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TECHNOLOGY OF HIGH SPEED PACKET ACCESS (HSPA)

WHITE PAPER

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HIGH SPEED PACKET ACCESS TECHNOLOGY (HSPA)

1. SUMMARY

Today's mobile communication systems have been enhanced recently to more efficiently support packet switched services. In UMTS HSDPA and E-DCH have been specified in downlink and uplink respectively.

By now UMTS is a well-established technology with manifold networks running globally and competitive terminals on the market. A significant shift from traditional circuit-switched, often constant bit-rate services to IP packet switched services is expected in the near future. UMTS Release 99, based on dedicated resource allocation per user, is not well suited for IP packet data traffic. Therefore High Speed Packet Downlink Access (HSDPA) and Enhanced Dedicated Channel (E-DCH) have been introduced as new features of UMTS for Downlink and Uplink in UMTS Release 5 and Release 6, respectively. This technology called High Speed Packet Access (HSPA) claims significant enhancements in end-to-end service provisioning for IP based services. This introduces these future technology enhancements and assesses the potential gains for future applications and in term user perception.

In addition to the paradigm change from using dedicated resources to making use of shared radio resources, the main technology changes introduced are:

- Fast Node B scheduling with adaptive coding and modulation (only downlink) to exploit the varying radio channel and interference variations and accommodate bursty IP traffic,
- Node B based Hybrid ARQ to reduce retransmission round trip times and add robustness to the system by allowing soft combining of retransmissions,
- Reduced transmission time interval (TTI) for latency reduction and to support fast scheduler decisions and quick HARQ retransmissions.

These added functionalities have been specified in several new MAC sub-layers and modifications of the physical layer as is depicted in Figure 1.

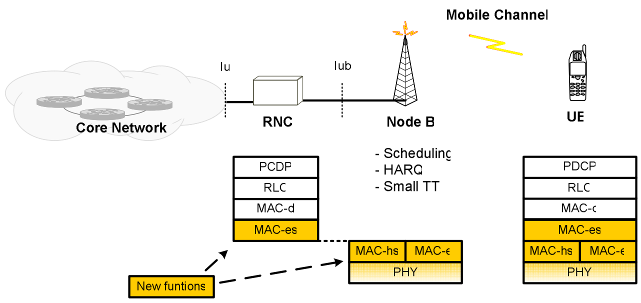

Figure 1: New UMTS Radio Network Protocol Architecture

In general retransmissions are now performed directly between Node B and the User equipment (UE). This reduces latency and saves resources on the Iub interface. The distributed scheduling performed by RNC and Node B requires an additional scheduling buffer in the Node B as well as having an additional flow control on the Iub interface. Furthermore the Node B needs to be made aware of certain QoS parameter to ensure that the data transmission complies with the traffic requirements. Nevertheless HSDPA and HSUPA can be implemented in the standard 5 MHz carrier of UMTS networks and can co-exist with the existing 3GPP Release 99 networks. In the following sections the principles of HSDPA and E-DCH are explained in more detail.

In downlink a new entity called MAC-hs contains the new HSDPA functionality as seen in Figure 1. Instead of a fixed code allocation with fast power control, the code and power resource is now shared amongst all active HSDPA users. For this purpose a new transport channel, the **High Speed Downlink Shared Channel (HS-DSCH)**, has been defined that supports adaptive coding and modulation, whereby every 2ms the transmission format can change dynamically.

In good radio channel condition 16QAM modulation can be used instead of QPSK and the rate 1/3 turbo code may be punctured down to enable higher data rates. Depending on the UE capabilities up to 15 codes with a fixed spreading factor of 16 can be received if all codes are allocated to a single UE. Since power control is replaced by rate control with adaptive coding and modulation the maximum data rate as received by the user directly depends on the channel and interference conditions as well as the user position in the cell.

The Node B scheduler must take care that fairness is maintained. The dynamic resource allocation by the scheduler (per 2ms TTI) is signalled to the users on a new downlink control channel called **High Speed Signalling Control Channel (HS-SCCH)**. The following information is carried on the HS-SCCH:

- UE Identity (UE ID) via a UE specific CRC which allows addressing specific UEs on the shared control channel.
- Transport Format and Resource Indicator (TFRI) which identifies the scheduled resource and its transmission format.
- Hybrid-ARQ-related information to identify redundancy versions for the combining process.

Each user can monitor up to 4 HS-SCCHs. For the support of channel based scheduling and HARQ the following feedback signalling is transmitted on the **High Speed Dedicated Physical Control Channel (HS-DPCCH)** in the uplink:

- Channel Quality Information (CQI) to inform the scheduler about the instantaneous channel condition.
- HARQ ACK/NACK information to let the sender know the outcome of the decoding process and to request retransmissions.

Figure 2 depicts the data and signalling flow during HSDPA transmission. Based on the UE channel quality report the Node B scheduler sends data on the shared downlink channel to the user. The UE will then reply with an ACK or NACK message based on the outcome of the decoding. Note that the standard does not specify scheduling and resource allocation which leaves significant freedom to Node-B implementations.

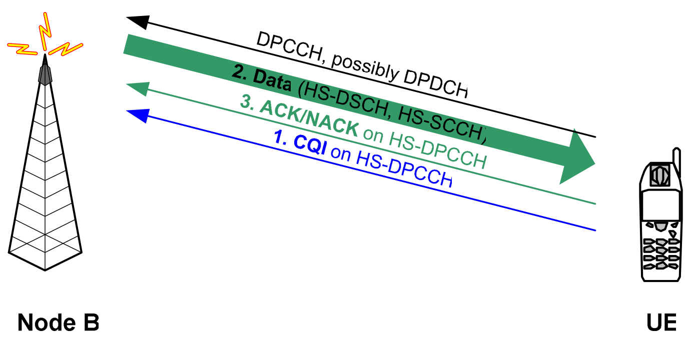

Figure 2. Simplified HSDPA transmission scheme

Due to the non-orthogonal uplink transmission in W-CDMA the principles applied for the newly defined transport channel **Enhanced Dedicated Channel (E-DCH)** are fundamentally different from HSDPA. The shared resource in the system is the received interference at the Node B and a transmission at a single UE can impact the raise over thermal noise as received by different Node B. Continuous uplink power control is still an essential means of link adaptation due to the well known near-far problem. Consequently it was decided to support soft handover for E-DCH to minimize intercell interference. Unlike HSDPA the scheduler is not aware of the transmission buffer status, channel state and the UE transmission capabilities. Partly this information will be signalled to the Node B via control signalling.

For the support of the new functionality several new physical channels were introduced.

- **E-DPDCH: E-DCH Dedicated Physical Data Channel** for dedicated uplink data transmission. During data transmission so-called Scheduling Information such as buffer status, data priority and power headroom can be piggybacked.
- **E-DPCCH: E-DCH Dedicated Physical Control Channel** with the associated control data for E-DPDCH detection and decoding. For the support of the scheduler there is a Happy Bit that informs if the UE has sufficient resources for transmission.
- **E-HICH: E-DCH HARQ Acknowledgement Indicator Channel** to transmit HARQ feedback information (ACK/NACK)
- **E-RGCH: E-DCH Relative Grant Channel** to grant dedicated resources (up, down, hold) to a UE
- **E-AGCH: E-DCH Absolute Grant Channel** is a shared channel that allocates an absolute resource for one or several UE.

In Figure 3 the E-DCH data and signalling flow is illustrated. Based on the rate request (Scheduling Information or Happy Bit) the Node B may respond with a resource allocation via the absolute or a relative grant. The UE will use the grant for data transmission and the Node B will acknowledge the received packets.

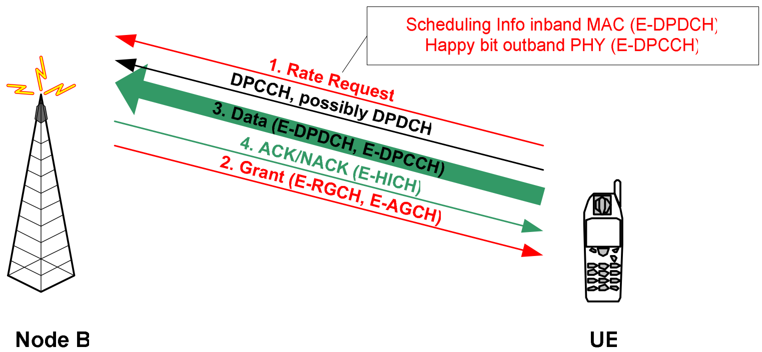

Figure 3. Simplified E-DCH transmission scheme

The HARQ protocol defined for HSDPA and for E-DCH is based on an n-channel stop-and-wait protocol. Since out of sequence delivery is a regular event for this protocol, there is a reordering function in place to provide in-sequence delivery to higher layer protocols. Unlike in HSDPA this function is contained in a separate sub-layer called MAC-es. MAC-es is located in the RNC since E-DCH supports soft handover and the packets can be received by different Node Bs. It must also be noted that the ACK/NACK reception is not reliable and there may be unwanted repetitions or even packet losses caused by ACK/NACK misinterpretations at the sender. In that case RLC can recover the packets if configured in acknowledged mode (AM).

4. BENEFITS FOR END-TO-END PERFORMANCE

Besides an increase in radio and transport network efficiency for packet based services, HSPA improves user perception by significantly increased peak data rates and a reduced overall latency. Peak data rates depend on the supported reference classes. Typically the operator will upgrade the network successively. The first terminals will be a data cards enabling 1.8 Mbit/s peak data rate
(Category 12) and 3.6 Mbit/s peak data rate (Category 6).

Table 1. Selected HS-DSCH physical layer categories

Category	Max peak rate [Mbps]	Max. codes number	Min. inter-TTI interval	Max. bit number within TTI
12	1.8	5	1	3630
6	3.6	5	1	7298
10	14.4	10	1	27952
Note: Spreading factor = 16; Transmission Time Interval = 2ms				

Table 1 and Table 2 depict several categories and their associated physical layer parameter restrictions for HSDPA and E-DCH respectively [3GPP TS 25.306].

Table 2. Example of E-DCH physical layer categories

Category	Max peak rate [Mbps]	Max. code number	Min. spread factor	TTI Support	Max. bit number within a TTI
1	0.7296	1	SF4	10	7110
2	1.4592	2	SF4	10 / 2	14484/2798
4	2.9185	2	SF2	10 / 2	20000/5772
6	5.76	4	SF2	10 / 2	20000/11484

At the final state of HSPA Release 6 deployment a maximum of 14.4 Mbps will be supported in the downlink and 5.76 Mbps in the uplink. However it should be emphasized that the peak data rates are temporary rates at the physical layer and neglect protocol overhead at the different layer. Furthermore an optimistically high channel code rate at the physical layer is assumed. HSPA networks are not expected to be deployed before 2007.

In terms of end-to-end delay significant enhancements can be expected due to fast Node-B HARQ re-transmission as well as reduced transmission time interval. Fast HARQ by the Node B will save at least two times Iub transmission delay compared to RLC ARQ retransmission. Note that the Iub is susceptible to congestion due to missing statistical multiplexing on the low capacity last mile. HARQ uses on synchronous ACK/NACK feedback and does not rely on infrequent event based RLC status reports. Furthermore the interleaving delay decreases proportionally to the TTI reduction. On the other hand the HARQ generally operates at higher block error rate and will thus have a higher number of retransmissions.

In general there is no easy calculation of the system throughput and latency reduction due to various functions performed at the different layer. All protocol functions must be modelled realistically to take into account the impact of encapsulation, segmentation, retransmission, reordering etc. Results will be highly dynamic and depend on the selected scenario and parameters. Furthermore the gain for a single link may also not necessarily turn into improvement of overall system performance. Simulations on system level considering multiple cells and multiple users are well established as means to evaluate system performance in today's complex mobile communication systems. Due to the high complexity those simulations are very time consuming and generally run offline.

Nevertheless, in our research effort Nomor Research has implemented a standard compliant UMTS system with the enhanced features of HSPDA and E-DCH in our RealNeS platform. The Real-time Network Simulation (RealNeS) tool with our HSPA implementation as described above allows applications to be tested live and even provide means to perform measurements and parameter reconfigurations in real-time.

ABOUT NOMOR

Nomor Research GmbH is a leading company in the area of real time system emulation and specialized in the implementation of future radio access networks. In sustained research projects with strategic partner companies we develop and implement leading edge technologies such as HSPA, MBMS, WiMAX and Long Term Evolution. By our end-to-end emulation platform running in real-time Nomor is able:

- to design, test and verify algorithms across all layers
- to demonstrate system performance and feasibility
- to show the actual experienced user perception of applications,

years before systems are actually deployed or available in hardware. Nomor is active in various standardisation bodies to enhance today's mobile communication systems with a main focus on future radio access schemes, protocols and applications.

Nomor Research is an independent company. Our customers gain from our capabilities in research, standardisation and implementation as well as our standard conform simulation environment. We invite you to find out more about our mission, goals, and competences and how we can help YOU.

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