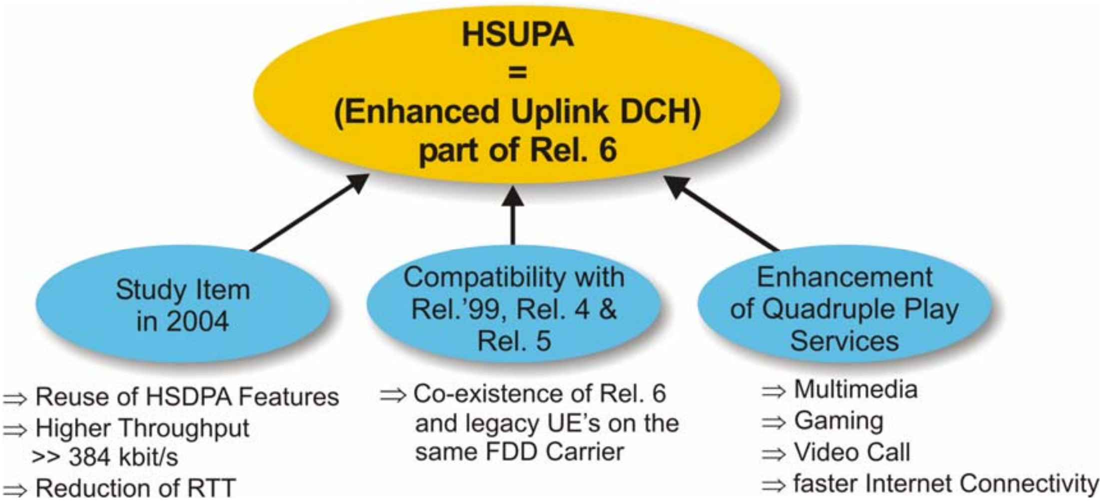
1.1 HSUPA Introduction



The objective of this section is firstly to indicate that the uplink of WCDMA is enhanced in Rel. 6 and secondly to explain the reasons behind for improving the uplink of WCDMA.

The key points of this section are:
1. The above three mentioned items lead to the creation of the HSUPA standard by 3GPP.
2. Well known HSDPA features were studied to see if they are also beneficial for the uplink performance in WCDMA.
3. Legacy and Rel. 6 UE's can operate independently in the same 5 MHz spectrum.
4. Triple Play (and Quadruple Play as HSUPA allows also for mobility) Services are efficiently transmitted over WCDMA networks. A more "intelligent" uplink channel is deployed in Rel. 6 with HSUPA, also known as E-DCH.

Study Item in 2004
In 3GPP RP-020658 a study item for enhancements of uplink DCH was approved. The justification of the study item was to improve the coverage and throughput as well as the delay of the uplink since the use of IP based services becomes more important in the long run than circuit switched services.
This study item includes topics related to HSDPA in order to enhance the uplink for UTRA FDD. In general the goal was to improve uplink performance and in particular for non-real time services. The following Rel. 5 features after successful completion of 1st release of HSDPA were tried:

- **Beneficial Items**
  ⇒ Fast Layer 1 Hybrid ARQ ⇔ adaptive coding

⇒ NodeB Controlled Scheduling
⇒ Shorter Frame Size (e.g. 2 ms TTI)

- **Less Beneficial Items**
  ⇒ Adaptive Modulation ⇔ no higher order modulation for FDD in release 6
  ⇒ Fast DCH Setup; was shifted to another release

- **Higher Throughput >> 384 kbit/s**
  HSUPA provides a flexible path beyond the 384 kbit/s uplink throughput. This data rate can be seen as the realistic maximum for WCDMA networks before HSUPA. With more and more sophisticated consumer applications the need for improved backhaul rises. If that bandwidth cannot be provided to the end user, loss of revenue may threaten operators. For example there are applications such as the “Slingbox” (visit: <http://www.slingbox.com>) which demands certain bandwidth in the uplink and more applications are surely to come with a similar or higher requirement for speed in the uplink

- **Abbreviations of this Section:**

3GTR	3rd Generation Technical Report	**HSDPA**	High Speed Downlink Packet Access (3GTS 25.301, 25.308, 25.401, 3GTR 25.848)
3GTS	3rd Generation Technical Specification	**HSUPA**	High Speed Uplink Packet Access (3GTS 25.301, 25.309, 25.401, 3GTR 25.896)
8-PSK	8 Symbol Phase Shift Keying	**RTT**	Round Trip Time (RFC 793)
ARIB	Association of Radio Industries and Businesses (Japanese)	**TDD**	Time Division Duplex
ARQ	Automatic Repeat Request	**TTI**	Transmission Time Interval
DCH	Dedicated Channel (Transport)	**UE**	User Equipment
DSL	Digital Subscriber Line	**UMTS**	Universal Mobile Telecommunication System
E-DCH	Enhanced Uplink Dedicated Transport Channel (3GTS 25.211, 25.309)	**UTRA**	UMTS (Universal Mobile Telecommunication System)Terrestrial Radio Access
ETSI	European Telecommunications Standard Institute	**WCDMA**	Wide-band Code Division Multiple Access
FDD	Frequency Division Duplex	**WiMax**	Worldwide Interoperability for Microwave Access (IEEE 802.16)

Compatibility with Rel. ’99, Rel. 4 and Rel. 5
It shall be possible to introduce the HSUPA features in the network having terminals from legacy releases and also operating both legacy and Rel. 6 UE’s on the same FDD Carrier. Another goal was that the UE and network complexity shall be minimized for a certain level of system performance, so to speak a cost efficient investment in network upgrade with quick pay off for the operator.

Enhancement of Quadruple Play Services
Quadruple play services are known as telecom services comprising of broadband internet, telephony, and TV, combined with mobility. Applications that could benefit from enhanced uplink may include services like video-clips upload, multimedia transfer, interactive gaming, video streaming etc. As competitive technologies like WiMax or W-LAN or DSL have started to take market share from 3G due to their partial mobility it is vital for 3GPP to provide a higher uplink throughput than just 384 kbit/s. Thus HSUPA in conjunction with HSDPA boosts the look and feel of applications run over WCDMA networks and operator can keep or even increase their subscriber base.
[3GTR 25.896]

Although HSUPA is the term used broadly in the market, in 3GPP the standardization for HSUPA was done under the name “enhanced uplink dedicated channel (E-DCH) work item. Both terms HSUPA and E-DCH are used interchangeable throughout this book.

Room for your Notes

- **Abbreviations for this Section:**

DSL	Digital Subscriber Line	**UMTS**	Universal Mobile Telecommunication System
E-DCH	Enhanced Uplink Dedicated Transport Channel (3GTS 25.211, 25.309)	**UTRA**	UMTS (Universal Mobile Telecommunication System) Terrestrial Radio Access
ETSI	European Telecommunications Standard Institute	**W-LAN**	Wireless Local Area Network (IEEE 802.11)
FDD	Frequency Division Duplex	**WCDMA**	Wide-band Code Division Multiple Access
HSDPA	High Speed Downlink Packet Access (3GTS 25.301, 25.308, 25.401, 3GTR 25.848)		

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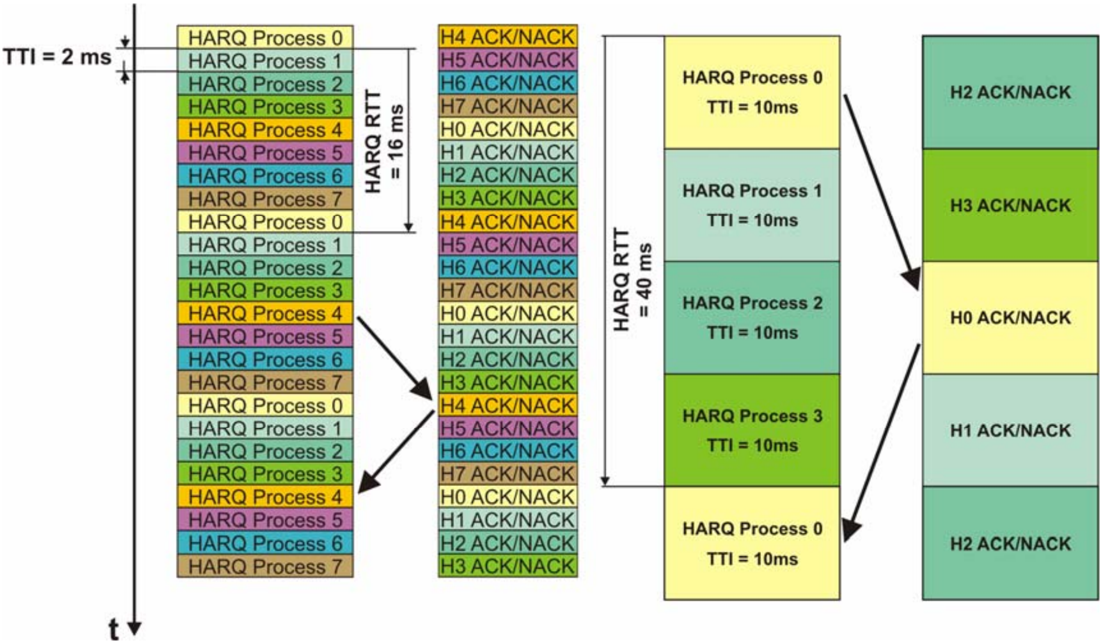
1.2.1 Overview on N-Stop & Wait Scheme



The objective of this section is to give an overview of the fast layer 1 HARQ protocol and how it relates to N-Stop & Wait.

The key points of this section are:

1. Stop & Wait scheme is a very basic automatic request and repeat protocol where the transmission and retransmission timing is pre-defined for every Stop & Wait process or respectively HARQ process. This allows operating without sequence numbering as the fix timing and order of HARQ processes make numbering obsolete.
2. HSUPA employs a synchronous N-Stop & Wait scheme in uplink <u>and</u> downlink with N = 8 in case of 2 ms TTI and N = 4 in case of 10 ms TTI. This means that the same HARQ process repeats in a pre-defined time interval. Therefore the UE knows exactly when it has to (re-)transmit and NodeB knows exactly when it will receive Data. On the other side the UE knows exactly when NodeB transmits the ACK/NACK info per HARQ process.
3. Stop & Wait enforces a tight delay requirement with the advantage of being able to limit the layer 1 buffer (soft-buffer in NodeB). However, a certain amount of HARQ processes is necessary in order to provide NodeB some processing time for E-DCH decoding and sending of ACK/NACK and on the reverse side UE needs again some time to prepare new or retransmissions. A Stop and Wait scheme with N > 1 is always a compromise between layer 1 buffer size, processing speed and RTT (re- or transmission time interval for the same process).

4. The TTI of 2 ms is optional whereas 10 ms TTI is mandatory for all HSUPA capable UE's.
5. With TTI of 2 ms a faster RTT of 16 ms is achieved compared to slower RTT of 40 ms with TTI = 10 ms.

Hybrid ARQ Protocol

The HARQ protocol is a retransmission protocol allowing the Node B to request retransmissions of incorrectly received data packets from UE. Furthermore, the NodeB can soft combine the retransmission with the original transmission to increase the likelihood that the packet can be decoded correctly. ACK/NACK information is conveyed to the terminal on the E-HICH (see chapter 1.4.1 for details) in the downlink. In order to overcome the limitations of the Stop-and-Wait type protocol, Hybrid ARQ processes are introduced. By this, packets can be transmitted continuously from the UE, without requiring to wait for the ACK/NACK response from the NodeB. In case of 10 ms TTI, 4 HARQ processes are configured (corresponding to 40 ms RTT). In case of 2 ms TTI, 8 HARQ processes are configured (= 16 ms RTT).

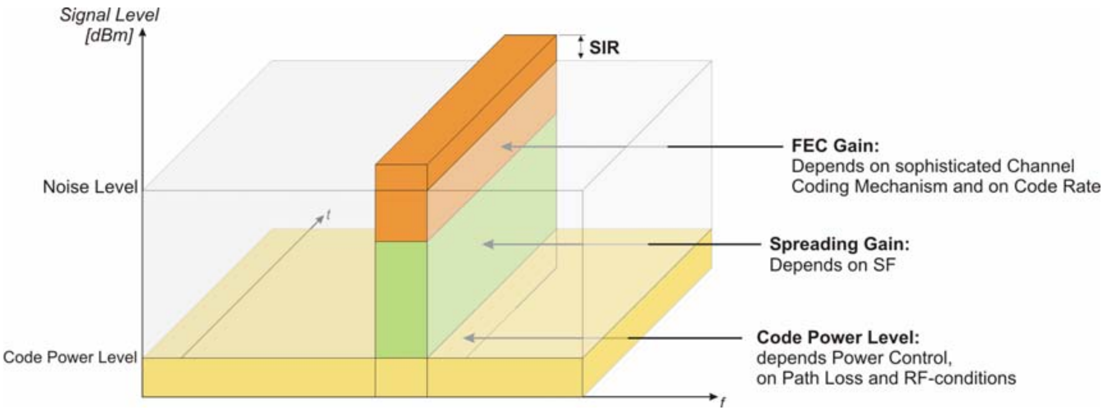
HARQ means that the physical layer stores the faulty block in the buffer, requests retransmissions and combines initial transmission with possible one or more retransmissions, thus the physical layer performs OSI Layer 2 tasks additional.

- **Abbreviations for this Section:**

ACK	Acknowledgement (3GTS 25.214, 25.308, 25.309)	**HSUPA**	High Speed Uplink Packet Access (3GTS 25.301, 25.309, 25.401, 3GTR 25.896)
ARQ	Automatic Repeat Request	**NACK**	Negative Acknowledgement (3GTS 25.214, 25.308, 25.309)
DCH	Dedicated Channel (Transport)	**HARQ RTT**	Round Trip Time of HARQ processes: The same HARQ process is served again after 16 ms (TTI = 2 ms) or 40 ms (TTI = 10 ms)
E-DCH	Enhanced Uplink Dedicated Transport Channel (3GTS 25.211, 25.309)		
E-HICH	E-DCH HARQ Acknowledgement Indicator Channel (3GTS 25.211)	**TTI**	Transmission Time Interval
HARQ	Hybrid ARQ (3GTS 25.212)		

1.3 Operation of HSUPA

1.3.1 Review: SIR Considerations in a CDMA-system



The objective of this section is to illustrate how any CDMA-system achieves a given SIR.

Key points of this section are that:
1. A CDMA-system can usually transmit at a very low output power level because of the inherent spreading gain. Tendency: The higher the spreading factor the lower the output power can be.
2. Of course, this rule works both ways: In HSUPA with a spreading factor of only 2, almost no more spreading gain is left which ultimately requires an increase of the output power level on the UE-side.
3. Ultimately, this increases the noise level for all other users which means that simultaneous operation of multiple HSUPA-users with full throughput rate is not possible.

- **More Information**
  - ⇒ One of the most critical issues in every CDMA-system is power control, because each user is an interferer for each other user. The power control mechanism needs to be fast enough to cope with the rapidly changing RF-conditions and it needs to provide for the absolute minimum output power that provides for the ordered SIR (Signal to Interference Ratio).
  - ⇒ As the figure illustrates, the signal level of one user does not only depend on the RSCP (Received Signal Code Power). CDMA allows hiding a signal underneath the noise level, because it is particularly the spreading gain and the channel coding gain which allows recovering a user data signal from the spread signal.

⇒ At any given time, the overall signal level depends on the code power (⇔transmit power), on the spreading gain and on the channel coding gain. In UTRA, the spreading gain varies between 6 dB and 27 dB. The channel coding gain is app. 6 dB (1/2-rate convolutional coding) – 9.5 dB (1/3-rate turbo coding).

- **The Consequences are:**
  ⇒ The required output power can be reduced by the same amount of dB which is added to the overall signal level through the channel coding gain and the spreading gain.
  ⇒ Vice versa, if high throughput rates and therefore low spreading factors (⇔ small spreading gain) are requested, the necessary output power needs to be increased accordingly.

Spreading Gain

⇒ 10 x LOG10(SF)

Example: SF256 ⇔ spreading gain = 10 x LOG10(256) = 24 dB

- **Abbreviations for this Section:**

CDMA	Code Division Multiple Access	**SF**	Spreading Factor
FEC	Forward Error Correction	**SIR**	Signal to Interference Ratio
HSUPA	High Speed Uplink Packet Access (3GTS 25.301, 25.309, 25.401, 3GTR 25.896)	**UE**	User Equipment
RF	Radio Frequency	**UTRA**	UMTS (Universal Mobile Telecommunication System) Terrestrial Radio Access
RSCP	Received Signal Code Power (3GTS 25.215)	**dBm**	The unit dBm measures a power. The conversion of a power value from Watt [W] to dBm is done in the following way:X [dBm] = 10 x log10(X [W] / 0.001 [W])
SF	Spreading Factor obtained from OVSF-tree		

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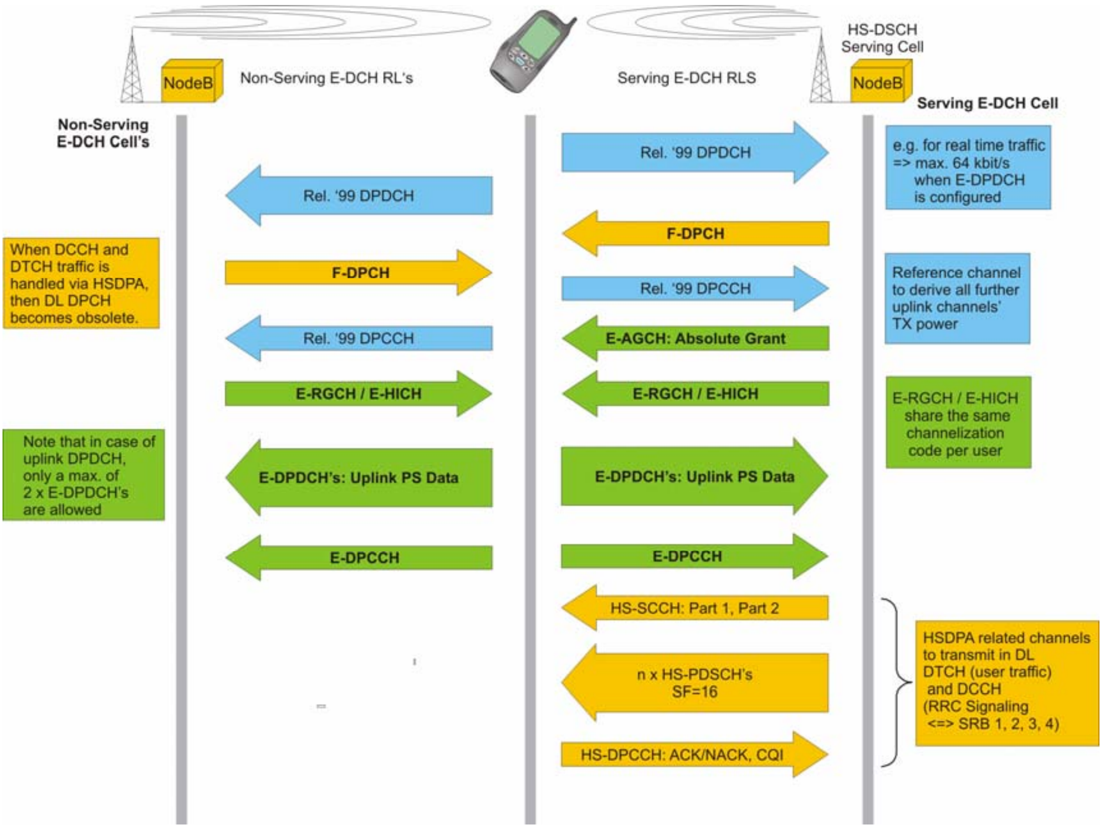
1.4.3 Operation of HSPA and Rel. '99 Channels



The objective of this section is to show all channels a Rel. 6 UE may get assigned for CS and PS operation at the same time. The channel combination could be called "Rel. '99 + HSDPA + HSUPA. The above figure would correspond to a UE being allocated in CELL_DCH state with a TrCH combination of "HS-DSCH / E-DCH + DCH".

The key points of this section are:

1. Serving E-DCH Cell and HS-DSCH serving cell are always identical. [3GTS 25.309 (6.3.2)]
2. The serving E-DCH RLS may consist of one or more RL's (cells) whereas the non-serving E-DCH RL's are independently <=> every non-serving E-DCH cell may operate independently on RGCH.
3. If the E-DCH serving RLS contains several RL's, then a soft combining of E-DPDCH and E-DPCCH as well DPCCH (and also DPDCH is available) is performed in uplink. At the same time in downlink, only one ACK/NACK and RG is transmitted via all E-HICH's and E-RGCH's part of the E-DCH serving RLS.

Within the HSUPA framework, the E-DCH is introduced as a new transport channel for carrying user data on the uplink. With it comes a bunch of other supporting physical channels. The figure above depicts a UE operating HSUPA and HSDPA as well handling F-DPCH instead of regular DL DPCH.

- **Control Plane Uplink**
  ⇒ Rel. '99 DPCCH: Layer 1 Control <=> TPC (Fast Inner Loop Power Control); TFCI signaling, uplink channel estimation through PILOT Bits
  ⇒ Rel. '99 DPDCH: e.g. used for carrying DCCH's (SRB1, 2, 3 and 4)
  ⇒ Rel. 6 E-DPCCH: Sending of E-TFCI and Happy-bit.
  ⇒ Rel. 5 HS-DPCCH: HSDPA feedback channel providing ACK/NACK and DL quality reporting through CQI to HS-DSCH serving cell (= E-DCH serving Cell).

- **Control Plane Downlink**
  ⇒ E-AGCH is only transmitted from the serving E-DCH cell.
  ⇒ E-HICH and E-RGCH are transmitted from radio links that are part of the serving E-DCH RLS and from non-serving E-DCH RL's. Both physical channels **share** the same channelization code @ SF128 and use QPSK modulation. They are differentiated by a signature hopping pattern as described in chapter 2.
  ⇒ F-DPCH can be used in downlink alternatively to DPCH. It has been introduced in Rel. 6 in order to optimize the downlink channelization code usage for HSDPA UE's.
  ⇒ Rel. '99 DL DPCH (DPCCH/DPDCH) – actual not needed anymore in case of non-real time traffic as DTCH and DCCH are both supported via HS-DSCH and E-DCH in Rel. 6.
  ⇒ Rel. 5 HS-SCCH is necessary in downlink as HSDPA uses an asynchrony (re-) transmission scheme with a flexible order of HARQ processes. Compared to that HSUPA uses a dedicated channel – not a shared channel and does not need a shared control, rather a dedicated physical control channel is needed to signal the transport block size used on E-DPDCH's.

- **User Plane Uplink**
  ⇒ E-DPDCH('s) – support of non-real time PS services and maybe also streaming services (in the near future).
  ⇒ Rel. '99 UL DPDCH – max. 64 kbit/s is allowed with E-DPDCH configured at the same time. CS services (real time) like AMR 12.2 could be handled. [3GTS 25.301, 302]

- **User Plane Downlink**
  ⇒ DPDCH / DCH's
  ⇒ HS-PDSCH's / HS-DSCH

- **Serving E-DCH Radio Link Set**
  Set of cells which contains at least the Serving E-DCH cell and from which the UE can receive and combine one Relative Grant. The UE has only one Serving E-DCH RLS. So the serving RLS is determined by the UTRAN if the cells in the same NodeB being in the E-DCH active set should also transmit the same RG like the E-DCH serving cell.

- **Non-Serving E-DCH Radio Link(‘s)**
  Cell’s which belong to the E-DCH active set but do not belong to the Serving E-DCH RLS and from which the UE can receive one Relative Grant. The UE can have zero, one or several non-serving E-DCH RL(‘s). The UTRAN wants to indicate to the UE, that these non-serving E-DCH cells transmit independent RG’s.

- **Serving E-DCH cell**
  Cell from which the UE receives Absolute Grants from the NodeB scheduler. A UE has one Serving E-DCH cell.

Table 2: Uplink DPCCH Field – Slot Format

Slot Format #i	Channel Bit Rate (kbit/s)	Channel Symbol Rate (ksps)	SF	Bits/ Frame	Bits/ Slot	N pilot	N TPC	N TFCI	N FBI	Trans-mitted 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

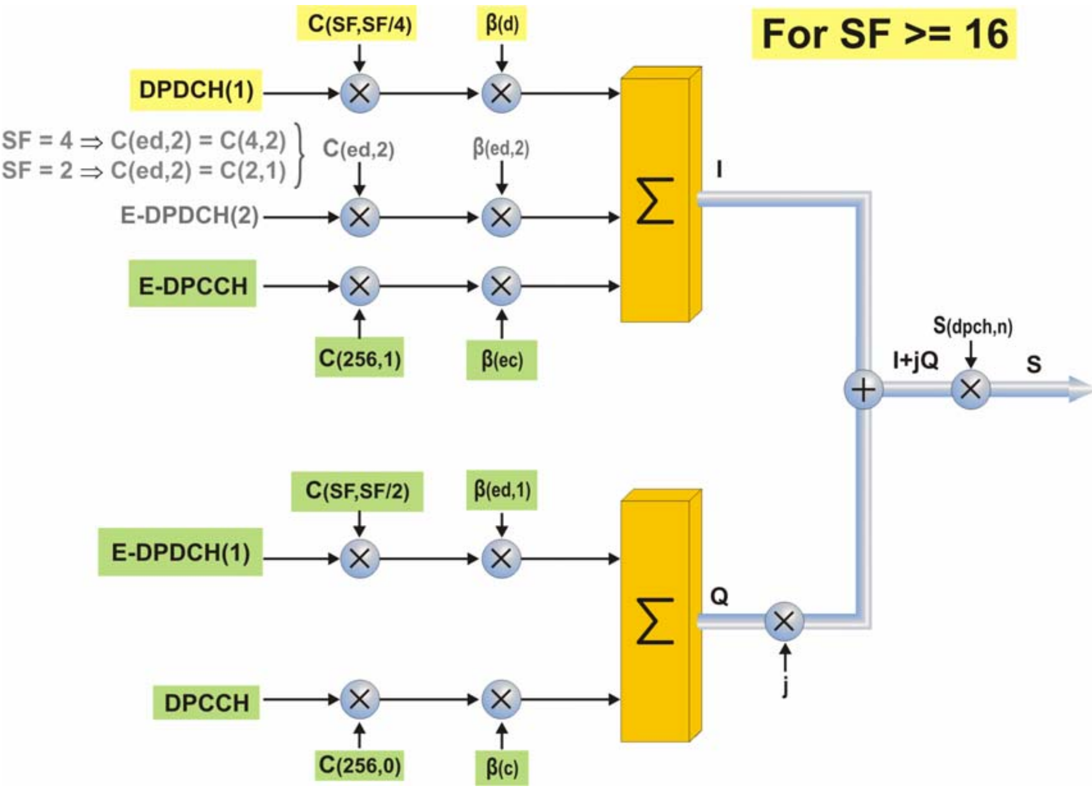
In uplink the slot format #1 is used in case that uplink DPDCH is not configured as both DCCH’s and DTCH(‘s) are mapped on E-DCH. Therefore no TFCI bits are necessary as no TFC has to be conveyed to the NodeB.

Room for your Notes

- **Abbreviations for this Section:**

AMR	Adaptive Multirate Encoding (3GTS 26.090)	**HS-DSCH**	High Speed Downlink Shared Transport Channel (3GTS 25.211, 25.212, 25.308)
CELL_DCH	RRC State where the UE needs to perform fast power control and soft handover in order to limit the interference	**HS-PDSCH**	High Speed Physical Downlink Shared Channel (3GTS 25.211)
CQI	Channel Quality Indicator (3GTS 25.214)	**HS-SCCH**	High Speed Shared Control Channel (3GTS 25.211, 25.214)
CS	Circuit Switched	**HSDPA**	High Speed Downlink Packet Access (3GTS 25.301, 25.308, 25.401, 3GTR 25.848)
DCCH	Dedicated Control Channel (UMTS Logical Channel)	**HSPA**	High Speed Packet Access (operation of HSDPA and HSUPA)
DPCH	Dedicated Physical Channel (UMTS / Term to combine DPDCH and DPCCH)	**PILOT**	Pilot bits are known bits used for channel estimation and slot synchronization purpose
DTCH	Dedicated Traffic Channel (UMTS Logical Channel)	**QPSK**	Quadrature Phase Shift Keying (3GTS 25.213)
E-AGCH	E-DCH Absolute Grant Channel (3GTS 25.211)	**RG**	Relative Grant (3GTS 25.309)
E-DCH	Enhanced Uplink Dedicated Transport Channel (3GTS 25.211, 25.309)	**RL**	Radio Link (3GTS 25.433)
E-DPCCH	Enhanced Uplink Dedicated Physical Control Channel (3GTS 25.211)	**RLS**	Radio Link Set (3GTS 25.309, 25.433)
E-DPDCH	Enhanced Uplink Dedicated Physical Data Channel (3GTS 25.211)	**SF**	Spreading Factor obtained from OVSF-tree
E-HICH	E-DCH HARQ Acknowledgement Indicator Channel (3GTS 25.211)	**SRB**	Signaling Radio Bearer
E-RGCH	E-DCH Relative Grant Channel (3GTS 25.211)	**TFC**	Transport Format Combination
E-TFCI	E-DCH Transport Format Combination Identifier (Enhanced Dedicated Channel)	**TFCI**	Transport Format Combination Identifier
F-DPCH	Fractional Dedicated Physical Channel (3GTS 25.211)	**TPC**	Transmit Power Command
FBI	Feedback Indicator Information (used for closed loop downlink transmit diversity)	**TrCH**	Transport Channel (UMTS)

1.4.4.5 DPCCH + 1 x DPDCH + 1 x E-DPDCH



The objective of this section is to show a possible uplink physical channel combination of E-DCH with only one E-DPDCH(1) being spread on Q-plane.

The key points of this section are:
1. The mapping of E-DPDCH's follows a specific order depending on the number of E-DPDCH's, DPDCH being configured or not and whether HSDPA is configured or not.
2. If DPDCH is configured only up to two E-DPDCH's are possible. Note that only one DPDCH is allowed to be used in conjunction with E-DPDCH's.
3. BPSK modulation scheme is used for E-DPDCH and E-DPCCH.
4. The E-DPCCH is transmitted using a channelization code of 256,1 and is always mapped on I-plane.
5. The green color coding of the physical channels should highlight the realistic channels being deployed / configured in the networks.

I-Q Branch Mapping for E-DPDCH:
Note that "1 in column "iq(ed,k)" means that the E-DPDCH is mapped on I-branch and "j" means that the E-DPDCH is mapped on Q-branch.

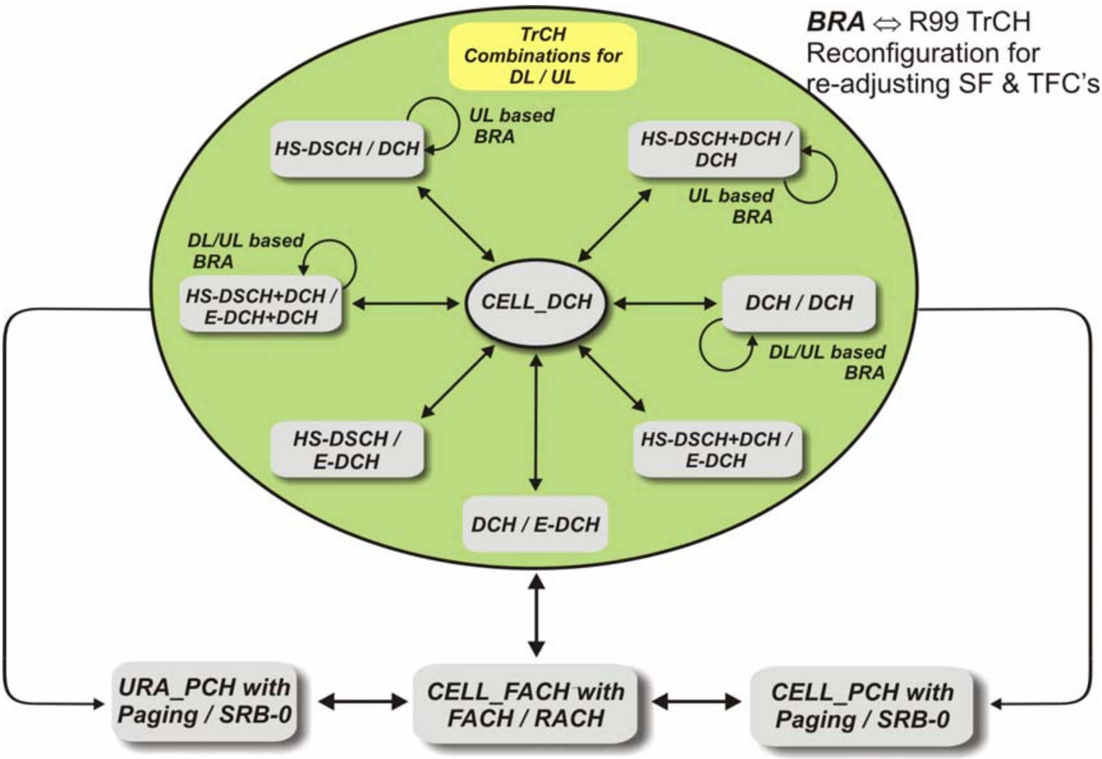
N(max-dpdch)	**HS-DSCH configured**	**E-DPDCH(k)**	**iq(ed,k)**
0	No/Yes	E-DPDCH$_1$	1
		E-DPDCH$_2$	j
		E-DPDCH$_3$	1
		E-DPDCH$_4$	j
1	No	E-DPDCH$_1$	j
		E-DPDCH$_2$	1
1	Yes	E-DPDCH$_1$	1
		E-DPDCH$_2$	j

For all HSUPA mobile categories, the uplink UL DPCH capability with simultaneous E-DCH configuration is limited to 64 kbit/s when E-DCH is configured for the radio link. [3GTS 25.306 (4.12), 3GTS 25.309 (6.2)]

Maximum Number of E-DCH Codes transmitted
Defines the maximum number of E-DCH codes and spreading factors the UE is capable of transmitting. The UE can support 1, 2 or 4 E-DPDCH's using either SF=2 or/and SF=4. [3GTS 25.306 (4.5.4)]

UL DPCH capability with simultaneous E-DCH configuration	**64 kbit/s**
Transport Channel Parameters	
Maximum sum of number of bits of all transport blocks being transmitted at an arbitrary time instant	3840
Maximum sum of number of bits of all convolutionally coded transport blocks being transmitted at an arbitrary time instant	640
Maximum sum of number of bits of all turbo coded transport blocks being transmitted at an arbitrary time instant	3840
Maximum number of simultaneous transport channels	8
Maximum total number of transport blocks transmitted within TTI's that end at the same time	8
Maximum number of TFC	32
Maximum number of TF	32
Support for turbo encoding	Yes
Physical Channel Parameters (FDD)	
Maximum number of DPDCH bits transmitted per 10 ms	2400 ⇔ SF = 16

1.7.3 Transport Channel Type Switching with HSUPA



The objective of this section is to indicate the most important RRC states and especially for CELL_DCH the various TrCH combinations possible with HSDPA / HSUPA and DCH.

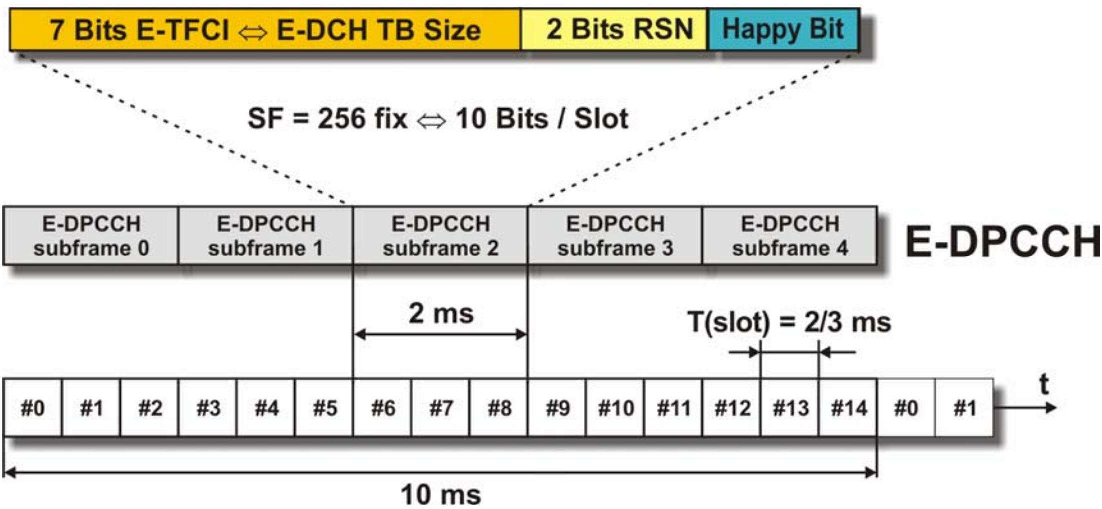
The key points of this section are:
1. Up to 6 different TrCH combinations in CELL_DCH state are possible in Rel. 6 but it is very likely that the UTRAN will not configure all possible combinations. However, HSUPA capable UE's must support all of them.
2. HS-DSCH / E-DCH without downlink DCH may not be used in the first phase of HSUPA deployment because of the danger transferring SRB's over a shared channel. On the other side, E-DCH is safer to be used for carrying DCCH's as it is still a dedicated channel and a minimum E-TFCI can be configured by UTRAN allowing always the transmission of RRC signaling even zero grant or no grant has been issued.
3. CELL_DCH with HS-DSCH + DCH / E-DCH will be the most likely TrCH combination followed by HS-DSCH + DCH / E-DCH + DCH if GBR services like voice should be handled at the same time however, NodeB scheduler and / or PS core network are not yet capable of handling them via HS-DSCH and E-DCH.

In CELL_DCH state the SRNC has following TrCH multiplexing options:
The RB's can be multiplexed with transport channel type "DCH + HS-DSCH" for the DL, when both the corresponding DCH transport channel and MAC-d flow are configured, and with transport channel type "E-DCH" for the UL, when the corresponding E-DCH MAC-d flow is configured.
Or
The RB's can be multiplexed with transport channel type "DCH + HS-DSCH" for the DL, when both the corresponding DCH transport channel and MAC-d flow are configured, and with transport channel type "DCH" for the UL, when the corresponding DCH transport channel is configured.
Or
The RB's can be multiplexed with transport channel type "HS-DSCH" for the DL, when the corresponding MAC-d flow is configured, and with transport channel type "E-DCH" for the UL, when the corresponding E-DCH MAC-d flow is configured.
Or
The RB's can be multiplexed with transport channel type "HS-DSCH" for the DL, when the corresponding MAC-d flow is configured, and with transport channel type "DCH" for the UL, when the corresponding DCH transport channel is configured.
Or
The RB's can be multiplexed with transport channel type "DCH" for the DL, when the corresponding DCH transport channel is configured, and with transport channel type "E-DCH" for the UL, when the corresponding E-DCH MAC-d flow is configured.
Or
The RB's can be multiplexed with transport channel type "DCH" for the DL, when the corresponding DCH transport channel is configured, and with transport channel type "DCH" for the UL, when the corresponding DCH transport channel is configured.
[3GTS 25.331 (8.5.21)]

- **Abbreviations for this Section:**

BRA	Bit Rate Adaptation (other term is DBC), Adjusting the SF and TFCS in downlink and/or uplink	**HS-DSCH**	High Speed Downlink Shared Transport Channel (3GTS 25.211, 25.212, 25.308)
DCCH	Dedicated Control Channel (UMTS Logical Channel)	**MAC-d**	Medium Access Control for the Dedicated Transport Channel (3GTS 25.321)
DCH	Dedicated Channel (Transport)	**RB**	Radio Bearer
DSCH	Downlink Shared Channel (UMTS Transport Channel)	**RRC**	Radio Resource Control (3GTS 25.331)
E-DCH	Enhanced Uplink Dedicated Transport Channel (3GTS 25.211, 25.309)	**SF**	Spreading Factor obtained from OVSF-tree
E-TFCI	E-DCH Transport Format Combination Identifier (Enhanced Dedicated Channel)	**SRB**	Signaling Radio Bearer (SRB1-4)
FACH	Forward Access Channel (UMTS Transport Channel)	**TFCI**	Transport Format Combination Identifier
GBR	Guaranteed Bit Rate Service	**TrCH**	Transport Channel (UMTS)

2.1.2 E-DPCCH Frame Structure



The objective of this section is to explain the E-DPCCH a new uplink physical channel used for transmitting out-of-band information about E-DPDCH transmission from UE to the NodeB.

The key points of this section are:
The E-DPCCH slot format is fix and does not distinguish between 2 ms TTI or 10 ms TTI. In the latter case, three slots comprise one subframe and five subframes are transmitted with 10 ms.
The E-DPCCH exists in parallel to all uplink legacy dedicated channels and always accompanies E-DPDCH transmission.
To some extent the E-DPCCH does the same for E-DPDCH transmission as the DPCCH does for DPDCH – that is, the control channel delivers the info needed to decode the corresponding data channel transmission.
The control channel info consists of transport blocks size info, HARQ scheme usage and a fast indicator for the NodeB scheduler if the UE is satisfied with the SG allocation.

> Note that the slot structure of E-DPCCH remains the same for both E-DCH TTI's. If the TTI length of the E-DPDCH is 10 ms for example, then the 30-bit E-DPCCH subframe is repeated five times allowing reduced power level. With this procedure the same E-DPCCH structure can be employed regardless of the TTI used.

E-DPCCH Fields and Details

- ⇒ There is at most one E-DPCCH on each radio link.
- ⇒ E-DPCCH (and E-DPDCH) are always transmitted simultaneously, except for the case that E-DPDCH but not E-DPCCH is DTX'd due to power scaling (e.g. max. UE TX Pwr reached).

⇒ E-DPCCH shall not be transmitted in a slot unless DPCCH is also transmitted in the same slot.

The figure above shows the E-DPCCH (sub)frame structure. Each radio frame is divided in 5 subframes, each of length 2 ms; the first subframe starts at the start of each radio frame and the 5th subframe ends at the end of each radio frame. The E-DPCCH slot format is listed in 3GTS 25.211 table 5C.

- Table 5C: E-DPCCH Slot formats

Slot Format #i	Channel Bit Rate (kbit/s)	SF	Bits/ Frame	Bits/ Subframe	Bits/Slot N data
0	15	256	150	30	10

E-TFCI

E-DCH transport Block sizes from 18 Bits … 20000 Bits is signaled on E-DPCCH by UE depending on E-DCH TTI and table index: Note that per TTI two tables are defined in 3GTS 25.321 (Annex B). In essence, from the E-TFCI the NodeB can derive how many E-DPDCH's are transmitted by UE in parallel and what SF is used.

Information Field Mapping of Retransmission Sequence Number

To indicate the redundancy version (RV) of each HARQ transmission and to assist the NodeB soft buffer management a two bit retransmission sequence number (RSN) is signaled from the UE to the Node B. The Node B can avoid soft buffer corruption by flushing the soft buffer associated to one HARQ process in case more than 3 consecutive E DPCCH transmissions on that HARQ process can not be decoded or the last received RSN is incompatible with the current one.

Note that UTRAN may configure for E-DCH MAC-d flow the maximum number of retransmissions (range: 0…15) according to 3GTS 25.331 (10.3.5.1b)

Happy Bit Meaning

The UE is not "happy" when it has power available to send data at higher rates and the total buffer content would require more than X ms to be transmitted with the current SG times the ratio of active processes to the total number of processes (that ratio is always “1” for TTI = 10 ms).

3GTS 25.212 (4.9.2.3) Table 16A

"Happy" bit	*Bit Value*
Happy	1
Not happy	0

⇒ One bit of the E-DPCCH is used to indicate whether or not the UE is satisfied (‘happy’) with the current Serving Grant. This bit shall always be present during uplink transmission of E-DPCCH.

The UE shall indicate that it is ‘unhappy’ if the following criteria are met:

1) UE is transmitting as much scheduled data as allowed by the current Serving Grant; and

2) UE has enough power available to transmit at higher data rate; and

3) Total buffer status would require more than Happy_Bit_Delay_Condition of x ms (configured by RRC) to be transmitted with the current Serving_Grant × the ratio of active processes to the total number of processes.

⇒ The first criteria is always true for a deactivated process and the ratio of the third criteria is always 1 for 10ms TTI.

⇒ If one of the three above criteria is not fulfilled, the UE shall indicate that it is ‘happy’.

[3GTS 25.309 (9.3.1.2)]

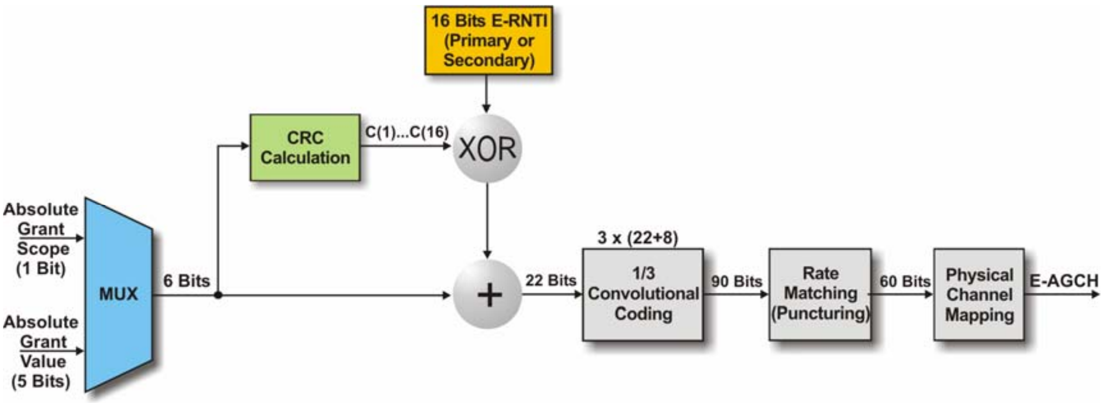
Room for your Notes

Room for your Notes

- **Abbreviations for this Section:**

DCH	Dedicated Channel (Transport)	**MAC-d**	Medium Access Control for the Dedicated Transport Channel (3GTS 25.321)
DPCCH	Dedicated Physical Control Channel (UMTS Physical Channel)	**RSN**	Retransmission Sequence Number (HSUPA)
DPDCH	Dedicated Physical Data Channel(UMTS Physical Channel)	**SF**	Spreading Factor
DTX	Discontinuous Transmission	**SG**	Serving Grant respectively Power Grant (3GTS 25.213, 25.309, 25.321)
E-DCH	Enhanced Uplink Dedicated Transport Channel (3GTS 25.211, 25.309)	**TB**	Transport Block
E-DPCCH	Enhanced Uplink Dedicated Physical Control Channel (3GTS 25.211)	**TFCI**	Transport Format Combination Identifier
E-DPDCH	Enhanced Uplink Dedicated Physical Data Channel (3GTS 25.211)	**TTI**	Transmission Time Interval
E-TFCI	E-DCH Transport Format Combination Identifier (Enhanced Dedicated Channel)	**TX**	Transmit
HARQ	Hybrid ARQ (3GTS 25.212)	**UE**	User Equipment
MAC	Medium Access Control (UMTS 3GTS 25.321)	**UTRAN**	UMTS (Universal Mobile Telecommunication System) Terrestrial Radio Access Network

2.2.6.1 E-AGCH Processing Chain



The objective of this section is to show the multiplexing and channel coding of E-AGCH message bits from NodeB point of view. The UE must do the reverse decoding!

The key points of this section are:

1. Primary / secondary UE-id or primary / secondary E-DCH radio network temporary identity is used to mask the CRC of the E-AGCH. Therefore only the right UE applying the correct E-RNTI gets a correct CRC out for the six messages bits out of an E-AGCH subframe.
2. Each UE may have up to two UE-ids for E-DCH operation which it checks from E-AGCH and if it detects one or the other as matching (via CRC) it knows that the E-AGCH was destined for it.
3. The UE must be able of decoding both E-RNTI's in parallel as it does not know if the NodeB scheduler sends a primary or secondary AG.

The following information is transmitted by means of the absolute grant channel (E AGCH):

- Absolute Grant Value: 5 Bits
- Absolute Grant Scope:1 Bit

The Absolute Grant Value information is explained in the next section.

E-AGCH Coding

The E AGCH sub frame is described in previous section. The six message bits are multiplexed according to 3GPP rule. Then a 16-bit CRC value is added respectively appended to the six message bits. The 16 CRC bits are generated out of the six message bits in order to allow for error detection in the receiver. However before the CRC bits are added to the message bits, they are masked / XOR'd with the proper E-RNTI. The new total of 22 bits is then coded using 1/3 convolutional encoder with 8 registers inside thus 8 tailbits (zero bits) must be added to those 22 bits. The output of the encoder delivers 90 encoded bits which must be rate matched / punctured down to 60 bits according to 3GPP rule.

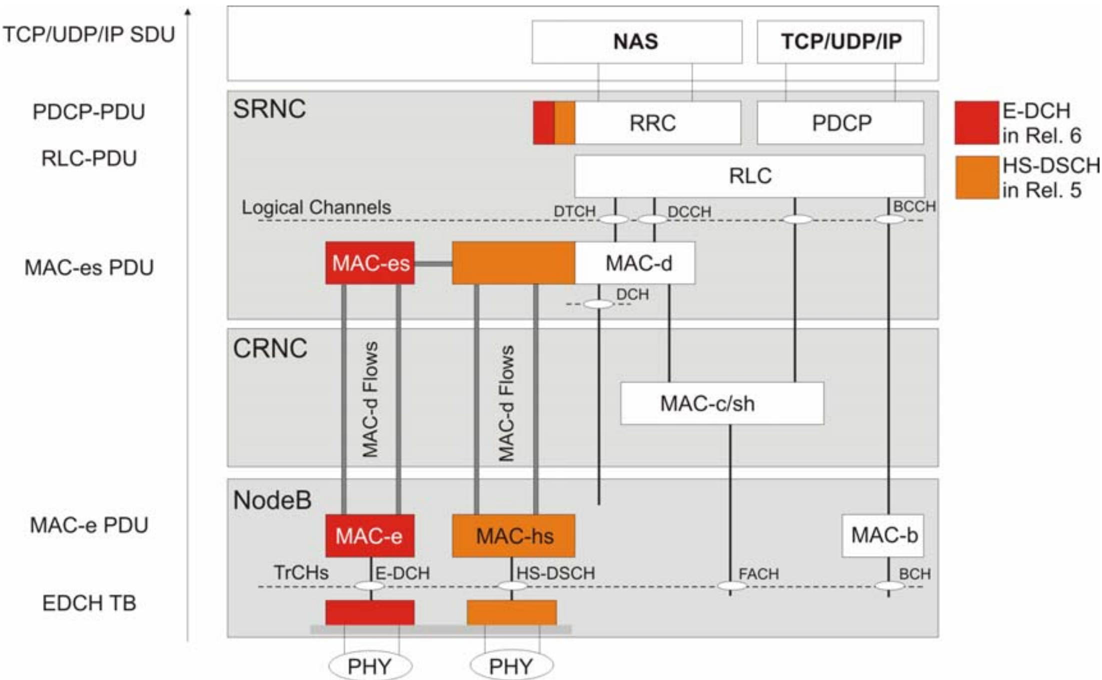
[3GTS 25.212 (4.10.2, 4.10.3, 4.10.4, 4.10.5)]

Room for your Notes

- **Abbreviations for this Section:**

AG	Absolute Grant (3GTS 25.309)	**E-DCH**	Enhanced Uplink Dedicated Transport Channel (3GTS 25.211, 25.309)
AGCH	Access Grant Channel (GSM)	**E-RNTI**	E-DCH Radio Network Temporary Identifier (3GTS 25.401)
CRC	Cyclic Redundancy Check	**MUX**	Multiplex
DCH	Dedicated Channel (Transport)	**RNTI**	Radio Network Temporary Identifier
E-AGCH	E-DCH Absolute Grant Channel (3GTS 25.211)	**XOR**	Exclusive-Or Logical Combination

3.2. E-DCH UTRAN Architecture



The objective of this section is to show the evolution of UTRAN architecture from Rel. 5 to Rel. 6 and highlight the enhancements / protocol additions.

The key points of this section are:
1. E-DCH requires additions to RRC for configuring and re-configuring E-DCH and physical channels of HSUPA.
2. RLC UM and AM remain unchanged.
3. Note that E-DCH only carries MAC-d PDU's of RLC-UM / RLC-AM entities.
4. There is a new MAC-es entity required in SRNC with link to MAC-d
5. A New MAC-e entity is required in the NodeB, however, several MAC-e entities may serve one UE in case of SHO

Overall architecture

The detailed UTRAN MAC architecture, which is shown in the next few sections, includes a new MAC-e entity and a new MAC-es entity. For each UE that uses E-DCH, one MAC-e entity per NodeB and one MAC-es entity in the SRNC are configured. MAC-e, located in the NodeB, controls access to the E-DCH and is connected to MAC-es, located in the SRNC. MAC-es is further connected to MAC-d. For control information, new connections are defined between MAC-e and a MAC Control SAP in the NodeB, and between MAC-es and the MAC Control SAP in the SRNC.

There is one Iub transport bearer per MAC-d flow (i.e. MAC-es PDU's carrying MAC-d PDU's from the same MAC-d flow).
[3GTS 25.309 (7.3)]

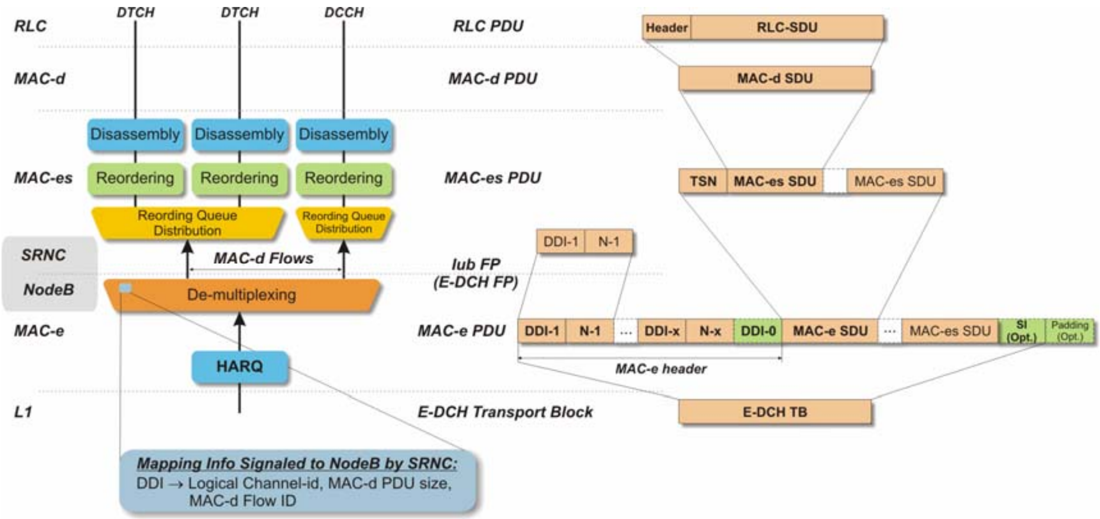
Room for your Notes

- **Abbreviations for this Section:**

AM	Acknowledged Mode operation (e.g. in UMTS-RLC)	**RLC**	Radio Link Control (UMTS 3GTS 25.322)
MAC	Medium Access Control (UMTS 3GTS 25.321)	**RRC**	Radio Resource Control (3GTS 25.331)
MAC-d	Medium Access Control for the Dedicated Transport Channel (3GTS 25.321)	**SDU**	Service Data Unit (the payload of a PDU)
MAC-e	MAC-E-DCH (3GTS 25.321)	**SRNC**	Serving Radio Network Controller
MAC-es	MAC-E-DCH SRNC (3GTS 25.321)	**TB**	Transport Block
MAC-hs	MAC-High Speed (3GTS 25.308, 25.321)	**TCP**	Transmission Control Protocol
NAS	Non-Access-Stratum (UMTS)	**UDP**	User Datagram Protocol (RFC 768)
PDCP	Packet Data Convergence Protocol (3GTS 25.323)	**UM**	Unacknowledged Mode operation (UMTS-RLC)
PDU	Protocol Data Unit or Packet Data Unit		

3

3.3.3 MAC-d / Flow Interworking in UTRAN



The objective of this section is to highlight that in UTRAN and UE the same MAC-d flow can serve several logical channels which are mapped onto different MAC-es PDU's.

The key points of this section are:
The DDI field is the important parameter in the MAC-e PDU to allow the transport of complicated traffic types, e.g. an application requiring two logical channels, one for audio and one for video.
The signaling bearers are a good example for multiplexing even RLC-AM and RLC-UM within the same MAC-d flow but always on different MAC-es PDU's.

Reordering entity
The re-ordering entity is part of a separate MAC sub-layer, MAC-es, in the SRNC. Data coming from different MAC-d flow's are reordered in different reordering queues. There is one reordering queue per logical channel.
The reordering is based on a specific TSN included in the MAC-es PDU and on NodeB tagging with a (CFN, subframe number). For each MAC-es PDU, the SRNC receives the TSN originating from the UE, as well as the (CFN, subframe number) originating from the NodeB to perform the re-ordering. Additional mechanisms (e.g. timer-based and/or window-based) are up to SRNC implementation and are not standardized. Furthermore, the reordering entity detects and removes duplicated received MAC-es PDU's.

As shown in figure above, a MAC-e PDU enters MAC from layer 1. After Hybrid ARQ handling, the MAC-e PDU is de-multiplexed to form MAC-es PDU's aimed for one or more MAC-d flow's. The DDI field in the MAC-e PDU supports the de-multiplexing of MAC-es PDU's and MAC-d PDU's onto the correct MAC-d flow. The mapping between the DDI and the MAC-d flow and MAC-d PDU size is provided to the NodeB by the SRNC. The mapping of the MAC-d flow into its Iub bearer is defined by the SRNC. A special value of the DDI field indicates that no more data is contained in the remaining part of the MAC-e PDU but a scheduling Info reports is appended. The MAC-es PDU's are sent over Iub to MAC-es, where they are distributed on the reordering queue of each logical channel. After re-ordering, the in-sequence data units are disassembled. The resulting MAC-d PDU's are forwarded to MAC-d and RLC.
[3GTS 25.309 (7.1.2)]

Room for your Notes

- **Abbreviations for this Section:**

AM	Acknowledged Mode operation (e.g. in UMTS-RLC)	**MAC-d**	Medium Access Control for the Dedicated Transport Channel (3GTS 25.321)
ARQ	Automatic Repeat Request	**MAC-e**	MAC-E-DCH (3GTS 25.321)
DCCH	Dedicated Control Channel (UMTS Logical Channel)	**MAC-es**	MAC-E-DCH SRNC (3GTS 25.321)
DCH	Dedicated Channel (Transport)	**PDU**	Protocol Data Unit or Packet Data Unit
DDI	Data Description Indicator (3GTS 25.309, 25.331)	**RLC**	Radio Link Control (UMTS 3GTS 25.322)
DTCH	Dedicated Traffic Channel (UMTS Logical Channel)	**SDU**	Service Data Unit (the payload of a PDU)
E-DCH	Enhanced Uplink Dedicated Transport Channel (3GTS 25.211, 25.309)	**SI**	Service Indicator
FP	Frame Protocol	**SRNC**	Serving Radio Network Controller
HARQ	Hybrid ARQ (3GTS 25.212)	**TB**	Transport Block
L1	Layer 1 (physical layer)	**TSN**	Transmission Sequence Number (3GTS 25.321)
MAC	Medium Access Control (UMTS 3GTS 25.321)	**UM**	Unacknowledged Mode operation (UMTS-RLC)