Cellular Wireless Networks

3G Evolution

3G Evolution

- 3GPP releases 5 to 7

Outline

- Last Lecture
    - IMT2000
    - UMTS
    - CDMA2000
    - EDGE

- This Lecture
    - UMTS Evolved Architecture [HT 04], [HT 10] chapter 5
    - HSDPA [HT 04] chapter 11 or [HT 10] chapter 12
    - HSUPA [HT 10] chapter 13
    - HSPA+ [HT 10] chapter 15

3G Evolution (source: Nokia)

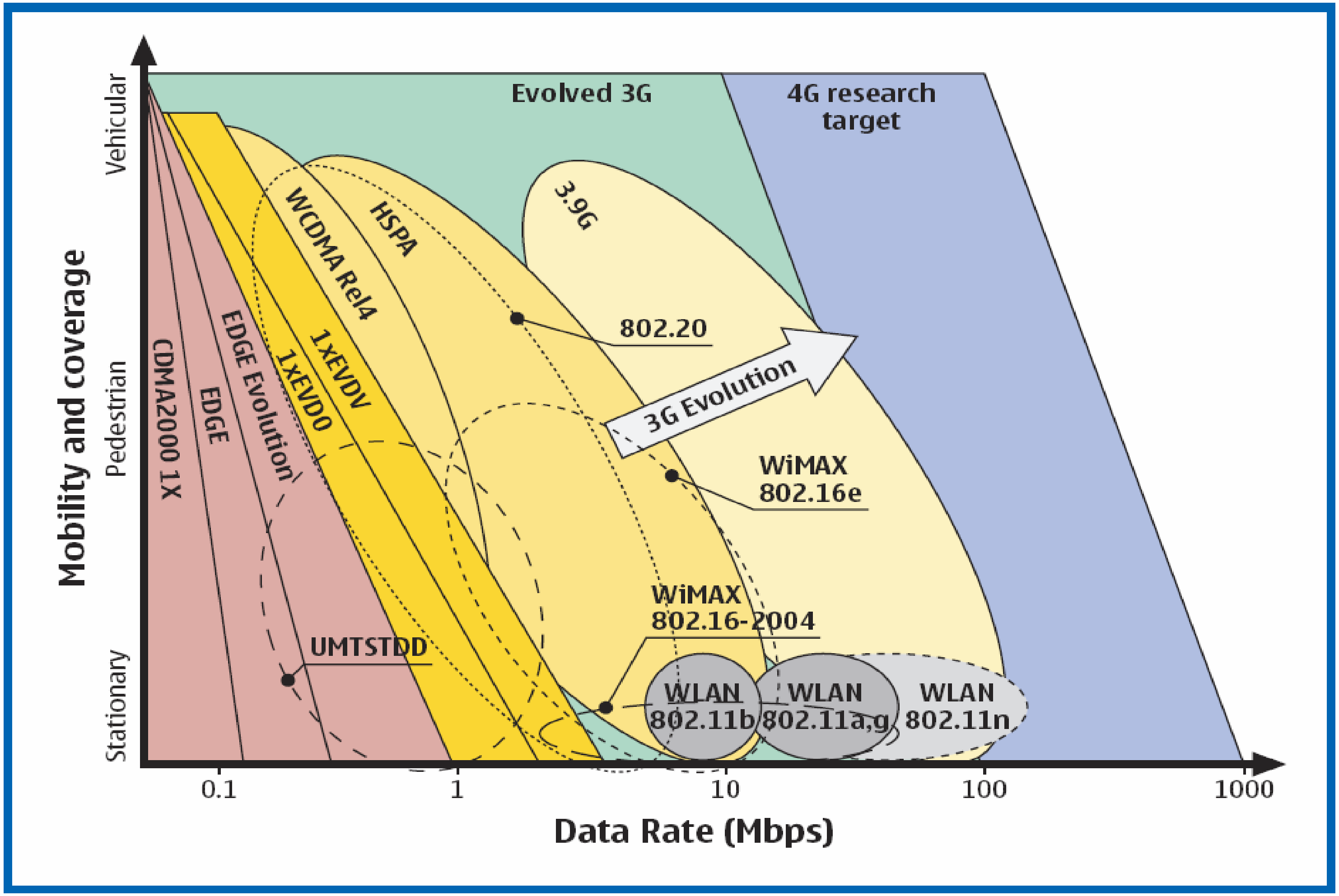
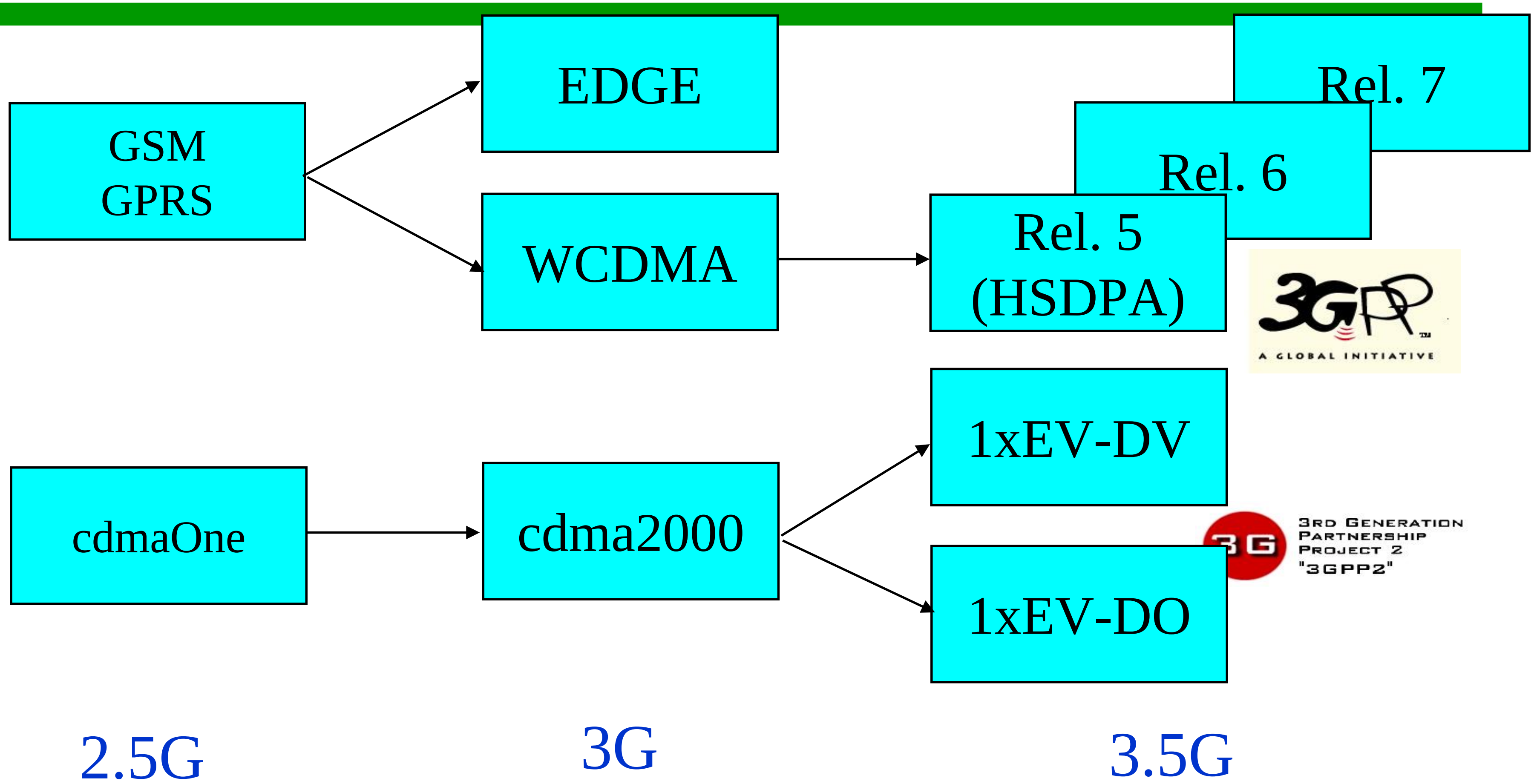


Figure 7. Mobility and coverage vs. the data rates of different radio technologies

Evolution to 3G and Beyond



3G / 3.5G Focus on high data rate packet modes

UMTS Evolution [HT 04]

- Enhancement of the architecture and related specification needed in order to:
  - support new WCDMA radio interface features
  - need to provide a more efficient, scalable and robust 3GPP system architecture
- The most significant additions to the UTRAN architecture introduced in R5 are:
  - IP Transport in UTRAN and all IP RAN Concept : user plane Frame Protocol frames can be conveyed over UDP/IP protocols on Iur/Iub, and over RTP/UDP/IP protocols in Iu CS, in addition to the option of AAL2/ATM
  - Flexible I_u Interface - allows one RNC to have more than one Iu PS and Iu CS interface instances with the core. It also allows interworking between GERAN and UTRAN
  - Stand alone SMLC (Serving Mobile Location Centre) and I_{upc} Interface

UMTS Core Network and IP Multimedia Sub-system

- Changed Core Network in CS domain (R4)
  - MSC was divided into MSC server and Media Gateway (MGW) and GMSC was divided into GMSC server and MGW
    - The MSC or GMSC server, takes care of the control functionality as MSC or GMSC respectively, but the user data goes via the Media Gateway (MGW)
      - One MSC/GMCS server can control multiple MGWs
    - MGW performs the actual switching for user data and network inter working processing, e.g., echo cancellation or speech decoding/encoding
- R5 introduces IP Multimedia Sub-system (IMS), which enables a standardised approach for IP-based service provision via PS domain
  - IMS allows the provision of services similar to CS domain services from the PS domain
  - The key protocol between the terminal and the IMS is the Session Initiation Protocol (SIP), which is the basis for IMS-related signalling

UMTS Core Network and IP Multimedia Sub-system

Media Resource Function

Call Session Control Function

Media Gateway Control Function

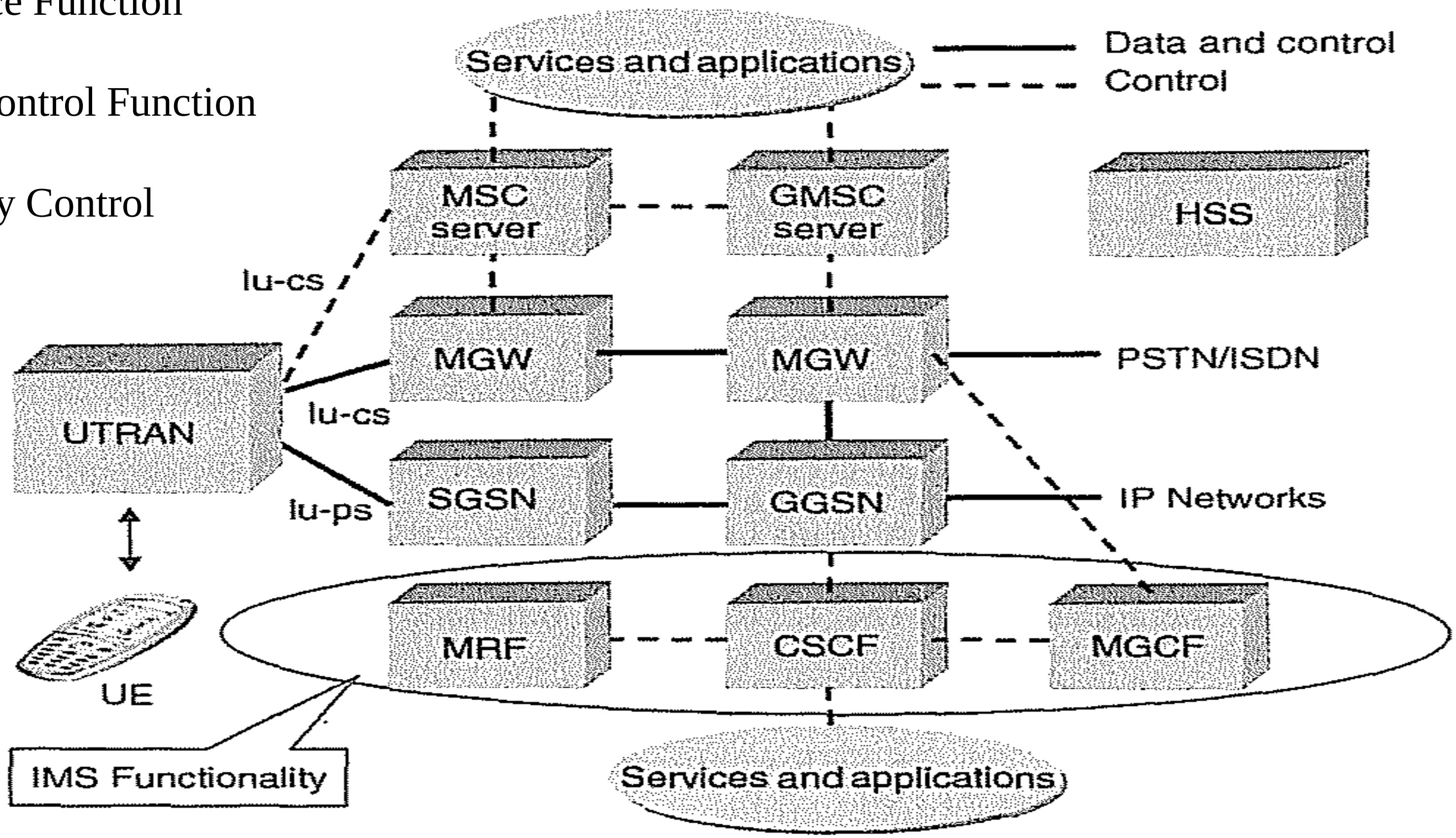


Figure 5.13. Release 5 UMTS core network architecture

Stand Alone SMLC and Iupc Interface [HT 04]

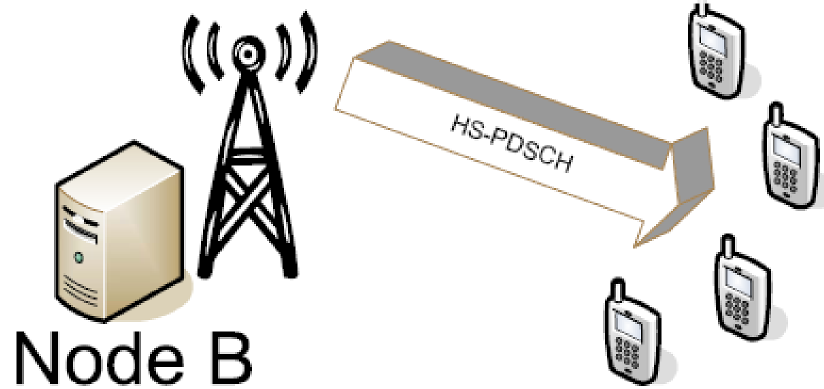
- Location-based services are very important source of revenue for the mobile operators
  - Examples are discount calls in a certain area, broadcasting of a service over a limited number of sites (broadcasting video on demand), and retrieval and display of location-based information, such as the location of the nearest gas stations, hotels, restaurants, and so on
- UTRAN architecture also includes a Stand Alone Serving Mobile Location Centre (stand alone SMLC, or simply SAS)
  - which is a new network element for the handling of positioning measurements and the calculation of the mobile station position
  - The SAS is connected to the RNC via the Iupc interface, but they are optional elements, since SMLC functionality can be integrated in the RNC as well

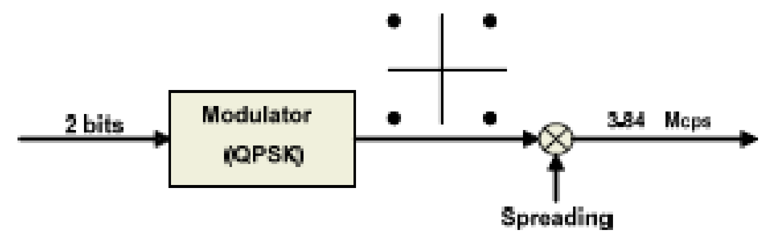
Location Services in WCDMA [HT 04]

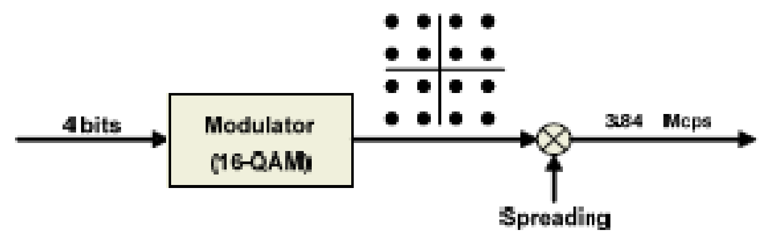
- A location-based service is provided either by an operator or by a third party service provider that utilises available information on the terminal location
  - The service is either push (e.g. automatic distribution of local information) or pull type (e.g. localisation of emergency calls)
- The location information can be input by the user or detected by the network or mobile station
- UMTS specifies the following positioning methods (they are complementing not competing methods):
  - Cell coverage based positioning method
  - Observed Time Difference Of Arrival - Idle Period Downlink (OTDOA-IPDL)
  - Network-assisted GPS method

HSDPA [Q 06]

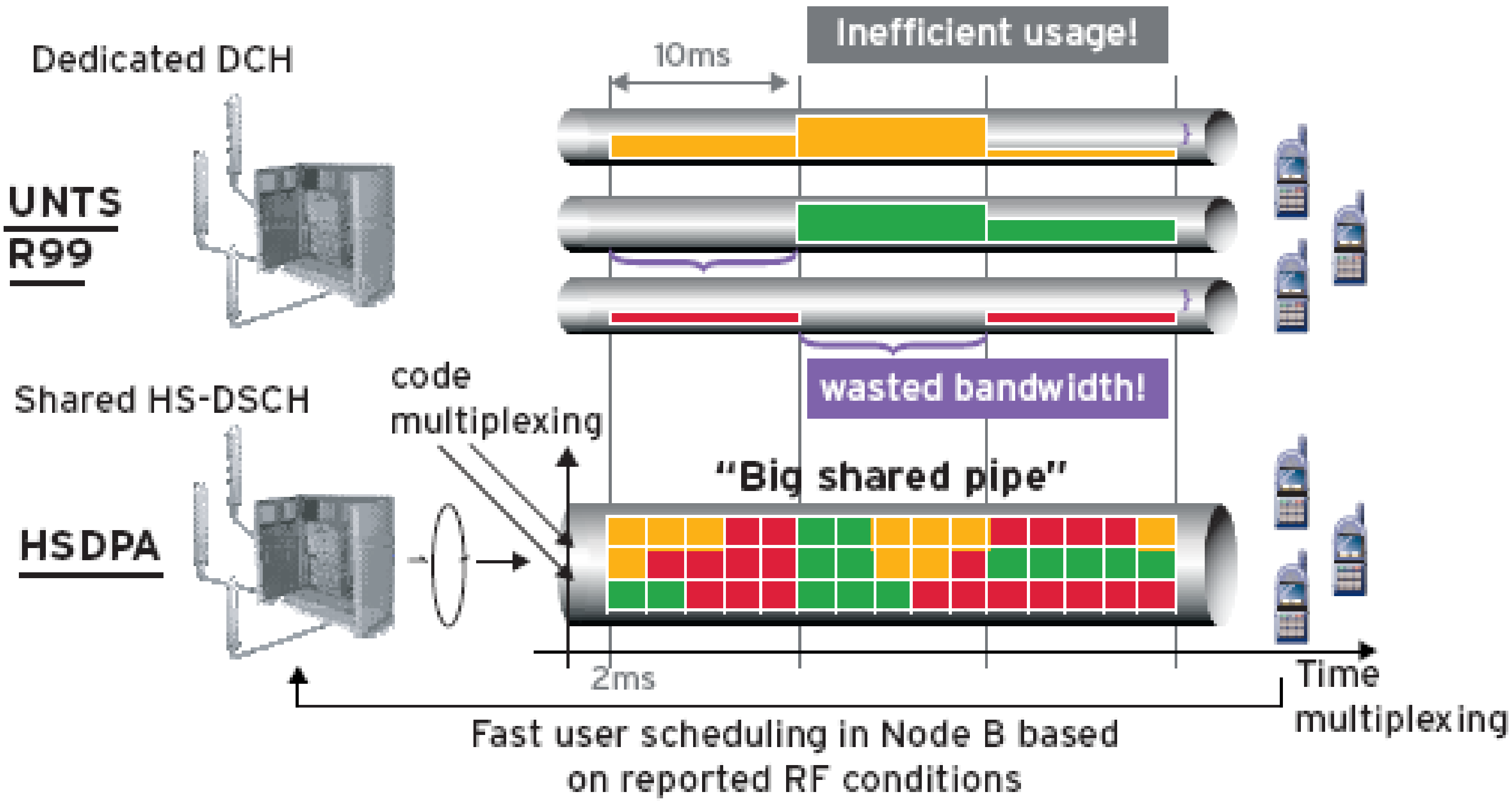
- Extension of the DSCH (Downlink Shared Channel)
- Multi-code operation
- Adaptive modulation and coding
  - QPSK and 16-QAM
  - Coding from R=1/3 to R=1
  - Fast feedback of channel condition
- Improve transmission efficiency
  - Fast retransmission and Physical Layer HARQ
- Fast resource management
  - Node B scheduling
- Reduce transmission latency
  - 2ms frame (TTI – Transmission Time Interval)







Time multiplexing downlink channel with HSDPA



Adaptive modulation and coding

HS-DSCH Category	Max number of HS-DSCH codes (SF16) received	Minimum inter TTI interval	Modulation	Max peak rate
Category 1	5	3	QPSK & 16-QAM	1.2Mbps
Category 2	5	3	QPSK & 16-QAM	1.2Mbps
Category 3	5	2	QPSK & 16-QAM	1.8Mbps
Category 4	5	2	QPSK & 16-QAM	1.8Mbps
Category 5	5	1	QPSK & 16-QAM	3.6Mbps
Category 6	5	1	QPSK & 16-QAM	3.6Mbps
Category 7	10	1	QPSK & 16-QAM	7.3Mbps
Category 8	10	1	QPSK & 16-QAM	7.3Mbps
Category 9	15	1	QPSK & 16-QAM	10.2Mbps
Category 10	15	1	QPSK & 16-QAM	14.4Mbps
Category 11	5	2	QPSK only	900kbps
Category 12	5	1	QPSK only	1.8Mbps

HSDPA capability per 3GPP category

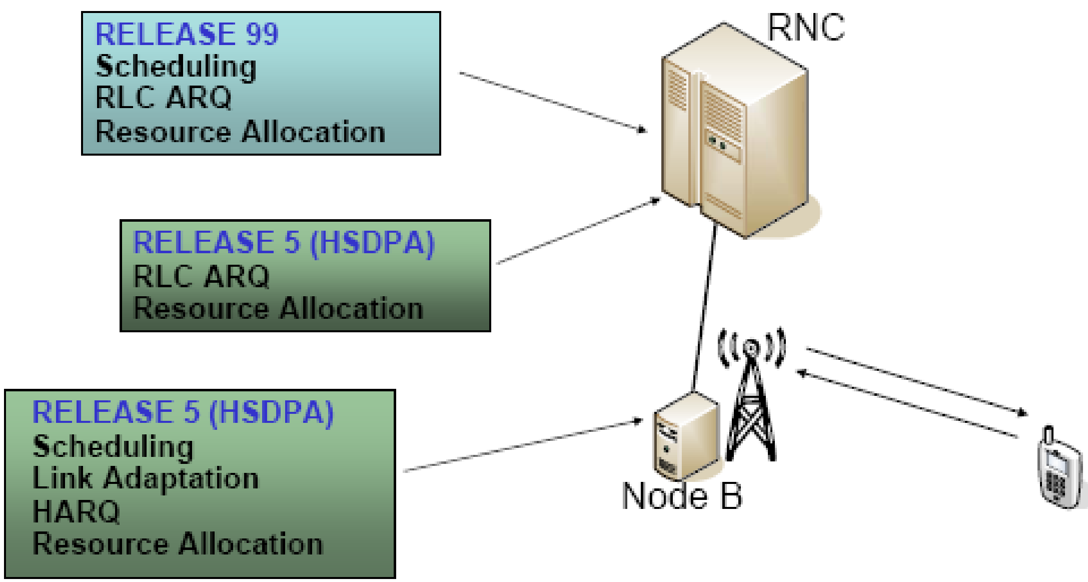
High-speed Downlink Packet Access (HSDPA) [HT 04]

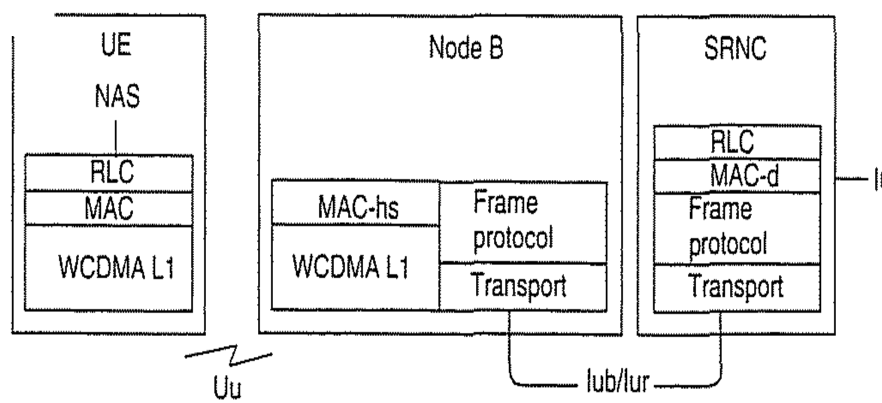
- HSDPA concept increases packet data throughput with methods known already from Global System for Mobile Communications (GSM)/Enhanced Data rates for Global Evolution (EDGE) standards, including link adaptation and fast physical layer (L1) retransmission combining
- To accomplish physical layer retransmission in HSDPA, architectural changes were needed to bring the control for link adaptation closer to the air interface
- The transport channel carrying the user data with HSDPA operation is denoted as the High-speed Downlink Shared Channel (HS-DSCH)
- A simple illustration of the general functionality of HSDPA is:
  - The Node B estimates the channel quality of each active HSDPA user on the basis of, for instance, power control, ACK/NACK ratio, and HSDPA-specific user feedback
  - Scheduling and link adaptation are then conducted at a fast pace depending on the active scheduling algorithm and the user prioritisation scheme
  - The channels needed to carry data and downlink/uplink control signalling are described later
- With HSDPA variable SF and fast power control are disabled and replaced by means of adaptive modulation and coding

High-speed Downlink Packet Access (HSDPA) [HT 04]

- Before, the retransmission procedure for the packet data was only located in the serving RNC, which also handles the connection for the particular user to the core network
- With the introduction of HS-DSCH, additional intelligence in the form of an HSDPA Medium Access Control (MAC) layer was installed in the Node B
  - retransmissions can be controlled directly by the Node B, leading to faster retransmission and shorter delay with packet data operation
  - the Iub interface between Node B and RNC requires a flow control mechanism to ensure that Node B buffers are used properly and that there is no data loss
  - 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
- 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

HSDPA Features [HT 10] [Q 06]



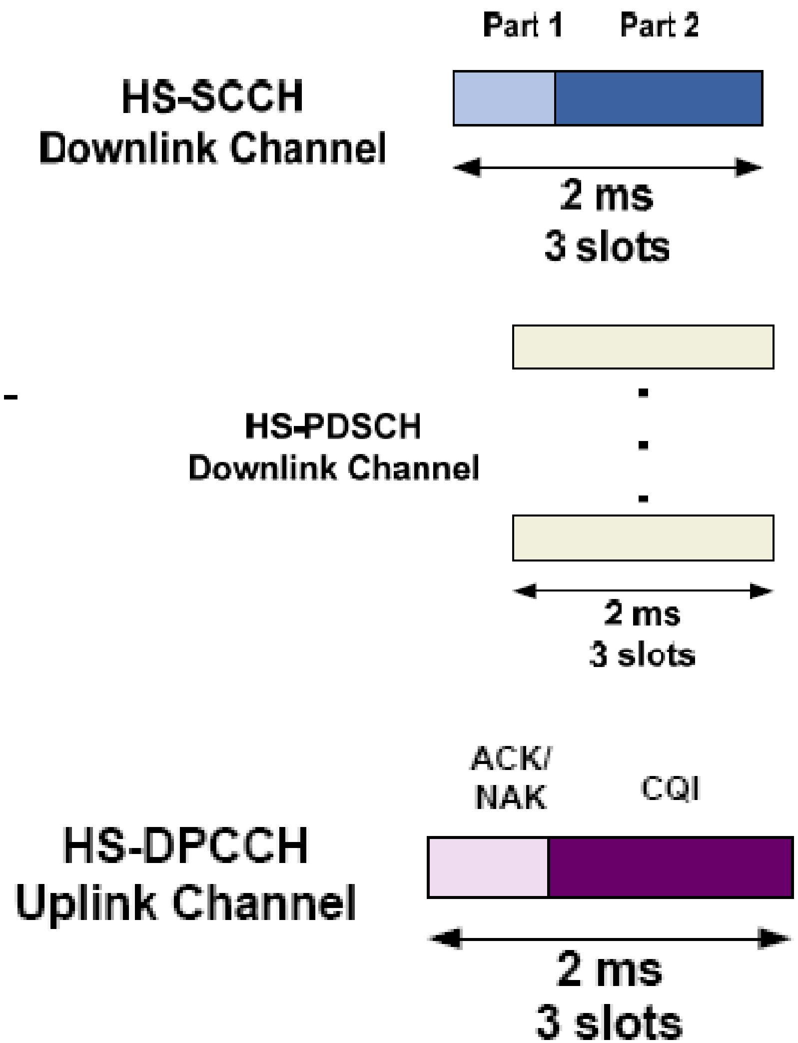


HSDPA user plane

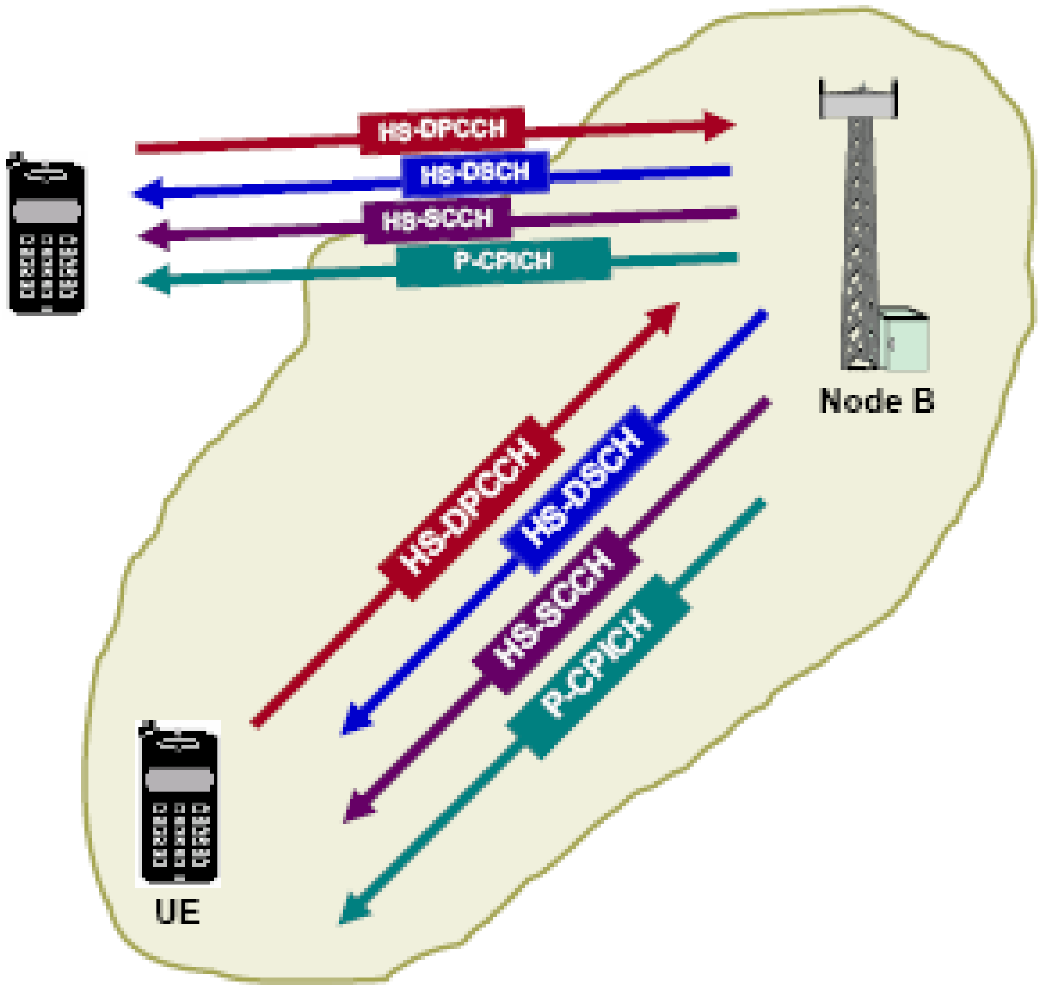
Figure 11.3. HSDPA protocol architecture

New HSDPA channels [Q 06]

- Transport Channel
  - High Speed Downlink Shared Channel (HS-DSCH)
    - Downlink transport channel
- Physical Channels
  - High Speed Shared Control Channel (HS-SCCH)
    - Downlink control channel
  - High Speed Physical Downlink Shared Channel (HS-PDSCH)
    - Downlink data channel
  - High Speed Dedicated Physical Control Channel (HS-DPCCH)
    - Uplink control channel



HSDPA Operation [Q 06]



HSDPA Operation

1. Each UE reports channel quality on HS-DPCCH.
2. The Node B determines which and when each UE is to be served.
3. The Node B informs the UE to be served via HS-SCCH.
4. Then deliver the data to the UE via HS-DSCH.
5. The UE sends feedback (ACK/NAK) back to Node B on HS-DPCCH.

Key mechanisms of HSDPA

Mechanism	Description
New downlink shared transport channel	• HS-DSCH is shared by all users of a sector • HS-SCCH enables the UE to identify which codes of the HS-DSCH contain its data • DPCCH is responsible of Uplink signaling
Fast link adaptation Adaptative modulation and coding	It enables to change modulation and coding format in accordance with variations in the channel conditions which leads to a higher data rate for users in favorable positions and reduced interference
Hybrid Automatic Request (HARQ)	HARQ retransmission protocol is implemented in MAC Layer instead of the RLC Layer, decreasing the delay associated with retransmissions. HARQ is placed in the Node B.
Fast scheduling	The Scheduler is placed in the Node B in order to quickly respond to the changes in channel conditions. A compromise between a Round Robin and a Max C/I scheduler will be used.
Fast cell selection	The scheduled nature of HSDPA makes it impossible to use a soft HO mechanism. A hard HO is used for HS-DSCH: the UE indicates the best cell which should serve it through uplink signaling.

The TTI of 2 ms leads to a reduced round trip delay and a higher validity of the channel estimation.

High Speed Uplink Packet Access – HSUPA [HT 10] [Q 06]

- Key feature of R6
- In 3GPP the term Enhanced DCH (E-DCH) is used instead HSUPA, which is used by the industry
  - E-DCH is comparable with DCH from R99 and R4
  - Comparison of basic properties is shown in table 13.1

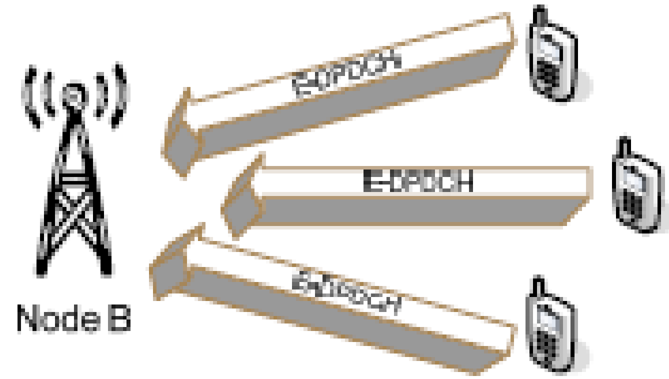


Table 13.1. Comparison of fundamental properties of DCH and E-DCH

Feature	DCH	E-DCH
Variable SF	Yes	Yes
Fast power control	Yes	Yes
Adaptive modulation	No	No
Multi-code operation	Yes (in specs, not used)	Yes, extended
Fast L1 HARQ	No	Yes
Soft handover	Yes	Yes
Fast BTS scheduler	No	Yes

General functionality of HSUPA [HT 10]

- The technologies applied with HSUPA improve uplink packet data performance by means of fast physical layer (L1) retransmission and transmission combining, as well as fast Node B scheduling
- General Functionality:
  - The Node B estimates the data rate transmission needs of each active HSUPA user based on the device-specific feedback
  - The scheduler in Node B then provides instruction to devices on the uplink data rate to be used at a fast pace depending on the feedback received, the scheduling algorithm and the user prioritisation scheme
  - The retransmissions are initiated by the Node B feedback

General functionality of HSUPA [HT 10]

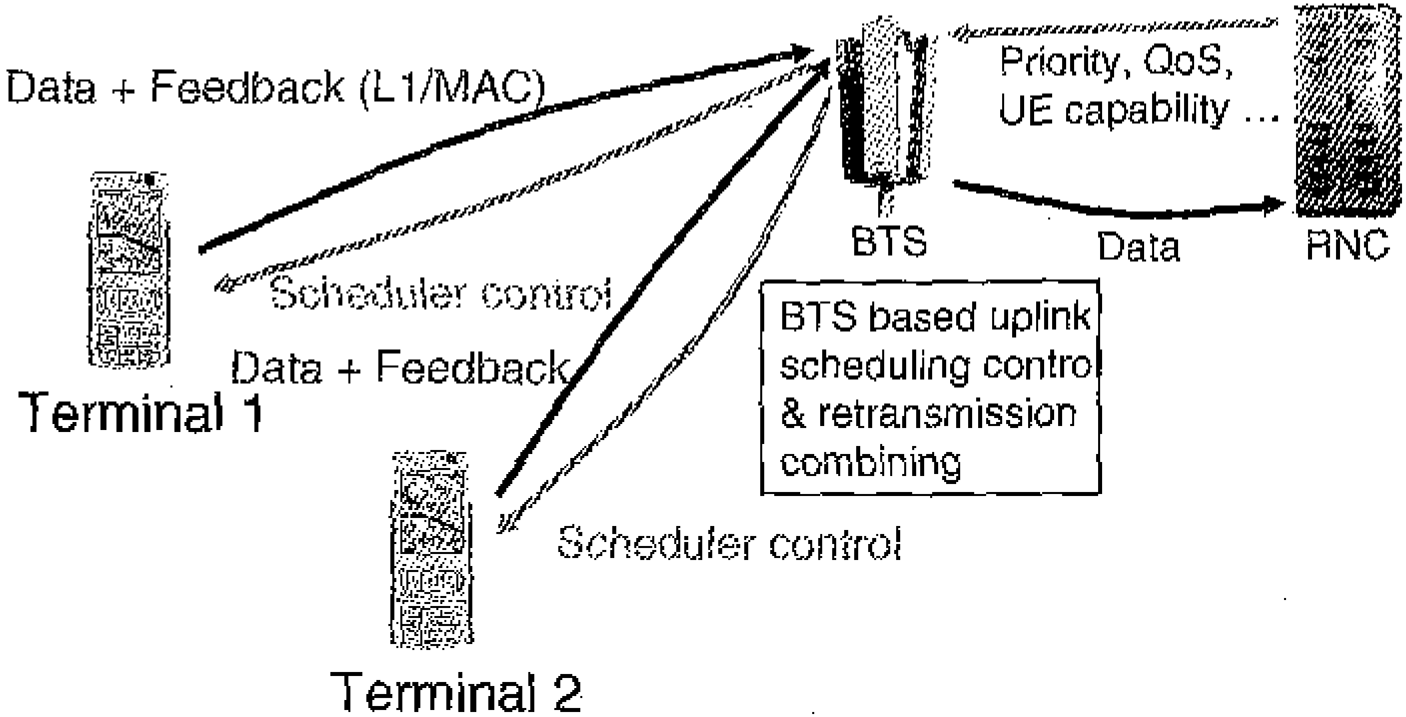
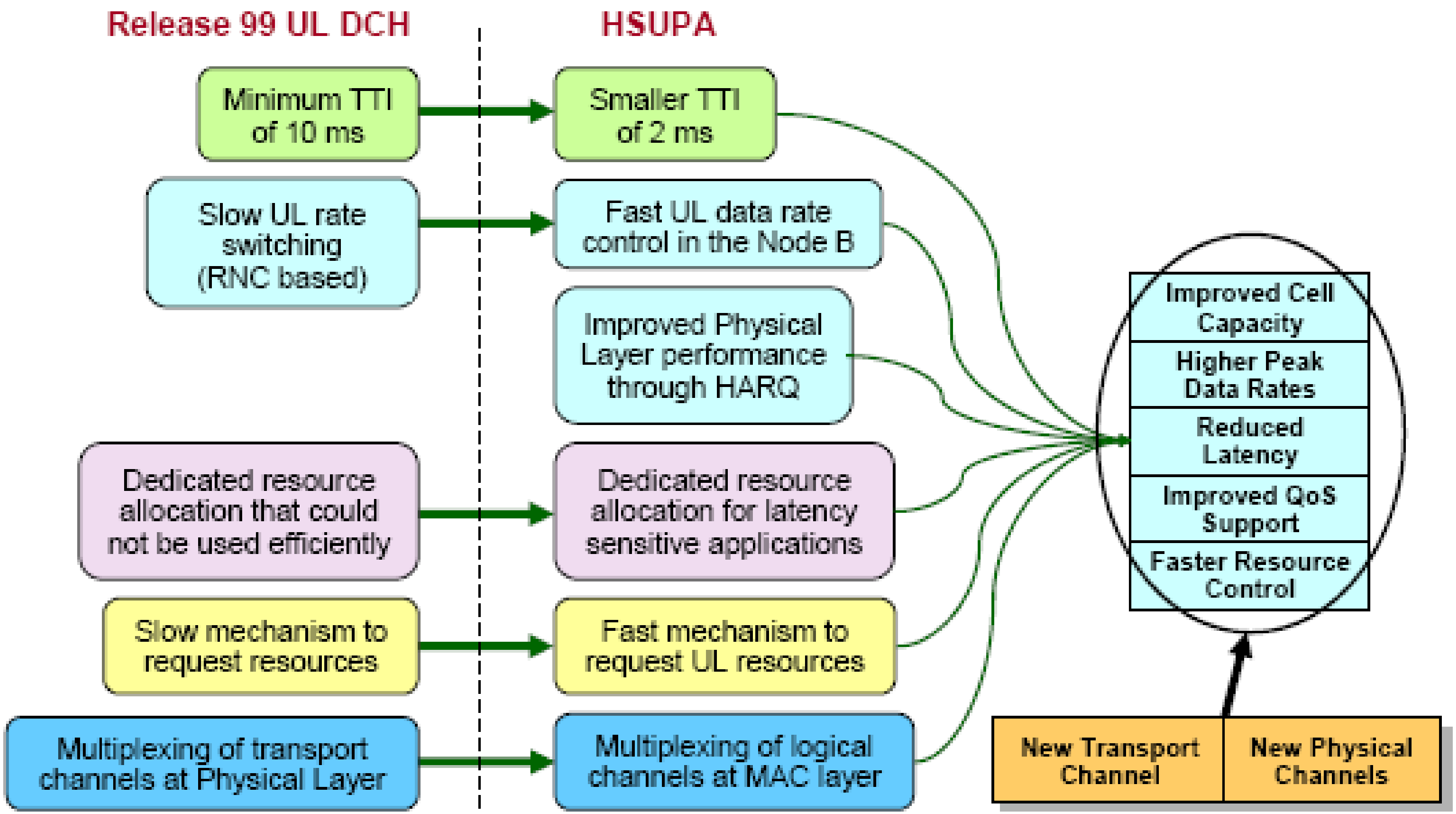


Figure 13.1. General operation principle of HSUPA

HSUPA – How enhancements are achieved? [Q 06]



HSDPA versus HSUPA [Q 06]

HSDPA	HSUPA
New high-speed Shared Channel	Dedicated Channel with Enhanced Capabilities
HARQ with Fast Retransmission at Layer 1	
Rate/Modulation Adaptation Single Serving Cell	Fast Power Control Soft Handover
Fast Node-B Scheduler "One-to-Many" Shared Node-B Power and Code	Fast Node-B Scheduler "Many-to-One" Rise-over-Thermal (RoT)

HSUPA RAN Protocol Architecture [HT 10]

- The purpose of the new Node B MAC functionality (MAC-e) is to handle the Automatic Repeat reQuest (ARQ) functionality and scheduling, as well as the priority handling
- In the UE side, the new functionality represents the uplink scheduling and retransmission handling (being controlled by the MAC-e in Node B)
- The MAC-es functionality in the RNC is to cover for packet reordering to avoid changes to the layers above
  - This reordering is needed due to the uplink soft handover operation which may cause the packets to arrive out of sequence from different base stations

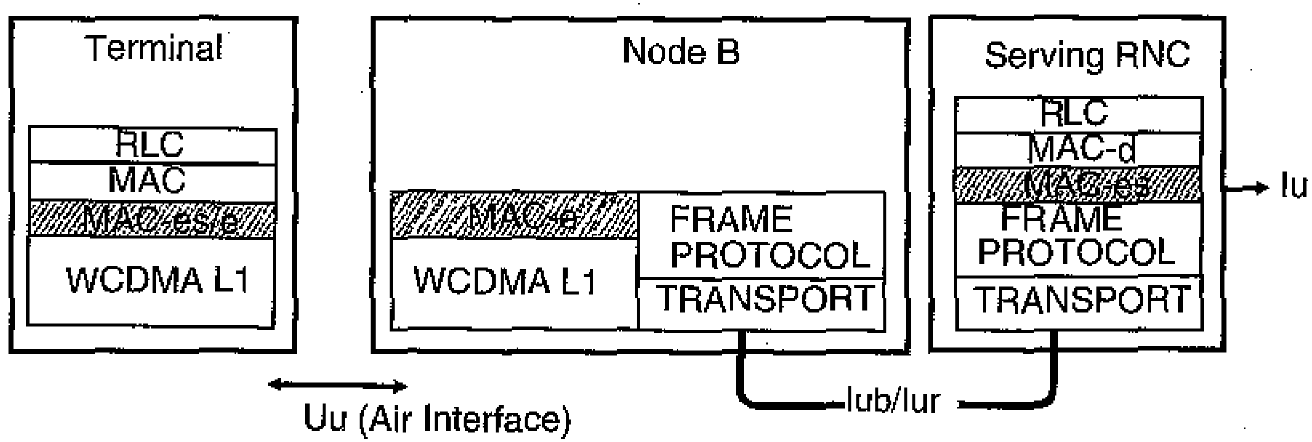


Figure 13.3. HSUPA protocol architecture

HSUPA RAN Architecture [HT 10]

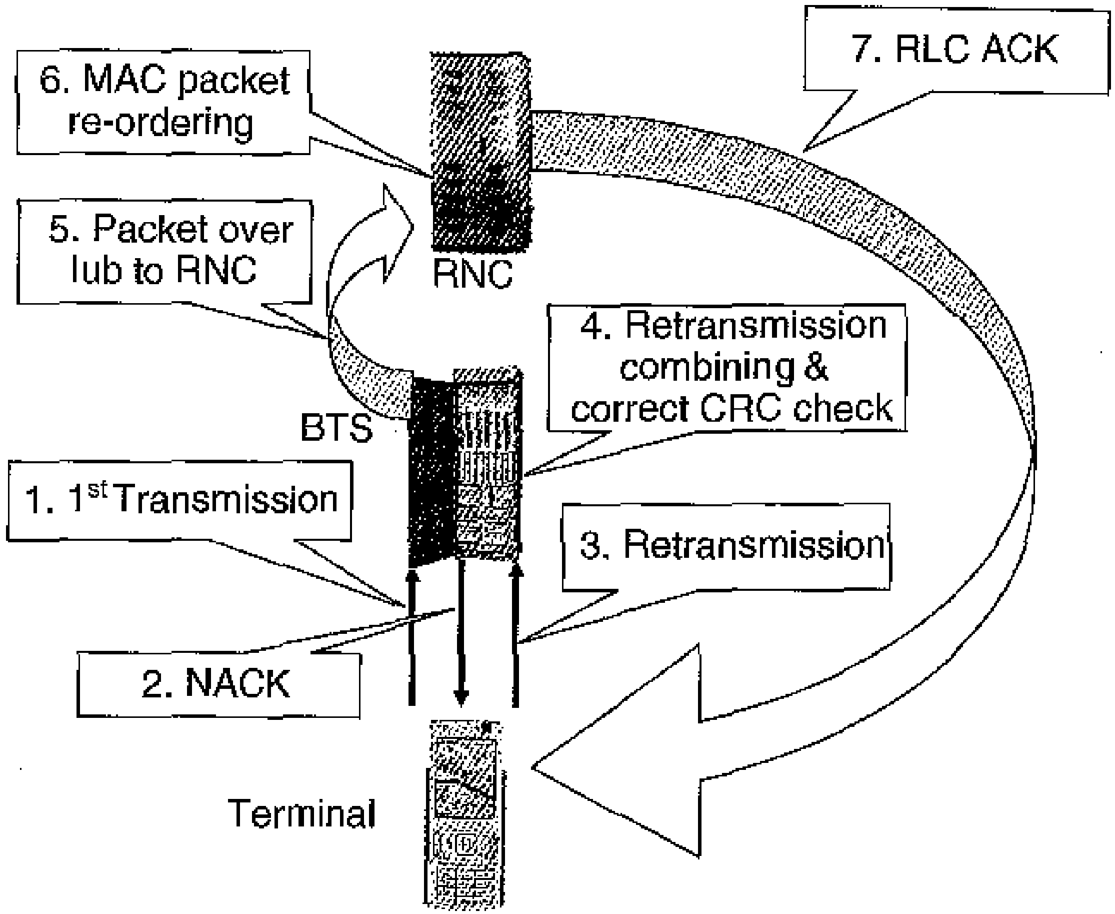
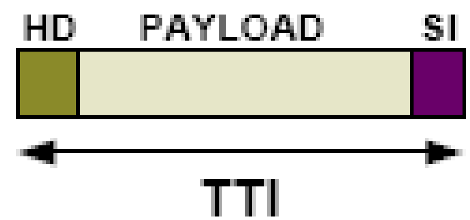
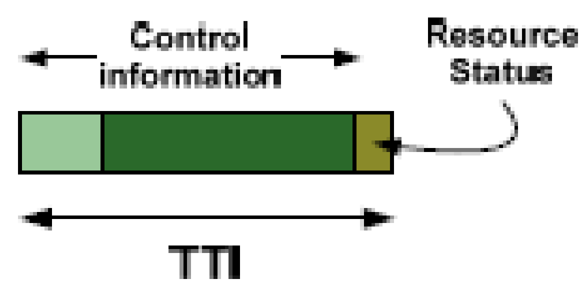


Figure 13.2. HSUPA retransmission control in the network

New HSUPA Channels [Q 06]

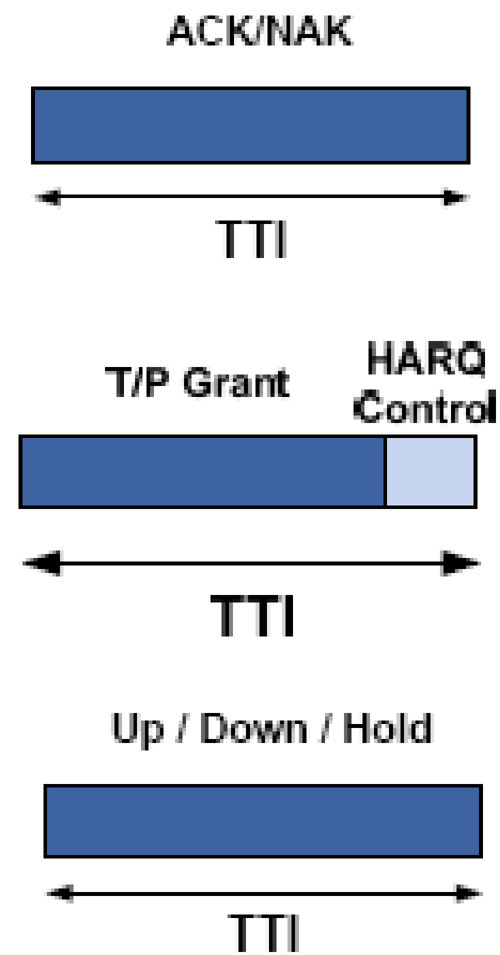
- Uplink Channels
  - Enhanced Uplink Dedicated Channel (E-DCH)
    - Uplink transport channel
  - E-DCH Dedicated Physical Data Channel (E-DPDCH)
    - Carries the payload, it may include a scheduling request from UE to Node B
  - E-DCH Dedicated Physical Control Channel (E-DPCCH)
    - Carries control information required to decode the payload carried by E-DPDCH
    - Carries an indication from UE to indicate to the Node B whether the assigned resources are adequate



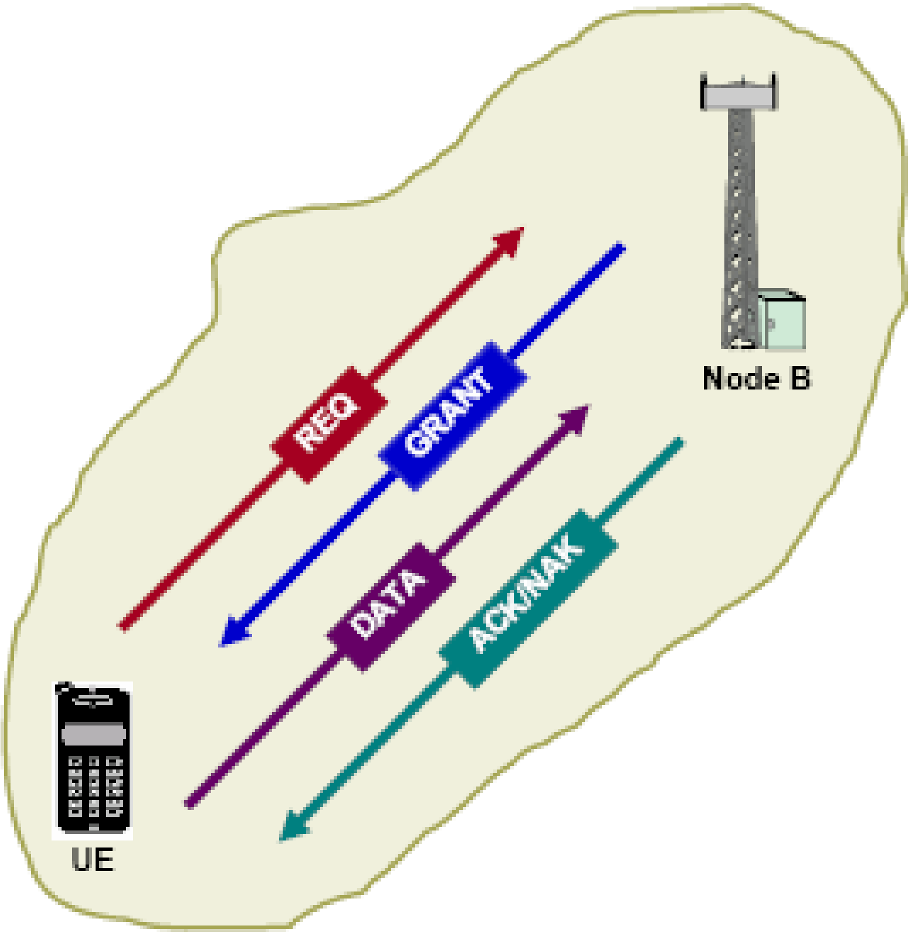


New HSUPA Channels [Q 06]

- Downlink Physical Channels
  - E-DCH Hybrid ARQ Indicator Channel (E-HICH)
    - Gives feedback to the UE about previous data transmission, carrying Acknowledge (ACK) or Not Acknowledge (NAK)
  - E-DCH Absolute Grant Channel (E-AGCH)
    - It carry the Node B scheduling control information to control the uplink transmission rate
      - The absolute grant carries maximum allowed E-DPDCH/DPCCH ratio.
      - Carries information that controls HARQ process
  - E-DCH Relative Grant Channel (E-RGCH)
    - The relative grant carries a simple command to increase (UP), Decrease (DOWN), or keep (HOLD) the current grant



HSUPA Operation [Q 06]



HSUPA Operation

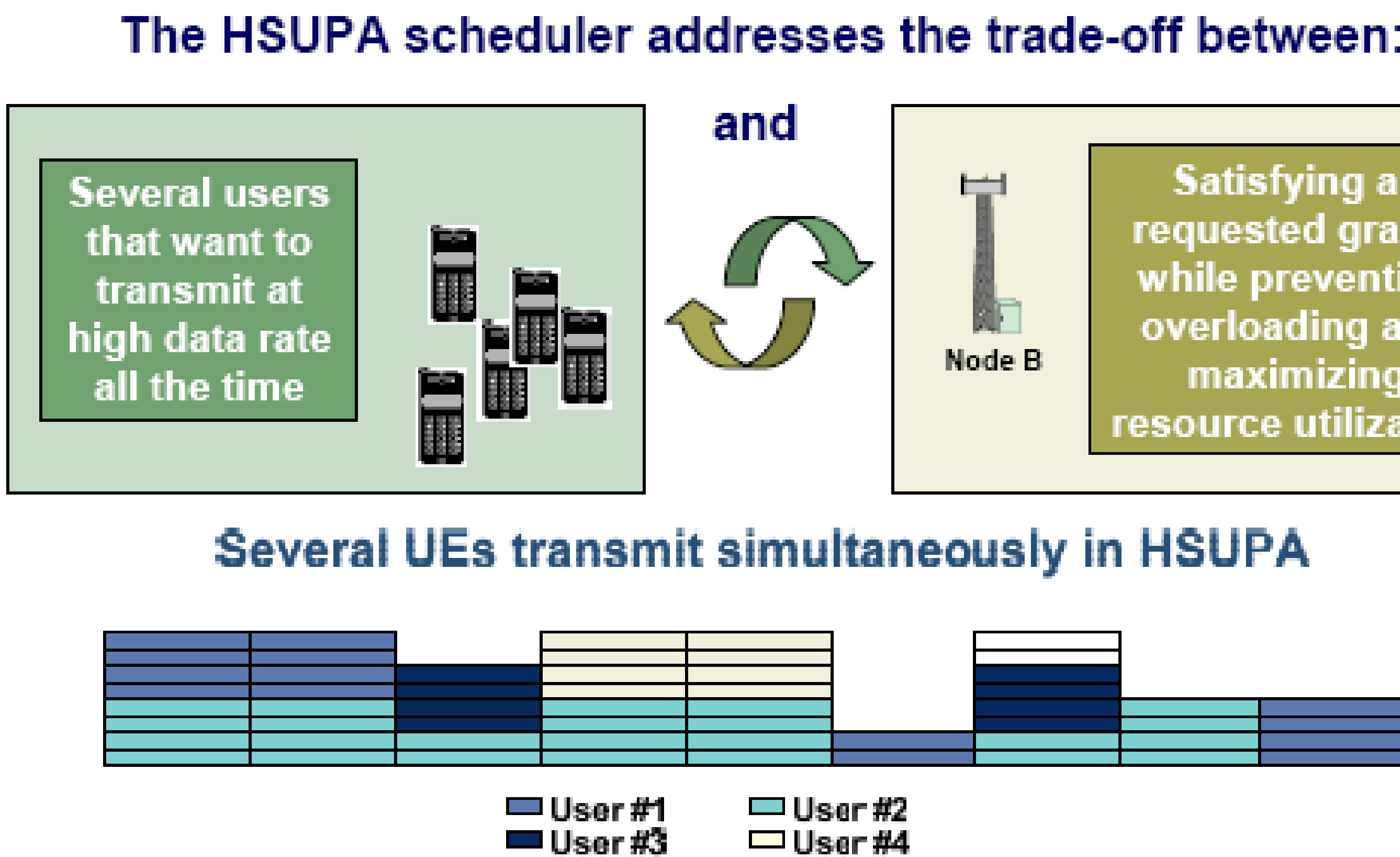
1. The UE sends a Transmission Request to the Node B for getting resources.

2. The Node B responds to the UE with a Grant Assignment, allocating Uplink band to the UE.

3. The UE uses the grant to select the appropriate transport format for the Data Transmission to the Node B.

4. The Node B attempts to decode the received data and send ACK/NAK to the UE. In case of NAK, data may be retransmitted.

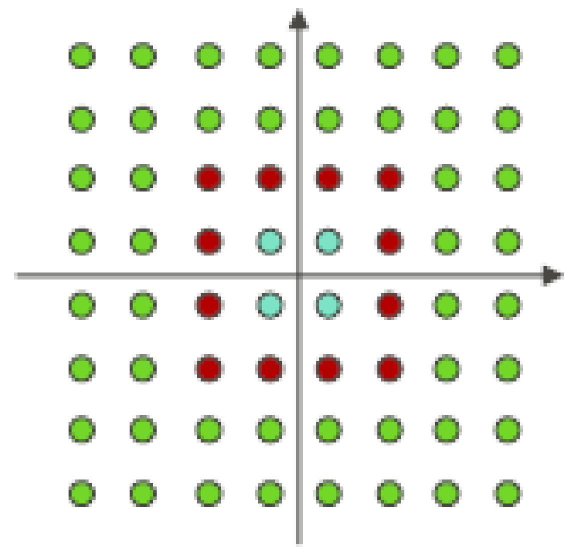
Node B Scheduler [Q 06]



HSPA + Release 7 [HT 10]

HSDPA

- 16 QAM => 64 QAM
  - Peak rate: 14.4 Mbps => 21.6 Mbps
- In R8: MIMO + 64 QAM
  - Peak rate: 43.2 Mbps



HSUPA

- QPSK => 16 QAM
  - Peak rate: 11.52 Mbps
- 64-QAM requires good accuracy when modulating
- Similarly to MIMO, good channels needed

Class Quiz

- How is the 3G Evolved?
- What is HSDPA?
- What is HSUPA?

References

- [HT 04] Harry Holma and Antti Toskala. WCDMA for UMTS – radio Access for Third generation Mobile Communications. 3rd Edition, Wiley 2004.
- [HT 10] Harry Holma and Antti Toskala. WCDMA for UMTS: HSPA Evolution and LTE . 5th Edition, Wiley 2010.
- [Q 06] Qualcomm university tutorials: "Understand HSPA". www.qualcommuniversity.com