Enhanced High-Speed Packet Access HSPA+

- Background: HSPA Evolution
- Higher data rates
- Signaling Improvements
- Architecture Evolution/ Home NodeB

HSPA+ (HSPA Evolution) Background

- For operators deploying High Speed Packet Access (HSPA*) now, there is the need to continue enhancing the HSPA technology
  - 3GPP Long Term Evolution (LTE) being standardized now, but not backwards compatible with HSPA
  - 412 HSDPA networks in service in 157 countries (Oct. 11)**
  - Investment protection needed for current HSPA deployments

- HSPA+ effort introduced in 3GPP in March 2006
  - Initiated by 3G Americas & the GSMA
  - HSPA+ defines a broad framework and set of requirements for the evolution of HSPA
    - Rel.-7: improvements mainly in downlink
    - Rel.-8: mainly uplink enhancements
    - Rel.-9/10: further improvements

*HSPA is the combination of HSDPA and HSUPA

**http://www.4gamericas.org -> Statistics

HSPA+ introduced to continue focus on enhancements to HSPA

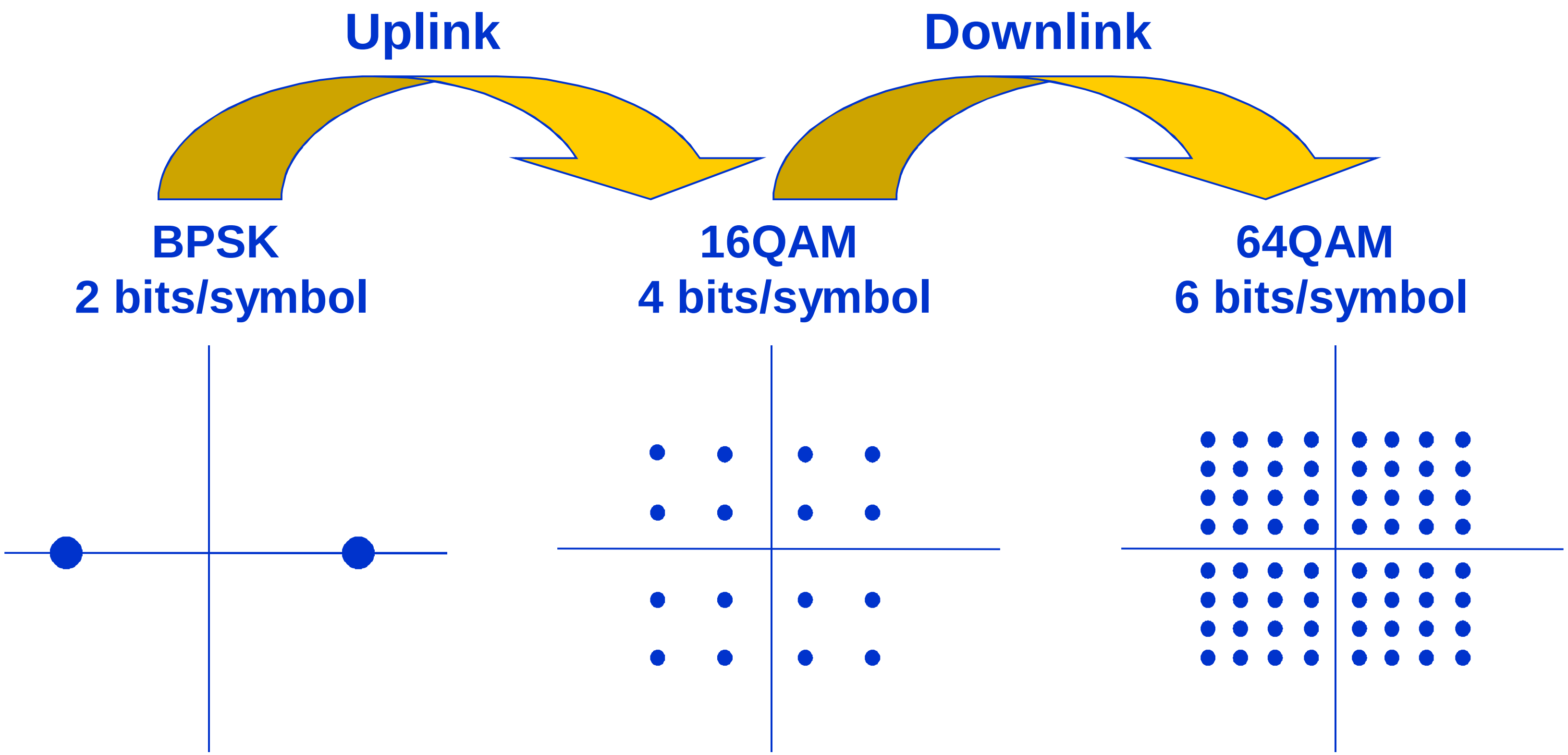
HSPA+ Goals

Based on the importance of the HSPA-based radio network, 3GPP agreed that HSPA+ should:

- Provide **spectrum efficiency, peak data rates & latency** comparable to LTE in 5 MHz
  - Exploit full potential of the CDMA air interface before moving to OFDM
- Allow operation in an **optimized packet-only** mode for voice and data
  - Utilization of shared channels only
- Be **backward compatible** with Release 99 through Release 6
- Offer a **smooth migration path to LTE/SAE** through commonality, and facilitate joint technology operation
- Ideally, only need a simple infrastructure upgrade from HSPA to HSPA+
- HSPA evolution is two-fold
  - Improvement of the radio
  - Architecture evolution

Aggressive HSPA+ goals for enhancing HSPA

Higher Order Modulations (HOMs)



- Increases the peak data rate in a high SNR environment
- Very effective for micro cell and indoor deployments

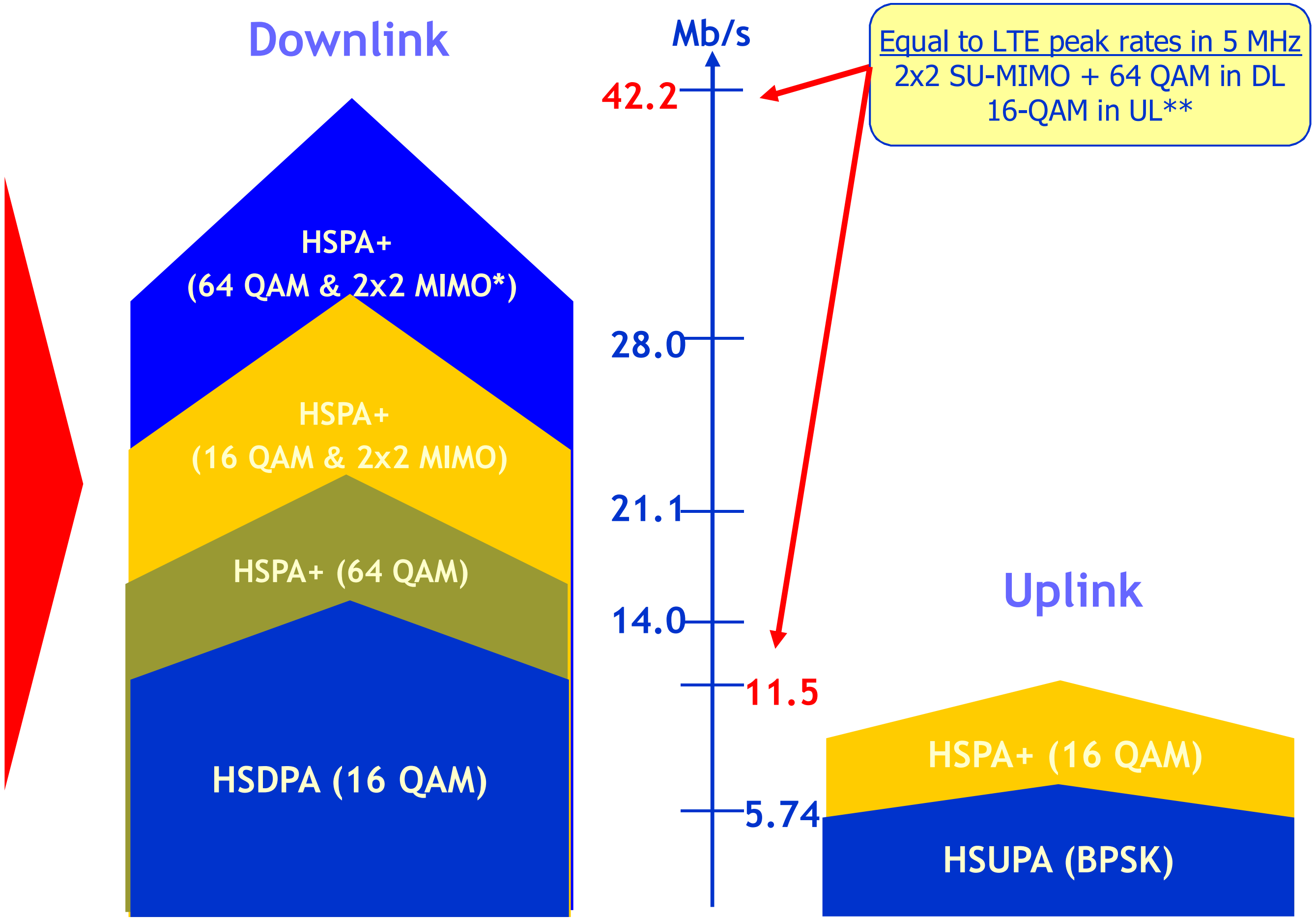
HOMs increase the number of bits/symbols transmitted, thereby increasing the peak rate

HOM Peak Rate Performance Benefits: DL 64-QAM & UL 16-QAM

The use of Higher Order Modulations significantly increases the theoretical peak rates of HSPA

Provides data rate benefits for users in very good channel conditions (e.g. quasi-static or fixed users close to the cell center, lightly loaded conditions)

***Part of 3GPP Rel-8**



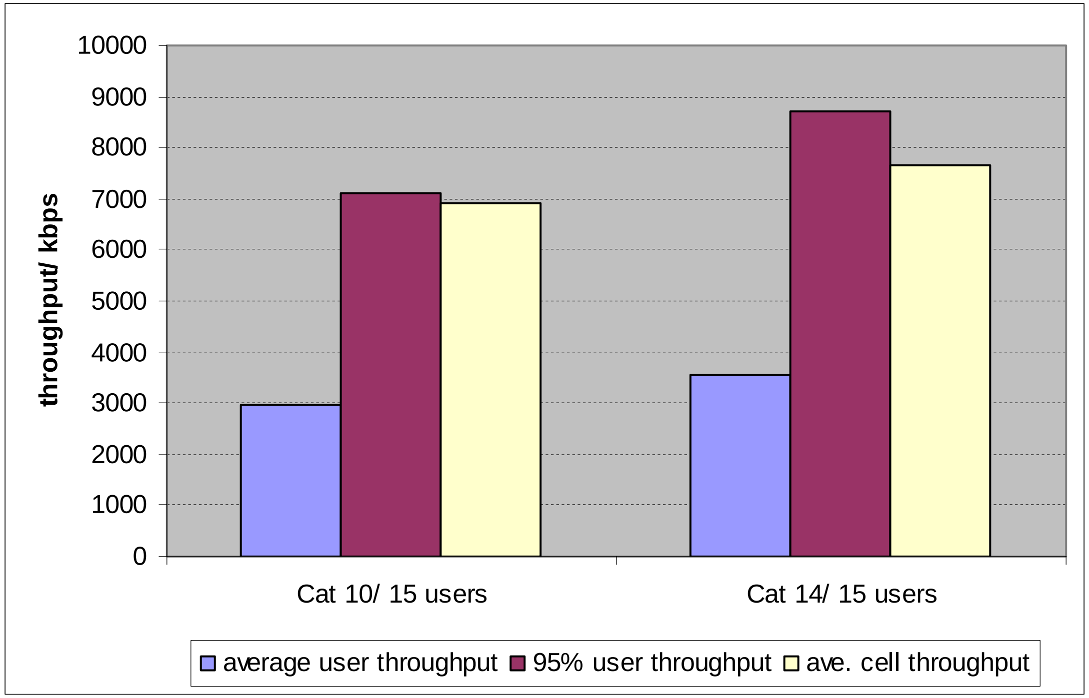
Theoretical Max Peak Rates In Perfect RF Conditions

Higher order modulations provide peak rate benefits for users in very good channel conditions

**Using 2 resource blocks for PUCCH and max prime factor restriction = 5

HSDPA Performance with 64QAM

Single micro-cell scenario, advanced receivers required

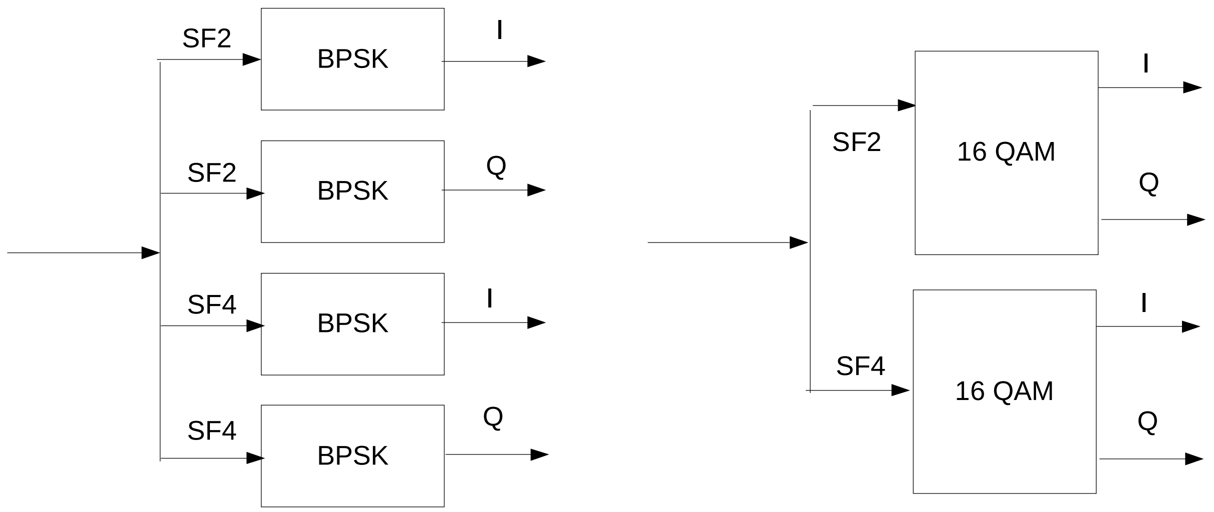


	Without 64-QAM	With 64-QAM	Gain
Cell Throughput	6.9 Mbit/s	7.65 Mbit/s	*10.7%*
95%-tile User Throughput	7.1 Mbit/s	8.7 Mbit/s	*22.5%*

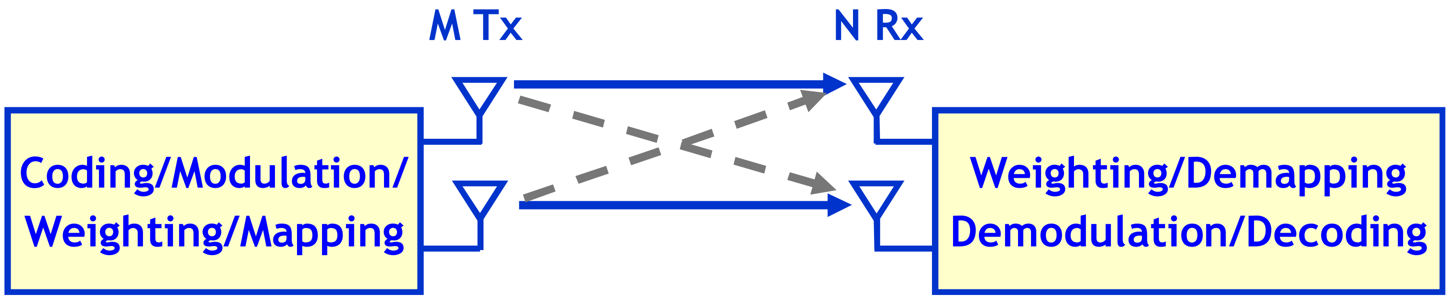
HOMs provide significant improvements for “hot spot” deployments

16-QAM for E-DCH

- 16-QAM being considered in the uplink for HSPA Evolution, for use with the 2ms TTI and with 4 multicodes (2xSF2 + 2xSF4)
  - Increases peak rate from 5.76 Mbps to 11.52 Mbps
- Simulation results showed:
  - 16 QAM requires very high SNR at the receiver
  - 16 QAM can be used only in case of one single HSUPA active user per cell



Basic MIMO Channel



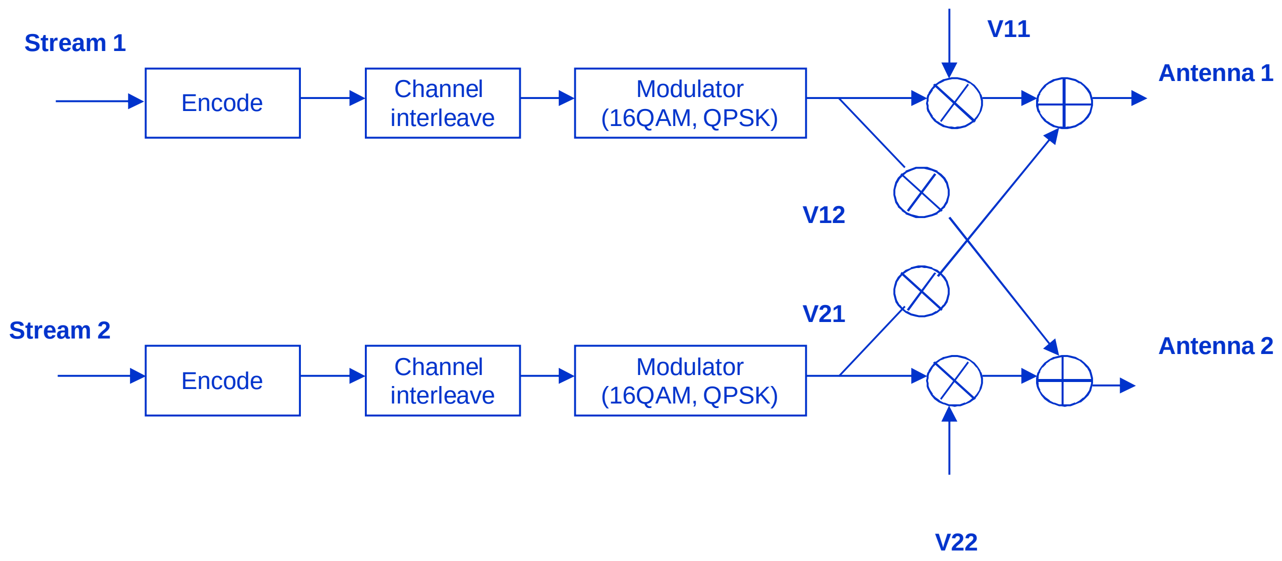
- The MIMO channel consists of M Tx and N Rx antennas
- Each Tx antenna transmits a different signal
- The signal from Tx antenna j is received at all Rx antennas i
- Channel capacity can increase linearly

$$C_{MIMO} \leq \min\{M,N\} \bullet C_{SISO}$$

MIMO in HSPA+

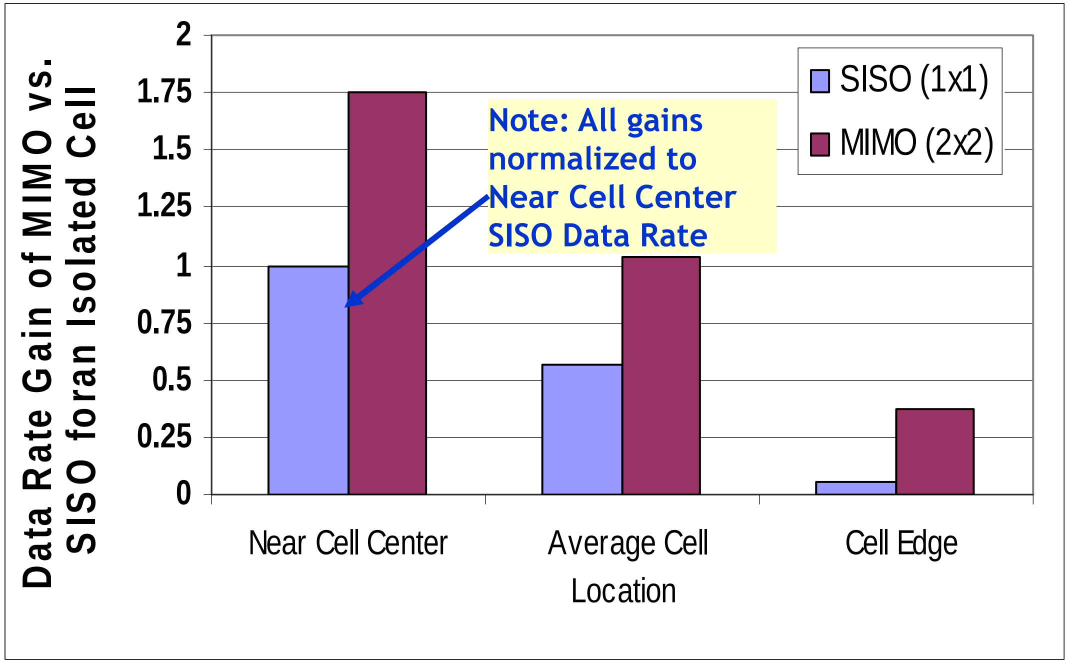
Release 7 MIMO for HSDPA (D-TxAA)

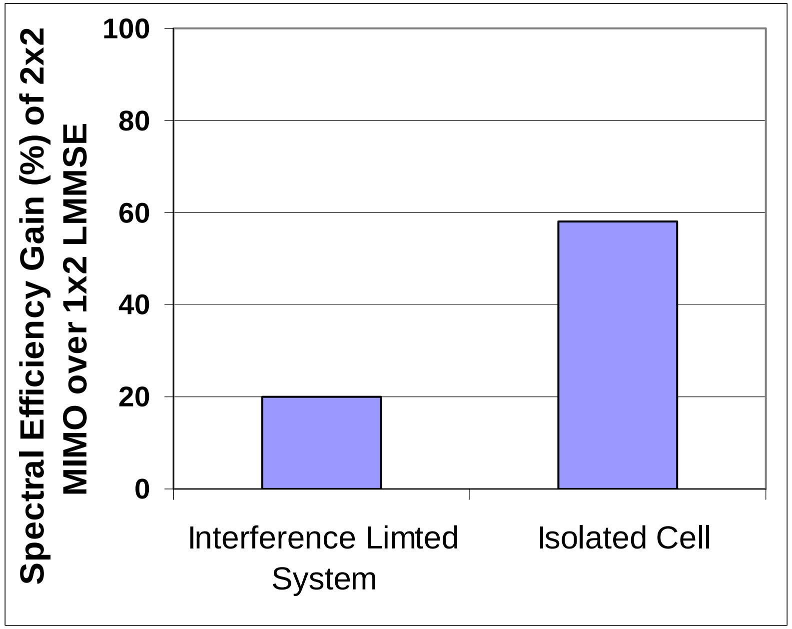
- 2 x 2 MIMO scheme
- 4 rank-1 precoding vectors and 4 rank-2 precoding matrices are defined
  - The rank-2 matrices are unitary (the columns are orthogonal)
- The mobile reports the rank of the channel and the preferred precoding weights periodically
- Dynamic switching between single stream and dual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



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





MIMO provides significant data rate and spectral efficiency benefits for isolated, noise limited cells

Overview of Dual Cell Operation

3GPP Rel-8 scope:

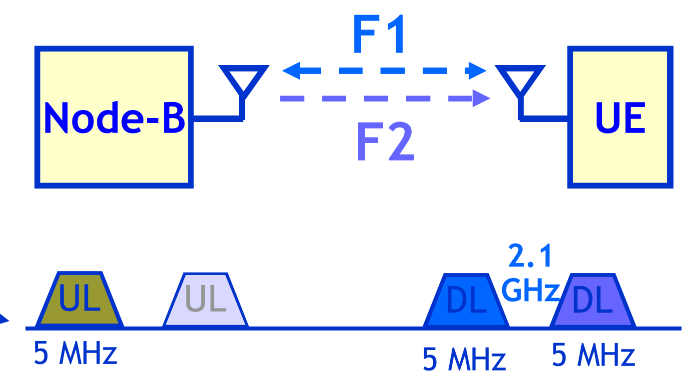
- The dual cell operation only applies to downlink HS-DSCH
  - Uplink traffic is carried in one frequency
- The two cells belong to the same Node-B and are on adjacent carriers
- The two cells operate with a single TX antenna
  - Max two streams per user

Improvements in Rel.-9

- Dual-Band HSDPA
- MIMO in dual cell operation
- Dual Cell uplink

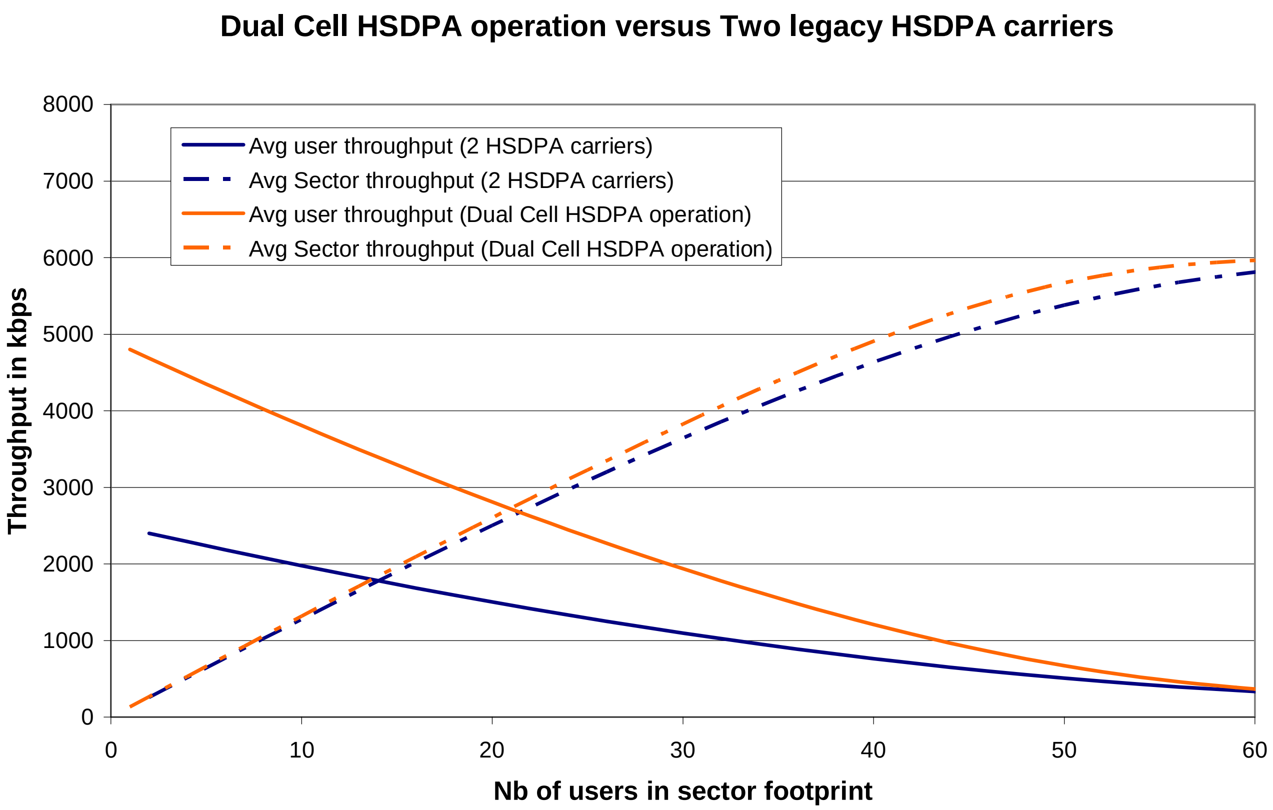
Multi-carrier HSDPA

UTRAN configures one of the cell as the serving cell for the uplink



Dual Cell HSDPA Operation for Load Balancing

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



Simple traffic and capacity model

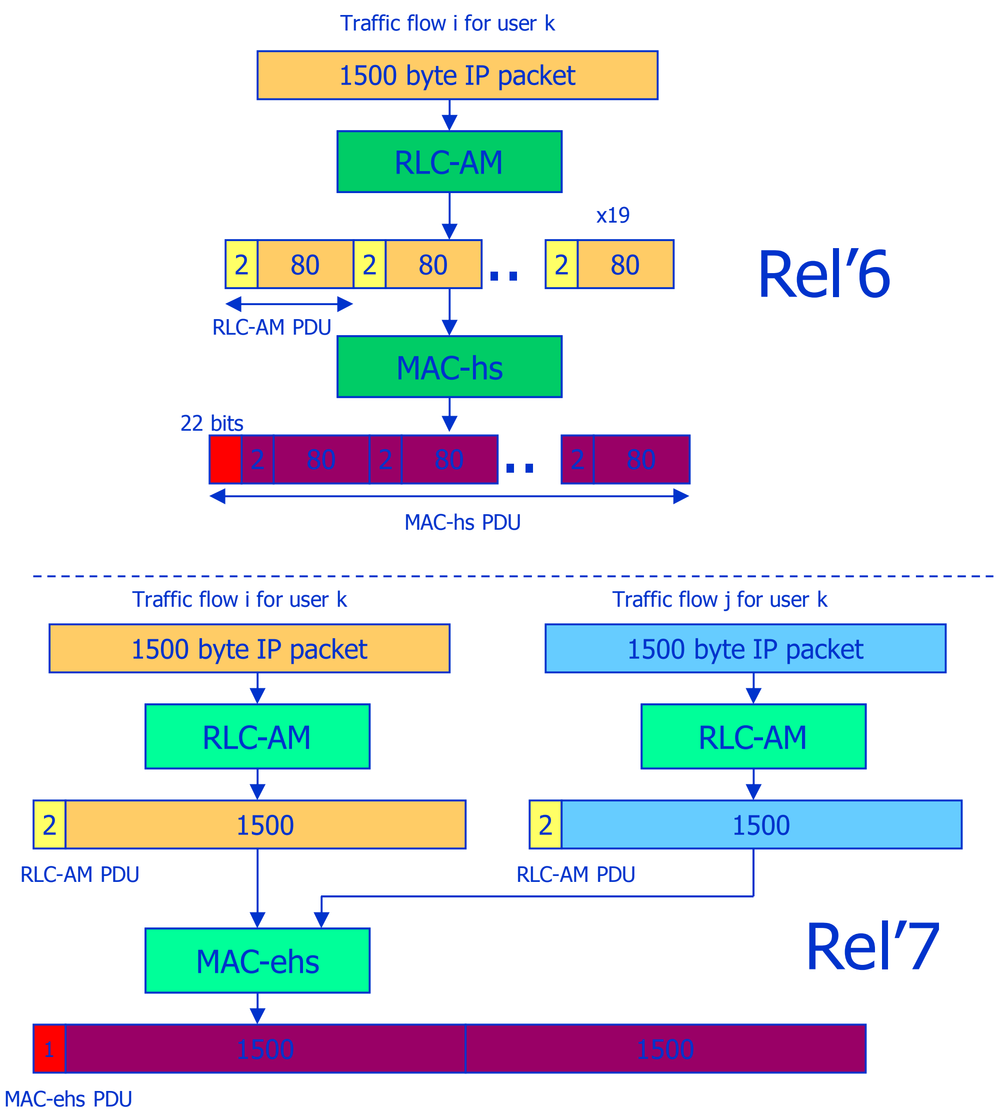
Avg Transfer size : 1000 kbytes

Avg Time between transfers : 60 sec

No gain at very high load

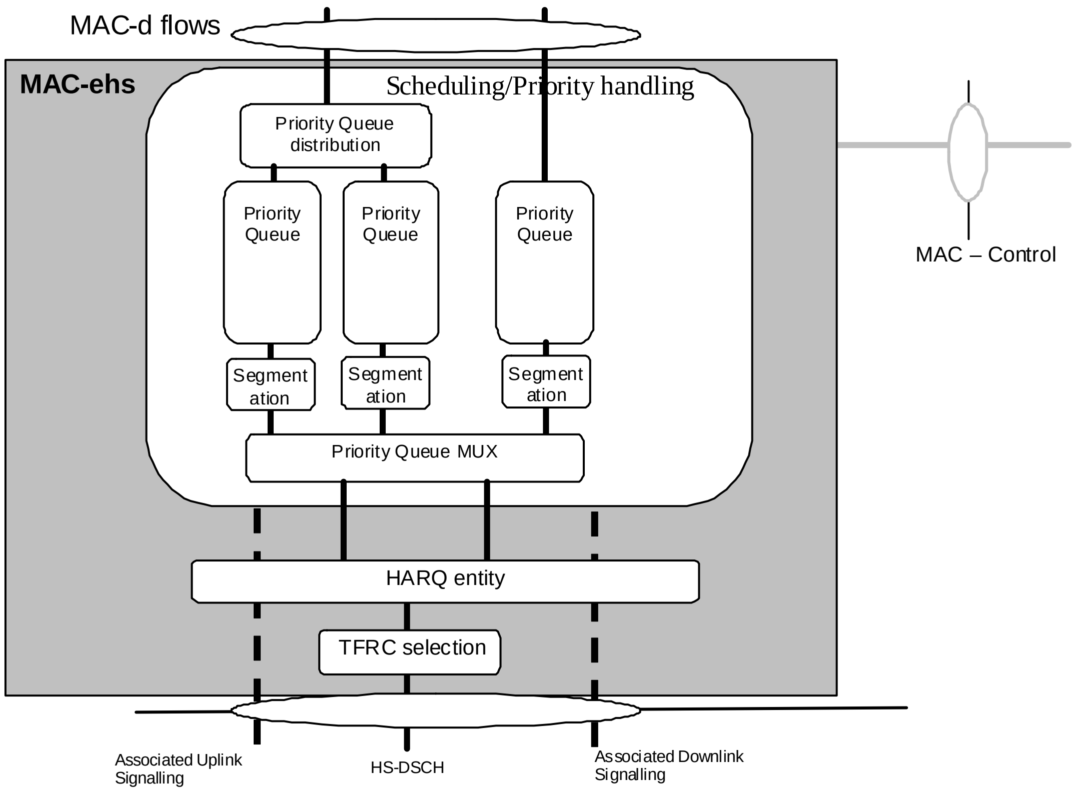
Enhanced Layer-2 Support for High Data Rates

- Release 6 RLC layer cannot support new peak rates offered by HSPA+ features such as MIMO & 64-QAM
  - 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



Layer-2 enhancements to support higher rates of HSPA+

MAC-ehs in NodeB



MAC-ehs Functions (TS 25.321)

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

HSDPA – UE Physical Layer Capabilities

HS-DSCH Category	Maximum number of HS-DSCH multi-codes	Supported Modulation Formats	Minimum inter-TTI interval	Maximum MAC-hs TB size	Total number of soft channel bits	Theoretical maximum data rate (Mbit/s)
Category 1	5	QPSK, 16QAM	3	7298	19200	1.2
Category 2	5	QPSK, 16QAM	3	7298	28800	1.2
Category 3	5	QPSK, 16QAM	2	7298	28800	1.8
Category 4	5	QPSK, 16QAM	2	7298	38400	1.8
Category 5	5	QPSK, 16QAM	1	7298	57600	3.6
Category 6	5	QPSK, 16QAM	1	7298	67200	3.6
Category 7	10	QPSK, 16QAM	1	14411	115200	7.2
Category 8	10	QPSK, 16QAM	1	14411	134400	7.2
Category 9	15	QPSK, 16QAM	1	20251	172800	10.1
Category 10	15	QPSK, 16QAM	1	27952	172800	14.0
Category 11	5	QPSK	2	3630	14400	0.9
Category 12	5	QPSK	1	3630	28800	1.8
Category 13	15	QPSK, 16QAM, 64QAM	1	35280	259200	17.6
Category 14	15	QPSK, 16QAM, 64QAM	1	42192	259200	21.1
Category 15	15	QPSK, 16QAM	1	23370	345600	23.3
Category 16	15	QPSK, 16QAM	1	27952	345600	28.0
Category 17	15	QPSK, 16QAM, 64QAM/ MIMO: QPSK, 16QAM	1	35280/ 23370	259200/ 345600	17.6/ 23.3
Category 18	15	QPSK, 16QAM, 64QAM/ MIMO: QPSK, 16QAM	1	42192/ 27952	259200/ 345600	21.1/ 28.0
Category 19	15	QPSK, 16QAM, 64QAM	1	35280	518400	35.2
Category 20	15	QPSK, 16QAM, 64QAM	1	42192	518400	42.2

Note: UEs of Categories 15 – 20 support MIMO

cf. TS 25.306

E-DCH – UE Physical Layer Capabilities

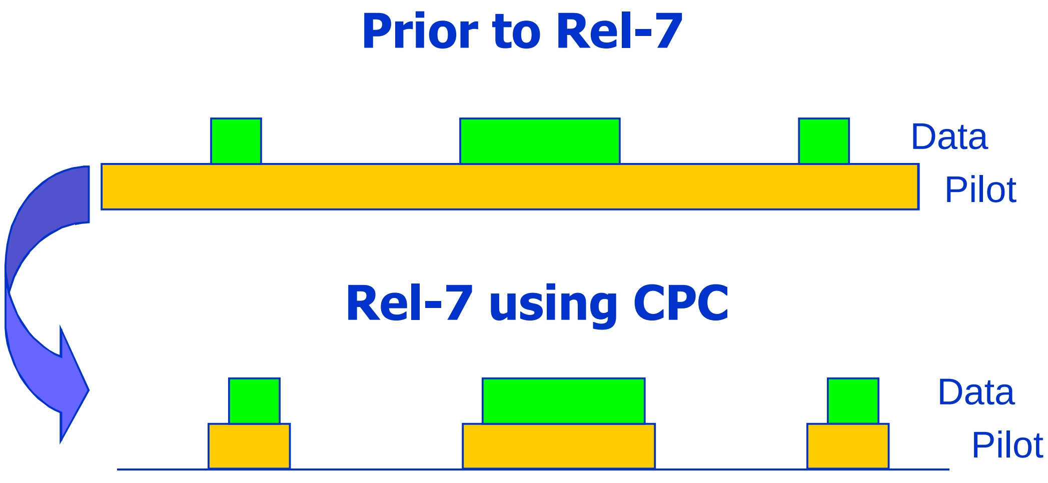
E-DCH Category	Max. num. Codes	Min SF	EDCH TTI	Maximum MAC-e TB size	Theoretical maximum PHY data rate (Mbit/s)
Category 1	1	SF4	10 msec	7110	0.71
Category 2	2	SF4	10 msec/ 2 msec	14484/ 2798	1.45/ 1.4
Category 3	2	SF4	10 msec	14484	1.45
Category 4	2	SF2	10 msec/ 2 msec	20000/ 5772	2.0/ 2.89
Category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

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. 25.306

Continuous Packet Connectivity (CPC)

- Uplink DPCCH gating during inactivity → significant reduction in UL interference
- F-DPCH gating during inactivity
- New uplink DPCCH slot format optimized for transmission DPCCH only

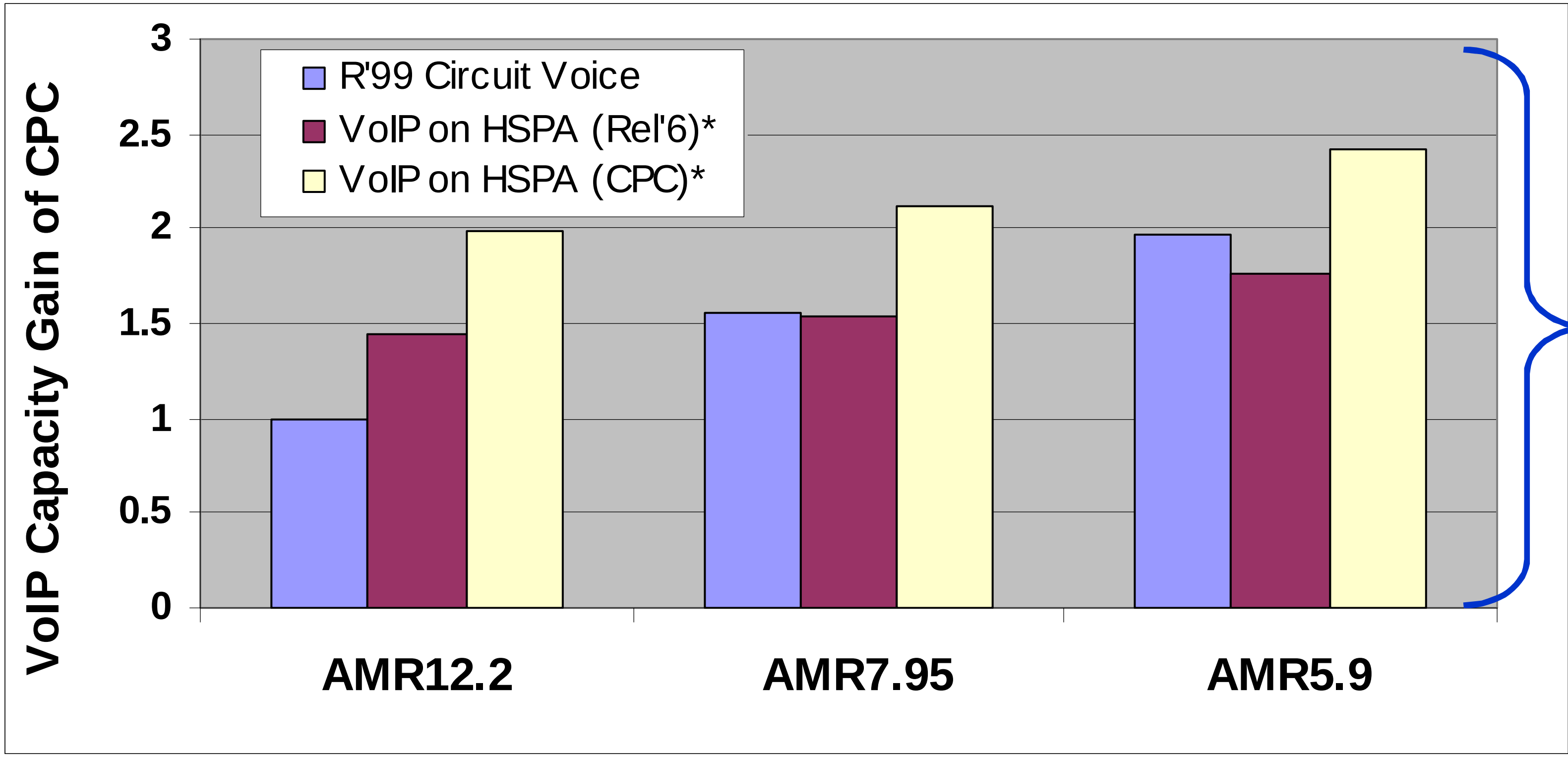


- HS-SCCH-less transmission introduced to reduce signaling bottleneck for real-time-services on HSDPA

CPC significantly reduces control channel overhead for low bit rate real-time services (e.g. VoIP)

CPC Performance Benefits

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



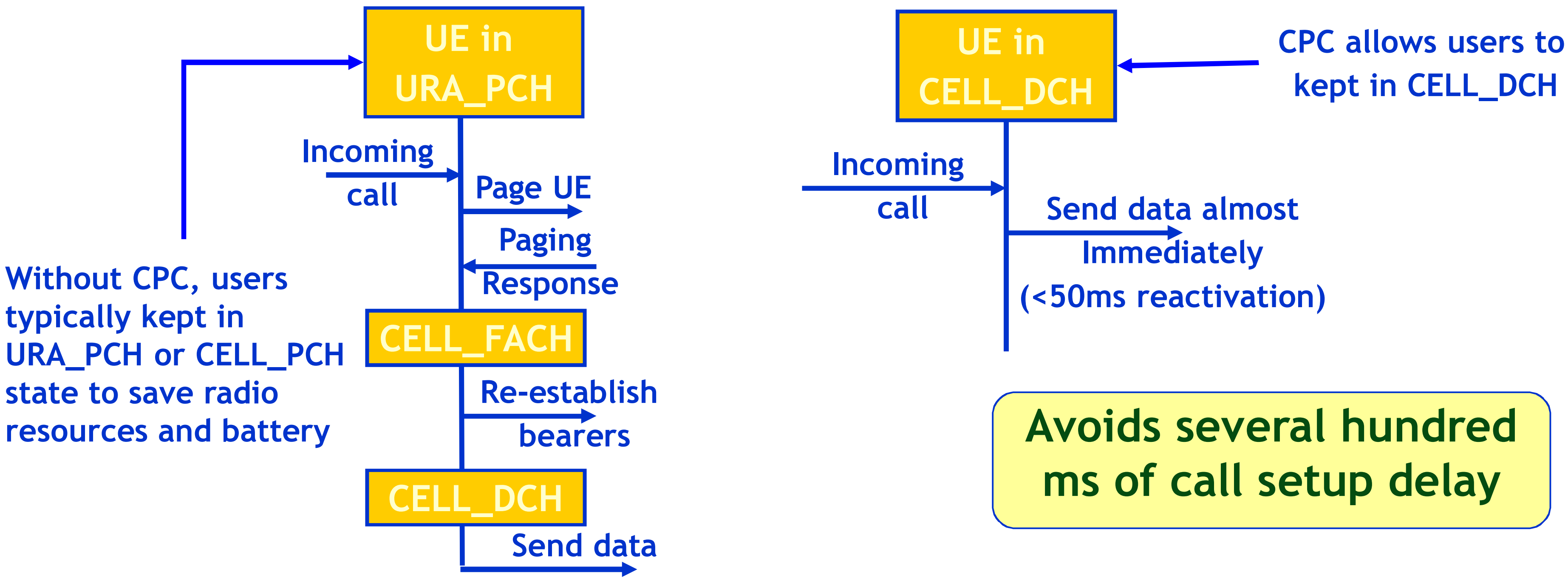
Note: All capacity gains normalized to AMR12.2 Circuit Voice Capacity

CPC provides significant VoIP on HSPA capacity benefits

*** All VoIP on HSPA capacities assume two receive antennas in the terminal**

“Always On” Enhancement of CPC

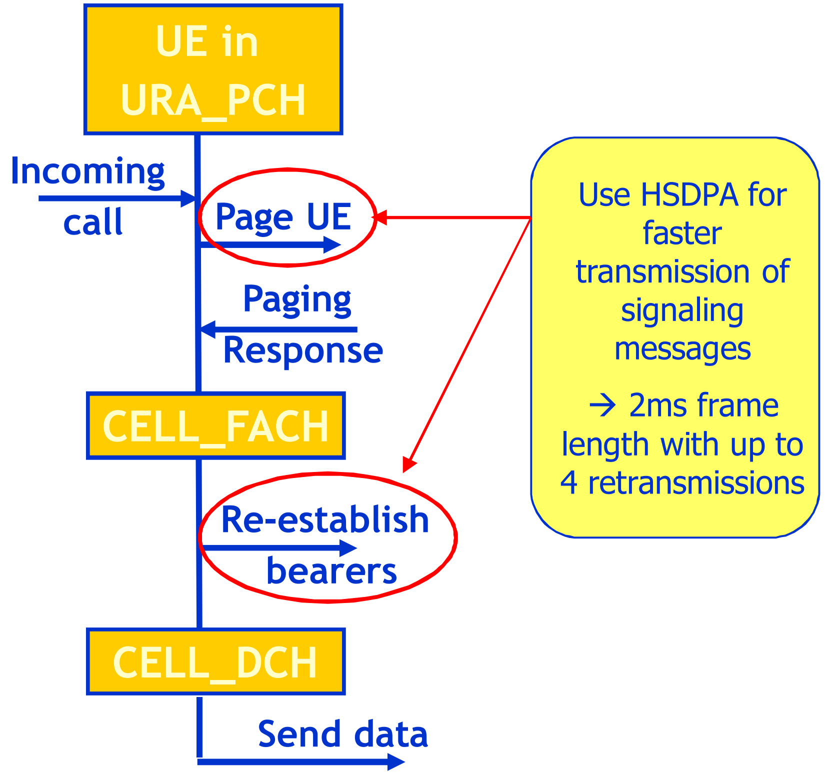
- CPC allows UEs in CELL_DCH to “sleep” during periods of inactivity
  - Reduces signaling load and battery consumption (in combination with DRX)
- Allows users to be kept in CELL_DCH with HSPA bearers configured
- Need to page and re-establish bearers leads to call set up delay



CPC avoids re-establishment delays → improves “always on” experience

Enhanced CELL_FACH & Enhanced Paging Procedure

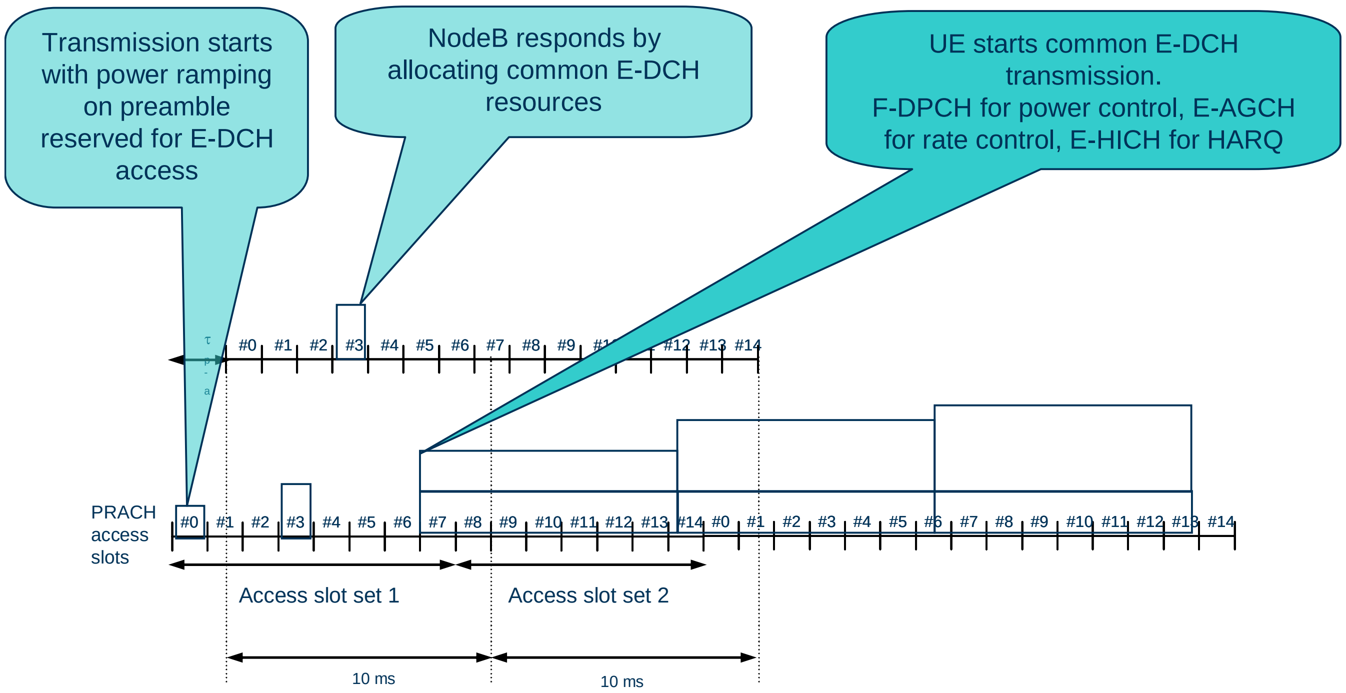
- UEs are not always kept in CELL_DCH state, eventually fall back to CELL_PCH/URA_PCH
- HSPA+ introduces enhancements to reduce the delay in signaling the transition to CELL_DCH → use of HSDPA in CELL_FACH and URA/CELL_PCH states instead of S-CCPCH
  - Enhanced CELL_FACH
  - Enhanced Paging procedure
- In Rel.-8 improved RACH procedure
  - Direct use of HSUPA in CELL_FACH



Enhanced CELL_FACH/Paging/RACH reduces setup delay → improves PoC

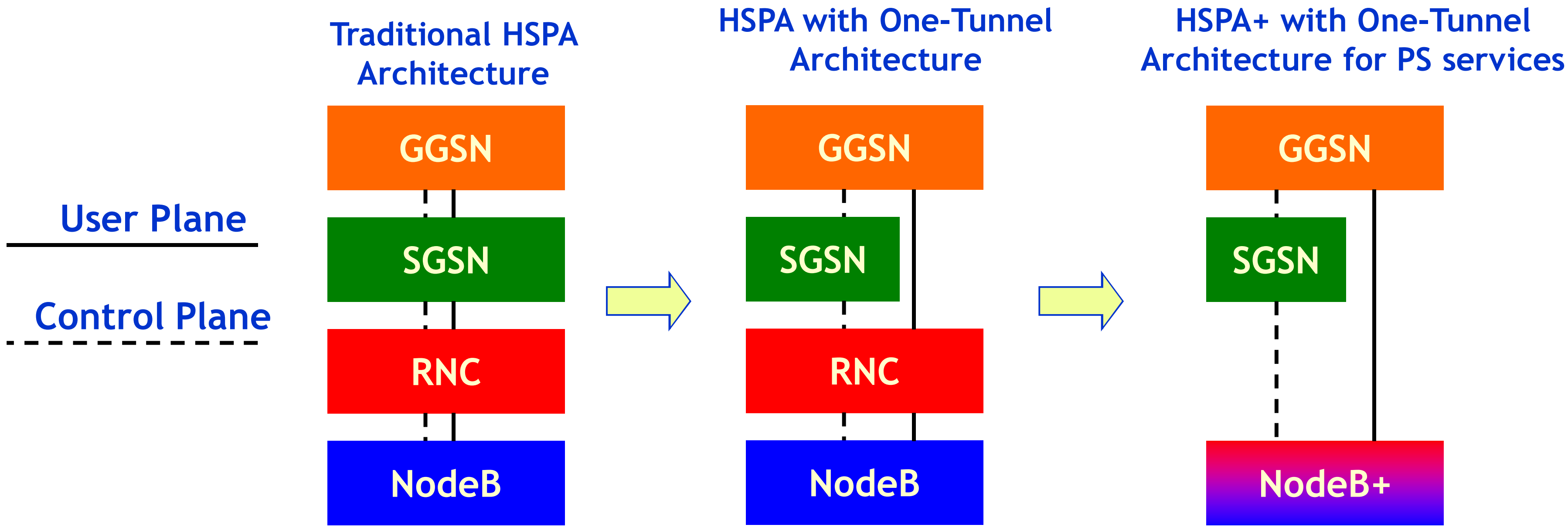
E-RACH – High level description

- 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

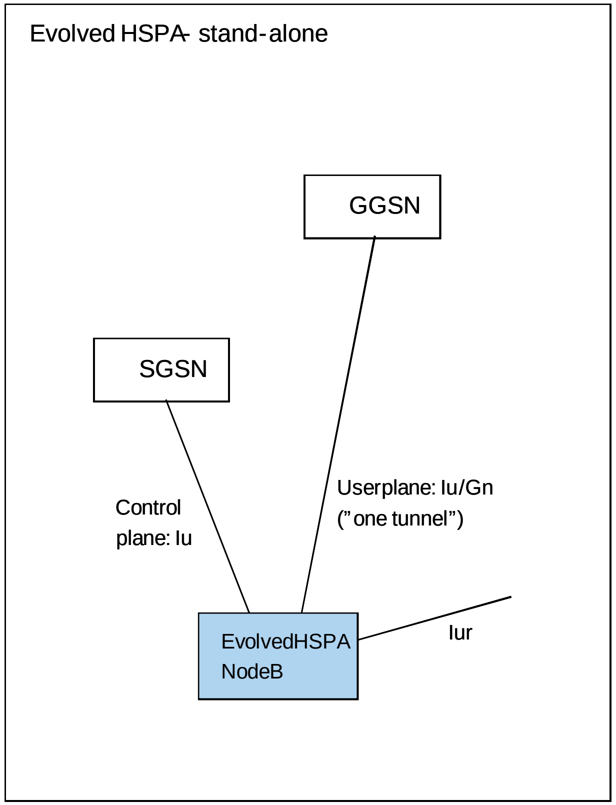
- Integration of some or all RNC functions into the NodeB provides benefits in terms of:
  - Network simplicity (fewer network elements)
  - Latency (fewer handshakes, particularly in combination with One-Tunnel)
  - Synergy with LTE (serving GW, MME, eNB)
- Backwards compatible with legacy terminals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

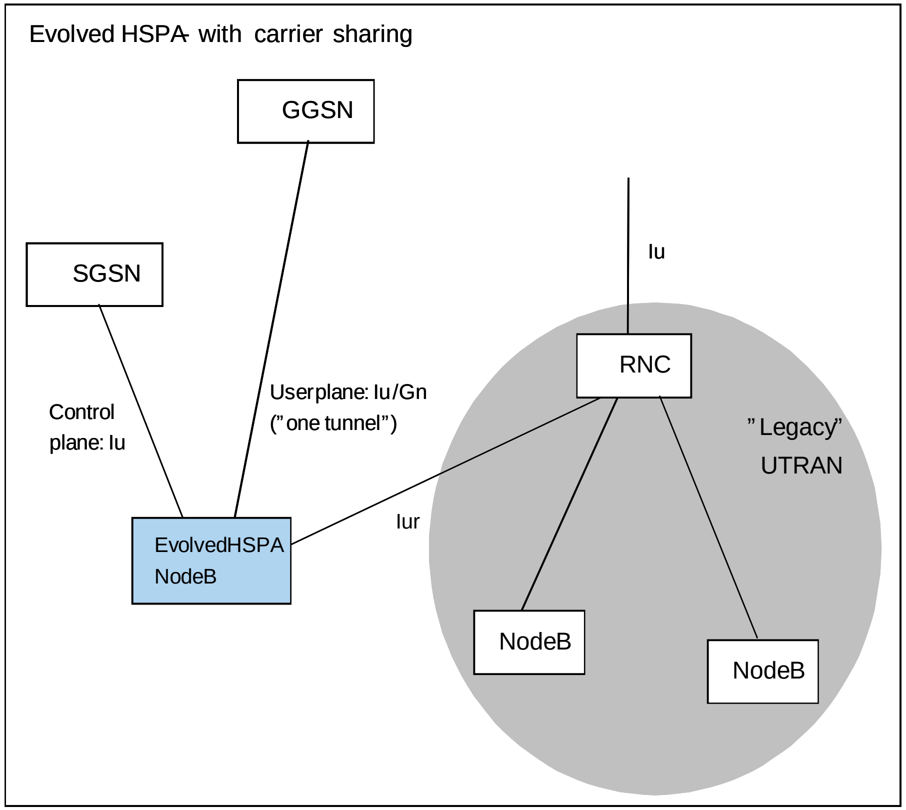


HSPA+ offers flexibility for a flatter network architecture option

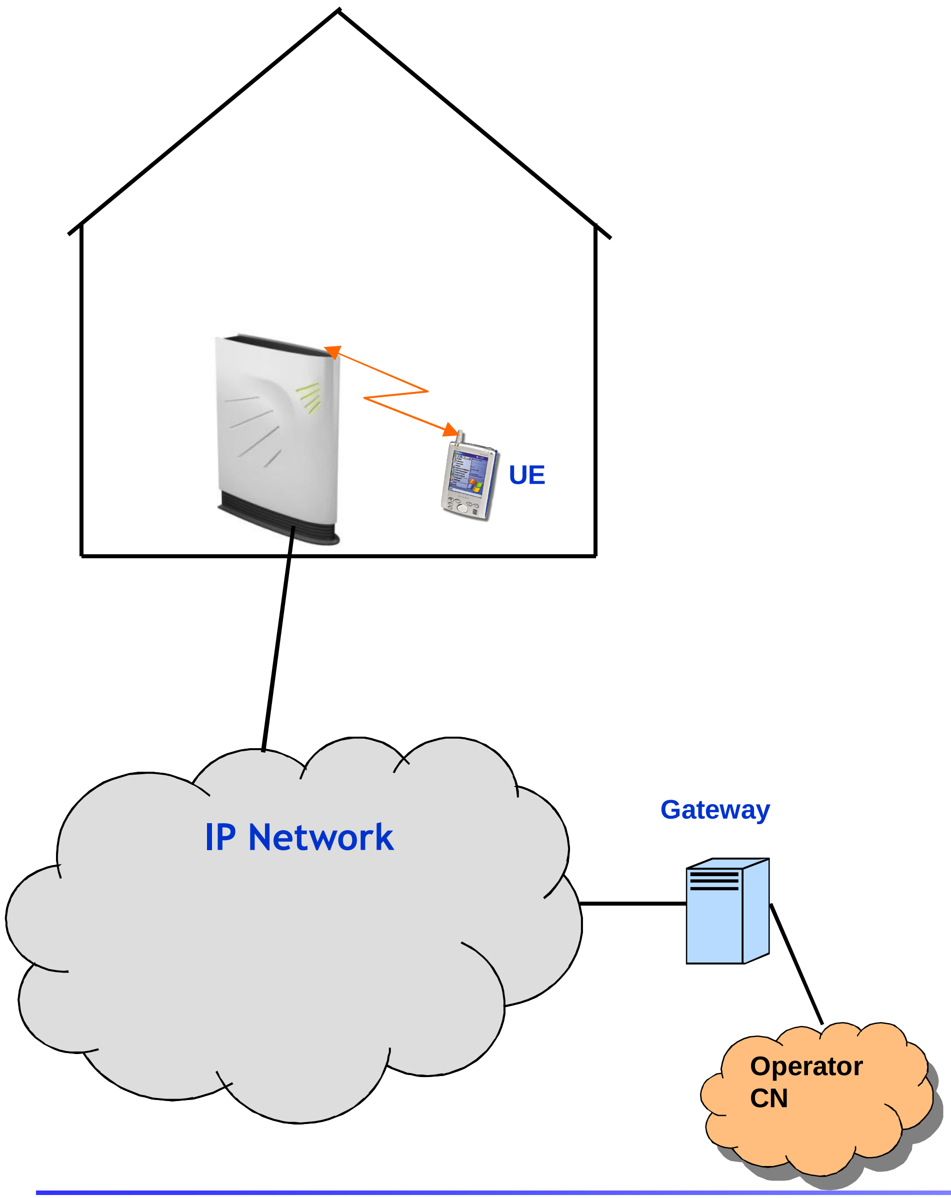
Evolved HSPA Architecture – Full RNC/NodeB collapse

- 2 deployment scenarios: standalone UTRAN or carrier sharing with “legacy” UTRAN



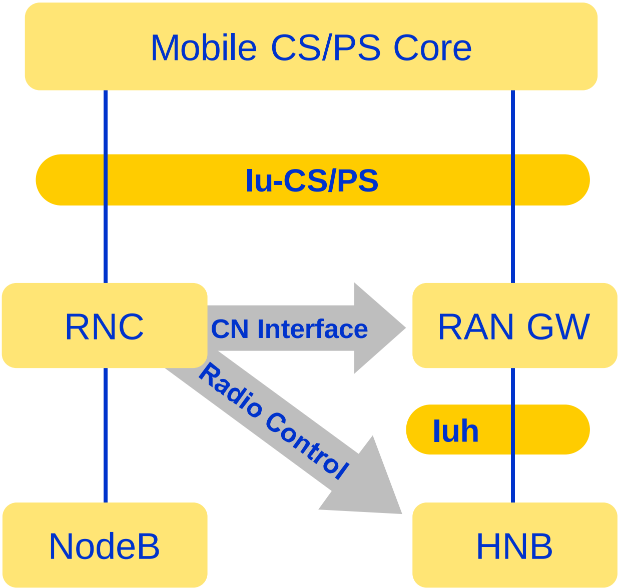


Home NodeB – Background



- Home NodeB (aka Femtocell) located at the customers premise
  - Connected via customers fixed line (e.g. DSL)
  - Small power (~100mW) 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

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
    - FMS interface

Summary

- Enhancements for HSDPA & E-DCH specified in UMTS Rel.-7 & 8
  - Investment protection for HSPA operators
  - Fill the gap before deployment of LTE
  - Provide alternative to LTE in some selected scenarios
- Improvements on capacity and performance
  - Higher peak data rates
  - Signaling improvements
  - Architecture evolution
- HSPA+ features were designed to provide a smooth evolution from Rel-99 or Rel-5/Rel-6 HSPA by enabling:
  - Backwards compatibility
    - Legacy Rel-99/Rel-5/Rel-6 terminals can be supported on an HSPA+ carrier simultaneously with HSPA+ traffic
    - New HSPA+ terminals likely with support Rel-99 and/or Rel-5/Rel-6 HSPA
  - Simple upgrade of existing infrastructure (for both HW & SW)
- Further improvements in Rel.-9 & 10 to further increase peak data rate
  - E.g. Dual Cell E-DCH (Rel.-9), 4 cell HSDPA (Rel.-10)
- Meanwhile, 164 HSPA+ networks in service in 81 countries (Oct. 11)**

HSPA+ References

- Papers:
  - H. Holma et al: “HSPA Evolution,” Chapter 15 in Holma/ Toskala: “WCDMA for UMTS,” Wiley 2010
  - R. Soni et al: “Intelligent Antenna Solutions for UMTS: Algorithms and Simulation Results,” Communications Magazine, October 2004, pp. 28–39
- Standards
  - TS 25.xxx series: RAN Aspects
  - TR 25.308 “HSDPA: UTRAN Overall Description (Stage 2)”
  - TR 25.319 “Enhanced Uplink: Overall Description (Stage 2)”
  - 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

AICH	Acquisition Indicator Channel
AMR	Adaptive Multi-Rate
BPSK	Binary Phase Shift Keying
CLTD	Closed Loop Transmit Diversity
CPC	Continuous Packet Connectivity
CQI	Channel Quality Information
DSL	Digital Subscriber Line
E-RACH	Enhanced Random Access Channel
F-DPCH	Fractional Dedicated Physical Control Channel
GW	Gateway
HNB	Home NodeB
HOM	Higher Order Modulation
HSPA	High-Speed Packet-Access
IA	Intelligent Antenna
LTE	Long Term Evolution
MAC-ehs	enhanced high-speed Medium Access Control
MAC-i/is	improved E-DCH Medium Access Control
MIMO	Multiple-Input Multiple-Output
Mux	Multiplexing
PARC	Per Antenna Rate Control
PCI	Precoding Control Information
PDU	Protocol Data Unit
Rx	Receive
RTT	Round Trip Time
SDU	Service Data Unit
SAE	System Architecture Evolution
S-CPICH	Secondary Common Pilot Channel
SDMA	Spatial-Division Multiple-Access
SINR	Signal-to-Interference plus Noise Ratio
SISO	Single-Input Single-Output
SM	Spatial Multiplexing
Tx	Transmit
VoIP	Voice over Internet Protocol
16QAM	16 (state) Quadrature Amplitude Modulation
64QAM	64 (state) Quadrature Amplitude Modulation