

# HSPA+

## Technology Introduction

### Application Note 1MA121

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, further improvements to HSPA have been specified in the context of HSPA+ or HSPA evolution. This application note introduces key features of HSPA+ and outlines the changes to the radio interface.



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# 1 Introduction

Currently, UMTS networks worldwide are being upgraded to High Speed Downlink Packet Access (HSDPA) in order to increase data rate and capacity for downlink packet data. In the next step, High Speed Uplink Packet Access (HSUPA) will boost uplink performance in UMTS networks. While HSDPA was introduced as a release 5 feature in 3GPP (3<sup>rd</sup> Generation Partnership Project), HSUPA is an important feature of 3GPP release 6. The combination of HSDPA and HSUPA is often referred to as HSPA (High Speed Packet Access).

However, even with the introduction of HSPA, evolution of UMTS has not reached its end. **HSPA+** will bring significant enhancements in 3GPP release 7. Objective is to enhance performance of HSPA based radio networks in terms of spectrum efficiency, peak data rate and latency, and exploit the full potential of WCDMA based 5 MHz operation. Important features of HSPA+ are:

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

This application note introduces HSPA+ technology and provides an overview of the different features. Focus is on radio protocols.

**Chapter 2** describes the HSPA+ MIMO concept.

**Chapter 3** outlines the concept of introducing higher order modulation schemes.

**Chapter 4** explains continuous packet connectivity.

**Chapter 5** describes the layer 2 enhancements.

**Chapter 6** describes the concept of enhanced CELL\_FACH state.

**Chapters 7-9** provide additional information including literature references.

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

# 2 Downlink MIMO for HSPA+

## 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 distinguished. 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].

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. 2 transmit antennas at the base station side, and 2 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 MIMO 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.

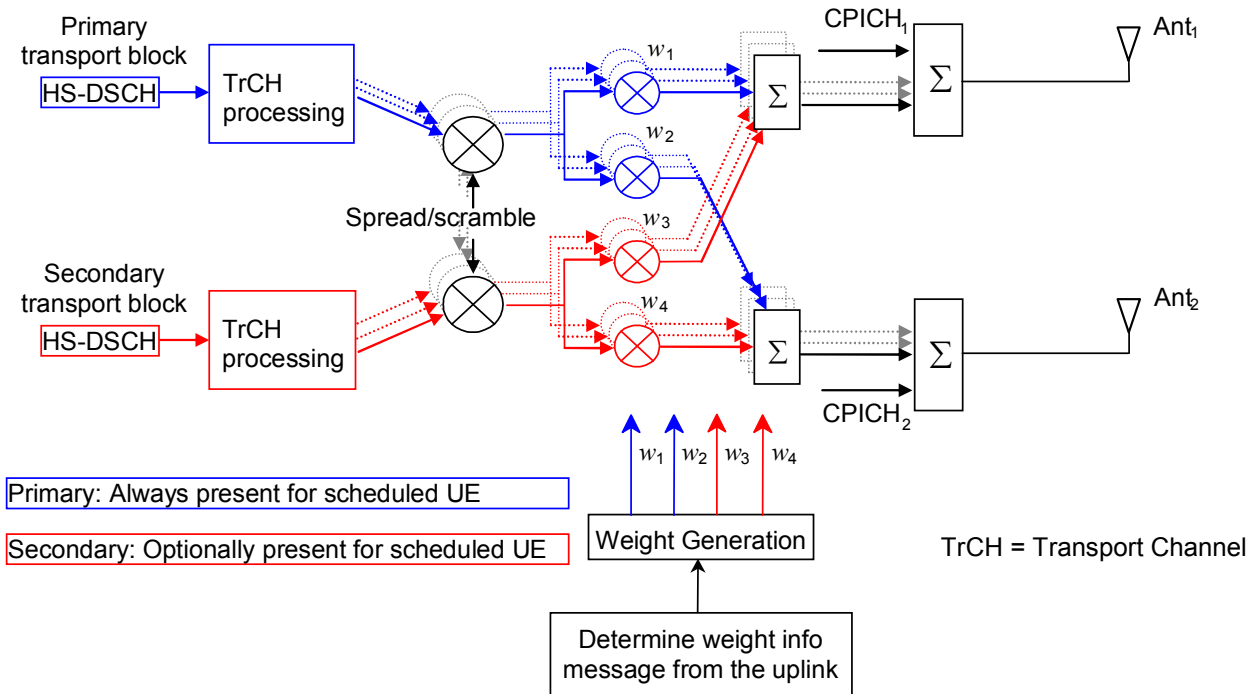


Figure 1 MIMO for HSPA+ [2]

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

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

$$w_4 = -w_2,$$

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

Note that  $w_1$  is always fixed, and only  $w_2$  can be selected by the base station. Weights  $w_3$  and  $w_4$  are automatically derived from  $w_1$  and  $w_2$ , because they have to be orthogonal.

The base station selects the optimum weight factors based on proposals reported by the UE in uplink. This feedback reporting is described in more detail below.

After multiplication with the weight factors, the two data streams are summed up before transmission on each antenna, so that each antenna transmits a part of each stream. Note that the two different transport blocks can have a different modulation and coding scheme depending on data rate requirements and radio channel condition.

The UE has to be able to do channel estimation for the radio channels seen from each transmit antenna, respectively. Thus, the transmit antennas have to transmit a different pilot signal. One of the antennas will transmit the antenna 1 modulation pattern of P-CPICH (Primary Common Pilot Channel). The other antenna will transmit either the antenna 2 modulation pattern of P-CPICH, or the antenna 1 modulation pattern of S-CPICH. The modulation patterns for the common pilot channel are defined in [3].

Also the UE receiver has to know the precoding weights that were applied at the transmitter. Therefore, the base station signals to the UE the precoding weight  $w_2$  via the **HS-SCCH (High Speed Shared Control Channel)**. The 2 bit precoding weight indication is used on HS-SCCH to signal one out of four possible  $w_2$  values. The other weights applied on HS-DSCH can then be derived from  $w_2$ . The precoding weight adjustment is done at the subframe border.

D-TxAA requires a **feedback signaling** from the UE to assist the base station in taking the right decision in terms of modulation and coding scheme and precoding weight selection. The UE has to determine the preferred primary precoding vector for transport block 1 consisting of  $w_1$  and  $w_2$ . Since  $w_1$  is fixed, the feedback message only consists of a proposed value for  $w_2$ . This feedback is called **precoding control information (PCI)**. The UE also recommends whether one or two streams can be supported in the current channel situation. In case dual stream transmission is possible, the secondary precoding vector consisting of weights  $w_3$  and  $w_4$  is inferred in the base station, because it has to be orthogonal to the first precoding vector with  $w_1$  and  $w_2$ . Thus, the UE does not have to report it explicitly. The UE also indicates the optimum modulation and coding scheme for each stream. This report is called **channel quality indicator (CQI)**.

Based on the composite PCI/CQI reports, the base station scheduler decides whether to schedule one or two data streams to the UE and what packet sizes (transport block sizes) and modulation schemes to use for each stream.

Note that in case only one stream can be supported due to radio channel conditions, the approach is basically to fall back to the conventional closed loop transmit diversity scheme as of 3GPP release 99, cmp. [2].

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### MIMO UE capabilities

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

- **Categories 15 and 16:**
  - o Support of MIMO with modulation schemes QPSK and 16QAM
  - o No support of 64QAM
  - o Maximum data rate of category 16 is 27.6 Mbps
- **Categories 17 and 18:**
  - o Support of MIMO with modulation schemes QPSK and 16QAM
  - o Support of 64QAM, but not simultaneously with MIMO
  - o Maximum data rate of category 18 is 27.6 Mbps

Additional UE categories with simultaneous MIMO and 64QAM support are planned for later releases.

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

HS-DSCH category	Maximum number of HS-DSCH codes received	Minimum inter-TTI interval	Maximum number of bits of an HS-DSCH transport block received within an HS-DSCH TTI	Total number of soft channel bits
Category 1	5	3	7298	19200
Category 2	5	3	7298	28800
Category 3	5	2	7298	28800
Category 4	5	2	7298	38400
Category 5	5	1	7298	57600
Category 6	5	1	7298	67200
Category 7	10	1	14411	115200
Category 8	10	1	14411	134400
Category 9	15	1	20251	172800
Category 10	15	1	27952	172800
Category 11	5	2	3630	14400
Category 12	5	1	3630	28800
Category 13	15	1	34800	259200
Category 14	15	1	43128	259200
Category 15	15	1	23370	345600
Category 16	15	1	27952	345600
Category 17	15	1	34800 (no MIMO), 23370 (no 64QAM)	259200 (no MIMO), 345600 (no 64QAM)
Category 18	15	1	43128 (no MIMO), 27952 (no 64QAM)	259200 (no MIMO), 345600 (no 64QAM)

### 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 M** for MIMO operation defined. If **one transport block** is transmitted, the following information is transmitted by HS-SCCH type M (changes to regular HS-SCCH marked in italics):

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- 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 M:

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

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

Table 2 Interpretation of “Modulation scheme and number of transport blocks info” sent on HS-SCCH

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

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

**Redundancy versions** for the primary transport block and for the secondary transport block are signaled. Four redundancy version values are possible (unlike HSDPA in 3GPP release 5 where eight values for the redundancy version could be signaled).

Also the signaling of the **HARQ processes** differs from HSDPA in 3GPP release 5. In 3GPP release 5, up to eight HARQ processes can be signaled. 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 signaling overhead quite significantly (to 8 bits), since each possible combination of HARQ processes would need to be addressed.

To save signaling overhead, a restriction is introduced: HARQ processes are only signaled for the primary transport block within 4 bits, the HARQ process for the secondary transport block is derived from that according to a fixed rule [4]. Thus, there is a one-to-one mapping between the HARQ process used for the primary transport block and the HARQ process used for the secondary transport block. The relation is shown in Table 3 for the example of 12 HARQ processes configured:

Table 3 *Combinations of HARQ process numbers for dual stream transmission (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

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

**MIMO uplink control channel support**

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

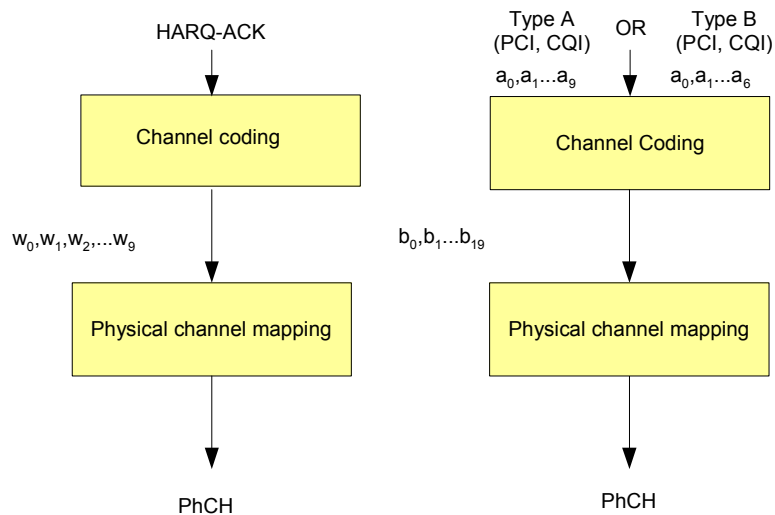


Figure 2 *Channel coding for HS-DPCCH*

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



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transport block.

Table 4 Interpretation of HARQ-ACK in MIMO operation

HARQ-ACK message to be transmitted		w <sub>0</sub>	w <sub>1</sub>	w <sub>2</sub>	w <sub>3</sub>	w <sub>4</sub>	w <sub>5</sub>	w <sub>6</sub>	w <sub>7</sub>	w <sub>8</sub>	w <sub>9</sub>
HARQ-ACK in response to a single scheduled transport block											
ACK		1	1	1	1	1	1	1	1	1	1
NACK		0	0	0	0	0	0	0	0	0	0
HARQ-ACK in response to two scheduled transport blocks											
Response to primary transport block	Response to secondary transport block										
ACK	ACK	1	0	1	0	1	1	1	1	0	1
ACK	NACK	1	1	0	1	0	1	0	1	1	1
NACK	ACK	0	1	1	1	1	0	1	0	1	1
NACK	NACK	1	0	0	1	0	0	1	0	0	0
PRE/POST indication											
PRE		0	0	1	0	0	1	0	0	1	0
POST		0	1	0	0	1	0	0	1	0	0

In MIMO case, two types of CQI reports shall 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.
- **type B CQI reports** are used for single stream transmission according to what has been defined from 3GPP release 5 onwards.

For type A CQI reports, the UE selects the appropriate CQI<sub>1</sub> and CQI<sub>2</sub> values for each transport block in dual stream transmission, or the appropriate CQI<sub>s</sub> value in single stream transmission, and then creates the CQI value to report on HS-DPCCH as follows:

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

For dual stream transmission, new CQI tables are required in [2] for correct interpretation of transport formats based on CQI<sub>1</sub> and CQI<sub>2</sub>, see the following tables.

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

CQI <sub>1</sub> or CQI <sub>2</sub>	Transport Block Size	Number of HS-PDSCH	Modulation	Equivalent AWGN SINR difference $\Delta$	N <sub>IR</sub>	X <sub>rvpb</sub> or X <sub>rvsb</sub>
0	4748	15	QPSK	-5.0	28800	0
1	4748	15	QPSK	-3.0		
2	4748	15	QPSK	-1.5		
3	4748	15	QPSK	0		
4	6101	15	QPSK	0		
5	7564	15	QPSK	0		
6	9210	15	16QAM	0		
7	10629	15	16QAM	0		
8	12488	15	16QAM	0		
9	14936	15	16QAM	0		
10	17548	15	16QAM	0		
11	20251	15	16QAM	0		
12	22147	15	16QAM	0		
13	22147	15	16QAM	2.0		
14	22147	15	16QAM	4.0		

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

CQI <sub>1</sub> or CQI <sub>2</sub>	Transport Block Size	Number of HS-PDSCH	Modulation	Equivalent AWGN SINR difference $\Delta$	N <sub>IR</sub>	X <sub>rvpb</sub> or X <sub>rvsb</sub>
0	4748	15	QPSK	-5.0	28800	0
1	4748	15	QPSK	-3.0		
2	4748	15	QPSK	-1.5		
3	4748	15	QPSK	0		
4	6101	15	QPSK	0		
5	7564	15	QPSK	0		
6	9210	15	16QAM	0		
7	10629	15	16QAM	0		
8	12488	15	16QAM	0		
9	14936	15	16QAM	0		
10	17548	15	16QAM	0		
11	20251	15	16QAM	0		
12	22147	15	16QAM	0		
13	24222	15	16QAM	0		
14	26490	15	16QAM	0		

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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  $\Delta$  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.

$N_{IR}$  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 to report in the uplink is created in the UE according to the preferred precoding weight  $w_2$  according to Table 7.

Table 7 Mapping of preferred precoding weight to PCI values

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

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

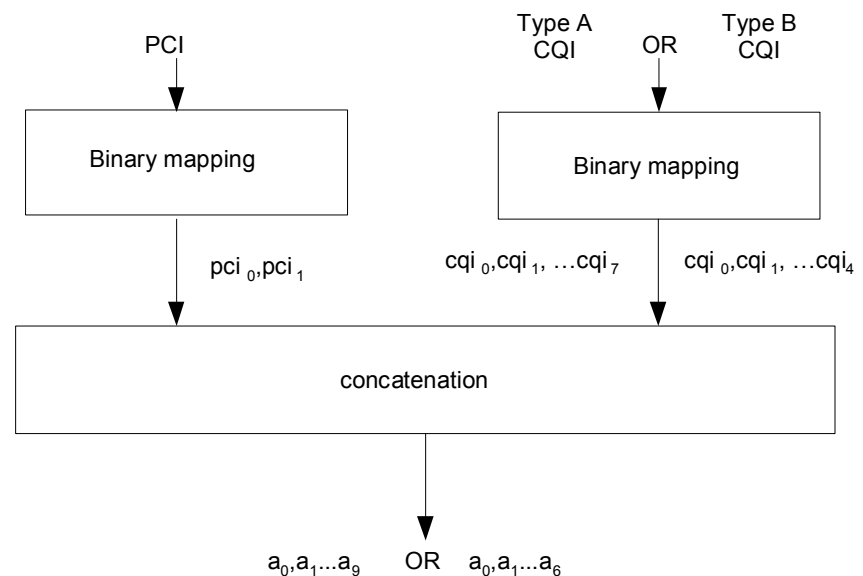


Figure 3 Composite PCI/CQI information

### 3 Higher Order Modulation

#### 64QAM in downlink

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

- **Categories 13 and 14:**
  - o Support of 64QAM
  - o No support of MIMO
  - o Maximum data rate of category 14 is 21 Mbps
- **Categories 17 and 18:**
  - o Support of 64QAM and MIMO, but not simultaneously
  - o Maximum data rate of category 18 is 27.6 Mbps when MIMO is used and 21 Mbps when 64QAM is used

See Table 8 for details on these categories. All other UE categories do not support 64QAM.

Additional UE categories with simultaneous MIMO and 64QAM support are planned for later releases.

Table 8 UE categories with 64QAM support

HS-DSCH category	Maximum number of HS-DSCH codes received	Minimum inter-TTI interval	Maximum number of bits of an HS-DSCH transport block received within an HS-DSCH TTI	Total number of soft channel bits
Category 1	5	3	7298	19200
Category 2	5	3	7298	28800
Category 3	5	2	7298	28800
Category 4	5	2	7298	38400
Category 5	5	1	7298	57600
Category 6	5	1	7298	67200
Category 7	10	1	14411	115200
Category 8	10	1	14411	134400
Category 9	15	1	20251	172800
Category 10	15	1	27952	172800
Category 11	5	2	3630	14400
Category 12	5	1	3630	28800
Category 13	15	1	34800	259200
Category 14	15	1	43128	259200
Category 15	15	1	23370	345600
Category 16	15	1	27952	345600
Category 17	15	1	34800 (no MIMO), 23370 (no 64QAM)	259200 (no MIMO), 345600 (no 64QAM)
Category 18	15	1	43128 (no MIMO), 27952 (no 64QAM)	259200 (no MIMO), 345600 (no 64QAM)

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

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64QAM, see Table 9. The theoretical peak data rate (physical channel bit rate) with 64QAM is accordingly:

Peak data rate (64QAM) =

$$15 [\text{codes}] * 2880 \text{ bits} / 2 \text{ ms} [\text{subframe}] = \underline{21.6 \text{ Mbps}}$$

Table 9 HS-DSCH slot formats

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

The coding of the control information on HS-SCCH has to be adapted in order to signal usage of 64QAM to the UE. Therefore, the interpretation of the bits on HS-SCCH has been changed, more precisely the seven bits that have been used so far exclusively to signal channelization code set (ccs) for HS-DSCH. The seventh bit is now used to indicate whether 64QAM is used.

The network informs the UE via higher layer signaling 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 signaling of the constellation version on HS-SCCH is combined with the signaling of redundancy versions (RV) as in 3GPP release 5.

Another change is required to the channel quality reporting procedure. New CQI tables have to be added in [2] so that the UE is able to propose the usage of transport formats including 64QAM.

### 64QAM Fixed Reference Channel: H-Set 8

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

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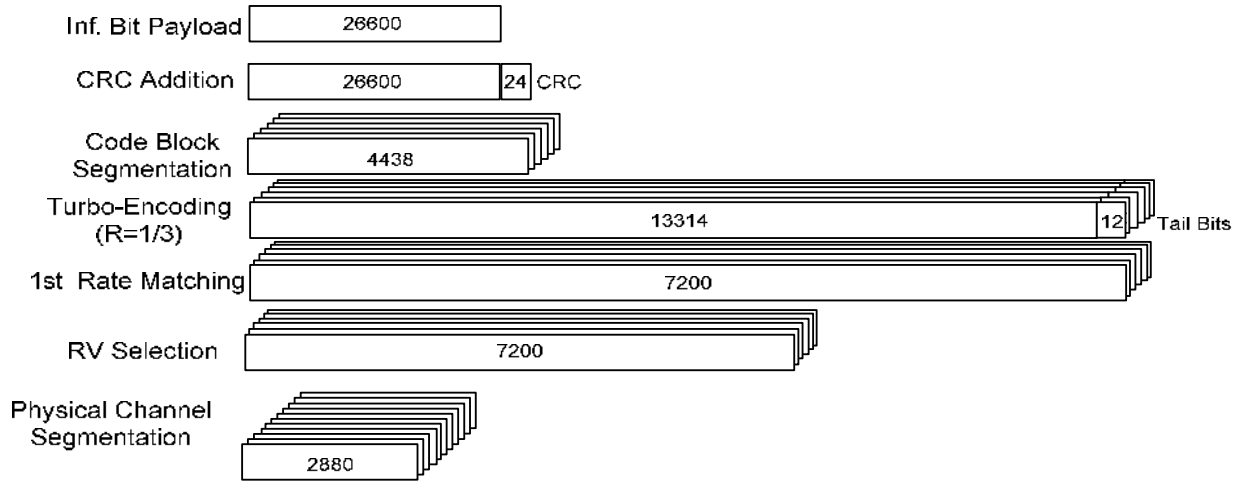


Figure 4 H-Set 8 parametrization

### 16QAM in uplink

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

Table 10 FDD E-DCH physical layer categories

E-DCH category	Maximum number of E-DCH codes transmitted	Minimum spreading factor	Support for 10 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
Category 1	1	SF4	10 ms TTI only	7110	-
Category 2	2	SF4	10 ms and 2 ms TTI	14484	2798
Category 3	2	SF4	10 ms TTI only	14484	-
Category 4	2	SF2	10 ms and 2 ms TTI	20000	5772
Category 5	2	SF2	10 ms TTI only	20000	-
Category 6	4	SF2	10 ms and 2 ms TTI	20000	11484
Category 7	4	SF2	10ms and 2 ms TTI	20000	22996

NOTE: When 4 codes are transmitted in parallel, two codes shall be transmitted with SF2 and two with SF4

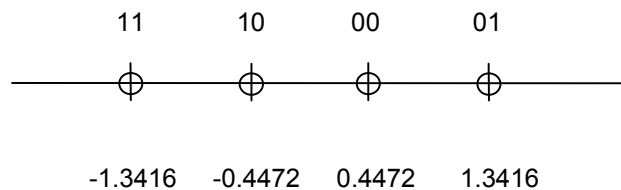
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Uplink transmission in HSPA+ is based on IQ multiplexing of E-DPDCH (Enhanced Dedicated Physical Data Channel) physical channels as in HSUPA of 3GPP release 6. In fact, the 16QAM constellation is made up of two orthogonal 4PAM (pulse amplitude modulation)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

Table 11 Mapping of E-DPDCH with 4PAM modulation

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

This results in the following symbol mapping:



An E-DPDCH may use BPSK or 4PAM modulation symbols. The new E-DPDCH slot formats 8 and 9 are shown in Table 12. M is the number of bits per modulation symbol i.e. M=1 for BPSK and M=2 for 4PAM. 2 Bits / symbol are available for spreading factor (SF) 2 and SF4. The resulting maximum uplink data rate in terms of physical channel bits is  $2 * 1920 \text{ kbps} + 2 * 3840 \text{ kbps} = 11520 \text{ kbps}$  (combination of 2 E-DPDCHs with SF2 and 2 E-DPDCHs with SF4).

Table 12 E-DPDCH slot formats

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

16QAM introduction also affects the transport format selection as well as uplink power setting and gain factor calculation. Bigger transport block sizes and higher grants become possible due to the higher order modulation scheme.

### 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 synchronization. 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 outlined.

#### Uplink Discontinuous Transmission (DTX)

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

To allow more flexibility, two uplink DPCCH activity patterns can be defined per UE:

- **UE DTX cycle 1**
- **UE DTX cycle 2**

UE DTX cycle 2 is used whenever there is no uplink data transmission activity. UE DTX cycle 1 is used temporarily depending on the duration of E-DCH inactivity. After a certain threshold of inactivity, UE changes from cycle 1 to 2. UE DTX cycle 2 therefore allows to transmit the uplink DPCCH less frequently. The use of UE DTX cycles 1 and 2 is shown in the examples of Figure 5 and Figure 6. 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.



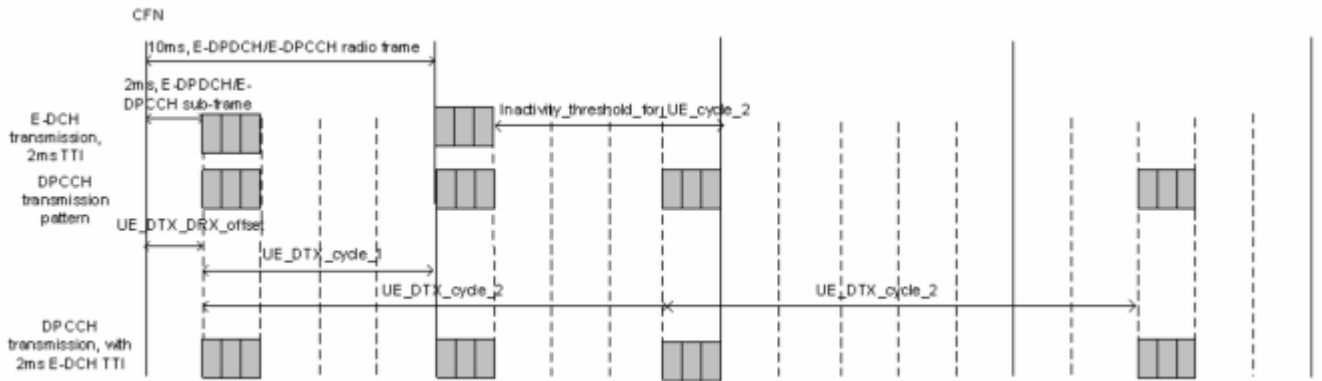


Figure 5 Uplink DTX example, 2 ms TTI (pre-/postambles not shown), [2]

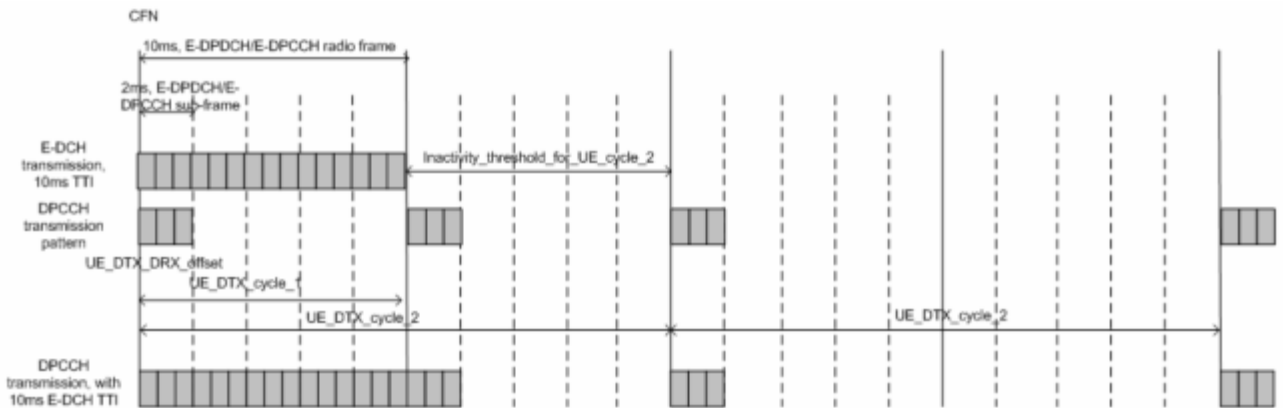


Figure 6 Uplink DTX example, 10 ms TTI (pre-/postambles not shown), [2]

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 13. These parameters can be configured by higher layers.

Table 13 *Parameters relevant for DTX operation*

Parameter	Possible values	Meaning
UE DTX cycle 1	1, 5, 10, 20 subframes for 10 ms TTI 1, 4, 5, 8, 10, 16, 20 subframes for 2 ms TTI	DPCCH activity pattern, 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 10 ms TTI 4, 5, 8, 10, 16, 20, 32, 40, 64, 80, 128, 160 subframes for 2 ms TTI	DPCCH activity pattern, 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, 2, 4, 8, 16, 32, 64, 128, 256 TTIs	When to activate the UE DTX cycle 2 after the last uplink data transmission
UE DTX long preamble length	2, 4, 15 slots (default 2)	Uplink preamble length
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 frames	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)

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 below the description of HS-SCCH orders.

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

### E-DCH Tx start time restrictions

This feature 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 14.

Table 14 Parameters relevant for E-DCH Tx start time restrictions

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

### 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 5<sup>th</sup> subframe.

The DRX also affects the monitoring of E-RGCH (E-DCH Relative Grant Channel) and E-AGCH (E-DCH Absolute Grant Channel) 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 15.

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 below the description of HS-SCCH orders.

Table 15 Parameters relevant for DRX operation

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

### 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 7. 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.

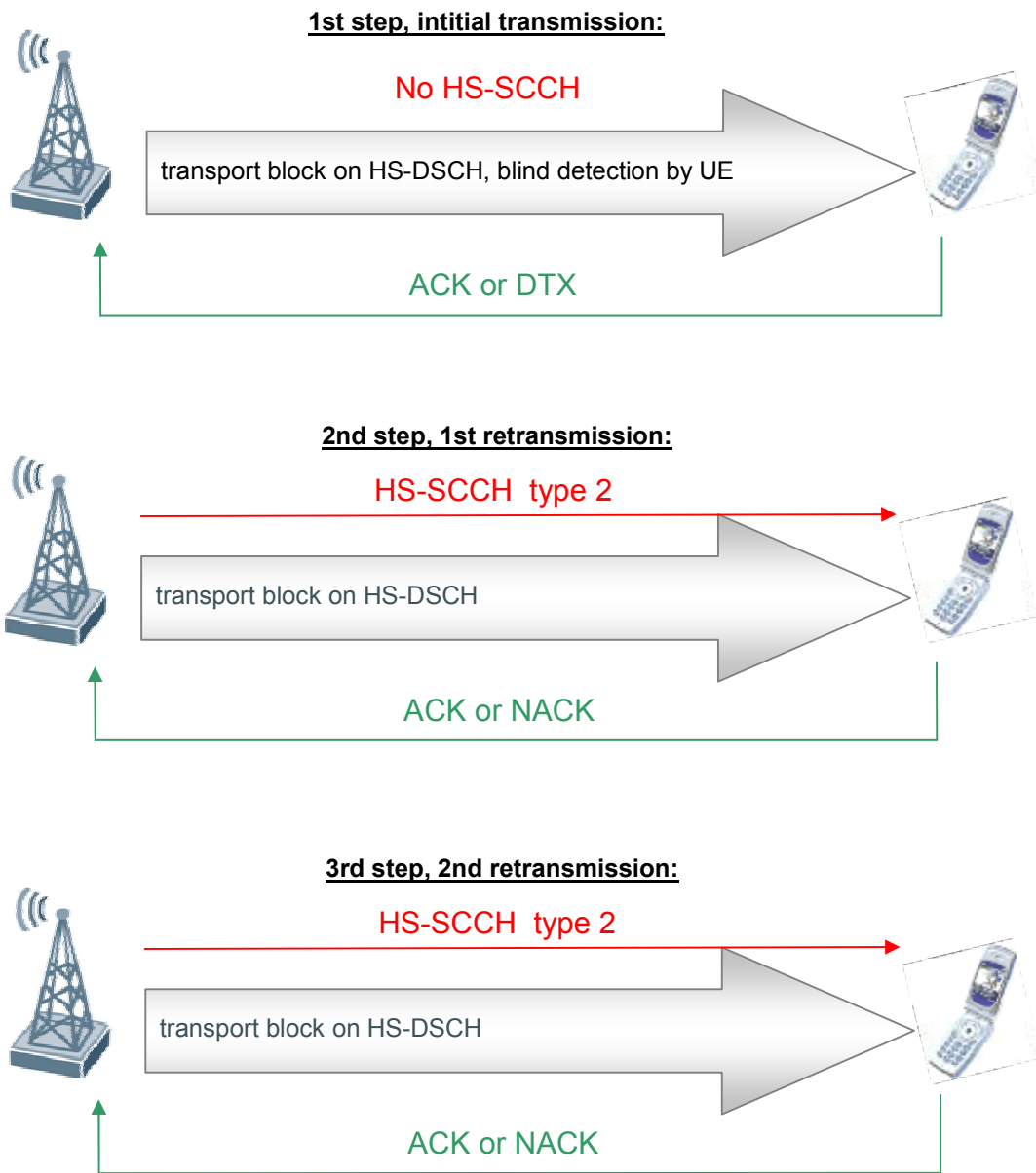


Figure 7 *HS-SCCH less operation*

### 1<sup>st</sup> 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 Xrv = 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.

### 2<sup>nd</sup> and 3<sup>rd</sup> 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 8 for a comparison of the two formats.

<u>HS-SCCH type 1:</u>	<u>HS-SCCH type 2:</u>
- Channelization-code-set information (7 bits):	- Channelization-code-set information (7 bits):
- Modulation scheme information (1 bit):	- Modulation scheme information (1 bit):
- Transport-block size information (6 bits):	- Special Information type (6 bits):
- Hybrid-ARQ process information (3 bits):	- Special Information (7 bits):
- Redundancy and constellation version (3 bits):	- UE identity (16 bits):
- New data indicator (1 bit):	
- UE identity (16 bits):	

Figure 8 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)

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- 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.

### HS-SCCH orders

HS-SCCH orders are fast commands sent on HS-SCCH type 2. They tell the UE whether to enable or disable discontinuous downlink reception or discontinuous uplink DPCCH transmission. No HS-PDSCH is associated with HS-SCCH orders. The special info type on HS-SCCH type 2 shall be set to '111101' to indicate an HS-SCCH order. Then, the special information bits are comprised of a 3 bit order type and a 4 bit order info. If order type = '000', then order info is comprised of a 1 bit DRX order activation and a 1 bit DTX order activation (remaining 2 bits are reserved). These bits can be used to activate or deactivate DRX or DTX, respectively.

Modulation scheme and channelization code set information are set to predefined values in this case.

### 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 9, and the parameters for the new uplink DPCCH slot format 4 are given in Table 16. 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.

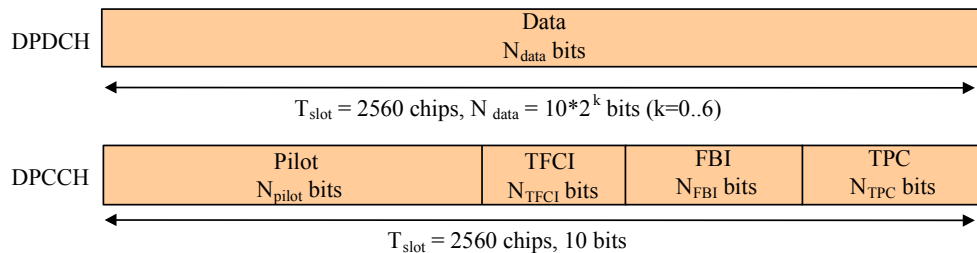


Figure 9 Uplink DPDCH/DPCCH slot format (one slot shown)

Table 16 Uplink DPCCH slot formats

Slot Format #i	Channel Bit Rate (kbps)	Channel Symbol Rate (ksps)	SF	Bits/ Frame	Bits/ Slot	$N_{pilot}$	$N_{TPC}$	$N_{TFCI}$	$N_{FBI}$	Transmitted slots per radio frame
0	15	15	256	150	10	6	2	2	0	15
0A	15	15	256	150	10	5	2	3	0	10-14
0B	15	15	256	150	10	4	2	4	0	8-9
1	15	15	256	150	10	8	2	0	0	8-15
2	15	15	256	150	10	5	2	2	1	15
2A	15	15	256	150	10	4	2	3	1	10-14
2B	15	15	256	150	10	3	2	4	1	8-9
3	15	15	256	150	10	7	2	0	1	8-15
4	15	15	256	150	10	6	4	0	0	8-15

New slot format #4: contains only TPC/pilot bits for reduction of uplink DPCCH TX power

## 5 Improved Layer 2 support for High Data Rates

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.

### 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 10** shows the UTRAN side MAC architecture including the new MAC-ehs.

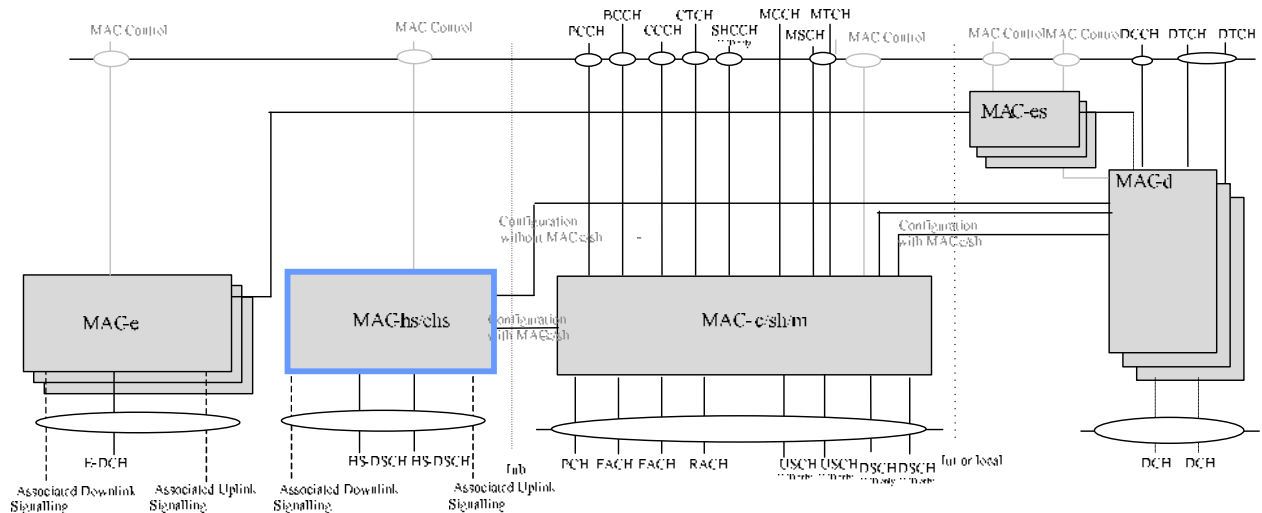


Figure 10 UTRAN side MAC architecture with MAC-ehs



Basically, MAC-ehs allows the support of flexible RLC PDU (Protocol Data Unit) sizes as well 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 11 shows the details of the MAC-ehs on UTRAN side.

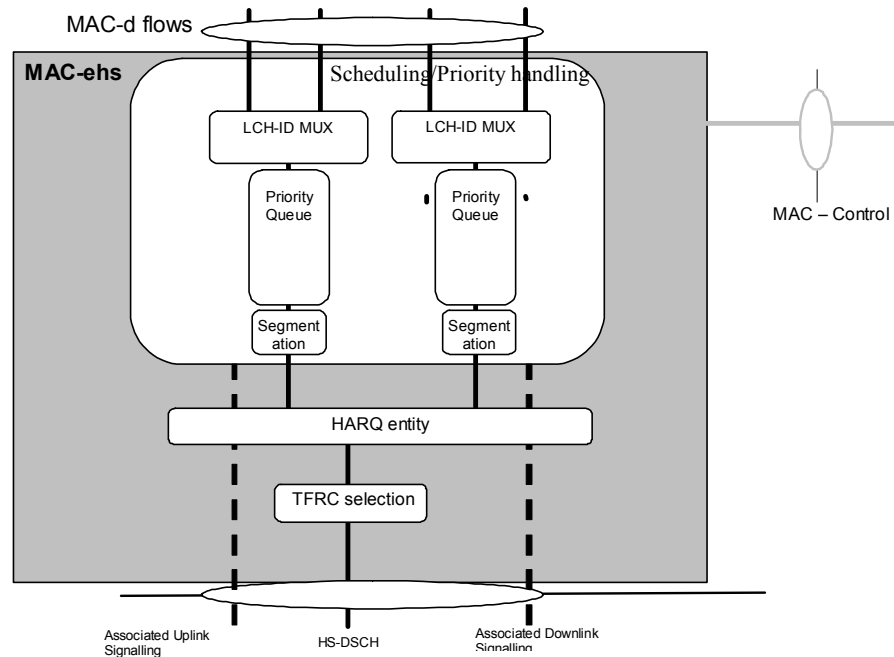


Figure 11 UTRAN side MAC-ehs details

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

Reordering on receiver side is based on priority queues. Transmission sequence numbers (TSN) are assigned within each reordering queue to enable reordering. On the receiver side, the MAC-ehs SDU (Service Data Unit) or segment of it is assigned to the correct priority queue based on the logical channel identifier.

MAC-ehs SDUs can be segmented and have to be reassembled on receiver side. A MAC-ehs SDU is either a MAC-c PDU (see next chapter on Enhanced CELL\_FACH state) 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.

### 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 12. Per transmission time interval, one MAC-ehs PDU can be transmitted (two in the MIMO case).

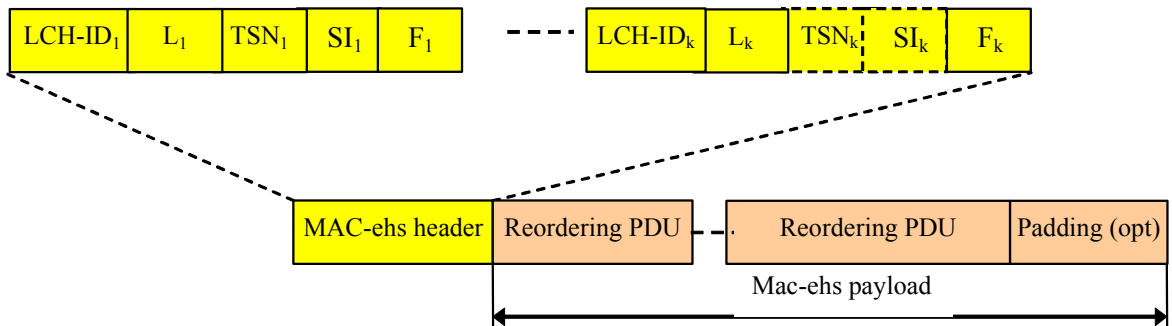


Figure 12 MAC-ehs PDU

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.

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 L 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 TSN<sub>1</sub> and SI<sub>1</sub> fields are always present.

The MAC-ehs header is octet aligned.

### Enhancements to RLC

In order to optimize HSPA+ operation, RLC has been enhanced to support flexible downlink RLC PDU sizes for acknowledged mode (AM) operation. 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.

## 6 Enhanced CELL\_FACH State

From release 99 onwards, four different protocol states have been defined for UEs in RRC connected mode:

- CELL\_DCH state
- CELL\_FACH state
- CELL\_PCH state
- URA\_PCH state

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, but also URA\_PCH and CELL\_PCH states.

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: Using HS-DSCH in CELL\_FACH state further increases the available data rate. Furthermore, because of the reduced transmission time interval of 2 ms, HS-DSCH allows to reduce signaling delays of downlink control messages. Also state transition to CELL\_DCH state can be accelerated.

Furthermore, the benefits of transmitting on HS-DSCH should also become available for CELL\_PCH and URA\_PCH states. This reduces signaling delays. Furthermore the possibility to transmit user data via HS-DSCH in CELL\_PCH state is introduced.

Table 17 provides an overview on the logical channels that may be transmitted on HS-DSCH in the different states.

Table 17 Support of logical channel transmission on HS-DSCH

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

The major differences to conventional HSDPA operation as of 3GPP release 5 / 6 can be summarized as follows for operation of HS-DSCH in CELL\_FACH, CELL\_PCH and URA\_PCH states:

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- 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 17
- 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

### 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 state.

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* 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.

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 shall switch to the associated HS-SCCHs and HS-PDSCHs. Figure 13 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  $T_{PICH}$  chips = 7680 chips (i.e. one subframe of three timeslots) after the transmitted PICH frame.

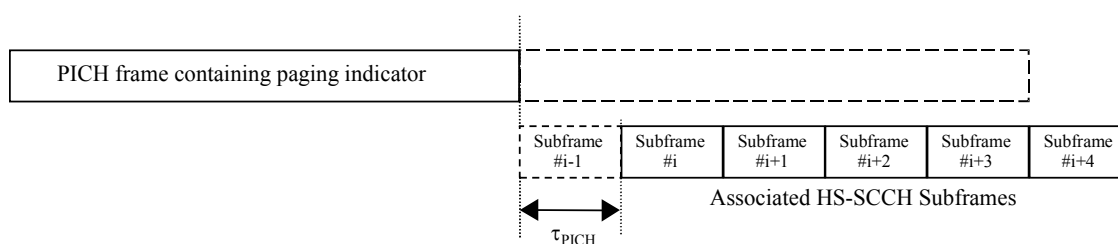


Figure 13 *Timing relation between PICH frame and associated HS-SCCH subframes*

Both operation with 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.

### 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. This information is also used when the UE is entering connected mode from idle mode by sending an RRC CONNECTION REQUEST message. 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 predefined 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 17, 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 13. 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).

### 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. In order 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 as well. 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.

### 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. After reception in the network, these measurements are then forwarded from radio network controller to base station via Iub interface and can be used as input for selecting the optimum modulation and coding scheme.

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).

### UE capabilities

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

## 7 Abbreviations

3GPP	3rd Generation Partnership Project
ACK	Acknowledgement
AM	Acknowledged Mode
Ant	Antenna
ARQ	Automatic Repeat Request
BCCH	Broadcast Control Channel
CCCH	Common Control Channel
CPC	Continuous Packet Connectivity
CPICH	Common Pilot Channel
CQI	Channel Quality Indicator
CRC	Cyclic Redundancy Check
DCCH	Dedicated Control Channel
DL	Downlink
DPCCH	Dedicated Physical Control Channel
DPDCH	Dedicated Physical Data Channel
DRX	Discontinuous Reception
DTCH	Dedicated Traffic Channel
DTX	Discontinuous Transmission
D-TxAA	Double Transmit Antenna Array
E-AGCH	E-DCH Absolute Grant Channel
E-DCH	Enhanced Dedicated Channel
E-DPDCH	Enhanced Dedicated Physical Data Channel
E-RGCH	E-DCH Relative Grant Channel
FACH	Forward Access Channel
FBI	Feedback Information
FDD	Frequency Division Duplex
HARQ	Hybrid Automatic Repeat Request

## **HSPA+**

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H-RNTI	HS-DSCH Radio Network Temporary Identifier
HSDPA	High Speed Downlink Packet Access
HS-DPCCH	High Speed Dedicated Physical Control Channel
HS-DSCH	High Speed Downlink Shared Channel
HSPA	High Speed Packet Access
HS-PDSCH	High Speed Physical Downlink Shared Channel
HS-SCCH	High Speed Shared Control Channel
HSUPA	High Speed Uplink Packet Access
IP	Internet Protocol
LCH	Logical Channel
MAC	Medium Access Control
MIMO	Multiple Input Multiple Output
NACK	Negative Acknowledgement
PAM	Pulse Amplitude Modulation
PCCH	Paging Control Channel
PCH	Paging Channel
PCI	Precoding Control Indication
P-CPICH	Primary Common Pilot Channel
PHY	Physical Layer
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
PCH	Paging Channel
PDU	Protocol Data Unit
PICH	Paging Indicator Channel
RACH	Random Access Channel
RAN	Radio Access Network
RAT	Radio Access Technology
RB	Radio Bearer
RF	Radio Frequency
RLC	Radio Link Control
RRC	Radio Resource Control
RV	Redundancy Version
S-CCPCH	Secondary Common Control Physical Channel
S-CPICH	Secondary Common Pilot Channel
SDU	Service Data Unit
SF	Spreading Factor
SI	Segmentation indication
TDD	Time Division Duplex



## **HSPA+**

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

## **8 Additional Information**

This application note is updated from time to time. Please visit the website [1MA121](#) to download the latest version.

Please send any comments or suggestions about this application note to [TM-Applications@rsd.rohde-schwarz.com](mailto:TM-Applications@rsd.rohde-schwarz.com).

## **9 References**

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- [2] 3GPP TS 25.214; Physical Layer Procedures (FDD), Release 7
- [3] 3GPP TS 25.211; Physical channels and mapping of transport channels onto physical channels (FDD), Release 7
- [4] 3GPP TS 25.212; Multiplexing and Channel Coding (FDD), Release 7
- [5] 3GPP TS 25.101; User Equipment (UE) radio transmission and reception (FDD), Release 7
- [6] 3GPP TS 25.321; Medium Access Control (MAC) protocol specification, Release 7



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