Enhanced High-Speed Packet Access
HSPA+

- Background: HSPA Evolution
- Higher Data Rates
- Signaling Improvements
- Architecture Evolution/ Home NodeB
HSPA+

◆ The evolution of UMTS HSPA
  ◆ Corresponding to UMTS Release 7 and beyond
◆ Motivation of HSPA+
  ◆ 3GPP Long Term Evolution (LTE) being rolled-out, but not backwards compatible with HSPA
  ◆ 556 HSPA networks in service in 203 countries (Oct. 14)**
  ◆ Investment protection needed for current HSPA deployments
◆ Main goals
  ◆ Performance and flexibility **comparable to LTE** in 5 MHz
  ◆ Optimized **packet-only mode** for voice and data
  ◆ **Backward compatible** with Release 99 through Release 6
  ◆ **Smooth migration path to LTE** through commonality and facilitate joint technology operation
  ◆ Requiring **simple infrastructure upgrade** from HSPA to HSPA+
◆ HSPA+ defines a broad framework and set of requirements
  ◆ Improvement of the radio interface
  ◆ Architecture evolution

**[source: 4GAmericas]**
Higher Order Modulations (HOMs)

- **Uplink**
  - BPSK
    - 1 bit/symbol
  - 16QAM
    - 4 bits/symbol

- **Downlink**
  - 16QAM
    - 6 bits/symbol
  - 64QAM
    - 6 bits/symbol

- Increases the peak data rate in a high SNR environment
- Very effective for micro cell and indoor deployments
Peak Rate Performance Benefits of HSPA+

Uplink and Downlink peak rates similar to LTE peak rates in 5 MHz

- Major increase HSPA peak rates by Higher Order Modulations
- Data rate benefits for users in ideal channel conditions (e.g. static users, fixed users close to the cell center, lightly loaded conditions)

*Release 8
HSDPA Performance with 64QAM

Single micro-cell scenario, advanced receivers required

<table>
<thead>
<tr>
<th></th>
<th>Without 64QAM</th>
<th>With 64QAM</th>
<th>Gain</th>
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<tbody>
<tr>
<td><strong>Cell Throughput</strong></td>
<td>6.9 Mbit/s</td>
<td>7.65 Mbit/s</td>
<td>10.7%</td>
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<tr>
<td><strong>95%-tile User Throughput</strong></td>
<td>7.1 Mbit/s</td>
<td>8.7 Mbit/s</td>
<td>22.5%</td>
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</table>
16QAM for E-DCH

- 16QAM specified in the uplink for HSPA Evolution, for use with the 2 ms TTI and with 4 multicodes (2xSF2 + 2xSF4)
  - Increases peak rate from 5.76 Mbps to 11.52 Mbps
- Performance results showed:
  - 16QAM requires very good radio conditions
  - Enhancement of the radio architecture needed (transmitter, receiver)
16QAM EDCH Performance

- Isolated radio cell with good radio conditions (AWGN) and HARQ retransm. rate of 1%
- Results show performance for 16QAM above 11 Mbps
  - Ideal channel conditions
  - Single user active
  - Advanced receiver
- RLC settings need to be adapted
  - Larger PDU size
  - Improved L2 provides some further gain
The HSDPA MIMO channel consists of 2 Tx and 2 Rx antennas. Each Tx antenna transmits a different signal. The signal from Tx antenna $j$ is received at all Rx antennas $i$. Channel capacity can be increased by up to a factor of two.
MIMO in HSPA+

Release 7 MIMO for HSDPA (D-TxAA)

- 2 x 2 MIMO scheme
- 4 rank-1 precoding vectors and 4 rank-2 precoding matrices are defined
  - The rank-2 matrices are unitary (the columns are orthogonal)
- The mobile reports the rank of the channel and the preferred precoding weights periodically (PCI)
- Dynamic switching between single stream and dual stream transmission is supported by the NodeB scheduler

```
Primary transport block
TrCH processing

Secondary transport block
TrCH processing

Spread/scramble

CPICH1

CPICH2

Determines weight info
message from the uplink

Weight Generation

Primary: Always present for scheduled UE
Secondary: Optionally present for scheduled UE
```
MIMO Performance Benefits

- 2x2 D-TxAA MIMO scheme doubles peak rate from 14.4 Mbps to 28.8 Mbps
- 2x2 D-TxAA MIMO provides significant experienced peak, mean & cell edge user data rate benefits for isolated cells or noise/coverage limited cells
- 2x2 D-TxAA MIMO provides 20% – 60% larger spectral efficiency than 1x2
Overview of Dual Cell Operation

3GPP Rel.8 scope:
- The dual cell operation only applies to downlink HS-DSCH
  - Uplink traffic is carried on one frequency
- The two cells belong to the same Node-B and are on adjacent carriers
- The two cells operate with a single TX antenna
  - Max two streams per user

Improvements in Rel.9
- Dual-Band HSDPA
- MIMO in dual cell operation
- Dual Cell uplink

Multi-carrier HSDPA

UTRAN configures one of the cell as the serving cell for the uplink
Dual Cell HSDPA can optimally balance the load on two HSDPA carriers by scheduling active users simultaneously or on least loaded carrier at given TTI.

Dual Cell HSDPA operation versus Two legacy HSDPA carriers

Simple traffic and capacity model

Avg. Transfer size : 1000 kbyte

Avg. Time between transfers : 60 sec

No gain at very high load
Enhanced Layer-2 Support for High Data Rates

- Release 6 RLC layer cannot support new peak rates offered by HSPA+ features such as MIMO & 64QAM
  - RLC-AM peak rate limited to ~13 Mbps, even with aggressive settings for the RLC PDU size and RLC-AM window size
- Release 7 introduces new Layer-2 features to improve HSDPA
  - Flexible RLC PDU size
  - MAC-ehs layer segmentation/reassembly (based on radio conditions)
  - MAC-ehs layer flow multiplexing
- Release 8 improves E-DCH
  - MAC-i/ MAC-is
MAC-ehs in NodeB

MAC-ehs Functions
- Flow Control
- Scheduling/ Priority handling
- HARQ handling
- TFRC Selection
- Priority Queue Mux
- Segmentation

MAC-ehs
- Flow Control
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Cf. 25.321
## HSDPA – UE Physical Layer Capabilities

<table>
<thead>
<tr>
<th>HS-DSCH Category</th>
<th>Maximum number of HS-DSCH multi-codes</th>
<th>Supported Modulation Formats</th>
<th>Minimum inter-TTI interval</th>
<th>Maximum MAC-hs TB size</th>
<th>Total number of soft channel bits</th>
<th>Theoretical maximum data rate (Mbit/s)</th>
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<tbody>
<tr>
<td>Category 6</td>
<td>5</td>
<td>QPSK, 16QAM</td>
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<td>7298</td>
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<td>345600</td>
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<td>Category 17</td>
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<td>17.6/23.3</td>
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</tbody>
</table>

Note: UEs of Categories 15 – 20 support MIMO

cf. TS 25.306
## E-DCH – UE Physical Layer Capabilities

<table>
<thead>
<tr>
<th>E-DCH Category</th>
<th>Max. num. Codes</th>
<th>Min SF</th>
<th>EDCCH TTI</th>
<th>Maximum MAC-e TB size</th>
<th>Theoretical maximum PHY data rate (Mbit/s)</th>
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<tbody>
<tr>
<td>Category 1</td>
<td>1</td>
<td>SF4</td>
<td>10 msec</td>
<td>7110</td>
<td>0.71</td>
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<td>Category 2</td>
<td>2</td>
<td>SF4</td>
<td>10 msec/ 2 msec</td>
<td>14484/2798</td>
<td>1.45/1.4</td>
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<tr>
<td>Category 3</td>
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<td>SF4</td>
<td>10 msec</td>
<td>14484</td>
<td>1.45</td>
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<tr>
<td>Category 4</td>
<td>2</td>
<td>SF2</td>
<td>10 msec/ 2 msec</td>
<td>20000/5772</td>
<td>2.0/2.89</td>
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<tr>
<td>Category 5</td>
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<td>SF2</td>
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<td>20000</td>
<td>2.0</td>
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<td>Category 6</td>
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<td>SF2</td>
<td>10 msec/ 2 msec</td>
<td>20000/11484</td>
<td>2.0/5.74</td>
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<td>Category 7 (Rel.7)</td>
<td>4</td>
<td>SF2</td>
<td>10 msec/ 2 msec</td>
<td>20000/22996</td>
<td>2.0/11.5</td>
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</table>

**NOTE 1:** When 4 codes are transmitted in parallel, two codes shall be transmitted with SF2 and two codes with SF4

**NOTE 2:** UE Category 7 supports 16QAM

cf. TS 25.306
Continuous Packet Connectivity (CPC)

- Uplink DPCCH gating during inactivity → significant reduction in UL interference
- F-DPCH gating during inactivity
- UE listens on HS-SCCH only when active

- HS-SCCH-less transmission introduced to reduce signaling bottleneck for real-time-services on HSDPA
CPC Performance Benefits

- CPC provides up to a factor of two VoIP on HSPA capacity benefit compared to R.99 AMR12.2 circuit voice and 35 – 40% benefit compared to Rel.6 VoIP on HSPA

Note: All capacity gains normalized to AMR12.2 Circuit Voice Capacity

* All VoIP on HSPA capacities assume two receive antennas in the terminal
“Always On” Enhancement of CPC

- CPC allows UEs in CELL_DCH to “sleep” during periods of inactivity
  - Reduces signaling load and battery consumption (in combination with DRX)
  - Allows users to be kept in CELL_DCH with HSPA bearers configured
  - Need to page and re-establish bearers leads to call set up delay

Without CPC, users typically kept in URA_PCH or CELL_PCH state to save radio resources and battery

CPC allows users to be kept in CELL_DCH

Avoids several hundred ms of call setup delay
Enhanced CELL_FACH & Enhanced Paging Procedure

- UEs are not always kept in CELL_DCH state, eventually fall back to CELL_PCH/URA_PCH

- HSPA+ introduces enhancements to reduce the delay in signaling the transition to CELL_DCH → use of HSDPA in CELL_FACH and URA/CELL_PCH states instead of S-CCPCH
  - Enhanced CELL_FACH
  - Enhanced Paging procedure

- In Rel.8 improved RACH procedure
  - Direct use of HSUPA in CELL_FACH

Use HSDPA for faster transmission of signaling messages → 2ms frame length with up to 4 retransmissions
E-RACH – High level description

- RACH preamble ramping as in R.99 with AICH/E-AICH acknowledgement
- Transition to E-DCH transmission in CELL_FACH
  - Possibility to seamlessly transfer to Cell_DCH
- NodeB can control common E-DCH resource in CELL_FACH
  - Resource assignment indicated from NodeB to UE
HSPA+ Architecture Evolution

- Integration of some or all RNC functions into the NodeB provides benefits in terms of:
  - Network simplicity (fewer network elements)
  - Latency (fewer handshakes, particularly in combination with One-Tunnel)
  - Synergy with LTE (serving GW, MME, eNB)
- Backwards compatible with legacy terminals
- Central management of common resources

![Diagram showing Traditional HSPA Architecture, HSPA with One-Tunnel Architecture, and HSPA+ with One-Tunnel Architecture for PS services]
2 deployment scenarios: standalone UTRAN or carrier sharing with “legacy” UTRAN
Home NodeB – Background

- Home NodeB (aka Femtocell) located at the customers premise
  - Connected via customers fixed line (e.g. DSL)
  - Small power (~100 mW) to only provide coverage inside/ close to the building

- Advantages
  - Improved coverage esp. indoor
  - Single device for home/ on the move
  - Special billing plans (e.g. home zone)

- Challenges
  - Interference
  - Security
  - Costs
Home NodeB architecture principles based on extending Iu interface down to HNB (new Iuh interface)

RAN Gateway Approach with new “Iuh” Interface

- **Approach**
  - Leverage Standard CN Interfaces (Iu-CS/PS)
  - Minimise functionality within Gateway
  - Move RNC Radio Control Functions to Home NodeB and extend Iu NAS & RAN control layers over IP network

- **Features**
  - Security architecture
  - Plug-and-Play approach
  - Femto local control protocol
  - CS User Plane protocol
  - PS User Plane protocol
  - HMS interface
HSPA+ Status & Outlook

- The HSPA+ enhancements provide an interim solution for ongoing UMTS network deployment
  - Investment protection for the existing HSPA operators
  - Fill the gap before deployment of LTE
  - Provide alternatives to LTE in some selected areas
- Currently, 365 HSPA+ networks are in service in 157 countries (Oct. 2014)**
  - Almost using 64QAM (often also with DC)
  - Only a few ones with MIMO
- 3GPP is working on further HSPA enhancements
  - Release 10: 4-carrier HSDPA
  - Release 11: 8-carrier HSDPA, 4x4 HSDPA MIMO, HSDPA multipoint transmission, UL MIMO + 64QAM
  - Release 12: enhancements on HSDPA signaling, EDCH improvements

**[source: 4GAmericas]
HSPA+ References

◆ Papers:

◆ Standards
  ◆ TS 25.xxx series: RAN Aspects
  ◆ TR 25.903 “Continuous Connectivity for Packet Data Users”
  ◆ TR 25.876 “Multiple-Input Multiple Output Antenna Processing for HSDPA”
  ◆ TR 25.999 “HSPA Evolution beyond Release 7 (FDD)”
  ◆ TR 25.820 (Rel.8) “3G Home NodeB Study Item Technical Report”
### Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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</tr>
</thead>
<tbody>
<tr>
<td>AICH</td>
<td>Acquisition Indicator Channel</td>
<td>Mux</td>
<td>Multiplexing</td>
</tr>
<tr>
<td>AMR</td>
<td>Adaptive Multi-Rate</td>
<td>PARC</td>
<td>Per Antenna Rate Control</td>
</tr>
<tr>
<td>BPSK</td>
<td>Binary Phase Shift Keying</td>
<td>PCI</td>
<td>Precoding Control Information</td>
</tr>
<tr>
<td>CLTD</td>
<td>Closed Loop Transmit Diversity</td>
<td>PDU</td>
<td>Protocol Data Unit</td>
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<tr>
<td>CPC</td>
<td>Continuous Packet Connectivity</td>
<td>Rx</td>
<td>Receive</td>
</tr>
<tr>
<td>CQI</td>
<td>Channel Quality Indicator</td>
<td>RTT</td>
<td>Round Trip Time</td>
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<td>DC</td>
<td>Dual Channel</td>
<td>SDU</td>
<td>Service Data Unit</td>
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<td>DSL</td>
<td>Digital Subscriber Line</td>
<td>SAE</td>
<td>System Architecture Evolution</td>
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<td>E-RACH</td>
<td>Enhanced Random Access Channel</td>
<td>S-CPICH</td>
<td>Secondary Common Pilot Channel</td>
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<tr>
<td>F-DPCH</td>
<td>Fractional Dedicated Physical Control Channel</td>
<td>SDMA</td>
<td>Spatial-Division Multiple-Access</td>
</tr>
<tr>
<td>GW</td>
<td>Gateway</td>
<td>SINR</td>
<td>Signal-to-Interference plus Noise Ratio</td>
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<td>HNB</td>
<td>Home NodeB</td>
<td>SISO</td>
<td>Single-Input Single-Output</td>
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<td>HOM</td>
<td>Higher Order Modulation</td>
<td>SM</td>
<td>Spatial Multiplexing</td>
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<td>Tx</td>
<td>Transmit</td>
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<td>IA</td>
<td>Intelligent Antenna</td>
<td>VoIP</td>
<td>Voice over Internet Protocol</td>
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<td>Multiple-Input Multiple-Output</td>
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