S-72.4210 PG Course in Radio Communications
Fall 2005

High-Speed Downlink Packet Access
HSDPA -
Improving the WCDMA downlink

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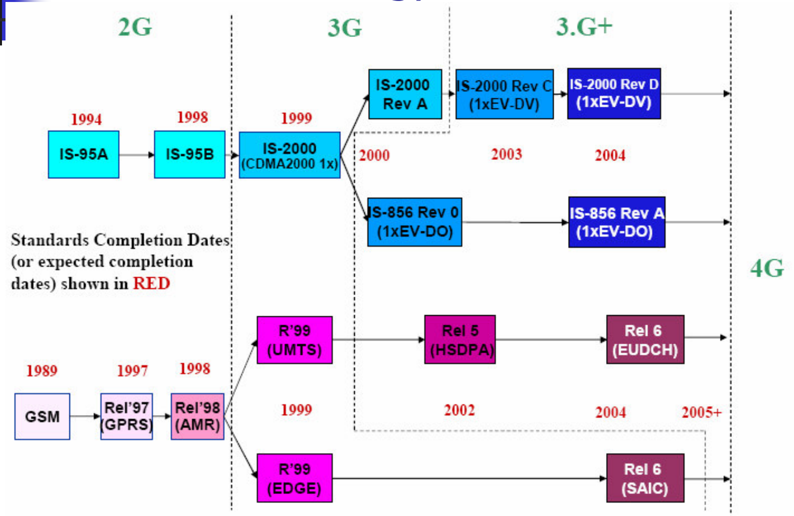
Contents

Cellular Technology Evolution



3GPP Release 5 functionally frozen in March 2002.

HSPDA and CDMA2000 1xEV-DV

Collaboration with 3GPP2:

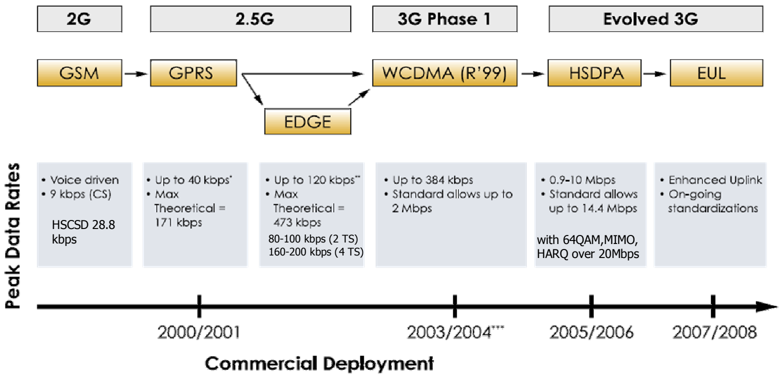
- 2001 Harmonization of HSDPA (3GPP) and 1xEV-DV (3GPP2)
  - Various issues noted: terminal design; services; spectrum; implications of All-IP
  - Initial attention on: common definitions for channel and traffic models; common physical requirements for future terminal designs
- June 2002 - Joint meeting of radio experts
  - radio-related aspects of HSDPA / 1xEV-DV harmonization

Feature	HSDPA	1xEV-DV
Downlink Frame Size	2ms TTI (3 Slots)	1.25, 2.5, 5, 10 ms Variable Frame Size (1.25 ms Slot size)
Channel Feedback	Channel quality reported at 2ms rate or 500 Hz	C/I feedback at 800 Hz (every 1.25 ms)
Data user multiplexing	TDM/CDM	TDM/CDM (variable frame)
Adaptive Modulation and Coding	QPSK & 16-QAM Mandatory	QPSK, 8-PSK & 16-QAM
Hybrid-ARQ	Chase or Incremental Redundancy (IR)	Async. Incremental Redundancy (IR)
Spreading Factor	SF=16 using UTRA OVSF Channelization Codes	Walsh Code Length 32
Control Channel Approach	Dedicated Channel pointing to Shared Channel	Common Control Channel

HSPDA and CDMA2000 1xEV-DV Comparison

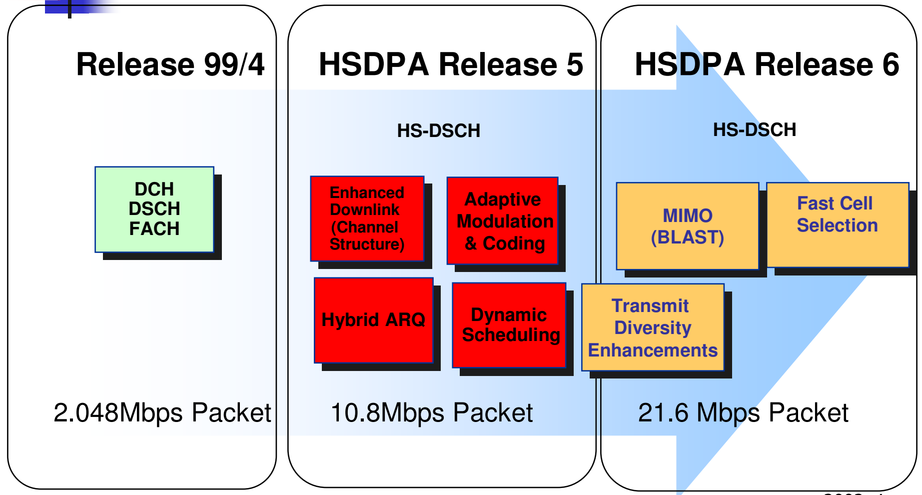
HSDPA Evolution

HSDPA is evolved from and backward compatible with R'99 WCDMA systems;
co-exists with R'99 in the same frequency band of 5MHz .



LATENCY
GPRS & EDGE around 600ms, Improved GPRS around 450ms
WCDMA – 200ms
HSDPA – 100ms

UMTS R99 Evolution to HSDPA



2002 view

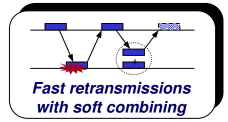
What does HSDPA offer?

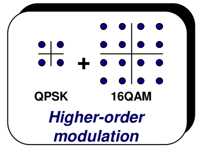
- **Speed**
  - Supports services requiring instantaneous high data rates in the downlink e.g. Internet browsing; video on demand; office applications
  - Faster downstream throughput
    - offering data rates of up to 10 Mbit/s and more (typically five times higher cf. WCDMA 2Mbit/s)
    - peak data rates many times higher than current 3G
      - ≈14 Mbps (theoretical), actual peak data rate depends on e.g. channel conditions, with MIMO ~ 20
      - peak data rate comparable to current wireless LAN at much lower cost per MB than current 2.5 and 3G solutions (typically one-fifteenth cf. GPRS and one-fifth cf. Release 99)
- Significant **capacity** increase
  - 3-4 times improved system capacity (Rel.5/6) at relatively low cost
  - 100-200% improvement for "best-effort" packet data (e.g. web-browsing)
  - Improved capacity also for streaming services (≈50%)
- **Reduced** (round-trip) **delay,** with HSDPA round trip times can be reduced to below 100 ms.
  - Quicker response time with interactive services
  - Higher data rates
  - Shorter TTI
  - Fast retransmissions
- Network **coverage**
  - Short time to market with existing sites, no new sites are needed (UMTS network architecture)
  - Simultaneous single carrier support for UMTS and R5 HSDPA (today you can run voice, video and PS data on the same carrier. Also HSDPA can run on the same carrier or on a separate carrier).
- Improved end-user quality
- Improved overall efficiency when interacting with higher-layer protocols
- Deployed in both Frequency Division Duplex (FDD) and Time Division Duplex (TDD) modes (both high and low chip rates)

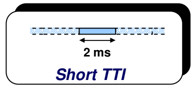
How will HSDPA do it? → HSDPA Features

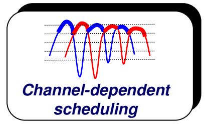
Basic principle: Adapt to variations in instantaneous radio-channel conditions!

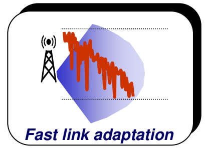
- Convenient and inexpensive to overlay on existing 3GPP systems
  - in some cases just a software upgrade
- More efficient processing
  - centred on base stations and thus closer to users
- Decreasing delay due to transmission errors, faster error correction
  - Fast Retransmissions and Hybrid Automatic Repeat Request (H-ARQ)
- Improving resources management - innovative, additional transport channel
  - High-Speed Downlink Shared CHannel (HS-DSCH)
- Adapting to environment
  - Adaptive Modulation and Coding - performance matched to user's priority and operating environment
- Fast scheduling
  - Channel Quality Feedback
- MIMO
- Decreasing HO failure
  - Fast cell site selection





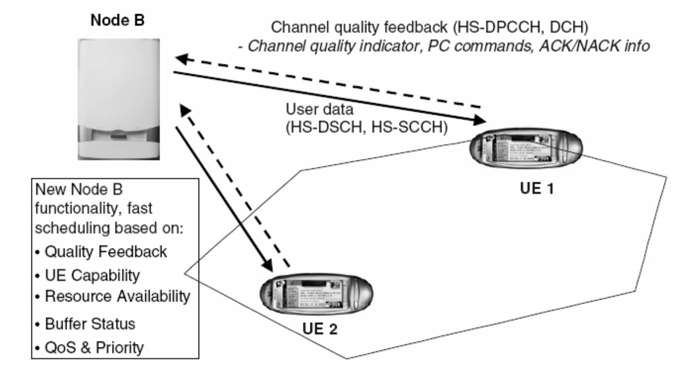






General functionality of HSDPA

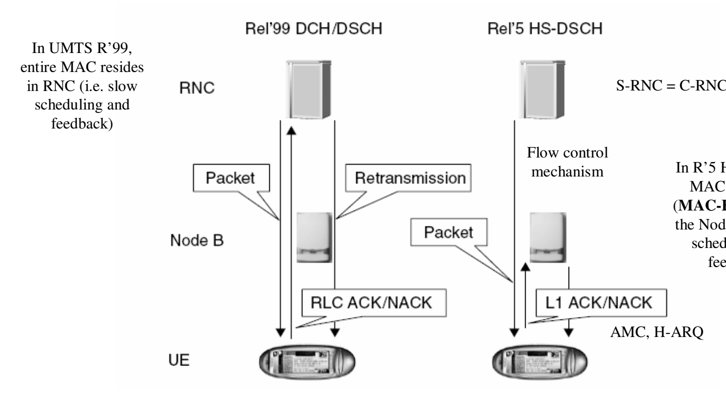
Large delays of the existing Radio Network Controller (RNC)-based Automatic Repeat reQuest ARQ architecture result in unrealistic amounts of memory on the terminal side. Thus, **architectural changes** are needed to arrive at feasible memory requirements as well as to bring the control for link adaptation closer to the air interface.



HSDPA is 3G performance enhancement technology.

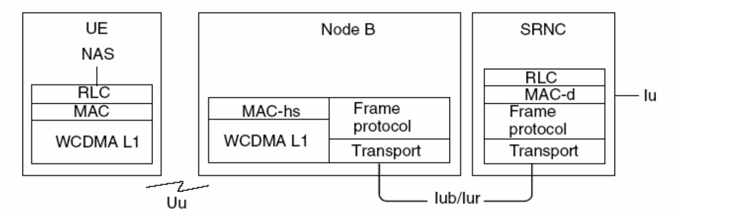
It does not change the core network, but only the radio interface in the downlink direction!

HSDPA Impact on Radio Access Network Architecture



Release'99 and Release 5 HSDPA retransmission control in the network

HSDPA Protocol architecture (user plane)



The key functionality of the new Node B MAC functionality (MAC-hs) is to handle the Automatic Repeat Request (ARQ) functionality and scheduling as well as priority handling. Scheduling strategy determines overall system behaviour. Mixed scheduling strategies can be implemented.

The RNC still retains the Rel'99/Rel'4 functionalities of the Radio Link Control (RLC), such as taking care of the retransmission in case the HS-DSCH transmission from the Node B would fail after, for instance, exceeding the maximum number of physical layer retransmissions.

Ciphering is done in any case in the RLC layer to ensure that the ciphering mask stays identical for each retransmission to enable physical layer combining of retransmissions.

Release '99 WCDMA Downlink Packet Data Capabilities

Channels in Release'99/Release 4 WCDMA specifications that can be used for downlink packet data are:

Dedicated Channel (DCH)

- used for any type of service
- fixed spreading factor (SF) in the downlink (it reserves the code space capacity according to the peak data rate for the connection). This can be used even up to 2 Mbps, but reserving the code tree for a very high peak rate with low actual duty cycle is not a very efficient use of code resources
- power-controlled and may be operated in soft handover

Downlink-shared Channel (DSCH)

- operates always together with a DCH. This way,channel properties can be defined to best suit packet data needs while leaving the data with tight delay budget, such as speech or video, to be carried by the DCH.
- dynamically varying SF informed on a 10-ms frame-by-frame basis with the Transport Format Combination Indicator (TFCI) signalling carried on the associated DCH.
- The DSCH code resources can be shared between several users and the channel may employ either single-code or multi-code transmission.
- fast power-controlled with the associated DCH but does not support soft handover. The associated DCH can be in soft handover, for example, speech is provided on DCH if present with packet data.

Forward Access Channel (FACH)

- carried on the secondary common control physical channel (S-CCPCH)
- operated normally on its own
- sent with a fixed SF and typically at rather high-power level to reach all users in the cell owing to the lack of physical layer feedback in the uplink
- no fast power control or soft handover for FACH
- cannot be used in cases in which simultaneous speech and packet data service is required

DSCH and HS-DSCH comparison

Feature	DSCH	HS-DSCH
Variable spreading factor	Yes	No
Fast power control	Yes	No
Adaptive modulation and coding (AMC)	No	Yes
Multi-code operation	Yes	Yes, extended
Fast L1 HARQ	No	Yes

Note: HARQ: Hybrid Automatic Repeat reQuest.

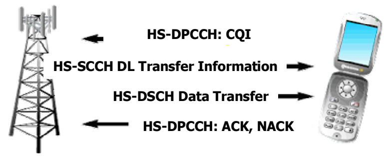
With HSDPA, two of the most fundamental features of WCDMA, variable SF and fast power control, are disabled and replaced by means of *adaptive modulation and coding,* extensive multi-code operation and a fast and spectrally efficient retransmission strategy!

With HSDPA, power control is now utilised by the link adaptation function and AMC to select a coding and modulation combination that requires higher *Ec/Ior*, which is available for the user close to the Node B (or with good interference/channel conditions in short-term sense). To enable a large dynamic range of the HSDPA link adaptation and to maintain a good spectral efficiency, a user may simultaneously utilise up to 15 multi-codes in parallel.
The use of more robust coding, fast Hybrid Automatic Repeat Request (HARQ) and multi-code operation removes the need for variable SF.

HSDPA Physical Layer Structure - Additional Physical Channels

The HSDPA is operated similar to DSCH together with DCH, which carries the services with tighter delay constraints, such as AMR speech.

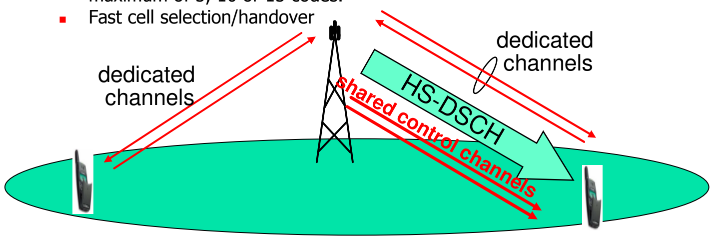
- High Speed Physical Downlink Shared Channel (HS-PDSCH)
  - HS-Downlink Shared Channel (HS-DSCH) carries the user data in the downlink direction, with the peak rate reaching up to 10-Mbps range with 16QAM (quadrature amplitude modulation).
  - HS-Shared Control Channel (HS-SCCH) carries the necessary physical layer control information to enable decoding of the data on HS-DSCH and to perform the possible physical layer combining of the data sent on HS-DSCH in case of retransmission or an erroneous packet.



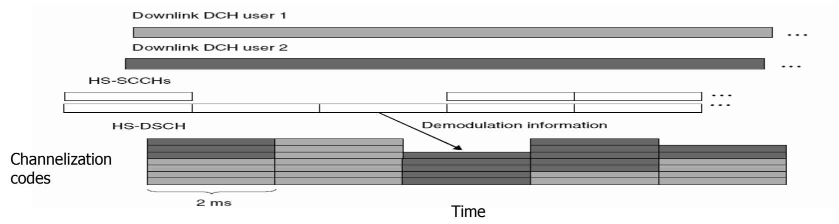
- Uplink High Speed Dedicated Physical Control Channel (HS-DPCCH) carries the necessary control information in the uplink, namely, ARQ acknowledgements (both positive and negative ones) and downlink quality feedback information.

HS-DSCH characteristics

- The high speed "Fat pipe" on which the packet data are transmitted
- Provision of 8 –10 Mbps peak user data rate by
  - Fast selection of modulation and coding scheme depending on channel conditions (no fast power control); adding higher order modulation scheme, 16 QAM
  - Short Transmission Time Interval (TTI), duration 2 ms (3 slots) [TTI sizes supported in Rel.'99 10,20,40,80ms]
    - to achieve short round-trip delay for the operation between the terminal and Node B for retransmissions while the channel is shared between several users
  - Fast hybrid ARQ (incremental redundancy and/or Chase combining)
  - Fast scheduling
  - SF is fixed; it is always 16, and multi-code transmission as well as code multiplexing of different users can take place. The maximum number of codes that can be allocated is 15, but depending on the terminal (UE) capability, individual terminals may receive a maximum of 5, 10 or 15 codes.
  - Fast cell selection/handover



HS - Downlink Shared Channel (HS-DSCH)



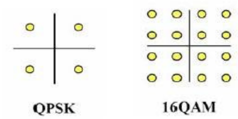
Shared channel transmission: Code multiplexing example with two active users

Two users are using the same HS-DSCH. Both users check the information from the HS-SCCHs to determine which HS-DSCH codes to despread as well as other parameters necessary for correct detection.

Adaptive Modulation & Coding (AMC)

- Link adaptation schemes:
  - Goal: efficient allocation of transmit resources to compensate for channel variations
  - Examples: power control and AMC
- Modulation & coding depends on channel quality condition
- Modulation Schemes:
  - QPSK (R´99)
  - 16QAM (addition to R´99)
- Different Code Rates used
  - 1/4, 1/2, 5/8 and ¾

QPSK and 16QAM constellations



Adaptive Modulation & Coding (AMC)

- 16QAM doubles the peak data rate compared to QPSK and allows up to 10-Mbps peak data rate with 15 codes of SF 16.
- The use of higher-order modulation is not without cost.
  - With Release'99 channels only a phase estimate is necessary for the demodulation process.
  - With 16QAM
    - amplitude estimation is required to separate the constellation points
    - more accurate phase information is needed since constellation points have smaller differences in phase domain compared to QPSK
  - The HS-DSCH capable terminal needs to obtain an estimate of the relative amplitude ratio of the DSCH power level compared to the pilot power level and this requires that Node B should not adjust the HS-DSCH power between slots if 16QAM is used in the frame. Otherwise, the performance is degraded as the validity of an amplitude estimate obtained from Common Pilot Channel (CPICH) and estimated power difference between CPICH and HS-DSCH would no longer be valid.

Modulation and Coding Schemes (Example)

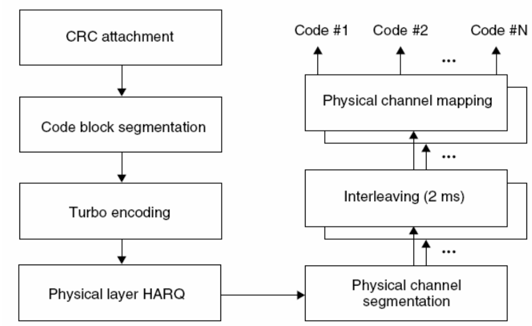
64QAM,	R=0.75	(12.96 Mbps)
64QAM,	R=0.50	(8.64 Mbps)
16QAM,	R=0.63	(7.20 Mbps)
16QAM,	R=0.38	(4.32 Mbps)
QPSK,	R=0.50	(2.88 Mbps)
QPSK,	R=0.25	(1.44 Mbps)

for 12 codes (of 16)

Hybrid – Automatic Repeat reQuest (H-ARQ)

- Provide Link Layer Retransmissions
- Moved From RNC to Node-B
- The physical layer packet combining means that the terminal stores the received data packets in soft memory and if decoding has failed, the new transmission is combined with the old one before channel decoding.
- Use two Schemes - Chase/Soft Combining (CC) and Incremental Redundancy (IR)
  - CC: the retransmission is identical to the first transmission
  - IR: contains different bits compared with the channel encoder output that was received during the last transmission.
- The IR method has a slightly better performance (one can achieve a diversity gain as well as improved decoding efficiency) but it also needs more memory in the receiver, as the individual retransmissions cannot be just added.
  - The terminal default memory requirements are done on the basis of soft combining and at maximum data rate (supported by the terminal). Hence, at the highest data rate, only soft combining may be used, while with lower data rates, also incremental redundancy can be used.

HS-DSCH channel coding chain



The HS-DSCH channel coding has some simplifications when compared to R'99:
- only one transport channel active on the HS-DSCH, the blocks related to the channel multiplexing for the same users can be left out
- interleaving only spans over a single 2ms period and there is no separate intra-frame or inter-frame interleaving
- turbo coding is the only coding scheme used

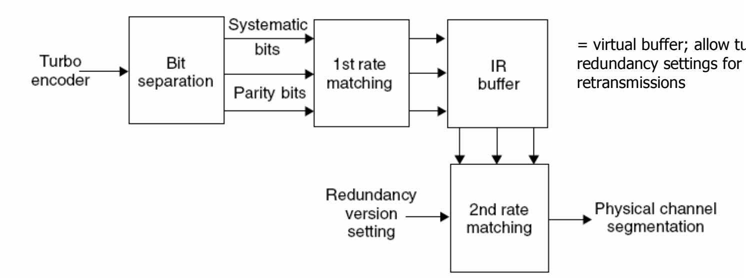
The major difference is the addition of the hybrid ARQ (HARQ) functionality!

When using QPSK, the R'99 channel interleaver is used and when using 16QAM, two parallel (identical) channel interleavers are applied.

The HSDPA-capable Node B has the responsibility to select the transport format to be used along with the modulation and number of codes on the basis of the information available at the Node B scheduler.

H-ARQ function principle

Two-stage rate-matching



= virtual buffer; allow tuning of the redundancy settings for different retransmissions

HS-DSCH vs. other Downlink Channel Types for Packet Data

Channel	HS-DSCH	DSCH	Downlink DCH	FACH
Spreading factor	Fixed, 16	Variable (256-4) frame-by-frame	Fixed, (512-4)	Fixed (256-4)
Modulation	QPSK/16QAM	QPSK	QPSK	QPSK
Power control	Fixed/slow power setting	Fast, based on the associated DCH	Fast with 1500 kHz	Fixed/slow power setting
HARQ	Packet combining at L1 (*)	RLC level	RLC level	RLC level
Interleaving	2 ms	10–80 ms	10–80 ms	10–80 ms
Channel coding schemes	Turbo coding	Turbo and convolutional coding	Turbo and convolutional coding	Turbo and convolutional coding
Transport channel multiplexing	No	Yes	Yes	Yes
Soft handover	For associated DCH	For associated DCH	Yes	No
Inclusion in specification	Release 5	Release'99	Release'99	Release'99

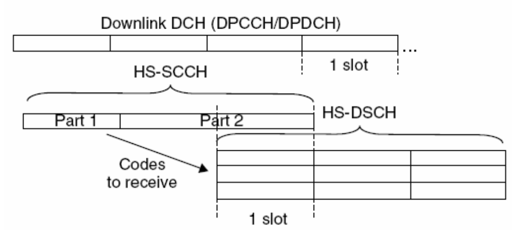
In all cases except for the DCH, the packet data itself is not operated in soft handover.
(*) The HARQ operation with HS-DSCH will also be employed at the RLC level if the physical layer ARQ timers or the maximum number of retransmissions are exceeded.

High-Speed Shared Control Channel (HS-SCCH)

HS-SCCH carries the key information necessary for HS-DSCH demodulation.

- The UTRAN needs to allocate a number of HS-SCCHs that correspond to the maximum number of users that will be code-multiplexed.
- Each terminal will only need to consider a maximum of **4** HS-SCCHs at a given time. The HS-SCCHs that are to be considered are signalled to the terminal by the network.
- Each HS-SCCH block has a three-slot duration that is divided into two functional parts.
  - The HS-SCCH Part 1: The first slot carries the time-critical information that is needed to start the demodulation process in due time to avoid chip level buffering.
    - Codes to despread. This also relates to the terminal capability in which each terminal category indicates whether the current terminal can despread a maximum of 5, 10 or 15 codes.
    - Modulation to indicate if QPSK or 16QAM is used.
  - The HS-SCCH Part 2: The next two slots contain less time-critical parameters including Cyclic Redundancy Check (CRC) to check the validity of the HS-SCCH information and HARQ process information.
    - Redundancy version information to allow proper decoding and combining with the possible earlier transmissions.
    - ARQ process number to show which ARQ process the data belongs to.
    - First transmission or retransmission indicator to indicate whether the transmission is to be combined with the existing data in the buffer (if not successfully decoded earlier) or whether the buffer should be flushed and filled with new data.
  - For protection, both HS-SCCH parts employ terminal-specific masking to allow the terminal to decide whether the detected control channel is actually intended for the particular terminal.
  - Parameters such as actual channel coding rate are not signalled but can be derived from the transport block size and other transport format parameters.
- The HS-SCCH uses SF 128 that can accommodate 40 bits per slot (after channel encoding) because there are no pilot or Transmit Power Control (TPC) bits on HS-SCCH.
- The HS-SCCH used half-rate convolution coding with both parts encoded separately from each other because the time-critical information is required to be available immediately after the first slot and thus cannot be interleaved together with Part 2.

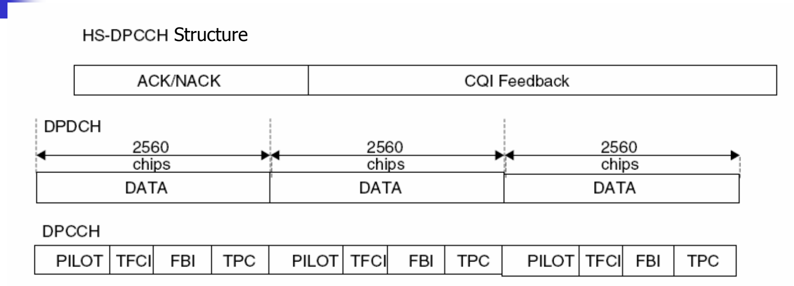
High-Speed Shared Control Channel (HS-SCCH)



HS-SCCH and HS-DSCH timing relationship

- The terminal has a single slot duration to determine which codes to despread from the HS-DSCH.
- The use of terminal-specific masking allows the terminal to check whether data was intended for it.
- The total number of HS-SCCHs that a single terminal monitors (the Part 1 of each channel) is at a maximum of 4, but in case there is data for the terminal in consecutive TTIs, then the HS-SCCH shall be the same for that terminal between TTIs to increase signalling reliability.
- The downlink DCH timing is not tied to the HS-SCCH (or consequently HS-DSCH) timing.

Uplink High-speed Dedicated Physical Control Channel (HS-DPCCH)



It was required to ensure operation in soft handover in the case that not all Node Bs have been upgraded to support HSDPA -> leave existing uplink channel structure unchanged and add the needed new information elements on a parallel code channel *Uplink* HS-DPCCH.

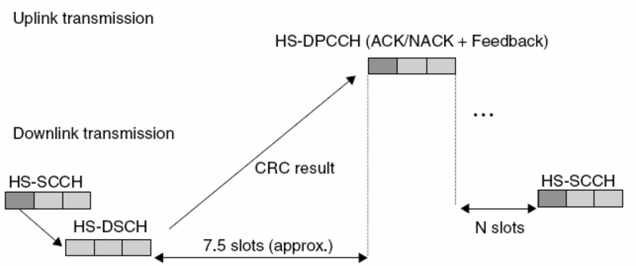
The HS-DPCCH is divided into 2 parts and carries the following information to be used in the Node B scheduler to determine to which terminal to transmit and at which data rate:

- ACK/NACK transmission, to reflect the results of the CRC check after the packet decoding and combining.
- Downlink Channel Quality Indicator (CQI) to indicate which estimated transport block size, modulation type and number of parallel codes could be received correctly (with reasonable BLER) in the downlink direction.

HSDPA Physical Layer Operation Procedure

- The scheduler in the **Node B** (vendor-specific implementation issue) evaluates for different users what are the channel conditions, how much data is pending in the buffer for each user, how much time has elapsed since a particular user was last served, for which users retransmissions are pending and so forth.
- Once a terminal has been determined to be served in a particular TTI, the Node B identifies the necessary HS-DSCH parameters, for instance, how many codes are available or can be filled, can 16 QAM be used and what are the terminal capability limitations? The terminal soft memory capability also defines which kind of HARQ can be used.
- The Node B starts to transmit the HS-SCCH two slots before the corresponding HS-DSCH TTI to inform the terminal of the necessary parameters. The HS-SCCH selection is free (from the set of maximum four channels) assuming there was no data for the terminal in the previous HS-DSCH frame.
- The **terminal** monitors the HS-SCCHs given by the network and once the terminal has decoded Part 1 from an HS-SCCH intended for that terminal, it will start to decode the rest of that HS-SCCH and will buffer the necessary codes from the HS-DSCH.
- Upon having the HS-SCCH parameters decoded from Part 2, the terminal can determine to which ARQ process the data belongs and whether it needs to be combined with data already in the soft buffer.
- Upon decoding the potentially combined data, the terminal sends in the uplink direction an ACK/NACK indicator, depending on the outcome of the CRC check conducted on the HS-DSCH data.
- If the network continues to transmit data for the same terminal in consecutive TTIs, the terminal will stay on the same HS-SCCH that was used during the previous TTI.

HSDPA Physical Layer Operation Procedure

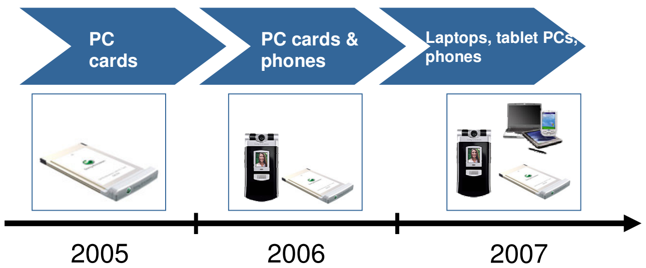


Terminal timing with respect to one HARQ process (timing relation ship between DL and UL)

- The HSDPA operation procedure has strictly specified timing values for the terminal operation from the HS-SCCH reception via HS-DSCH decoding to the uplink ACK/NACK transmission.
- The key timing value from the terminal point of view is the 7.5 slots from the end of the HS-DSCH TTI to the start of the ACK/NACK transmission in the HS-DPCCH in the uplink.
- The network side is asynchronous in terms of when to send a retransmission in the downlink (different amounts of time can be spent on the scheduling process in the network side).
- Terminal capabilities do not impact the timing of an individual TTI transmission but do define how often one can transmit to the terminal. The capabilities include information of the minimum inter-TTI interval that tells whether consecutive TTIs may be used or not. Value 1 indicates that consecutive TTIs may be used, while values 2 and 3 correspond to leaving a minimum of one or two empty TTIs between packet transmissions.

HSDPA Terminals

- New terminals are required to take advantage of HSDPA:
  - PC-cards will be the first on the market (end of 2005)
  - In the 1st phase terminals will offer:
    - Download 3,6 Mbps end user throughput
    - Upload 384 kbps
  - Hand-held terminals will follow
  - In a 2nd phase, peak data rates are increased to:
    - Download 14 Mbps
    - Upload 384 kbps



HSDPA Terminal Capability

Category	Maximum number of parallel codes HS-DSCH	Minimum inter-TTI interval	Transport channel bits per TTI	ARQ type at maximum data rate	Achievable maximum data rate (Mbps)
1	5	3	7300	Soft	1.2
2	5	3	7300	IR	1.2
3	5	2	7300	Soft	1.8
4	5	2	7300	IR	1.8
5	5	1	7300	Soft	3.6
6	5	1	7300	IR	3.6
7	10	1	14600	Soft	7.2
8	10	1	14600	IR	7.2
9	15	1	20432	Soft	10.2
10	15	1	28776	IR	14.4

For HSDPA operation, the terminal will not report individual values but only the category.

The HSDPA feature is optional for terminals in R'5. The HSDPA capability is otherwise independent from R'99-based capabilities, but if HS-DSCH has been configured for the terminal, then DCH capability in the downlink is limited to the value given by the terminal (32, 64, 128 or 384 kbps).

All HSDPA terminal capability categories defined in the first phase need to support 16QAM.

When will HSDPA do it?

- 3GPP Release 5 feature (2003)
- First HSDPA offerings rolled out by mid 2005
  - e.g. NTT DoCoMo (Japan)
  - e.g. SKT and KTF (South Korea)
  - other operators have declared their commitment to employ HSDPA in 2005-2006 timeframe
- HSDPA perceived as a key differentiator for GSM evolution
- Becomes even more appealing when associated with Enhanced Uplink (EDCH)

HSDPA DEMOs and NEWs

DEMOs:

http://www.nokia.com/nokia/0,8764,49693,00.html

http://products.nortel.com/go/product_content.jsp?parId=0&segId=0&catId=-9226&prod_id=52180&locale=en-US

NEWs:

http://hsdpa-coverage.com

http://www.tietoviikko.fi/doc.te?f_id=819653&s=u&wtm=tivi-07122005

http://www.tietoviikko.fi/doc.ot?d_id=256765

http://www.tietoviikko.fi/doc.ot?d_id=243743

Evolution Beyond Release 5

- Multiple Receiver and Transmit Antenna Techniques - MIMO (Multiple Input Multiple Output)
  - Higher data rates can be achieved either (1) by an improved antenna transmit and receive diversity leading to better channel quality or (2) by reusing the spreading code on different antennas (higher throughput per code due to data layering).
- FCS (Fast Cell site Selection)
  - supplements hard handover and provides both a decreased interference and an improved system capacity. With the FCS technique, the terminal determines which cell is best for downlink service through radio propagation measurements, and makes a report to the network. Only one Node B at a time can be included in the active set. The selection of the most suitable cell may also be based on the available power and code resources for the cells in the active set.
- Enhanced Uplink - High Speed Uplink Packet Access (HSUPA)

SUMMARY

Main HSDPA principles:

- High Speed Downlink Packet Access (HSDPA) is a concept within WCDMA specifications whose main target is to increase user peak data rates and quality of service, and to generally improve spectral efficiency for downlink asymmetrical and bursty packet data services. It is designed to increase packet data throughput by means of fast physical layer (L1) retransmission and transmission combining as well as fast link adaptation.
- When implemented, the HSDPA concept can co-exist on the same carrier as the current Release'99 WCDMA services, enabling a smooth and cost-efficient introduction of HSDPA into existing WCDMA networks. Furthermore a user can download packet-data over HSDPA, while at the same time having a speech call. HSDPA offers theoretical peak data rates on the order of 10 Mbps, and in practice more than 2Mbit/s.
- Compared to the Release'99 architecture, HSPDA introduces a short 2-ms transmission time interval (TTI), adaptive modulation and coding (AMC), multicode transmission, fast physical layer (L1) hybrid ARQ (H-ARQ), and moves the packet scheduler from the radio network controller (RNC) to the Node-B where it has easy access to air interface measurements. The latter facilitates advanced packet scheduling techniques, meaning that the user data rate can be adjusted to match the instantaneous radio channel conditions.
- While connected, an HSDPA user equipment periodically sends a Channel Quality Indicator (CQI) to the Node-B indicating what data rate (and using what coding and modulation schemes and number of multicodes) the user equipment can support under its current radio conditions.
- The user equipment also sends an acknowledgement (Ack/Nack) for each packet such that the Node-B knows when to initiate retransmissions. With the channel quality measurements available for each user equipment in the cell, the packet scheduler may optimize its scheduling among the users.

References

[1] H. Holma and A. Toskala, "WCDMA for UMTS", Radio Access for Third Generation Mobile Communications; Chapter 11 High-speed Downlink Packet Access pages 279-304, 2nd Edition, John Wiley & Sons, 2002.

[2] HSDPA in W-CDMA , http://www.umtsworld.com/technology/hsdpa.htm

[3] HSDPA presentations:

Validation Simulations of HSDPA, Networking Project, HSDPA Group, http://bart.sm.luth.se/~mohakh-4/, 10th March, 2005; Presentation--MidTermStatuus.ppt

The 3rd Generation Partnership Project – 3GPP™; sem27-02.ppt

HSDPA - High Speed Downlink Packet Access; hsdpa.ppt

Wireless Systems beyond 3G, Erik Dahlman, Expert Radio Access Technologies, Ericsson Research, Wireless IP, BEATS Workshop, 03.06.2003; LoenDahlman.ppt

Standards for Mobile Broadband Technology,Wireless Broadband Standardisation- the future roadmap, Jørgen Friis, Deputy Director-General ETSI, Asia-Pacific Telecommunication and ICT Development Forum, 18-21 July 2005, Goa, India; JFR_APT_ICT_3GPP.ppt

On the Performance of UMTS Packet Data Services, Wolfgang Granzow, Ericsson Research Corporate Unit, Ericsson Eurolab Deutschland, Nürnberg, (wolfgang.granzow@eed.ericsson.se), 30.11.2001; ftw-presentation.ppt

The Latest Development in 3G Mobile, Prof. OnChing Yue, Mobile Technologies Centre (MobiTeC) Director, The Chinese University of Hong Kong, Faculty of Engineering, 12.1.2005; HKIE20050112.ppt

Mobile Broadband Event, Ericsson, Cesare Avenia, 12.04.05; HSDPA_12aprile2005.ppt

Operator and end user performance, Michal Ptacin, 20.5.2005, T-110.456; Operator and end user performance NEW.ppt

For more information...

3GPP website: www.3GPP.org

New 3GPP Dedicated Specifications

- TR 25.308 HSDPA Overall description, Stage 2
- TR 25.858 HSDPA Physical layer aspects
- TR 25.877 HSDPA Iur/Iub protocol aspects

Other 3GPP HSDPA Specifications

- TS 25.855 HSDPA Overall UTRAN description
- TS 25.856 HSDPA Layer 2 and 3 aspects
- TS 25.876 Multiple-Input Multiple-Output Antenna Processing for HSDPA
- TS 25.890 HSDPA User Equipment (UE) radio transmission and reception (FDD)
- TR 25.899 HSDPA Enhancements; Release 5
- TR 29.950 UTRA HSDPA; Release 4

HSDPA included in ITU-R update of M.1457.

For more information...

Impacted 3GPP specifications:

HSDPA-IubIur:	
TS 25.401	UTRAN overall description
TS 25.420	UTRAN Iur Interface: General Aspects and Principles
TS 25.423	UTRAN Iur interface Radio Network Subsystem Application Part (RNSAP) signalling
TS 25.425	UTRAN Iur interface user plane protocols for CCH data streams
TS 25.430	UTRAN Iub Interface: General Aspects and Principles
TS 25.433	UTRAN Iub interface NBAP signalling
TS 25.435	UTRAN Iub interface user plane protocols for CCH data streams
TS 25.877	High Speed Downlink Packet Access (HSDPA) - Iub/Iur Protocol Aspects
TS 25.931	UTRAN Functions, examples on signalling procedures
HSDPA-IurIub:	
TS 25.413	UTRAN Iu interface Radio Access Network Application Part (RANAP) signalling
HSDPA-L23:	
TS 25.301	Radio Interface Protocol Architecture
TS 25.302	Services provided by the physical layer
TS 25.306	UE Radio Access capabilities definition
TS 25.308	UTRA High Speed Downlink Packet Access (HSDPA); Overall description; Stage 2
TS 25.321	Medium Access Control (MAC) protocol specification
TS 25.322	Radio Link Control (RLC) protocol specification
TS 25.331	Radio Resource Control (RRC) protocol specification
HSDPA-Phys:	
TS 25.201	Physical layer - general description
TS 25.211	Physical channels and mapping of transport channels onto physical channels (FDD)
TS 25.212	Multiplexing and channel coding (FDD)
TS 25.213	Spreading and modulation (FDD)
TS 25.214	Physical layer procedures (FDD)
TS 25.215	Physical layer; Measurements (FDD)
TS 25.221	Physical channels and mapping of transport channels onto physical channels (TDD)
TS 25.222	Multiplexing and channel coding (TDD)
TS 25.223	Spreading and modulation (TDD)
TS 25.224	Physical layer procedures (TDD)
TS 25.225	Physical layer; Measurements (TDD)
TS 25.306	UE Radio Access capabilities definition
HSDPA-RF:	
TS 25.101	User Equipment (UE) radio transmission and reception (FDD)
TS 25.102	User Equipment (UE) radio transmission and reception (TDD)
TS 25.104	Base Station (BS) radio transmission and reception (FDD)
TS 25.123	Requirements for support of radio resource management (TDD)
TS 25.141	Base Station (BS) conformance testing (FDD)
TS 25.142	Base Station (BS) conformance testing (TDD)

HSDPA related abbreviations

3GPP	Third Generation Partnership Project
AMC	Adaptive Modulation and Coding
ARQ	Automatic Repeat reQuest
BLER	Block Error Rate
CC	Chase Combing
C/I	Carrier-to-interference ratio
CQI	Channel Quality Indicator
DL	Downlink
DPCH	Dedicated Physical Channel
H-ARQ	Hybrid ARQ
HSDPA	High-Speed Downlink Packet Access
HS-DPCCH	High-Speed Dedicated Physical Control Channel
HS-DSCH	High-Speed Downlink Shared Channel
HS-PDSCH	High-Speed Physical Downlink Shared Channel
HS-SCCH	High-Speed Shared Control Channel
IR	Incremental Redundancy
MAC	Medium Access Control
QAM	Quadrature Amplitude Modulation
RLC	Radio Link Control
RNC	Radio Network Controller
SAW	Stop And Wait
TCP	Transmission Control Protocol
TPC	Transmit Power Control
TTI	Transmission Time Interval
UE	User Equipment
UL	Uplink
UTRA-FDD	Frequency Division Duplex

Homework

HARQ, identify and explain (7/10):

- how link layer ACKs/NACKs are implemented in UE and Node-B (3/10)
- how soft combining is used in HARQ processes (2/10)
- SAW (stop and wait) protocol used for HSDPA (2/10)

Fast Scheduling, identify and explain (3/10):

- scheduling algorithms at Node-B for HS-DSCH Channel