UNIVERSITÀ DELLA CALABRIA

Master Degree in Telecommunications Engineering

"Mobile Radio Networks" Class

6 – High Speed Downlink Packet Access (HSDPA)

Antonio Iera
DIMES Department - University of Calabria
Arcavacata di Rende, ITALY
antonio.iera@dimes.unical.it

UMTS evolution

- Release 99
  - UMTS voice and basic data service
- Release 5
  - HSDPA
- Release 6
  - HSUPA
- Release 7
  - HSPA+ 64 QAM
- Release 8
  - HSPA+ 2x2 MIMO
- Release 9/10
  - HSPA+ Multicarrier

- R99 data service
  - Maximum Throughput DL: 2 Mbps (with 4 channel at 768 kbps with SF4)
  - Throughput DL (single channel): 384 kbps
  - Latency between 100 and 200 ms

⋮

- R10 HSPA+ services
  - Maximum Throughput DL: 42.2 Mbps
  - Throughput DL : 11.5 Mbps
  - Latency usually < 100

Mobile Radio Networks

- ❑ HSPA (High Speed Packet Access)

Motivations for HSPA (1/2)

- The use of dedicated channels for packet data applications can give rise to inefficiencies in the use of the resources available on the interface when it is necessary to assign high data rates to individual users.
- On the other hand, still in packet data applications, higher available peak data-rates lead to an improvement in UTRA performance

Motivations for HSPA (2/2)

- These two reasons led, in Releases 5 and 6, to an additional and improved access method compared to the one initially envisaged in Release 99, namely High Speed Packet Access (HSPA).
- HSPA includes two components, with the goal of improving interface performance in *downlink* and *uplink* packet data transfer.

Proposed solutions for HSPA

- In the *downlink*, a new transport channel is added (to the dedicated transport channels) which is shared among the users who are active on the interface.
  - This new channel is the *High-Speed Downlink Shared Channel (HS-DSCH)* which allows to assign all available resources to one or more users in a very efficient way.
- In the *Uplink*, dedicated transport channels are enhanced to *Enhanced Dedicated Channels (E-DCH).*
  - Even though these channels are dedicated, uplink resources can be shared among interested users more efficiently.

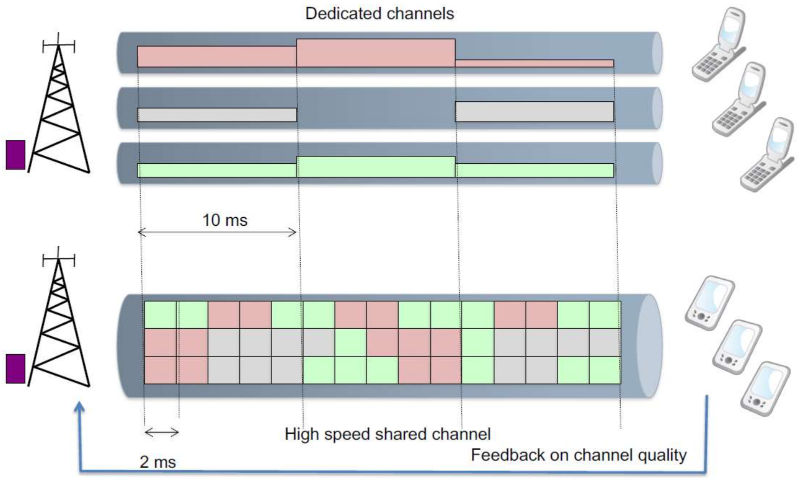
The three-stage evolution of HSPA (1/3)

3GPP identifies different stages in the evolution of HSPA.

Stage 1: Basic HSDPA

- The first phase, specified in 3GPP release 5, sees the introduction of several new basic functions with the aim of reaching a peak data rate of 10.8 Mbit/s:
  - High speed downlink shared channel supported by its control channels.
  - Adaptive Modulation (QPSK and 16QAM).
  - Shared medium access control (MAC-sh) in Node B.

UMTS vs. Basic HSDPA



The three-stage evolution of HSPA (1/3)

Stage 2: HSDPA enhancements + HSUPA

- The second phase, specified in 3GPP **release 6**, introduces HSUPA (High-Speed Uplink Packet Access) to bring some of the advanced features of HSDPA in the uplink
  - Introduction of evolved *Data Channel (eDCH)*
  - It could be used even without the HSDPA
  - Additional terminal categories with maximum throughput of 2 and 5 Mbps

Stage 3: New Air Interface ⇒ *...towards LTE*

The three-stage evolution of HSPA (1/3)

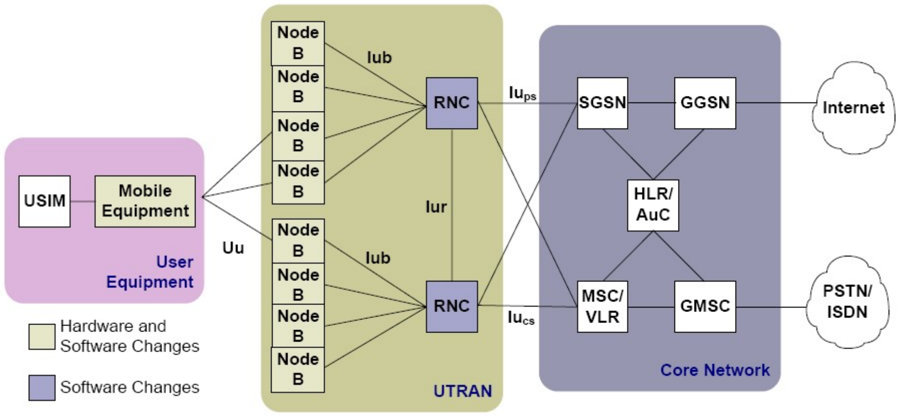
Stage 3: HSUPA+

- The third phase, specified in 3GPP **release 7 and 8**, introduces antenna array processing technologies to increase the peak data rate up to about 30 Mbit/s:
  - Smart antenna using beamforming techniques for mobile terminals with a single antenna.
  - MIMO technologies for mobile terminals with two to four antennas.
- Physical layer Orthogonal Frequency Division Multiplexing (OFDM) combined with multi-level modulation schemes
- The concept of flat network (then used in LTE) is introduced in HSPA+
  - Through a tunnel, the User Plane uses a direct connection from NodeB to GGSN without crossing RNC and SGSN

Mobile Radio Networks

- ❑ HDSPA (High Speed Downlink Packet Access)

UMTS architecture with HSDPA



New features of HSDPA (1/2)

- The intervention of HSPA on the downlink is called HSDPA (High Speed Downlink Packet Access) and *improves the performance of the downlink packet data transfer* through the following measures:

1. shared use of the new HS-DSCH transport channel;

2. rapid adaptation of the transmission parameters (in the HS-DSCH) to the conditions assumed by the radio channel instant by instant (*Fast Link Adaptation*);

New features of HSDPA (1/2)

3. adoption of an adaptive assignment of the HS-DSCH channel according to a strategy depending on the instantaneous conditions of the radio channel (*Fast Channel Dependent Scheduling*);

4. use of a more effective retransmission mechanism for incorrect data (*Fast Hybrid-ARQ with soft combining*);

1. shared use of HS-DSCH

- With the HS-DSCH a certain amount of *channelization codes* and the *transmitted power* in a cell are treated as a common resource, which is *dynamically* shared among the users.

- The sharing:
  - is managed with the criterion of assignment adaptive to the conditions of the radio channel, as will be clarified below;
  - can be changed every Transmission Time Interval (TTI) of 2 ms

1. shared use of HS-DSCH

- Three new physical channels are introduced to support the High-Speed Downlink Shared Channel:

DL

- High Speed Physical Downlink Shared Channel (HS-PDSCH):
  - It carries the actual data packets

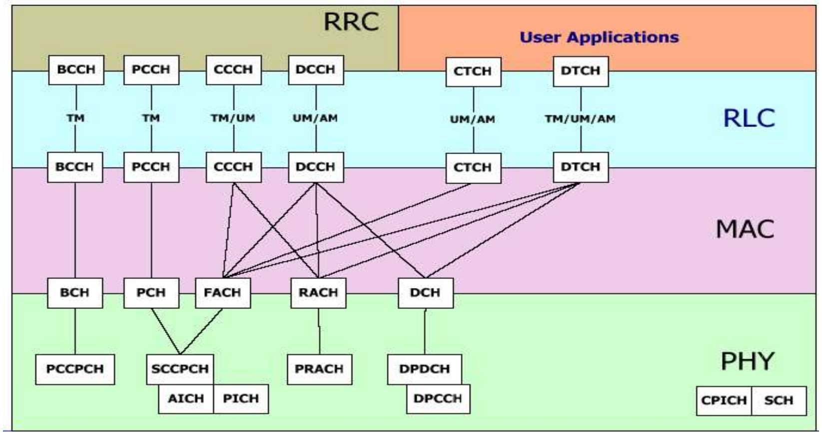
- High Speed Shared Control Channel (HS-SCCH):
  - Downlink channel carrying signaling information (*channel code set*, *modulation scheme*, *transport block size*, *HARQ process number*, UE *identity*, etc.)

UL

- High Speed Dedicated Physical Control Channel (HS-DPCCH):
  - Uplink channel carrying signaling information (*ACK/NACK* related to the ARQ process and *Channel Quality Indicator - CQI*)

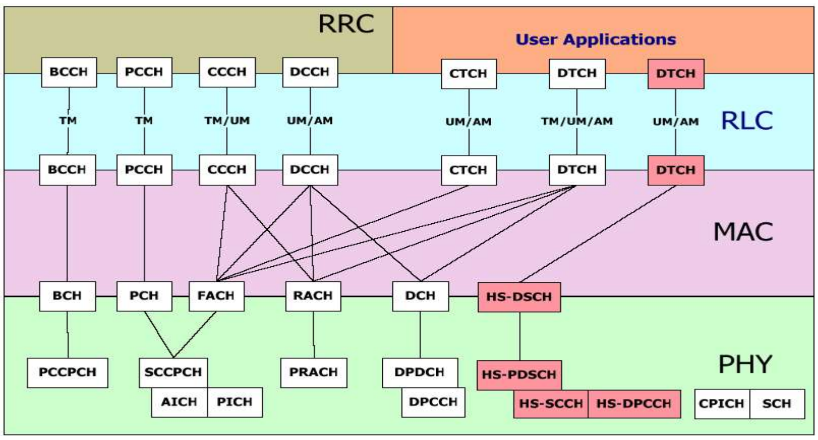
1. shared use of HS-DSCH

UMTS Channels in Release 99

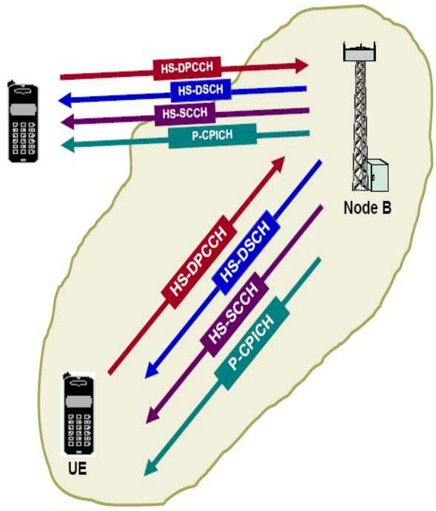


1. shared use of HS-DSCH

Channels of HSDPA



1. shared use of HS-DSCH



1. each UE communicates the channel quality on **HS-DPCCH**
2. Node B decides which UE and when to be served
3. Node B informs the UE to be served via **HS-SCCH**.
4. Then it sends the data to that UE via **HS-DSCH**
5. the served UE sends feedback (ACK/NAK) to Node B using the **HS-DPCCH**

2. Fast Link Adaptation

- The fast adaptation of the connection has the purpose of dealing with phenomena, such as those related to fading from multiple paths, which can also occur in a very diversified way in different downlink connections with fast variations in time and space.
- Instead of the solution adopted for the dedicated channels of the UTRA (fast power control to compensate for the differences and variations of the instantaneous conditions of the radio channel), the fast adaptation used in HSDPA modifies the transmission parameters.

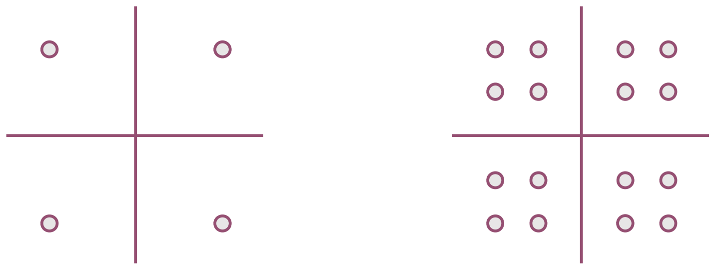
2. Fast Link Adaptation

- This change concerns
  - the *channel coding rate*, passing from lower to higher values;
  - the *modulation scheme*, choosing a lower or higher order, in relation to the conditions presented instant by instant by the radio channel.

- When these conditions are good, a higher order modulation and a lower coding rate are used; when, on the other hand, said conditions are bad, a modulation order and a coding rate are adopted which are more robust with respect to error events.

2. Fast Link Adaptation

- Depending on the conditions of the radio channel, the modulation scheme can switch from QPSK to 16QAM, which is spectrally more efficient and which, with the maximum amplitude of the transmitted signal being equal, is more sensitive than QPSK to the various degradation phenomena suffered by the signal received than sent:



2. Fast Link Adaptation

- Therefore, the 16QAM scheme is used in the presence of favorable radio conditions, since it allows to obtain a higher peak rate.
- On the other hand, when the propagation conditions worsen and therefore transmission errors increase, the QPSK scheme is used

3. Fast Channel Dependent Scheduling

- The assignment of the shared channel made according to the conditions of the radio channel determines, for each TTI, to which UE the transmission on the HS_DSCH is to be addressed.
- For this purpose, in close cooperation with the fast adaptation to the link conditions, it is decided by a scheduler how many channelization codes are to be used for each TTI, and, for each code, which modulation scheme.

3. Fast Channel Dependent Scheduling

- The idea behind this type of adaptive assignment instead of a static one (such as a cyclic one) aims at coping, in a highly reactive way, with short-term variations in the strength of the received signal, by transmitting with priority to the UE with more favorable channel conditions.
- Using this assignment method has the advantage of increasing the capacity of the link and allows for a better use of resources.
- The gain obtained by broadcasting to users with more favorable conditions is called "multi-user diversity".

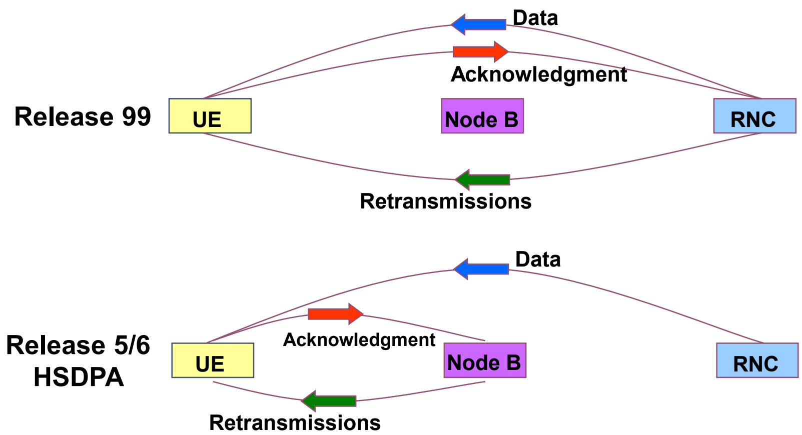
4. Hybrid-ARQ with soft combining (1/3)

- The UE can quickly request the retransmission of bad received data: this allows to reduce the transfer delay and increase the link capacity.
- Furthermore, before decoding the received information, the UE combines the information obtained from the first transmission with that of the subsequent retransmissions: this mode, called "soft combining", increases the capacity of the link and its robustness against errors.

4. Hybrid-ARQ with soft combining (2/3)

- Retransmission time reduction is achieved by implementing the Hybrid-ARQ mechanism in Node B.
- In uplink, the UE informs Node B of the correct or incorrect reception of the information blocks received; based on the feedback, Node B transmits new information or retransmits the corrupted ones received from the EU.

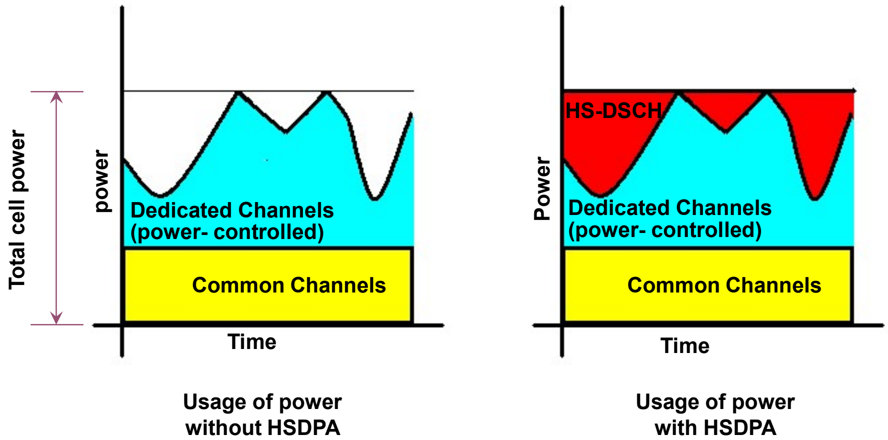
4. Hybrid-ARQ with soft combining (3/3)



Cell power utilization (1/2)

- HSDPA uses the power not used by dedicated channels: after serving the common and dedicated channels, it is possible to allocate the remaining power (compared to the total cell power) to the HS-DSCH, resulting in a more efficient use of the available power
- In fact, the dedicated channels are required, via the fast power control, to maintain a constant data rate; therefore, with only power-controlled channels it is difficult to make full use of the available transmission power.

Cell power utilization (2/2)



Advantages deriving from HSDPA

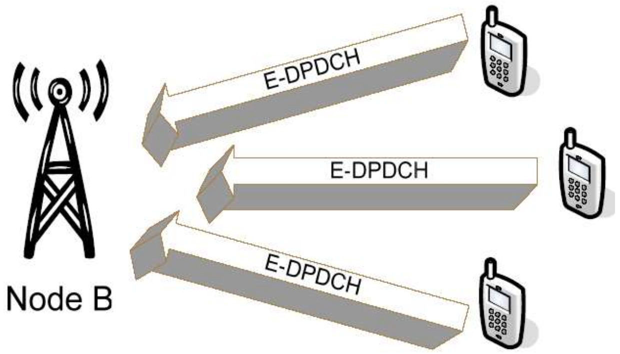
- Benefits for both users and operators are enabled:
  - for users, higher bit-rates, reduced transfer times and reduced RTT are possible;
  - for operators, greater system capacity can be achieved with an increase estimated at two to three times that of UTRA Release 99.

Mobile Radio Networks

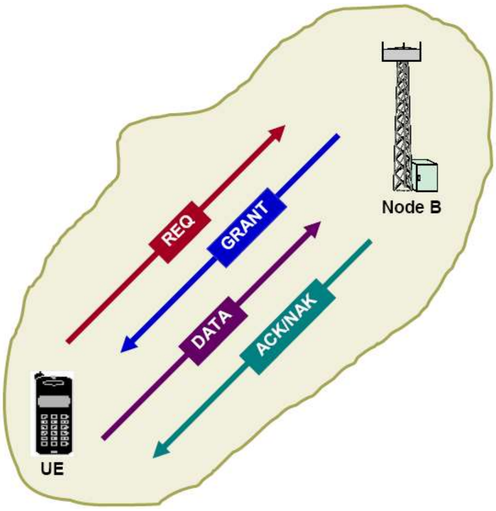
❑Uplink intervention: the E-DCHs of HSUPA

High Speed Uplink Packet Access (HSUPA)

- In the uplink of Node B, a set of high-speed channels is added
- Several users can be authorized to transmit at a given data rate and power via *fast scheduling*.

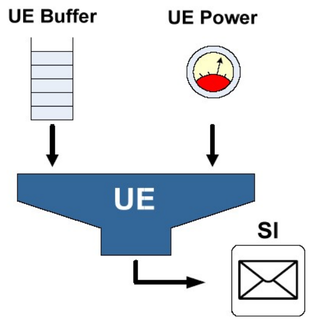


Channel operations in HSUPA



1. The EU sends a Transmission Request to Node B to receive resources.
2. Node B responds to the UE with a Grant Assignment, allocating bandwidth in the Uplink
3. The EU uses the grant to select the most appropriate transport format to perform a Data Transmission to Node B.
4. Node B tries to decode the data and sends an ACK/NAK to the UE. In the case of NAK the data can be retransmitted.

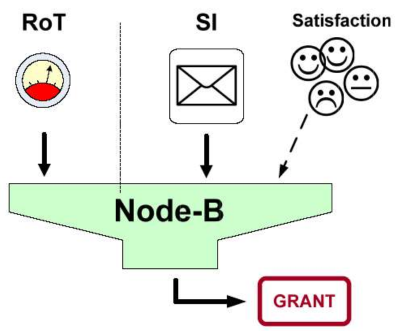
Channel operations in HSUPA



1. Transmission Request

- The EU requires data transmission via *Scheduling Information (SI),*
- SIs are determined based on EU Power and Buffer Data availability
- The SIs are sent to Node B in in-band mode

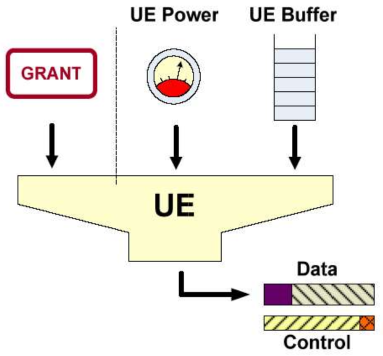
Channel operations in HSUPA



2. Grant Assignment

- Node B determines the UE Grant by monitoring the Uplink interference (RoT , rise over termal, at the receiver), and considering the UE requests and the level of satisfaction
- The grant is then reported to the EU through new grant channels.

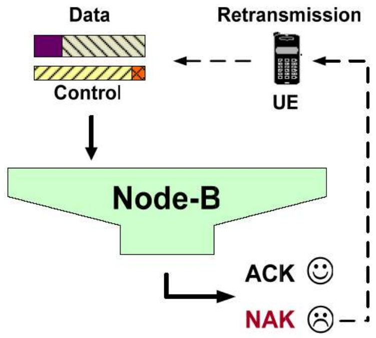
Channel operations in HSUPA



3. Data Transmission

- The EU uses the grant received and, based on its power and data availability, selects the Transport Format of the E-DCH and the corresponding Transmit Power.
- The data is then transmitted by the EU together with the related control information.

Channel operations in HSUPA



4. Data Acknowledgment

- Node B attempts to decode the received data and indicates to the UE via an ACK/NAK if it was successful.
- If no ACK is received from the UE the data can be retransmitted.

Mapping of HSUPA Channels