DSCH serving cell change the UE shall be ready to receive the full configured HS-SCCH set within 40 ms from the end of the TTI containing the HS-SCCH order. Note that an activation time may be signaled to the UE, which in this case would take preference above the 40ms requirement. The new requirement was added in section 5.11 in [14].

3.8.3.3 GCF requirements for Serving Cell Change Enhancements

GCF has not started the work on certification of Serving Cell Change Enhancements capable UEs.

4 HSPA+ Release 9

4.1 Dual cell HSUPA

Dual cell HSUPA extends the Dual Cell HSDPA feature in 3GPP Release 8 (see section 3.3) by also applying two uplink frequencies. Dual cell HSUPA operation requires the support of Dual Cell HSDPA, therefore a UE is configured with two adjacent downlink frequencies and two adjacent uplink frequencies from the same NodeB as illustrated in Figure 49. It can be seen as an obvious solution complementing the work already done for the downlink operation.

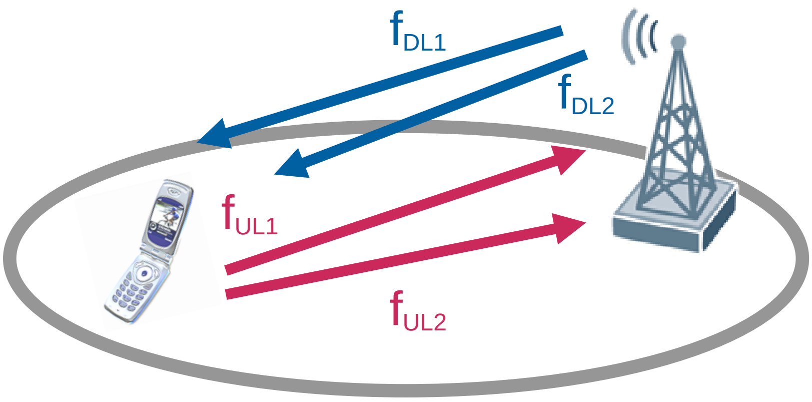


Figure 49: Dual Cell HSUPA operation (including Dual Cell HSDPA)

The two uplink frequencies are independently operated, i.e. one E-DCH transport channel is transmitted on each activated uplink frequency and each E-DCH transport channel has its own associated uplink signaling. Note that if Dual Cell E-DCH operation is configured in CELL_DCH state, dedicated channels (DCH) are not supported.

4.1.1 Physical channel structure

In Dual Cell HSUPA operation only 2 ms TTI is supported. E-DPDCH, E-DPCCH and DPCCH are transmitted on each of the two uplink frequencies. HS-DPCCH is only transmitted on the primary uplink frequency as described in section 3.3. For each uplink frequency, F-DPCH, E-HICH, E-RGCH and E-AGCH are configured on the corresponding downlink frequency. Additionally each E-DCH transport channel has its own associated uplink and downlink signaling, i.e. the associated uplink signaling is transmitted on the corresponding uplink frequency, and the associated downlink signaling is configured and transmitted on the corresponding downlink frequency. The F-DPCH transmitted on each downlink frequency associated to an uplink frequency have the same timing as required by [3].

The DPCCH, E-DPCCH and E-DPDCH transmitted on each uplink frequency also have the same timing. Downlink and uplink power control procedures are performed independently on each of the two uplink frequencies. The timing of the different involved channels are illustrated in Figure 50.

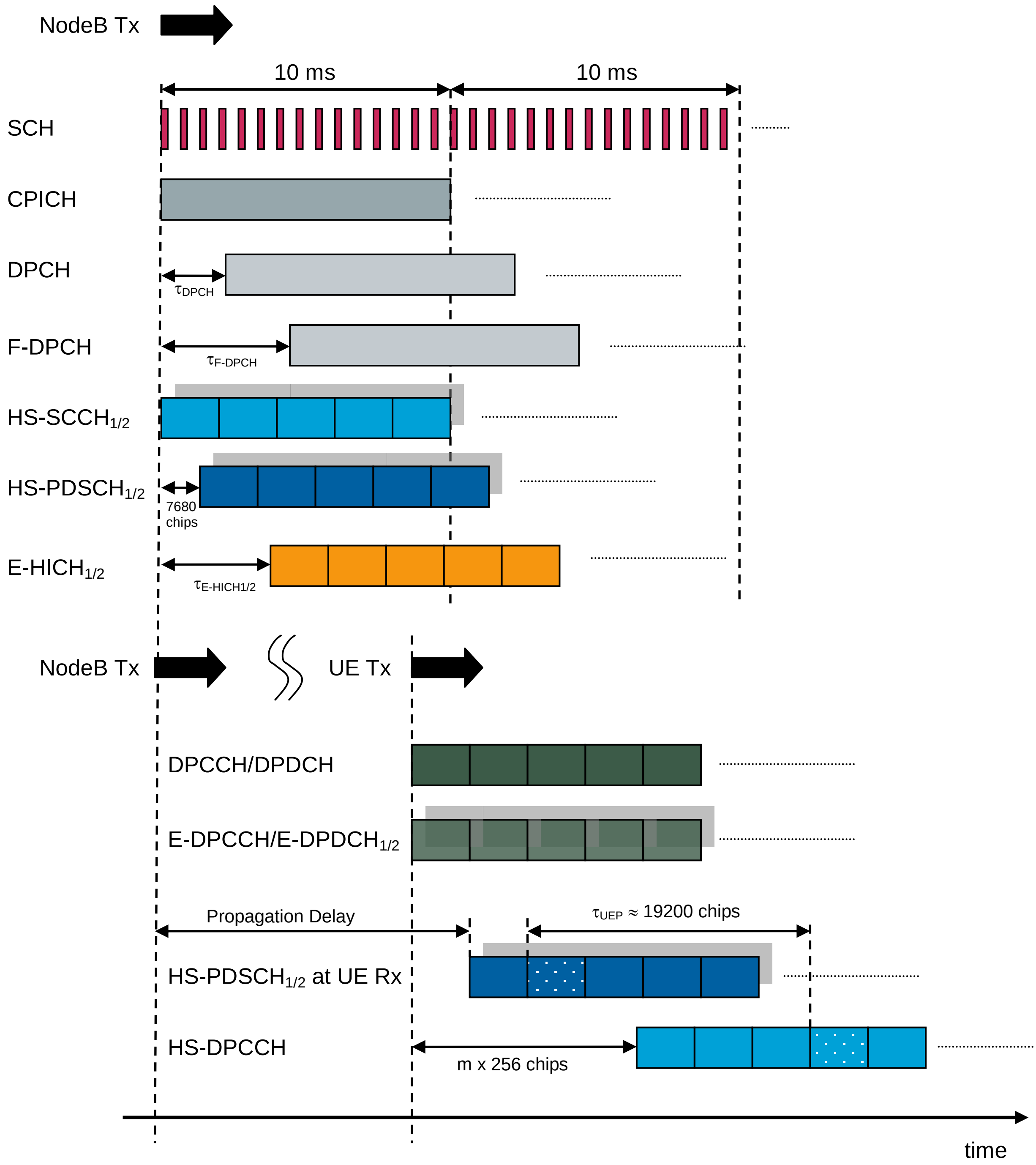


Figure 50: Timing relation of between physical channels in dual cell HSUPA operation

The HS-SCCH order concept as described in earlier sections is reused, i.e. 6 bits consisting of 3 bits *order type* and 3 bits *order*. In contrast to CPC operation (see) the *order type* is set to '001'. One of the three bits order field is reserved, the other two bits are used by the Node-B to activate and deactivate the secondary downlink frequency and secondary uplink frequency. When the frequency of the secondary serving HS-DSCH cell is deactivated using an HS-SCCH order, the secondary uplink frequency is also deactivated. However the deactivation of the secondary uplink frequency using an HS-SCCH order does not imply the deactivation of the secondary downlink frequency.

4.1.2 MAC architecture

For Dual Cell HSUPA operation only MAC-i/is entity is supported. In the UE side, the MAC-i/is has a multiplexing entity and TSN setting entity common to both E-DCH transport channels. However, there is a HARQ entity per E-DCH transport channel (see Figure 51).

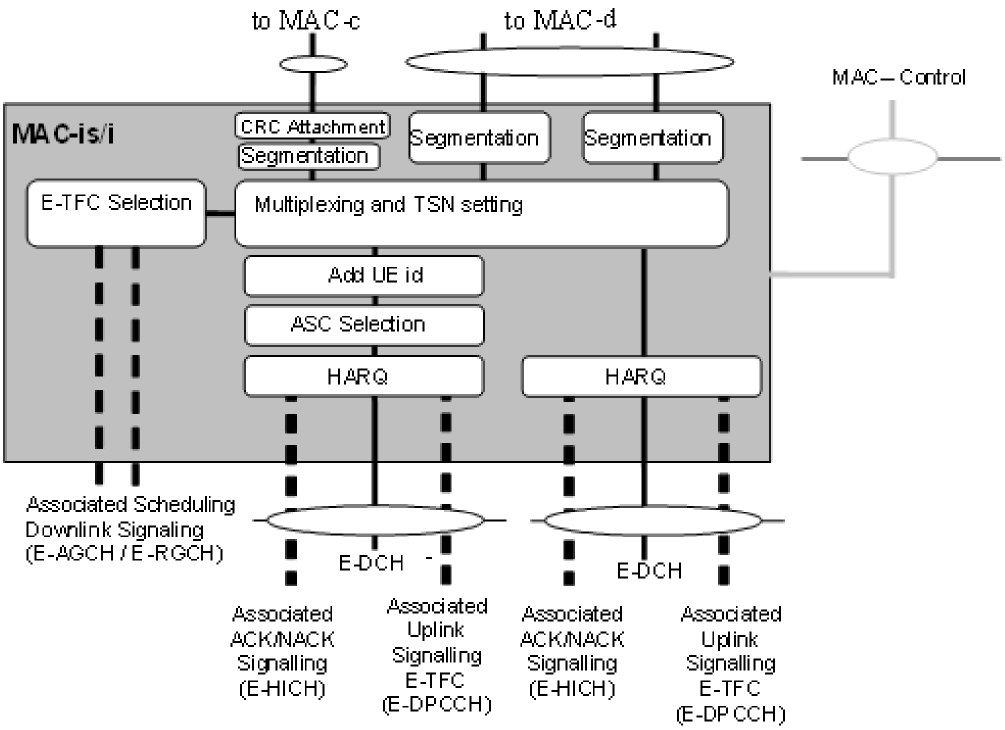


Figure 51:UE side MAC architecture / MAC-is/i details (FDD)

In the UTRAN side, the MAC-i has a HARQ entity and a de-multiplexing entity per E-DCH transport channel. The de-multiplexing entity de-multiplexes MAC-i PDUs and forwards the received MAC-is PDUs to the associated MAC-d flows (see Figure 52).

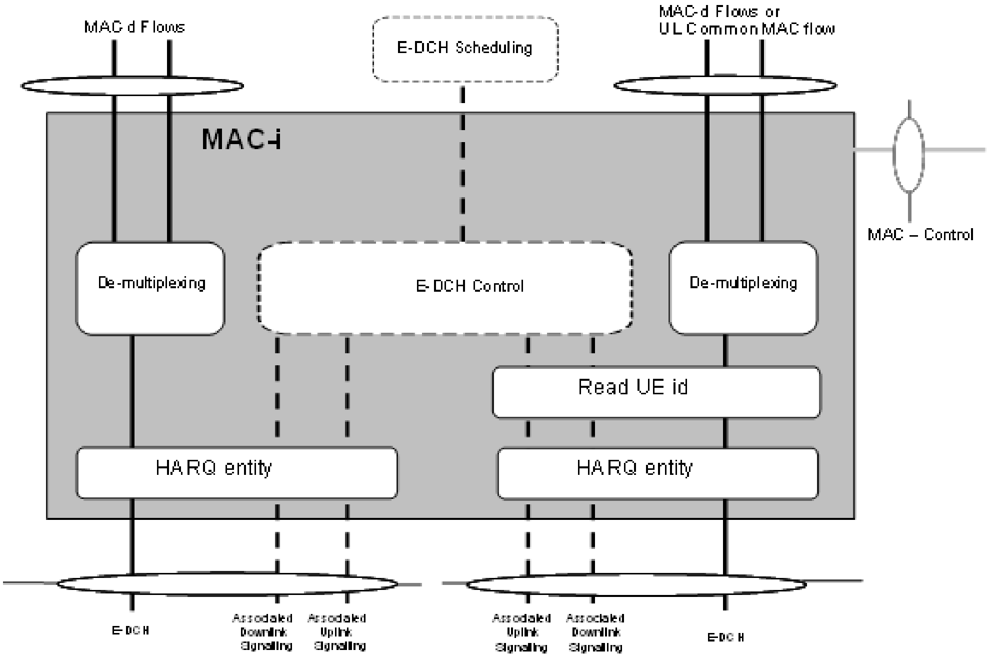


Figure 52: UTRAN side MAC architecture / MAC-i details

The reordering queue distribution entity in the MAC-is receives all the MAC-d flows from all the Node-Bs (Figure 53). Each HARQ entity is composed of multiple HARQ processes, whereas DCH is not supported.

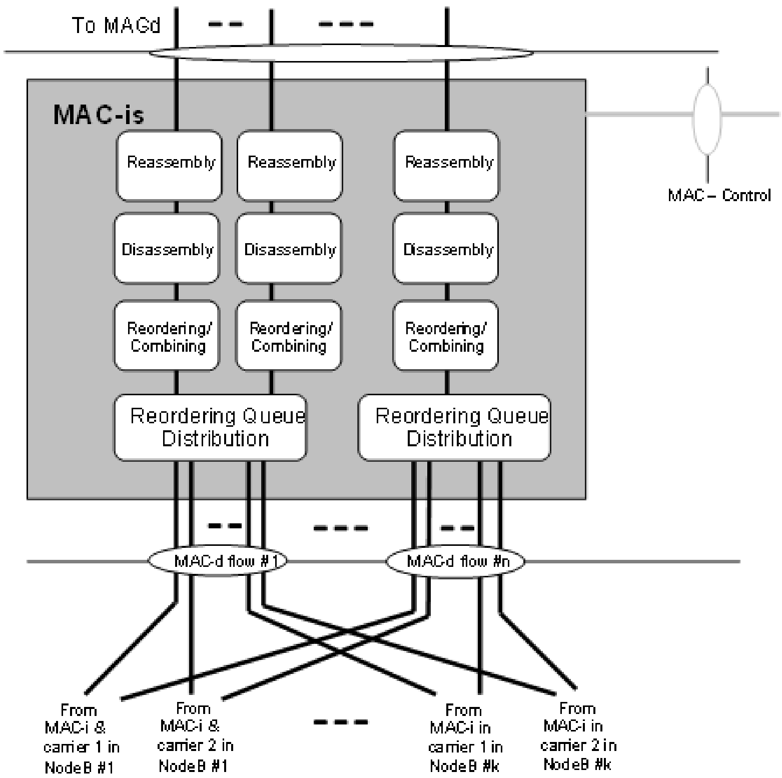


Figure 53: UTRAN side MAC architecture / MAC-is details

4.1.3 Scheduling procedures

When non-scheduled transmissions are configured by the serving RNC, the UE is allowed to send E-DCH data at any time, to a configured number of bits, without receiving any scheduling command from the Node B on the Primary Uplink Frequency. In case of scheduled transmissions the UE sends on any activated uplink frequency according the allocation received via absolute and relative grants on the related downlink frequency. A minimum E-TFCI set can be configured per configured uplink frequency. The UE can still be allocated with two different identity numbers, i.e. with a primary E-RNTI and a secondary E-RNTI per configured uplink frequency. The UE always follows the absolute grants transmitted using the primary E-RNTI and it can be commanded to follow the absolute grants transmitted using the secondary E-RNTI. This maintains the concept of grouping UEs with the primary E-RNTI, e.g. when UEs move from no transmission to transmission. Whereas the secondary E-RNTI may be used to control active UEs.
Note that access grant tables, E-DPCCH boosting and E-DPDCH reference factors are assumed to be common for both configured uplink frequencies. Otherwise the different uplink frequencies are operated independently, i.e. a Happy Bit is transmitted in each activated uplink frequency every E-DCH transmission, scheduling Information reporting mechanisms are evaluated per activated uplink frequency and the scheduling information is transmitted on the frequency which triggered the scheduling Information. Also if periodic scheduling information is configured by higher layers, each activated uplink frequency keeps its own, independently configured timers (T_SIG and T_SING). Upon deactivation of the secondary uplink frequency, the UE shall not maintain the serving grant. Upon a subsequent activation of the secondary uplink frequency, the UE needs to use an initial serving grant value, that is configured by higher layers.

4.1.4 Mobility measurements

The serving E-DCH cell and the Secondary Serving E-DCH cell belong to the same Node-B. Again the two operated uplink frequencies are treated independently in that there is an active set and E-DCH active for each of those. However the active set and E-DCH active set in the secondary frequency are identical. As long as the UE is configured in Dual E-DCH operation and regardless of the activation status of the secondary uplink frequency, the UE needs to maintain the secondary E-DCH active set. Also the UE performs measurements in the adjacent frequency (frequency associated to the secondary serving HS-DSCH cell) without compressed mode. All intra-frequency events are supported on the primary uplink frequency, while intra-frequency events 1A, 1B, 1C, 1E, 1F are supported on the secondary uplink frequency. Again mobility events are configured and triggered independently. The same compressed mode pattern is applied to both configured uplink frequencies.

4.1.5 Discontinuous transmission and reception

Regarding DTX/DRX operation, the following applies when dual cell HSUPA is configured. The DTX operation is independent for each activated uplink frequency, whereas the DRX operation is common on the corresponding downlink frequencies. Note that the DTX and DRX status is common for all activated uplink frequencies, this means that DTX/DRX is activated or deactivated in all activated uplink frequencies.

4.1.6 RRC procedures

The physical channel establishment is evaluated independently for downlink frequencies of the serving HS-DSCH cell and secondary serving HS-DSCH cell. The physical channel establishment is initiated upon activation of the secondary uplink frequency with HS-SCCH orders as described earlier. Actions upon a "radio link failure" or "physical channel failure" on the frequency of the serving HS-DSCH cell remain as in 3GPP Release 8. Upon a "radio link failure" or "physical channel failure" on the frequency of the secondary serving HS-DSCH cell, the UE simply deactivates the secondary uplink frequency.

4.1.7 Dual Cell HSUPA UE capability

Two new UE categories have been introduced for dual cell HSUPA operation as shown in Table 63. Category 8 UEs support only QPSK modulation, whereas category 9 UEs support QPSK and 16QAM modulation.

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 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
Category 8	4	2	2ms	-	11484	~ 11.50
Category 9	4	2	2ms	-	22996	~ 23.00
NOTE: When 4 codes are transmitted in parallel, two codes shall be transmitted with SF2 and two with SF4						

Table 63: Dual Cell HSUPA UE categories

4.1.8 Dual Cell HSUPA test and measurement requirements

4.1.8.1 NodeB test and measurement requirements

NodeB test requirements for Dual Cell HSUPA are specified in [9] and the corresponding test methods are detailed in [10]. In [9] it is clarified that for ACS, blocking and intermodulation characteristics, the negative offsets of the interfering signal apply relative to the assigned channel frequency of the lowest carrier frequency used and positive offsets of the interfering signal apply relative to the assigned channel frequency of the highest carrier frequency used.

No new performance requirements were added in section 8 of [9]. It is considered sufficient to verify the demodulation performance on each individual data stream on each received uplink carrier frequency in the same way as already done in earlier versions of the 3GPP test specifications. For performance requirements in multipath fading scenarios it is clarified that the fading of the signals for each cell need to be independent.

4.1.8.2 UE test and measurement requirements

UE test requirements for Dual Cell HSUPA transmission are specified in [5] and the corresponding test methods are detailed in [12] for RF conformance and in [13] for protocol conformance, respectively.
In [5] it is clarified that the maximum output power requirement applies to the sum of the broadband transmit powers of each carrier used by the UE. In the same way as for single uplink carrier operation a Maximum Power Reduction (MPR) is defined. In general existing requirements for single uplink carrier operation are applicable for each individual carrier frequency in case of Dual Cell HSUPA, e.g. for UE relative code domain power, frequency error (0,1PPM), power control steps (1dB, 2dB and 3dB) and related accuracy, transmit off power (-50dBm), occupied bandwidth, EVM and transmit intermodulation. Adaptations of the requirements have been introduced when necessary, e.g. regarding power control steps the test procedures allows to use the same steps on each individual uplink carrier assuming that DPCCH code power and total power of each carrier are the same.
A more significant change in requirements is applicable to spectrum mask, ACLR and spurious emissions. New spectrum mask requirements are specified according to Table 64 and Table 65 below.

Δf (MHz)	Spectrum emission limit (dBm)	Measurement bandwidth
± 5-6	-18	30 kHz
± 6-10	-10	1 MHz
± 10-19	-13	1 MHz
± 19-20	-25	1 MHz
Note: Δf is the separation between the carrier frequency and the centre of the measurement bandwidth.		

Table 64: Spectrum emission mask for DC-HSUPA

Δf (MHz)	Spectrum emission limit (dBm)	Measurement bandwidth
± 5-6	-18	30 kHz
± 6-19	-13	1 MHz
± 19-20	-25	1 MHz
Note: Δf is the separation between the carrier frequency and the centre of the measurement bandwidth.		

Table 65: Additional spectrum emission mask for DC-HSUPA in band II, IV, V and X

ACRL requirements are relaxed on the second adjacent carrier compared with single uplink carrier operation (see Table 66). In the case dual adjacent carriers are assigned on the uplink, ACLR is the ratio of the sum of the RRC filtered mean power centered on each of the two assigned channel frequencies to the RRC filtered mean powers centered on an adjacent channel frequency. It is noted in the specifications that the requirements reflect what can be achieved with present state of the art technology. Whereas the requirements should be reconsidered when technology advances.

Power Class	Adjacent channel frequency relative to the center of two assigned channel frequencies	ACLR limit
3	+ 7.5 MHz or – 7.5 MHz	33 dB
3	+ 12.5 MHz or – 12.5 MHz	36 dB
4	+ 7.5 MHz or – 7.5 MHz	33 dB
4	+ 12.5 MHz or -12.5 MHz	36 dB

Table 66: UE ACLR for DC-HSUPA

Regarding spurious emissions the same absolute limits are applicable also in Dual Cell HSUPA operation however the frequency offset to achieve these limits are increased compared to single carrier uplink operation. See section 6.6.3 in [5] for details.

A time alignment error requirement was newly added in [5]. The time alignment error in Dual Cell HSUPA transmission is specified as the delay between the signals from primary and secondary uplink frequencies at the antenna port. This error shall not exceed ¾ T_C.

For testing Dual Cell HSUPA requirements a new reference channel was defined according to Table 67 and Figure 54.

Parameter	Unit	Value
Maximum. Inf. Bit Rate	kbps	60
TTI	ms	2
Number of HARQ Processes	Processes	8
Information Bit Payload (N_{INF})	Bits	120
Binary Channel Bits per TTI (N_{BIN}) (3840 / SF x TTI sum for all channels)	Bits	480
Coding Rate (N_{INF}/ N_{BIN})		0.25
Physical Channel Codes	SF for each physical channel	{16}
E-DPDCH/DPCCH power ratio E-DPCCH/DPCCH power ratio	dB dB	4.08 -9.54

Table 67: E-DPDCH settings for DC-HSUPA reference measurement channel

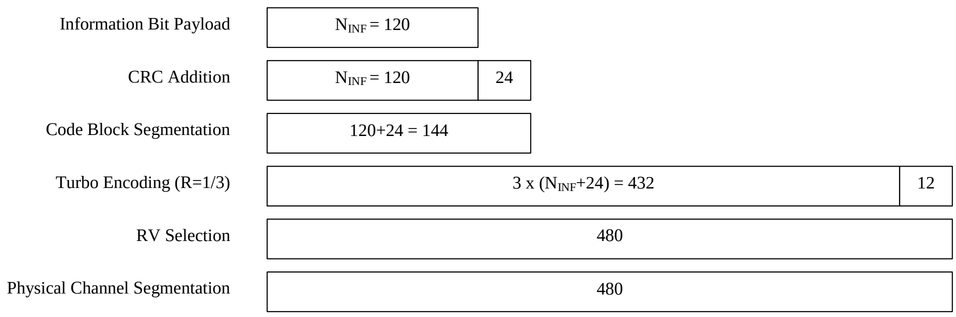


Figure 54: Coding rate for DC-HSUPA reference measurement channel

4.1.8.3 GCF requirements for Dual Cell HSUPA

GCF has not yet started the work on certification of Dual Cell HSUPA capable UEs.

4.2 Dual band dual cell HSDPA (DB-DC-HSDPA)

The support for dual cell HSDPA operation was already introduced in 3GPP Release 8 (see section 3.3). From 3GPP Release 9 onwards the restrictions for one frequency band only operation does not apply anymore. This extends the flexibility for the individual mobile network operator to combine data streams from two frequencies in different frequency bands to a single UE. In order to limit the complexity in the UE implementation, multi-band support has been restricted to the band combinations shown in Table 68. Basically the solution for dual cell HSDPA is maintained. Activation and deactivation is reusing the HS-SCCH order scheme as described in section 3.3.2. There is no impact from the dual band support for signaling apart from minor adaptations.

4.2.1 Dual band dual cell HSDPA UE capability

The support for dual band dual cell HSDPA is optional for the UE and is therefore part of the UE capability signaling to the network. Note that there are no specific dual band dual cell HSDPA UE categories defined. UEs supporting dual band dual cell HSDPA have the same UE category as dual cell HSDPA only UEs. However the UE provides an *Radio Access Capability Band Combination List* information element and a *band combination* information element to the network. These information elements indicate the basic support as well as which band configuration out of Table 68 is supported.

DB-DC-HSDPA Configuration	UL Band	DL Band A	DL Band B
1	I or VIII	I	VIII
2	II or IV	II	IV
3	I or V	I	V
4	I or XI	I	XI
5	II or V	II	V

Table 68: Dual band dual cell HSDPA band configurations [5]

4.2.2 Dual band dual cell HSDPA test and measurement requirements

4.2.2.1 NodeB test and measurement requirements

NodeB test requirements for dual band dual cell HSDPA are specified in [9] and the corresponding test methods are detailed in [10]. A time alignment error requirement was newly added in [9]. The time alignment error in dual band dual Cell HSDPA transmission is specified as the delay between the signals from the two cells at the antenna port. In contrast to the dual cell HSDPA, Tx Diversity and MIMO requirement of ¼ T_C, the dual band dual cell HSDPA requirement is significantly relaxed. This time alignment error shall not exceed 5* T_C.

4.2.2.2 UE test and measurement requirements

UE test requirements for dual band dual cell HSDPA transmission/reception are specified in [5] and the corresponding test methods are detailed in [12] for RF conformance and in [13] for protocol conformance, respectively.
The main impact from this feature is on the UE receiver side. In addition to the already specified performance requirements to be achieved on each individual carrier frequency, new requirements are included in section 7 of [5]. Additional reference sensitivity level requirements are specified according to Table 69 below.

DB-DC-HSDPA configuration	DL Band	UL Band	Unit	HS-PDSCH_Ec <REFSENS>	<REF$\hat{I}_{or}$>
1	I	I	dBm/3.84 MHz	-113	-102.7
	VIII		dBm/3.84 MHz	-110	-99.7
	I	VIII	dBm/3.84 MHz	-113	-102.7
	VIII		dBm/3.84 MHz	-110	-99.7
2	II	II	dBm/3.84 MHz	-110	-99.7
	IV		dBm/3.84 MHz	-112	-101.7
	II	IV	dBm/3.84 MHz	-110	-99.7
	IV		dBm/3.84 MHz	-112	-101.7
3	I	I	dBm/3.84 MHz	-113	-102.7
	V		dBm/3.84 MHz	-111	-100.7
	I	V	dBm/3.84 MHz	-113	-102.7
	V		dBm/3.84 MHz	-111	-100.7
4	I	I	dBm/3.84 MHz	-112	-101.7
	XI		dBm/3.84 MHz	-112	-101.7
	I	VI	dBm/3.84 MHz	-112	-101.7
	XI		dBm/3.84 MHz	-112	-101.7
5	II	II	dBm/3.84 MHz	-111	-100.7
	V		dBm/3.84 MHz	-111	-100.7
	II	V	dBm/3.84 MHz	-111	-100.7
	V		dBm/3.84 MHz	-111	-100.7

Table 69: Test parameters for reference sensitivity, additional requirement for DB-DC-HSDPA

Furthermore blocking requirements have been modified for dual band dual cell HSDPA. The existing dual cell HSDPA inband blocking requirements are also to be met in case of dual band dual cell HSDPA. Table 70 illustrates the additional out of band blocking requirements that have been specified.

Parameter	Unit	Frequency range 1	Frequency range 2	Frequency range 3	Frequency range 4
HS-PDSCH_Ec	dBm / 3.84 MHz	<REFSENS>+3 dB	<REFSENS>+3 dB	<REFSENS>+3 dB	<REFSENS> +3 dB
$\hat{I}_{or}$	dBm / 3.84 MHz	<REF$\hat{I}_{or}$> + 3 dB	<REF$\hat{I}_{or}$> + 3 dB	<REF$\hat{I}_{or}$> + 3 dB	<REF$\hat{I}_{or}$> + 3 dB
$I_{blocking}$ (CW)	dBm	-44	-30	-15	-15
F_{uw} (DB-DC-HSDPA Configuration 1)	MHz	865< f <910 975< f <1020 2050< f <2095 2185< f <2230	840< f ≤865 1020≤ f <1045 2025< f ≤2050 2230≤ f <2255	1< f ≤840 1045≤ f <2025 2255< f ≤ 12750	-
F_{uw} (DB-DC-HSDPA Configuration 2)	MHz	1870< f <1915 2005< f <2095 2170< f <2215	1845< f ≤1870 2215≤ f <2240	1< f ≤1845 2240≤ f <12750	1850≤ f ≤1910
F_{uw} (DB-DC-HSDPA Configuration 3)	MHz	809< f <854 909< f <954 2050< f <2095 2185< f <2230	784< f ≤809 954≤ f < 979 2025< f ≤2050 2230≤ f <2255	1< f ≤784 979≤ f <2025 2255< f ≤12750	824 ≤ f ≤ 849
F_{uw} (DB-DC-HSDPA Configuration 4)	MHz	1415.9 < f < 1460.9 1510.9 < f < 1555.9 2050<f <2095 2185<f <2230	1390.9 < f ≤ 1415.9 1555.9 ≤ f < 1580.9 2025 <f ≤2050 2230 ≤f <2255	1 < f ≤ 1390.9 1580.9 ≤ f < 2025 2255≤f<12750	-
F_{uw} (DB-DC-HSDPA Configuration 5)	MHz	809< f <854 909< f <954 1870<f <1915 2005<f <2050	784< f ≤809 954≤ f < 979 1845 <f ≤1870 2050 ≤f <2075	1< f ≤784 979< f ≤1845 2075≤f<12750	824 ≤ f ≤ 849 1850 ≤ f ≤ 1910
UE transmitted mean power	dBm	20 (for Power class 3 and 3bis) 18 (for Power class 4)			
DB-DC-HSDPA Configuration 1	For 910≤f ≤975 MHz and 2095≤f ≤2185 MHz, the appropriate in-band blocking or adjacent channel selectivity in subclause 7.5.2 and subclause 7.6.1A shall be applied.				
DB-DC-HSDPA Configuration 2	For 1915≤f ≤2005 MHz and 2095≤f ≤2070 MHz, the appropriate in-band blocking or adjacent channel selectivity in subclause 7.5.2 and subclause 7.6.1A shall be applied.				
DB-DC-HSDPA Configuration 3	For 854≤f≤909 MHz and 2095≤f ≤2185 MHz, the appropriate in-band blocking or adjacent channel selectivity in subclause 7.5.2 and subclause 7.6.1A shall be applied.				
DB-DC-HSDPA Configuration 4	For 1460.9≤f≤ 1510.9 MHz and 2095≤f ≤2185 MHz, the appropriate in-band blocking or adjacent channel selectivity in subclause 7.5.2 and subclause 7.6.1A shall be applied.				
DB-DC-HSDPA Configuration 5	For 854≤f≤909 MHz and 1915≤f ≤2005 MHz, the appropriate in-band blocking or adjacent channel selectivity in subclause 7.5.2 and subclause 7.6.1A shall be applied.				

Table 70: Out of band blocking for DB-DC-HSDPA

4.2.2.3 GCF requirements for dual band dual cell HSDPA

GCF has not yet started the work on certification of dual band dual cell HSDPA capable UEs.

4.3 Dual Cell HSDPA and MIMO

Another restriction up to 3GPP Release 8 is that MIMO operation is not possible when the UE is configured with a secondary HS-DSCH cell, i.e. when the UE is receiving data from two adjacent downlink frequencies. From 3GPP Release 9 onwards this restriction is not longer valid. A few modifications have been introduced in 3GPP specifications in order to support dual cell HSDPA with MIMO. Note that Tx diversity modes may be configured differently in the different cells, i.e. on the different carrier frequencies as summarized in Table 71 below.

Physical channel type	Open loop mode		Closed loop mode
	TSTD	STTD	Mode 1
P-CCPCH	–	X	–
SCH	X	–	–
S-CCPCH	–	X	–
DPCH	–	X	X
F-DPCH	–	X	–
PICH	–	X	–
MICH	–	X	–
HS-PDSCH (UE not in MIMO mode, UE configured without a secondary serving HS-DSCH cell)	–	X	X
HS-PDSCH (UE not in MIMO mode in this cell, UE configured with a secondary serving HS-DSCH cell) (*1) (*2)	–	X	–
HS-PDSCH (UE in MIMO mode in this cell) (*2)	–	–	–
HS-SCCH (*1)	–	X	–
E-AGCH	–	X	–
E-RGCH	–	X	–
E-HICH	–	X	–
AICH	–	X	–

Table 71: Application of Tx diversity modes on downlink physical channel types [3]

NOTE *1: The Tx diversity mode can be configured independently across cells.
NOTE *2: The MIMO mode can be configured independently across cells.

4.3.1 ACK/NACK and CQI reporting

A single channelization code HS-DPCCH is used to carry feedback information (ACK/NACK, CQI and precoding control information) related to the two carriers. The CQI reports to the two different carriers are transmitted in time division multiplex manner.

Regarding the acknowledgement, non-acknowledgement of the packets the available 10 feedback bits respond to four individual data stream (two due to MINO and two due to dual cell operation) according to Table 72. The feedback related to the serving HS-DSCH cell is given before the divider sign and the feedback related to the secondary serving HS-DSCH cell is given after the divider sign. ‘A’ means ‘ACK’, ‘N’ means ‘NACK’ and ‘D’ means ‘no transmission’ (‘DTX’). ‘AA’, ‘AN’, ‘NA’ and ‘NN’ refer to feedback for dual-stream transmission in one MIMO cell. For example, ‘AN’ means ACK on the primary stream and NACK on the secondary stream.

A/D	1	1	1	1	1	1	1	1	1	1		AA/A	0	1	1	0	0	0	0	1	0	0
N/D	0	0	0	0	0	0	0	0	0	0		AA/N	1	1	1	0	0	1	1	0	1	0
AA/D	1	0	1	0	1	1	1	1	0	1		AN/A	1	0	1	1	1	0	0	1	1	0
AN/D	1	1	0	1	0	1	0	1	1	1		AN/N	0	0	1	1	0	1	0	0	0	1
NA/D	0	1	1	1	1	0	1	0	1	1		NA/A	0	1	0	1	1	1	1	1	0	0
NN/D	1	0	0	1	0	0	1	0	0	0		NA/N	1	1	0	0	1	0	0	0	0	1
D/A	0	0	0	0	0	0	1	1	1	1		NN/A	0	0	0	0	1	1	0	0	1	0
D/N	1	1	1	1	1	1	0	0	0	0		NN/N	0	1	0	0	0	1	1	0	0	1
D/AA	1	0	0	0	1	0	0	0	1	1		AA/AA	0	1	1	0	1	1	0	1	1	1
D/AN	0	1	0	0	0	0	1	1	0	1		AA/AN	1	0	1	1	0	0	1	1	1	1
D/NA	0	0	0	1	1	1	1	1	1	0		AA/NA	1	1	0	1	1	1	1	0	0	1
D/NN	1	1	1	1	1	0	0	1	0	0		AA/NN	0	1	1	1	0	1	1	1	0	0
A/A	1	1	0	1	0	0	0	0	1	1		AN/AA	0	0	0	1	1	0	0	1	0	1
A/N	0	0	1	1	1	0	1	0	0	1		AN/AN	1	1	1	0	0	0	0	0	0	1
N/A	1	0	0	1	0	1	1	1	0	0		AN/NA	1	0	0	0	0	1	0	1	0	0
N/N	0	1	1	0	0	1	0	1	0	1		AN/NN	0	0	1	1	0	1	0	0	0	1
A/AA	1	0	1	0	0	1	1	0	0	0		NA/AA	1	1	0	0	1	0	1	1	1	0
A/AN	1	0	0	1	0	1	0	1	0	1		NA/AN	0	0	1	0	1	0	1	0	0	0
A/NA	0	0	1	1	1	0	1	0	0	1		NA/NA	1	0	1	1	1	1	0	0	1	0
A/NN	0	1	1	1	0	1	0	0	1	1		NA/NN	1	1	1	0	0	1	1	0	1	0
N/AA	1	1	0	1	0	0	1	0	1	0		NN/AA	0	1	0	1	0	0	0	0	1	0
N/AN	1	1	0	0	0	1	0	1	1	0		NN/AN	0	0	1	0	0	0	0	1	1	0
N/NA	0	1	1	0	1	0	1	0	1	0		NN/NA	0	1	0	0	1	1	0	0	0	0
N/NN	0	0	1	0	1	1	0	1	0	1		NN/NN	0	0	0	0	0	1	1	0	1	1

Table 72: Channel coding of HARQ-ACK when the UE is configured in dual cell HSDPA operation and is supporting MIMO [4]

4.3.2 Protocol layer impact

On the MAC layer a restriction regarding the number of reordering SDUs was introduced in order to avoid heavy processing complexity at the UE. It was agreed that the maximum number of SDUs per received MAC-ehs PDU within one TTI is 44 (see Figure 55).

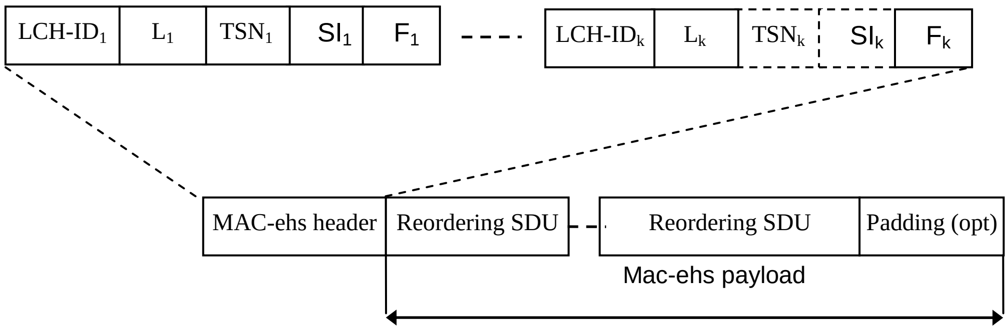


Figure 55: MAC-ehs PDU

The RRC protocol is enhanced because the maximum downlink data rate is significantly increased with the introduction of dual cell with MIMO operation. To facilitate the initial resource allocation of UE's supporting dual cell with MIMO operations in network nodes. The new information element *Dual cell MIMO support* is added to the RRC CONNECTION REQUEST message. The absence of this information element indicates that the UE does not support dual cell with MIMO operation on adjacent frequencies.

4.3.3 Dual cell HSDPA and MIMO UE categories

Four new UE categories have been introduced in [11] for dual cell HSDPA operation including MIMO support as shown in Table 73.

- **Categories 25 - 28:**
  - Support of dual cell and MIMO with modulation schemes QPSK, 16QAM and 64QAM
  - Maximum data rate of category 25/26 is 55.90 Mbps
  - Maximum data rate of category 27/28 is 84.40 Mbps

HS DSCH category	Dual Cell support	MIMO support	Modulation	Maximum number of HS DSCH codes received	Min. inter TTI interval	Maximum number of bits of an HS-DSCH transport block received within an HS-DSCH TTI	Maximum data rate [Mbps]
…		…	…	…	…	…	…
Category 23			QPSK / 16QAM / 64QAM			35280	~ 35.28
Category 24						42192	~ 42.20
Category 25	Yes	Yes	QPSK / 16QAM	15	1	23370	~ 46.74
Category 26						27952	~ 55.90
Category 27			QPSK / 16QAM / 64QAM			35280	~ 70.56
Category 28						42192	~ 84.40

Table 73: New Release 8 UE categories 25-28 supporting dual cell HSDPA and MIMO operation

4.3.4 Dual Cell HSDPA and MIMO test and measurement requirements

4.3.4.1 NodeB test and measurement requirements

NodeB test requirements for combining Dual Cell HSDPA with MIMO are specified in [9] and the corresponding test methods are detailed in [10]. Only the time alignment error requirement in [9] is modified. The four data streams transmitted from the two antennas ports in case of MIMO in combination with dual cell HSDPA operation (on adjacent frequencies in the same band) need to be synchronized within ½Tc.

4.3.4.2 UE test and measurement requirements

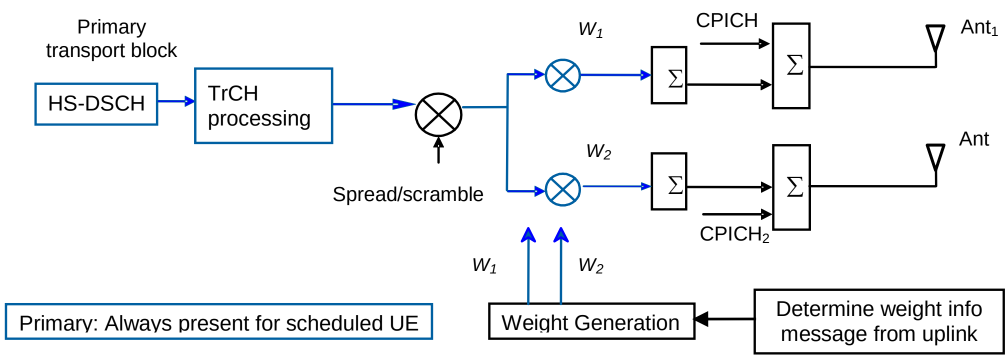
UE test requirements for combining Dual Cell HSDPA with MIMO transmission/reception are specified in [5] and the corresponding test methods are detailed in [12] for RF conformance and in [13] for protocol conformance, respectively. In general in terms of receiver requirements it is specified, that these UEs need to cover all existing dual cell HSDPA requirements. Additionally the CQI reporting performance requirements have been enhanced for all relevant cases, i.e. single stream transmission under fading conditions, dual stream transmission under fading conditions and dual stream in static orthogonal conditions (see details in section 9.3.4 in [5]). The principle of performance verification is maintained, i.e. BLER of 60% and 15% have to be achieved at CQI median and CQI median + 2, respectively.

4.3.4.3 GCF requirements for Dual Cell HSDPA and MIMO

GCF has not yet started the work on certification of dual band Dual Cell HSDPA and MIMO capable UEs.

4.4 TxAA extension for non-MIMO UEs

The 3GPP Release 7 MIMO features allows a fallback scheme to TX diversity in case propagation conditions does not allow dual stream transmission. Noticeable average cell physical layer throughput gains and cell edge physical layer bit rate increases are achieved using this fallback mode also for non-MIMO UEs. Through extension non-MIMO UE the fallback mode gains would even be available for 1 Rx UEs. This provides benefits as the usage of two base station Tx antennas is broadened to many different device categories including smaller handheld devices. The block diagram in Figure 1 for true MIMO signal generation is reduced to the one shown in Figure 56Figure 1. In 3GPP RAN1 specification the term “MIMO mode with single stream restriction” is used.



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

Figure 56: Generic downlink transmitter structure to support MIMO operation for HS-PDSCH transmission when single-stream restriction is configured

In case the UE is configured in MIMO mode with single stream restriction it provides only type B CQI reports (compare section 2.1.4). Note that when applying this feature the UE suggest one precoding vector W_2 out of the 4 possible values within its combined PCI/CQI reporting.

Whether a UE support this feature is indicated to the network as part of the UE capability signaling, i.e. there is a dedicated UE radio access capability parameter *support of MIMO only with single-stream restriction (Yes/No)*.

4.4.1 TxAA extension for non-MIMO UEs test and measurement requirements

4.4.1.1 NodeB test and measurement requirements

There is no impact on the NodeB due to the TxAA extension for non-MIMO UEs feature.

4.4.1.2 UE test and measurement requirements

UE test requirements for TxAA extension for non-MIMO UE transmission/reception are specified in [5] and the corresponding test methods are detailed in [12] for RF conformance and in [13] for protocol conformance, respectively.
Beside some clarifications the main change in [5] are the addition of specific performance requirements in sections 9.2.4, 9.3.4 (MIMO Performance) and 9.4.4 (HS-SCCH Type 3 Performance for MIMO only with single stream restriction). These concern minimum throughput requirements using QPSK and 16QAM modulation, CQI reporting performance and HS-SCCH Type 3 detection performance.

4.4.1.3 GCF requirements for TxAA extension for non-MIMO UEs

GCF has not yet started the work on certification of dual band Dual Cell HSDPA and MIMO capable UEs.

5 HSPA+ Release 10

5.1 Four carrier HSDPA

Building upon the MIMO functionality introduced in 3GPP Release 7, DC-HSDPA in 3GPP Release 8 and the combination with MIMO in 3GPP Release 9, performance gains are expected when operating more than 2 carriers. Consequently 3GPP RAN Working Group 1 has studied the performance, feasibility and complexity aspects of more than 2 carriers HSDPA. It was shown that the multi-carrier operation over 3 or 4 carriers provides substantial system level gains over the combination of single carrier and/or DC-HSDPA operation with the same number of carriers for all studied bursty traffic source models as well as lightly loaded systems (fewer number of users) with full buffer source models. For studied highly loaded systems (larger number of users) with full buffer traffic source models, the gains are smaller. Four carrier in downlink may or may not be combined with dual carrier HSUPA depending on UE capabilities ([11]).

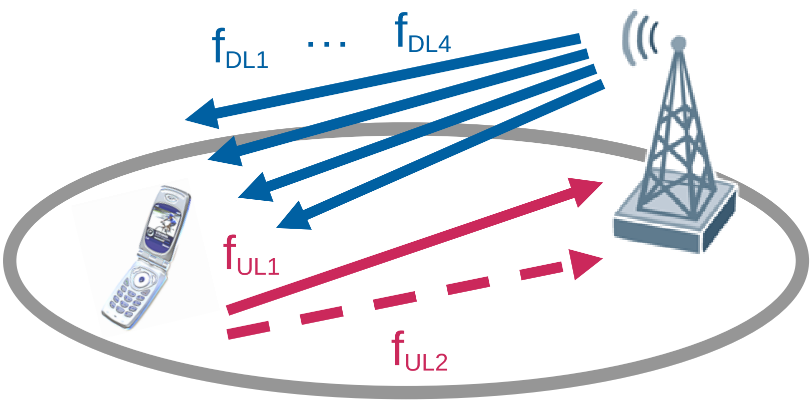


Figure 57: Principle of four carrier HSDPA operation

The related changes in specification to support this feature are explained in the following sections.

5.2 Serving / Secondary HS-DSCH cells and HS-SCCH orders

When a UE is configured into four carrier HSDPA operation, there is one serving HS-DSCH cell and up to three secondary serving HS-DSCH cells. When MIMO is not configured on any of the serving or secondary serving HS-DSCH cells, one HS-DSCH transport channel is transmitted on each configured serving and secondary serving HS-DSCH cells, and each of these HS-DSCH transport channels has its own associated uplink and downlink signaling, and own HARQ entity. Furthermore a UE may be configured into four carrier HSDPA operation with MIMO mode on any of the serving or secondary serving HS-DSCH cells. Depending on the MIMO configuration up to eight HS-DSCHs can be transmitted to UE per HS-DSCH TTI.

For activation and de-activation of the primary / secondary HS-DSCH cells again the HS-SCCH order concept as described in sections 3.3.2 and 4.1.1 is reused. However the scheme is extended in order to cover all cases as shown in Table 74.

Order Type	Order Mapping			Activation Status of Secondary Serving HS-DSCH cells and Secondary Uplink Frequency A= Activate; D = De-activate			
$x_{odt,1}$, $x_{odt,2}$, $x_{odt,3}$	$x_{ord,1}$	$x_{ord,2}$	$x_{ord,3}$	1st Secondary Serving HS-DSCH cell	2nd Secondary Serving HS-DSCH cell	3rd Secondary Serving HS-DSCH cell	Secondary Uplink Frequency
001	0	0	0	D	D	D	D
	0	0	1	A	D	D	D
	0	1	1	A	D	D	A
	0	1	0	D	A	D	D
	1	0	0	A	A	D	D
	1	0	1	A	A	D	A
	1	1	0	D	D	A	D
	1	1	1	A	D	A	D
010	0	0	0	A	D	A	A
	0	0	1	D	A	A	D
	0	1	0	A	A	A	D
	0	1	1	A	A	A	A
	1	0	0	Unused (Reserved)			
	1	0	1	Unused (Reserved)			
	1	1	0	Unused (Reserved)			
	1	1	1	Unused (Reserved)			

Table 74: Orders for activation and deactivation of Secondary serving HS-DSCH cells and Secondary uplink frequency

5.3 New HS-DPCCH slot format

Figure 58 illustrates the maintained frame structure of the HS-DPCCH. The HS-DPCCH carries uplink feedback signaling related to downlink HS-DSCH transmission and to HS-SCCH orders. The feedback signaling consists of Hybrid-ARQ Acknowledgement (HARQ-ACK) and Channel-Quality Indication (CQI) and in case the UE is configured in MIMO mode of Precoding Control Indication (PCI) as well. Each sub frame of length 2 ms (3*2560 chips) consists of 3 slots. The HARQ-ACK is carried in the first slot of the HS-DPCCH sub-frame. The CQI, and in case the UE is configured in MIMO mode also the PCI, are carried in the second and third slot of a HS-DPCCH sub-frame. The new slot format is shown in Table 75. A spreading factor SF = 128 is applied in this case achieving a higher channel bit rate of 30kbps.

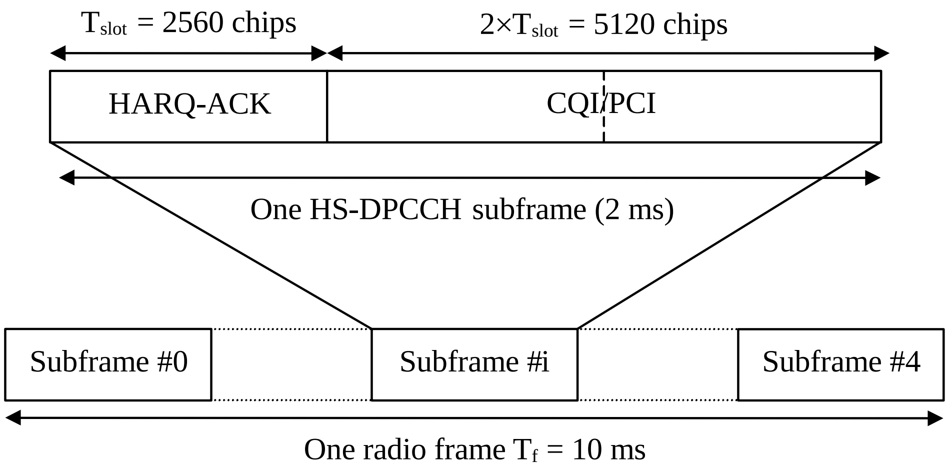


Figure 58: Frame structure for uplink HS-DPCCH

Slot Format #i	Channel Bit Rate (kbps)	Channel Symbol Rate (ksps)	SF	Bits/ Subframe	Bits/ Slot	Transmitted slots per Subframe
0	15	15	256	30	10	3
1	30	30	128	60	20	3

Table 75: HS-DPCCH fields

5.4 New four carrier HSDPA UE categories

Four new UE categories have been introduced in [11] for four carrier HSDPA operation including MIMO support as shown in Table 76.

- **Categories 29 - 32:**
  - Categories 29 and 30 support three carriers with or without MIMO
  - Categories 31 and 32 support four carriers with or without MIMO
  - Maximum data rate of category 29/30 is 84.40 Mbps
  - Maximum data rate of category 27/28 is 168.80 Mbps

HS DSCH category	Max. number of HS DSCH codes received	Min. inter TTI interval	Max. number of bits of an HS-DSCH transport block received within an HS-DSCH TTI	Total number of serving / second-ary serving HS-DSCH cells	Total Number of serving / secondary serving HS-DSCH cells in which MIMO can be configured	Supported modulations without MIMO operation with aggregated cell operation	Supported modulations with MIMO operation and aggregated cell operation	Maxi. data rate [Mbps]
…	…	…	…	…	…	…		…
Category 27	15	1	35280	2	2			~ 70.56

<table>
<tr><th>HS DSCH category</th><th>Max. number of HS DSCH codes received</th><th>Min. inter TTI interval</th><th>Max. number of bits of an HS-DSCH transport block received within an HS-DSCH TTI</th><th>Total number of serving / second-ary serving HS-DSCH cells</th><th>Total Number of serving / secondary serving HS-DSCH cells in which MIMO can be configured</th><th>Supported modulations without MIMO operation with aggregated cell operation</th><th>Supported modulations with MIMO operation and aggregated cell operation</th><th>Maxi. data rate [Mbps]</th></tr>
<tr><td>Category 28</td><td></td><td></td><td>42192</td><td></td><td></td><td></td><td></td><td>~ 84.40</td></tr>
<tr><td>Category 29</td><td rowspan="4">15</td><td rowspan="4">1</td><td>42192</td><td rowspan="2">3</td><td>0</td><td rowspan="2">QPSK, 16QAM, 64QAM</td><td>-</td><td>~ 63.28</td></tr>
<tr><td>Category 30</td><td>42192</td><td>3</td><td>QPSK, 16QAM, 64QAM</td><td>~ 126.6</td></tr>
<tr><td>Category 31</td><td>42192</td><td rowspan="2">4</td><td>0</td><td rowspan="2">QPSK, 16QAM, 64QAM</td><td>-</td><td>~ 84.40</td></tr>
<tr><td>Category 32</td><td>42192</td><td>4</td><td>QPSK, 16QAM, 64QAM</td><td>~ 168.8</td></tr>
</table>

Table 76: Four carrier HSDPA UE categories

6 Frequency bands and channel arrangement

This section summarizes the WCDMA/HSPA specified frequency bands up to 3GPP Release 10 (December 2011) as specified in [5].

Operating Band	UL Frequencies UE Tx, NB Rx	DL frequencies UE Rx, NB Tx	TX-RX frequency separation
I	1920 - 1980 MHz	2110 -2170 MHz	190 MHz
II	1850 -1910 MHz	1930 -1990 MHz	80 MHz.
III	1710-1785 MHz	1805-1880 MHz	95 MHz.
IV	1710-1755 MHz	2110-2155 MHz	400 MHz
V	824 - 849 MHz	869-894 MHz	45 MHz
VI	830-840 MHz	875-885 MHz	45 MHz
VII	2500-2570 MHz	2620-2690 MHz	120 MHz
VIII	880 - 915 MHz	925 - 960 MHz	45 MHz
IX	1749.9-1784.9 MHz	1844.9-1879.9 MHz	95 MHz
X	1710-1770 MHz	2110-2170 MHz	400 MHz
XI	1427.9 - 1447.9 MHz	1475.9 - 1495.9 MHz	48 MHz
XII	698 – 716 MHz	728 – 746 MHz	30 MHz
XIII	777 - 787 MHz	746 - 756 MHz	31 MHz
XIV	788 – 798 MHz	758 – 768 MHz	30 MHz
XV	Reserved	Reserved	-
XVI	Reserved	Reserved	-
XVII	Reserved	Reserved	-
XVIII	Reserved	Reserved	-
XIX	830 – 845MHz	875 – 890 MHz	45 MHz
XX	832 – 862 MHz	791 – 821 MHz	41 MHz
XXI	1447.9 – 1462.9 MHz	1495.9 – 1510.9 MHz	48 MHz
XXII	3410 – 3490 MHz	3510 – 3590 MHz	100 MHz
XXV	1850 – 1915 MHz	1930 – 1995 MHz	80 MHz

Figure 59: UTRA FDD frequency bands

7 Literature

[1] R&S application note 1MA102; Introduction to MIMO systems

[2] 3GPP TS 25.214; Physical Layer Procedures (FDD), Release 10

[3] 3GPP TS 25.211; Physical channels and mapping of transport channels onto physical channels (FDD), Release 10

[4] 3GPP TS 25.212; Multiplexing and Channel Coding (FDD), Release 10

[5] 3GPP TS 25.101; User Equipment (UE) radio transmission and reception (FDD), Release 10

[6] 3GPP TS 25.321; Medium Access Control (MAC) protocol specification, Release 10

[7] 3GPP TS 25.331; Radio Resource Control (RRC) protocol specification, Release 10

[8] 3GPP TS 25.213; Spreading and Modulation, Release 10

[9] 3GPP TS 25.104; Base Station (BS) radio transmission and reception (FDD), Release 10

[10] 3GPP TS 25.141; Base Station (BS) conformance testing (FDD), Release 10

[11] 3GPP TS 25.306; UE Radio Access capabilities, Release 10

[12] 3GPP TS 34.121-1; User Equipment (UE) conformance specification; Radio transmission and reception (FDD); Part 1: Conformance specification, Release 10

[13] 3GPP TS 34.123-1; User Equipment (UE) conformance specification; Part 1: Protocol conformance specification, Release 10

[14] 3GPP TS 25.133; Requirements for support of radio resource management (FDD), Release 10

8 Additional Information

This white paper is updated from time to time. Please visit the website 1MA205 to download the latest version.

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