HSDPA
High Speed Downlink Packet Access

Technology Update
adare GmbH
www.adare.de
Marija Skoda
Email: marija.skoda@adare.de

March 2006
HSDPA - Agenda

- GSM and UMTS evolution
  - Technological approach
  - Protocol architecture
  - HDSPA channels in UTMS Release 5
  - Mobility aspects
  - Outlook beyond Release 5
Evolution of GSM and UMTS in Europe

**Phase 1:**
- Tele (FR speech, SMS)/Bearer(9.6kbps)/Supplementary Services

**Phase 2:**
- Tele (HR speech, SMS)/Bearer(9.6kbps)/Supplementary Services

**Phase 2+:**
- HSCSD, GPRS, EDGE
  - Enhanced Bearer Services
  - (14.4kbps-50kbps-128kbps)

**3G**
- R’99:
  - UTRAN, WCDMA, MMS (up to 2Mbps)

**2.5G**
- R’96
- R’97
- R’98
- R’99

**2G**
- 1990-1991
- 1994
- 1997
- 1998
- 1999

**Year**
- 1999-2000
- 2001
- 2002
- 2005
- 2007

**3.5G**
- R’4-R’7:
  - VHE, IMS, HSDPA, HSUPA, PoC, E-DCH, MBMS, MIMO, WLAN integration

Increase in data transmission speed from 2Mbps to 30-50Mbps

* See the appendix for the abbreviation list
UMTS FDD radio access basics

- Channel bandwidth 5 MHz
- QPSK modulation
- Pulse shaping
- Direct sequence CDMA
- OVSF spreading codes
- Timing structure
- Transmission rate 3.84 Mchip/s
- Frequency reuse = 1
- Soft handover

**CDMA** – Code Division Multiple Access
**OVSF** – Orthogonal Variable Spreading Factor
**QPSK** – Quadrature Phase Shift Keying
CDMA principle

- **CDMA**-Code Division Multiple Access:
  - Narrow-band signal is *spreaded* with an OVSF code:
    - to increase the signal bandwidth
    - to achieve the orthogonality between signals from the same source
  - Wide-band signal then is *scrambled* with a scrambling code to distinguish between different sources
  - **Spreading factor** $SF = \text{Chiprate/Bitrate}$

- **Near-far problem**: - power control necessary to limit the interference between sources
Spreading example

Bipolar data

+1

-1

Spreading code

SF=8

(channelisation code x scrambling code)

+1

-1

Coded data

+1

-1
HSDPA Motivation

- **Reasons to deploy HSDPA:**
  - Saturated voice communication market
  - Growing demand and user expectation for the data services like broadband internet access, streaming, gaming, etc.
  - Competing High Speed wireless technologies
    - WLAN
    - WiMAX
    - 1xEvDo in CDMA 2000

- **Requirements:**
  - Short set-up and transfer delays
  - High system capacity
  - High peak data rates
  - Low mobility (user speed max 3km/h)
  - Low data transfer costs
## Rel. ’99 vs. Release 5

<table>
<thead>
<tr>
<th>Mode of Transmission</th>
<th>Release’99</th>
<th>Release 5 - HSDPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voice &amp; data over DCH; Max download rate 384 kbit/s, GPRS latency 700 ms</td>
<td></td>
<td><strong>High speed</strong> downlink broadcast shared channel for data Support of IP and radio bearers for IP-based services</td>
</tr>
</tbody>
</table>

| Network View | Release’99 cells | Release’99 Cells and mixed Rel.’99 – Rel.5 cells e.g. in hotspots |
HSDPA - Agenda

- GSM and UMTS evolution
- Technological approach
  - Protocol architecture
  - HDSPA channels in UTMS Release 5
  - Mobility aspects
  - Outlook beyond Release 5
High speed downlink broadcast channel

**Major objectives:**

- **Service aspect:**
  - Allow higher data rates for users in favourable positions
  - Decrease latency

- **Network aspect:**
  - Increase radio efficiency/capacity for data

HSDPA-capable UEs

NodeB

14.06.2006
Technologies for HSDPA support

- Adaptive Modulation and Coding (AMC)
- Hybrid Automatic Repeat Request (H-ARQ)
- Fast transmission/retransmission scheduling
Technologies for HSDPA support

- Adaptive Modulation and Coding (AMC)
  - Hybrid Automatic Repeat Request (H-ARQ)
  - Fast transmission/retransmission scheduling
AMC principle

**Release ‘99**

- Power level: \( \alpha \)
- Modulation: QPSK
- Turbo Code \( R=1/3 \)

**HSDPA**

- Power level: \( \alpha \)
- Modulation: 16-QAM
- Turbo Code \( R=1/3 \), rate matching: \( 3/4 \)

- Power level: \( \beta \)
- Modulation: QPSK
- Turbo Code \( R=1/3 \)

- Power level: \( \alpha \)
- Modulation: QPSK
- Turbo Code \( R=1/3 \), rate matching: \( 1/4 \)
Adaptive Modulation and Coding (AMC)

- **Main principle** – to dynamically modify
  - Signal modulation and
  - Coding scheme

  to compensate the variations in channel conditions

- **Benefits:**
  - Increased average cell throughput
  - Reduced interference variation
  - Higher data rates for users in favourable positions

- **Effective in a combination with scheduling techniques**
## Data throughput

<table>
<thead>
<tr>
<th>Modulation</th>
<th>Coding Rate</th>
<th>Throughput in kbps (1 code of SF=16)</th>
</tr>
</thead>
<tbody>
<tr>
<td>QPSK</td>
<td>1/4</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td>2/4</td>
<td>240</td>
</tr>
<tr>
<td></td>
<td>3/4</td>
<td>360</td>
</tr>
<tr>
<td>16-QAM</td>
<td>2/4</td>
<td>480</td>
</tr>
<tr>
<td></td>
<td>3/4</td>
<td>720</td>
</tr>
<tr>
<td></td>
<td>4/4</td>
<td>960</td>
</tr>
</tbody>
</table>
Technologies for HSDPA support

- Adaptive Modulation and Coding (AMC)
- Hybrid Automatic Repeat Request (H-ARQ)
- Fast transmission/retransmission scheduling
H-ARQ-type-III

- **Chase combining with one redundancy version:** the data are retransmitted with a little redundancy. The retransmitted signal is weighted by SNR and then combined with the first received signal.

![Diagram of H-ARQ-type-III process]

- **Data Bits with redundancy**
- **Coded data bits**
- **NACK**
- **Error detected:** store a packet, request a retransmission
- **1st transmission**
- **2nd transmission**
- **Decode combined data**

14.06.2006
**H-ARQ-type-II**

- **Incremental redundancy:** only *correction* data to the original data is retransmitted. The additional redundant data will be sent *incrementally* if NACK is received.

[Diagram showing the process of H-ARQ-type-II, including NodeB sending coded data bits with redundancy, UE receiving the data, NACK being sent if an error is detected, combining the stored packet with the received redundancy, and decoding the combined data.]
Timing structure Rel’99

- In UMTS Rel’99 the transmission time interval for transport channels is always multiple to 10 ms (10/20/40/80)

Time Slot TS

2560 chips

2/3 ms

TS0 — TS14

10 ms

F0 — F71

720 ms

Time slot is the shortest repetitive period

1Frame = 15TS

Frame is the shortest transmission duration

Superframe = 72F

TTI - Transmission Time Interval
Shorter time transmission interval (TTI)

- HSDPA introduces short TTI concept, where TTI=2ms

- **Advantages:**
  - Less probability of an error due to the change of the channel conditions
  - More efficient when packet retransmission is necessary
  - Decreased buffer size
Technologies for HSDPA support

- Adaptive Modulation and Coding (AMC)
- Hybrid Automatic Repeat Request (H-ARQ)
- Fast transmission/retransmission scheduling
Fast and fair scheduling in NodeB

Fast scheduling is based on a knowledge of an instantaneous channel quality and thus effectively avoids channel fading during the transmission of data.

UE capabilities, QoS requirements, Uu resources availability are also taken into account for the efficient scheduling.
HSDPA - Agenda

- GSM and UMTS evolution
- Technological approach
- **Protocol architecture**
- HDSPA channels in UTMS Release 5
- Mobility aspects
- Outlook beyond Release 5
Need for an architectural change to Rel’99

- **ARQ mechanism is placed in RNC**
  - **Disadvantage:** latency time up to 100 ms!
  - **Solution:** move it to node B
  - **Profit:** latency below 10 ms

- **Scheduling is controlled by RNC**
  - **Disadvantage:** important channel measurement information can be delayed
  - **Solution:** move scheduling close to the air interface
  - **Profit:** rescheduling is made within a short time
New protocol entities

- **Slow handshake** (RLC acknowledged mode)
- **Fast handshake**

Layer Stack Diagram:
- **PHY**
- **MAC hs**
- **MAC c/sh**
- **RLC**
- **MAC d**
- **PDCP**

Connections:
- **Uu**
- **Iub/Iur**

Device Icons:
- **UE**
- **NodeB**
- **RNC**

Date: 14.06.2006
Impact on the network

- New type of cell – Rel’5 cell, complement to Rel’99 cell and ensures HSDPA functioning

- New NodeB fast scheduling functionality that takes into account
  - Buffer status and resource availability
  - QoS and priority
  - UE capabilities and quality feedback

- Flow control mechanism on the Iub interface
HSDPA - Agenda

- GSM and UMTS evolution
- Technological approach
- Protocol architecture
- **HDSPA channels in UMTS Release 5**
  - Mobility aspects
  - Outlook beyond Release 5
HSDPA code allocation example

SF=1
SF=2
SF=4
SF=8
SF=16

HS-DSCH
Other channels

HS-DSCH – High Speed Downlink Shared Channel
HSPDA multiplexing

Users share channel resources in time domain and code domain.

Control channel is needed to transmit a resource allocation information.
## Data throughput

<table>
<thead>
<tr>
<th>Modulation</th>
<th>Coding Rate</th>
<th>Throughput in Mbps (5 codes)</th>
<th>Throughput in Mbps (10 codes)</th>
<th>Throughput in Mbps (15 codes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>QPSK</td>
<td>1/4</td>
<td>0.6</td>
<td>1.2</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>2/4</td>
<td>1.2</td>
<td>2.4</td>
<td>3.6</td>
</tr>
<tr>
<td></td>
<td>3/4</td>
<td>1.8</td>
<td>3.6</td>
<td>5.4</td>
</tr>
<tr>
<td>16-QAM</td>
<td>2/4</td>
<td>2.4</td>
<td>4.8</td>
<td>7.2</td>
</tr>
<tr>
<td></td>
<td>3/4</td>
<td>3.6</td>
<td>7.2</td>
<td>10.7</td>
</tr>
<tr>
<td></td>
<td>4/4</td>
<td>4.8</td>
<td>9.6</td>
<td>14.4</td>
</tr>
</tbody>
</table>
Throughput calculation example

- Calculate user data throughput in Mbps for a given transmission parameters:
  - Modulation: 16-QAM
  - Effective code rate: R=3/4
  - Number of allocated codes: N=5

- Formula:

\[
\text{Chips per Sec} \times \text{Number of Bits per Modulation Symbol} \times R \times N \div \text{SF}
\]

- Calculation:

\[
\frac{2560 \times 3/2 \text{ ms} \times 4 \times 3/4 \times 5}{16} = 3.6 \text{ Mbps}
\]
## HSDPA terminal classes

<table>
<thead>
<tr>
<th>Class</th>
<th>HS-DSCH channels</th>
<th>Min TTI</th>
<th>Modulation</th>
<th>Peak rate Mbps</th>
<th>Soft channel bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>3</td>
<td>both</td>
<td>1.2</td>
<td>19200</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>3</td>
<td>both</td>
<td>1.2</td>
<td>28800</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>2</td>
<td>both</td>
<td>1.8</td>
<td>28800</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>2</td>
<td>both</td>
<td>1.8</td>
<td>38400</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>1</td>
<td>both</td>
<td>3.6</td>
<td>57600</td>
</tr>
<tr>
<td>6</td>
<td>5</td>
<td>1</td>
<td>both</td>
<td>3.6</td>
<td>67200</td>
</tr>
<tr>
<td>7</td>
<td>10</td>
<td>1</td>
<td>both</td>
<td>7.2</td>
<td>1152100</td>
</tr>
<tr>
<td>8</td>
<td>10</td>
<td>1</td>
<td>both</td>
<td>7.2</td>
<td>134400</td>
</tr>
<tr>
<td>9</td>
<td>15</td>
<td>1</td>
<td>both</td>
<td>10.8</td>
<td>172800</td>
</tr>
<tr>
<td>10</td>
<td>15</td>
<td>2</td>
<td>both</td>
<td>14.4</td>
<td>172800</td>
</tr>
<tr>
<td>11</td>
<td>5</td>
<td>1</td>
<td>QPSK</td>
<td>0.9</td>
<td>14400</td>
</tr>
<tr>
<td>12</td>
<td>5</td>
<td>1</td>
<td>QPSK</td>
<td>1.8</td>
<td>28800</td>
</tr>
</tbody>
</table>
Channel set comparison

**Release ‘99**

- Dedicated channels: DCH
- Shared channels: DSCH

**HSDPA**

- Dedicated channels: HS-DCCH
- Shared channels: HS-SCCH, HS-DSCH

Node B

UE Rel'99 → UE Rel'5

14.06.2006
Associated Signalling

- **Uplink:**
  - Fast link adaptation (AMC) signalling
  - H-ARQ signalling

- **Downlink:**
  - UE-Id for a given HSDPA TTI
  - Transport Format and Resource Indicator (TFRI):
    - TB set size
    - Channelisation codes
    - H-ARQ information
  - Relative CPICH to HSDPA power ratio (for TTI)
Packet exchange

- HS-SCCH frame
- HS-DSCH frame
- UE

Time between transmission of HS-SCCH and HS-DSCH frames

UE-id, codes, modulation
H-ARQ information, CRC

Data bits
ACK/NACK
CQI

Time for a feedback information generation

Time for packet scheduling based on received information

1 slot = 0.67ms
2 slots = 1.33ms
2 slots = 1.33ms
HSDPA - Agenda

- GSM and UMTS evolution
- Technological approach
- Protocol architecture
- HDSPA channels in UTMS Release 5
- Mobility Aspects
- Outlook beyond Release 5
Mobility management

- **Only hard handover for HSDPA transmissions**

- **HSDPA handover types:**
  - Intra NodeB handover
  - Inter NodeB handover
  - HS-DSCH to Dedicated Channel handover
Intra-NodeB HSDPA handover

S-RNC commands NodeB to prepare for the serving HS-DSCH cell change at the activation time.

At activation time, S-RNC commands NodeB to prepare for the serving HS-DSCH cell change at the activation time.

No need to reset MAC-hs entity.

If necessary, the radio bearer reconfiguration procedure should be performed.
Inter-NodeB HSDPA handover

At activation time

*RLC for a transmission reception on HS-DSCH is stopped both at UE and UTRAN prior to and until the reconfiguration is completed*

Transport channel reconfiguration message includes MAC-hs reset flag
HSDPA - Agenda

- GSM and UMTS evolution
- Technological approach
- HDSPA channels in UTMS Release 5
- Protocol architecture
- Physical layer modifications
- Outlook beyond Release 5
High speed downlink broadcast channel

Major objectives:

Service aspect:
- Higher data rated for users in favourable positions
- Decrease delays

Network aspect:
- Increase throughput in the uplink
- Downward compatibility to Rel’99, Rel’4 and Rel’5
- Soft handover

Need to deploy an Enhanced Dedicated Channel (E-DCH) in UL/DL for UE for scheduling and H-ARQ operations

14.06.2006
MIMO technique allows to achieve higher data rates either:

when using the same spreading code on different antennas
attaining better channel quality by improved antenna transmit and receive diversity
HSPDA in Germany, Sample March 2006

Commercial offer T-Mobile (1,8 Mbit/s), large city coverage
Tariff example:

5 € p.m. Data Connect + 35 € p.m.
Option web'n'walk i.e. incl. 5 GB (quasi-flat) + 1 € p.d. used

Notebook card 1 €
24 month contract

UEs availability:

Today:
Only notebook cards (1,8 Mbit/s)

HSDPA Mobiles announced for Summer:
e.g. BenQ EF 91 (3,6 Mbit/s)

Vodafone: - Home zone DSL-like tariff e.g. 36 €, incl.5 GB p.m.
- Surcharge for mobility
Questions and Discussion

Thank you