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
  - 223 HSDPA operators in service in 93 countries (Oct. 08)**
  - 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: further uplink enhancements

*HSPA is the combination of HSDPA and HSUPA

**http://www.3gamericas.org/pdfs/Global_3G_Status_Update.pdf

HSPA+ introduced to continue focus on enhancements to HSPA

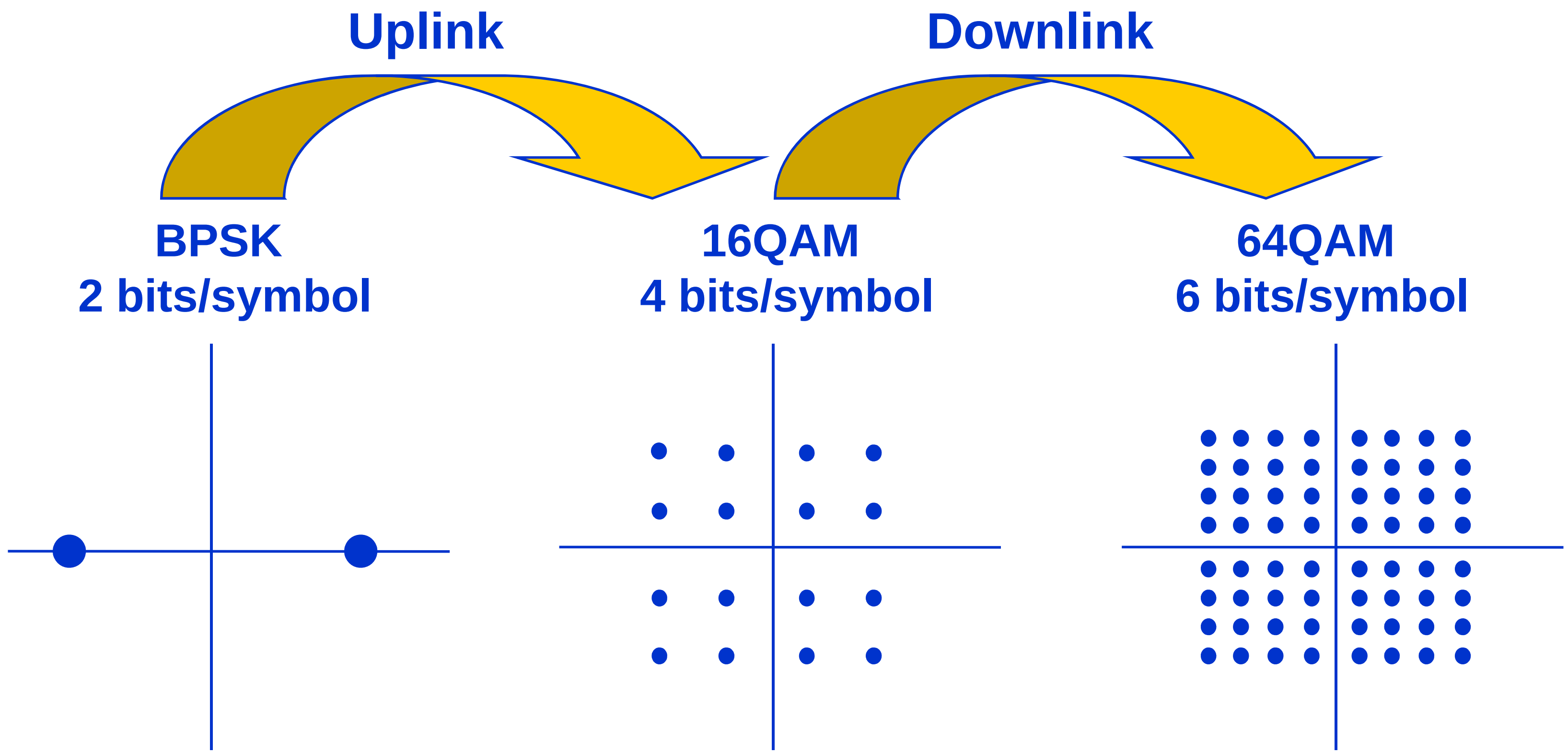
HSPA+ Goals

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

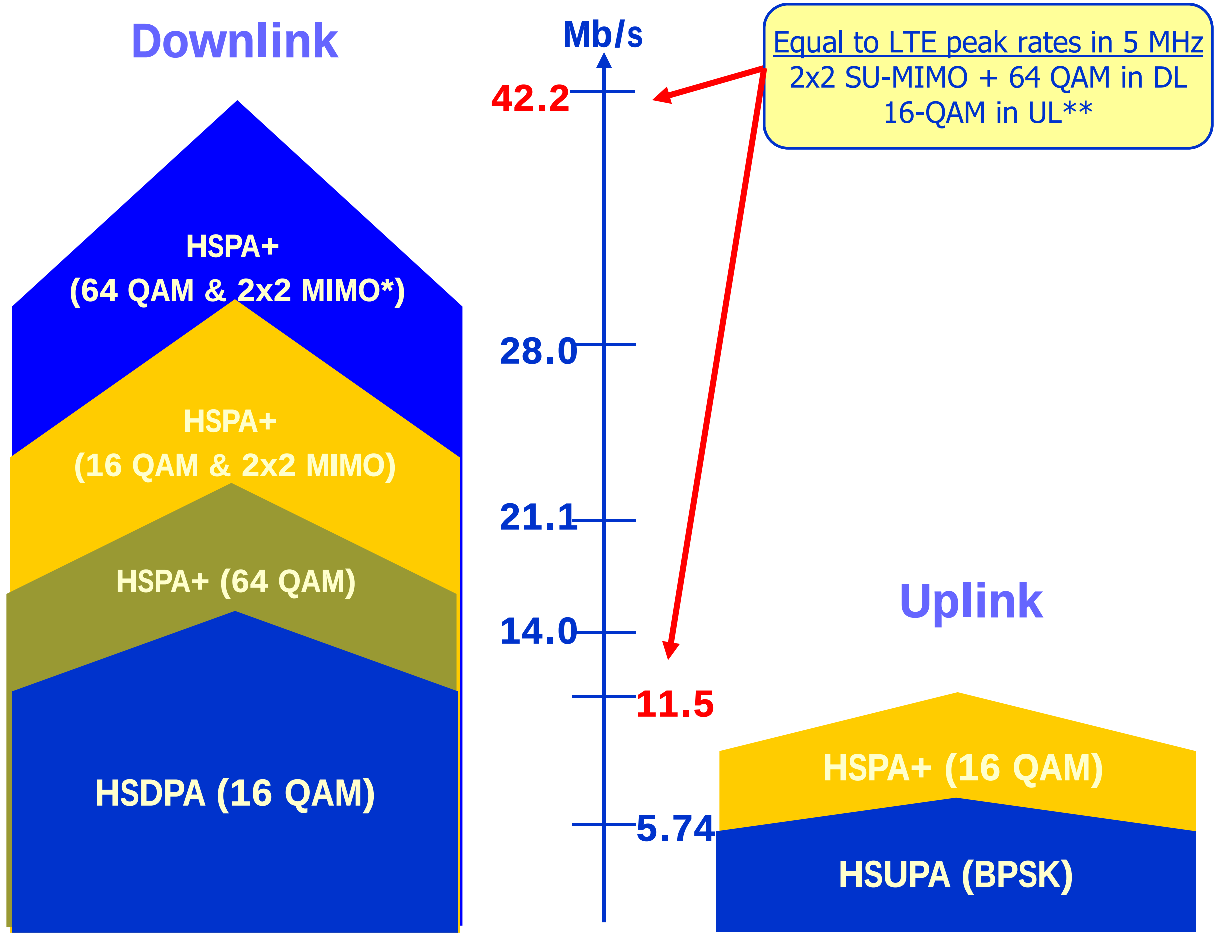
HOMs increase the number of bits/symbols transmitted, thereby increasing the peak rate

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**

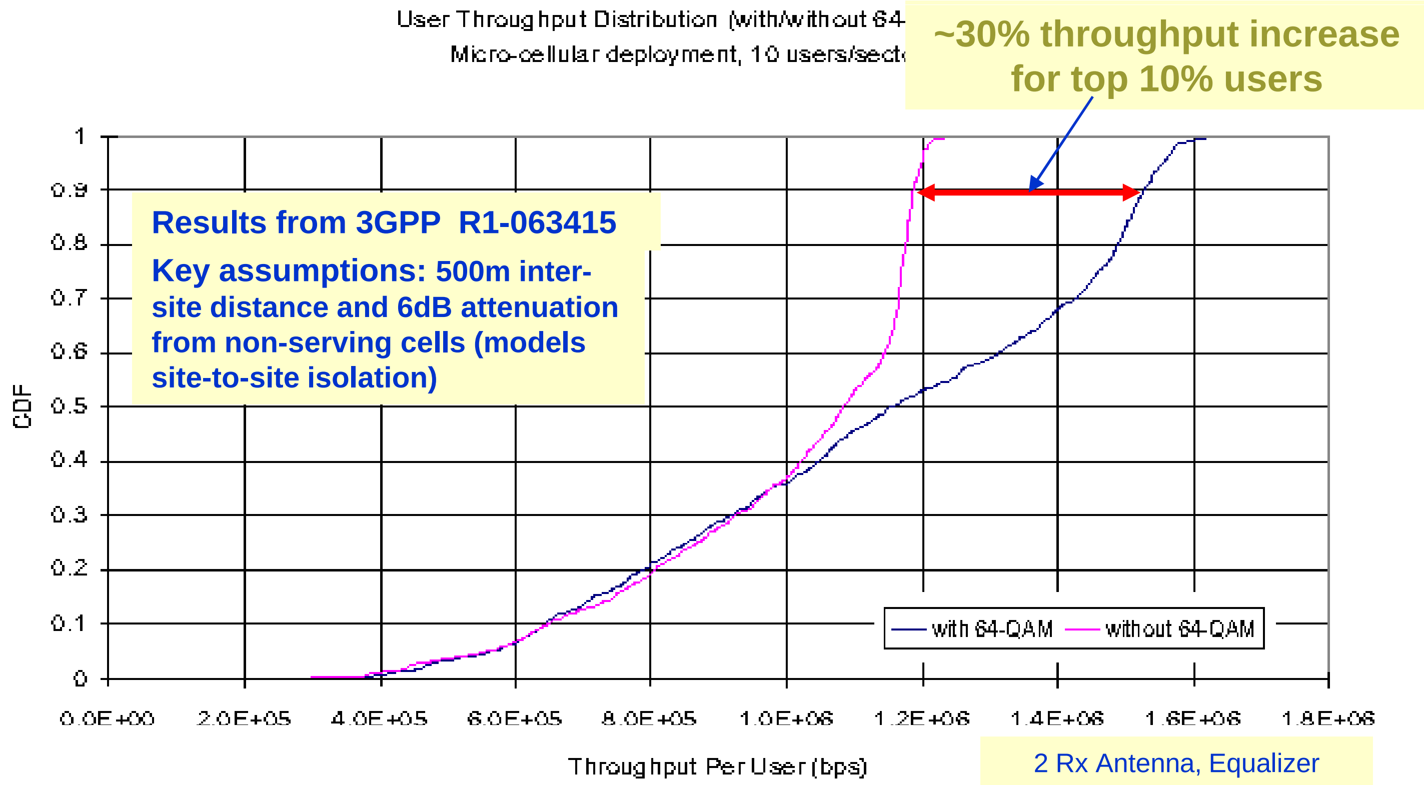


Theoretical Max Peak Rates In Perfect RF Conditions

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 64-QAM – Micro Cell / Hotspot Deployment

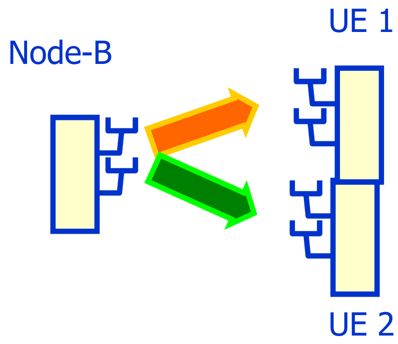


	Without 64-QAM	With 64-QAM	Gain
Sector Throughput	10 Mbit/s	11.3 Mbit/s	*13%*
90%-tile Throughput (normalized for 1 user per sector)	12 Mbit/s	15.6 Mbit/s	*30%*

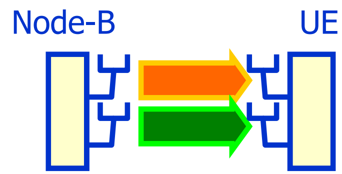
HOMs provide significant improvements for “hot spot” deployments

Multiple Antenna Techniques

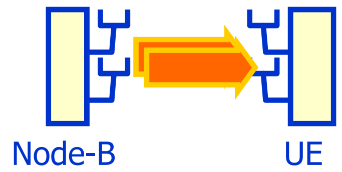
- **Spatial Division Multiple Access (SDMA) or Beamforming**
  - Different data streams sent to different users using the same codes
  - Improves throughput even in low SINR conditions (cell-edge)
  - Already supported in Release 5/6, works with single antenna UEs



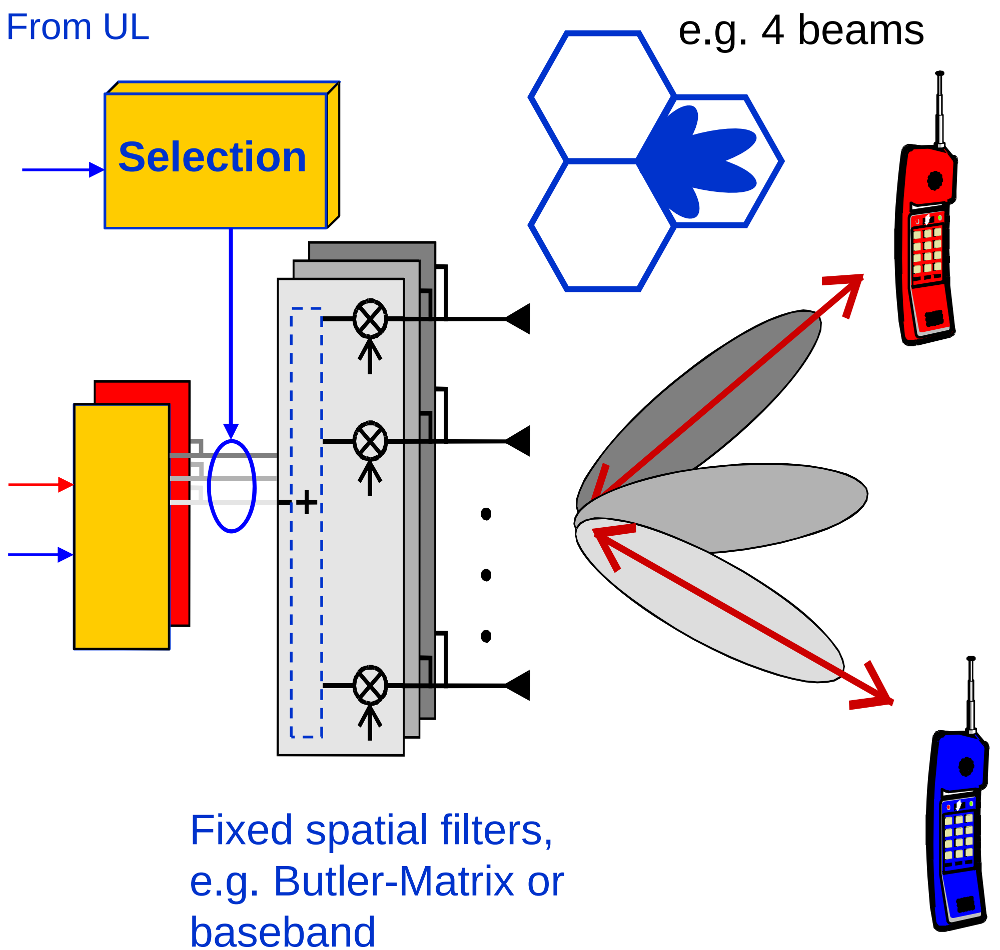
- **Spatial Multiplexing (SM) → SU-MIMO**
  - Multiple data streams sent to the same user
  - Significant throughput gains for UEs in high SINR conditions
  - **Double Transmit Adaptive Array (D-TxAA) was adopted for Rel-7 FDD and is based on dual codeword SU-MIMO**



- **Closed Loop Transmit Diversity (CLTD)**
  - Improves reliability on a single data stream
  - Fall back scheme if channel conditions do not allow SM



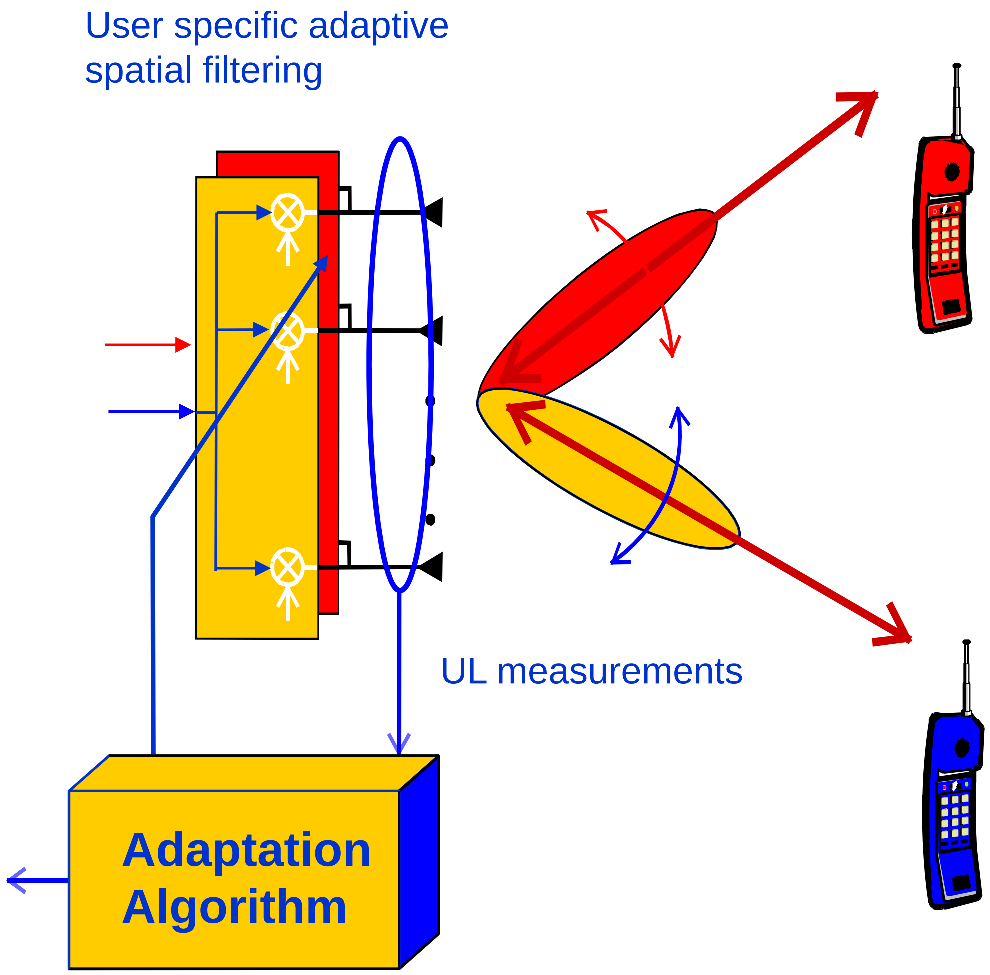
Fixed Beam Switching (FBS)



Fixed spatial filters, e.g. Butler-Matrix or baseband implementation

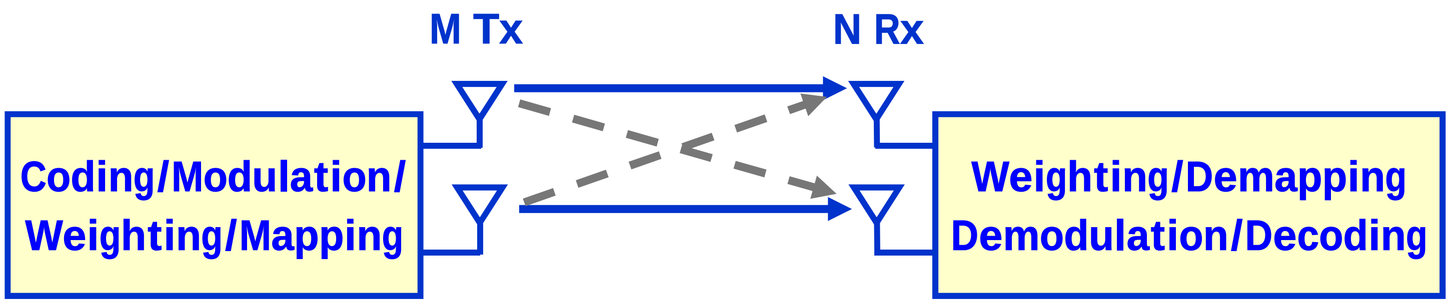
- Spatial partitioning of the sector area by help of a fixed number of beams
- S-CPICH (per beam) is introduced for improving UE channel estimation
- Beam specific secondary scrambling codes can be applied → code limitation preventable

Adaptive Beamforming/ Beam Pointing (BP)



- User specific antenna patterns are formed depending on a pre-defined optimisation criteria, e.g.
  - *MaxSINR*
  - *MaxSNR*
- *maxSNR* significantly outper-forms *maxSIR*
- For a low angular spread BP is nearly equivalent to *maxSNR*

Basic MIMO Channel



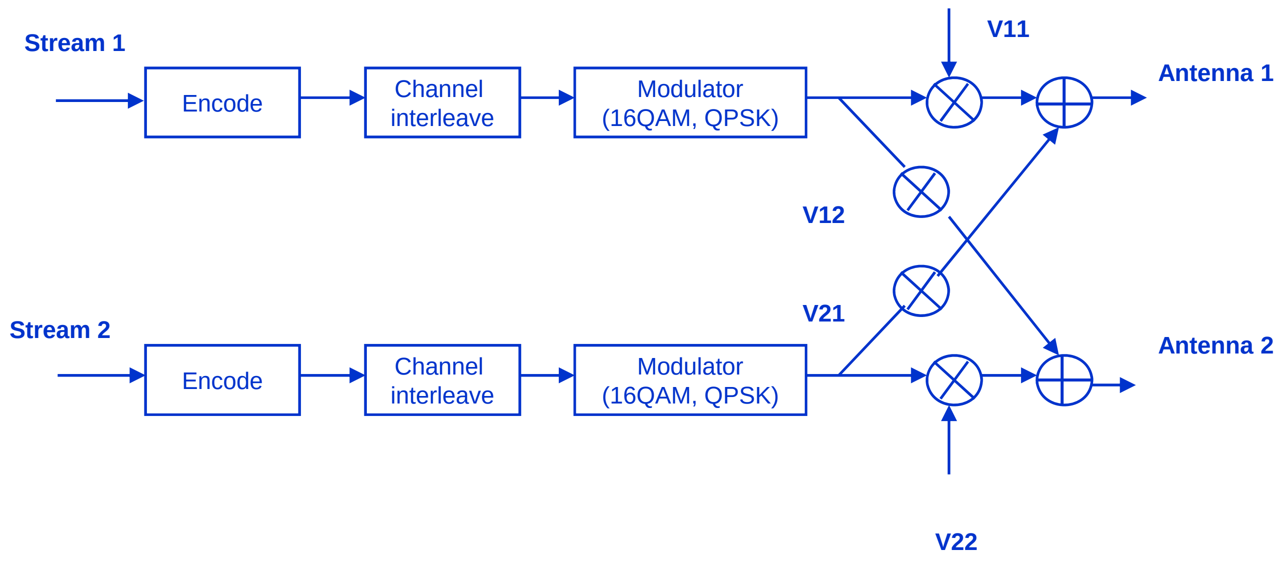
- The MIMO channel consists of M Tx and N Rx antennas
- Each Tx antenna transmits a different signal
- The signal from Tx antenna j is received at all Rx antennas i
- Channel capacity can increase linearly

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

MIMO in HSPA+

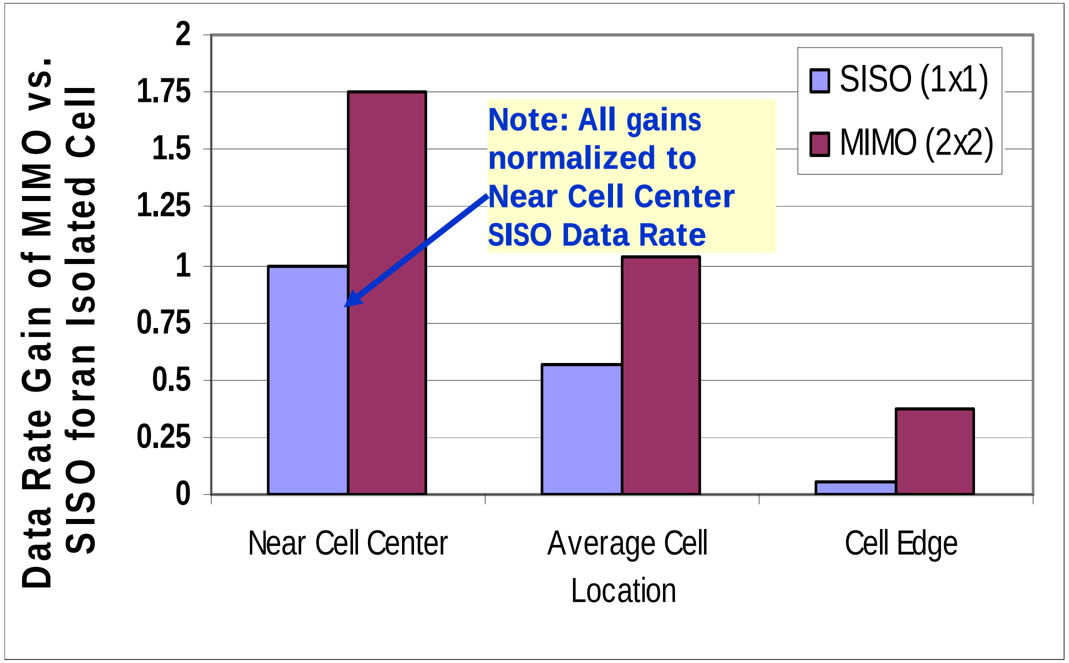
Release 7 MIMO for HSDPA

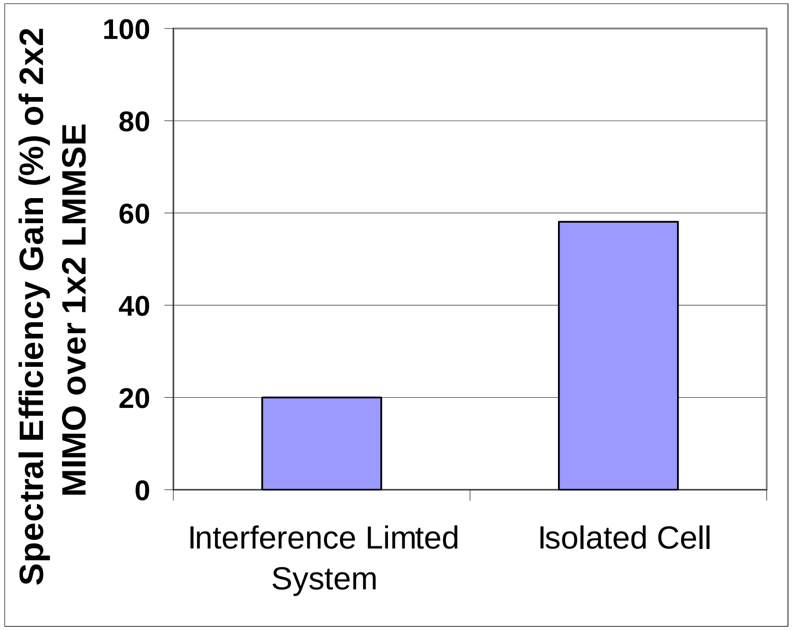
- 2x2
- D-TxAA, Mode 1
- HS-DPCCH-only feedback (CQI and PCI reported on HS-DPCCH)
- PARC Algorithm with support for dual stream and single stream (different from Tx diversity i.e.; change per subframe and no antenna verification)



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

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

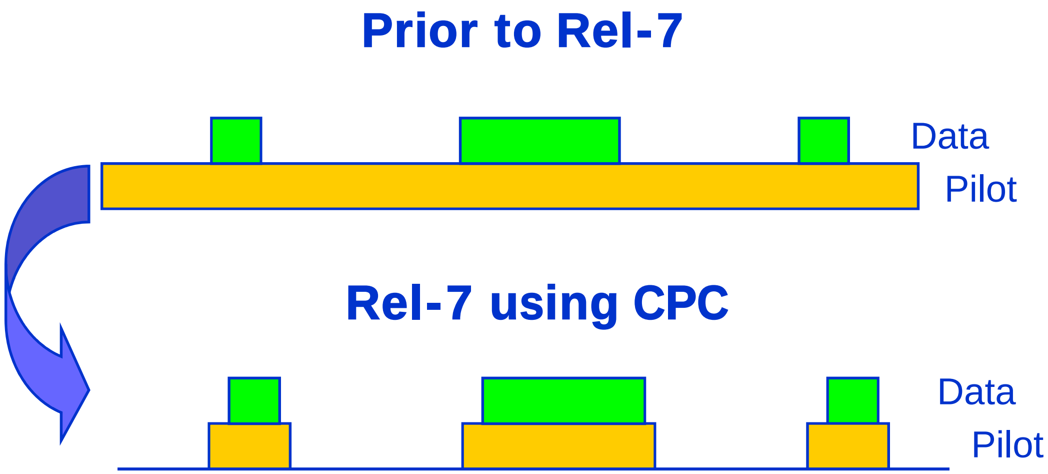
E-DCH Category	Max. num. Codes	Min SF	EDCH TTI	Maximum MAC-e TB size	Theoretical maximum PHY data rate (Mbit/s)
Category 1	1	SF4	10 msec	7110	0.71
Category 2	2	SF4	10 msec/ 2 msec	14484/ 2798	1.45/ 1.4
Category 3	2	SF4	10 msec	14484	1.45
Category 4	2	SF2	10 msec/ 2 msec	20000/ 5772	2.0/ 2.89
Category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

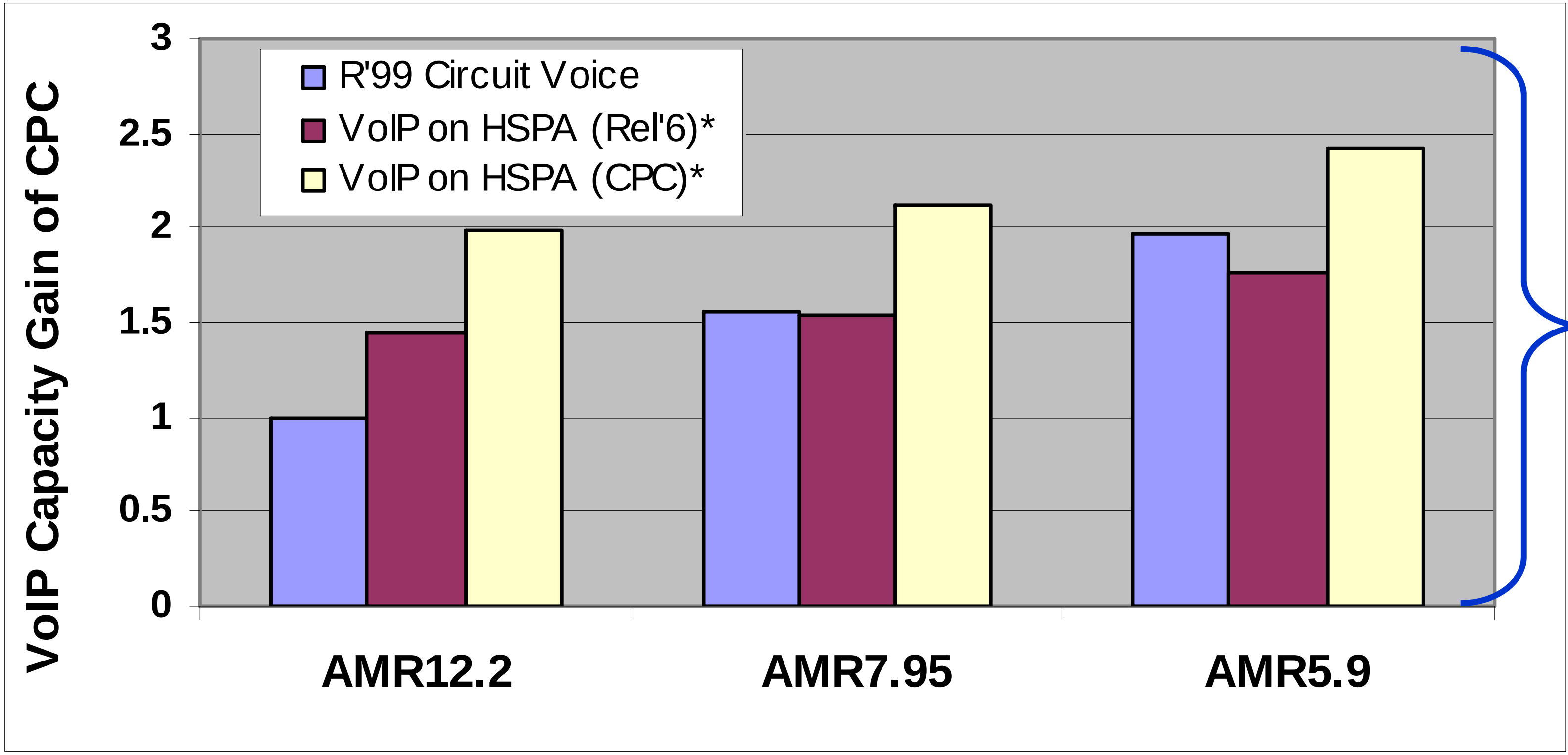


- HS-SCCH-less transmission introduced to reduce signaling bottleneck for real-time-services on HSDPA

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



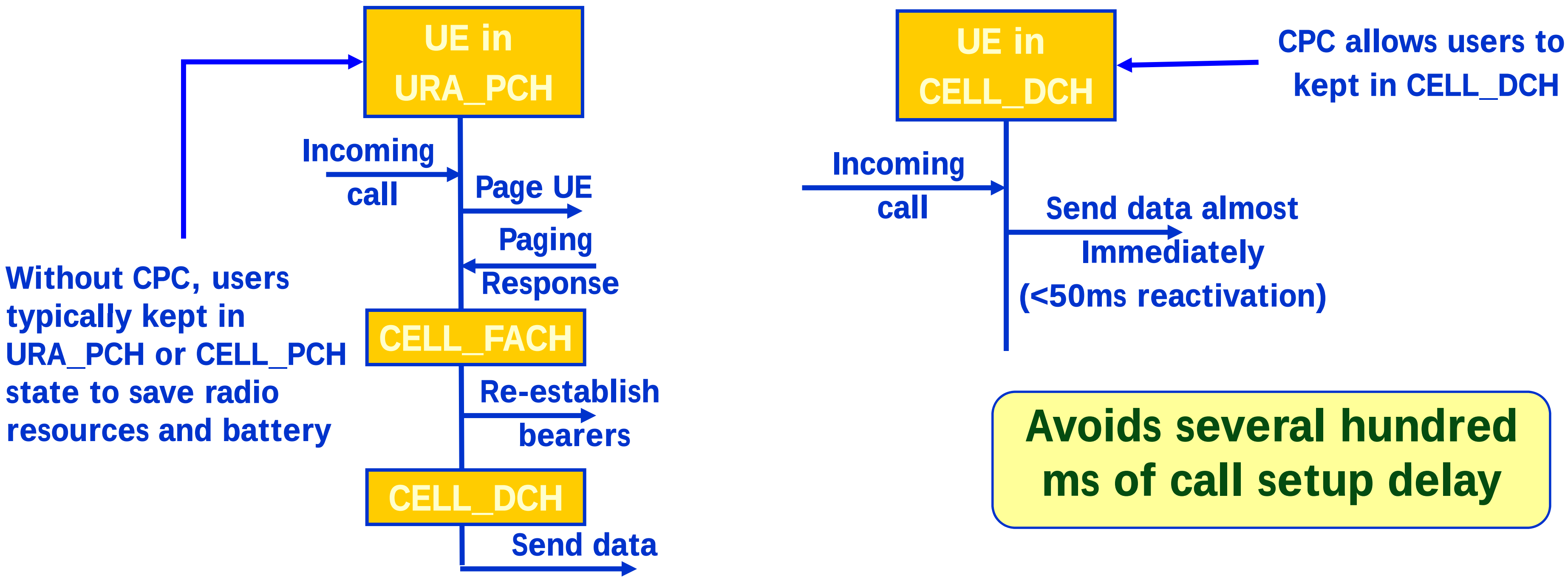
Note: All capacity gains normalized to AMR12.2 Circuit Voice Capacity

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

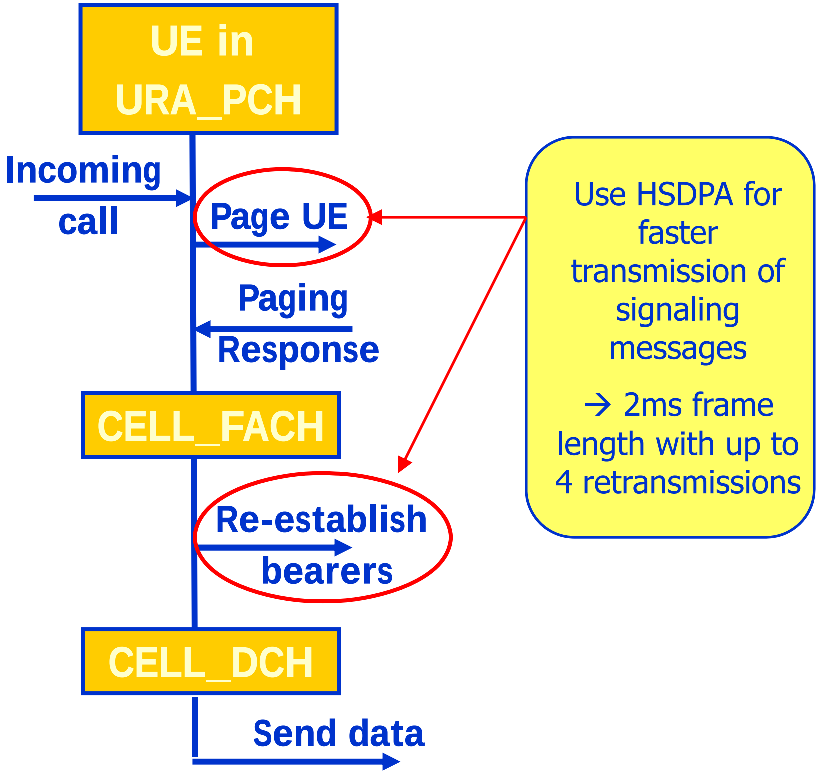
- CPC allows UEs in CELL_DCH to "sleep" during periods of inactivity
  - Reduces signaling load and battery consumption (in combination with DRX)
- Allows users to be kept in CELL_DCH with HSPA bearers configured
- Need to page and re-establish bearers leads to call set up delay



CPC avoids re-establishment delays → improves "always on" experience

Enhanced CELL_FACH & Enhanced Paging Procedure

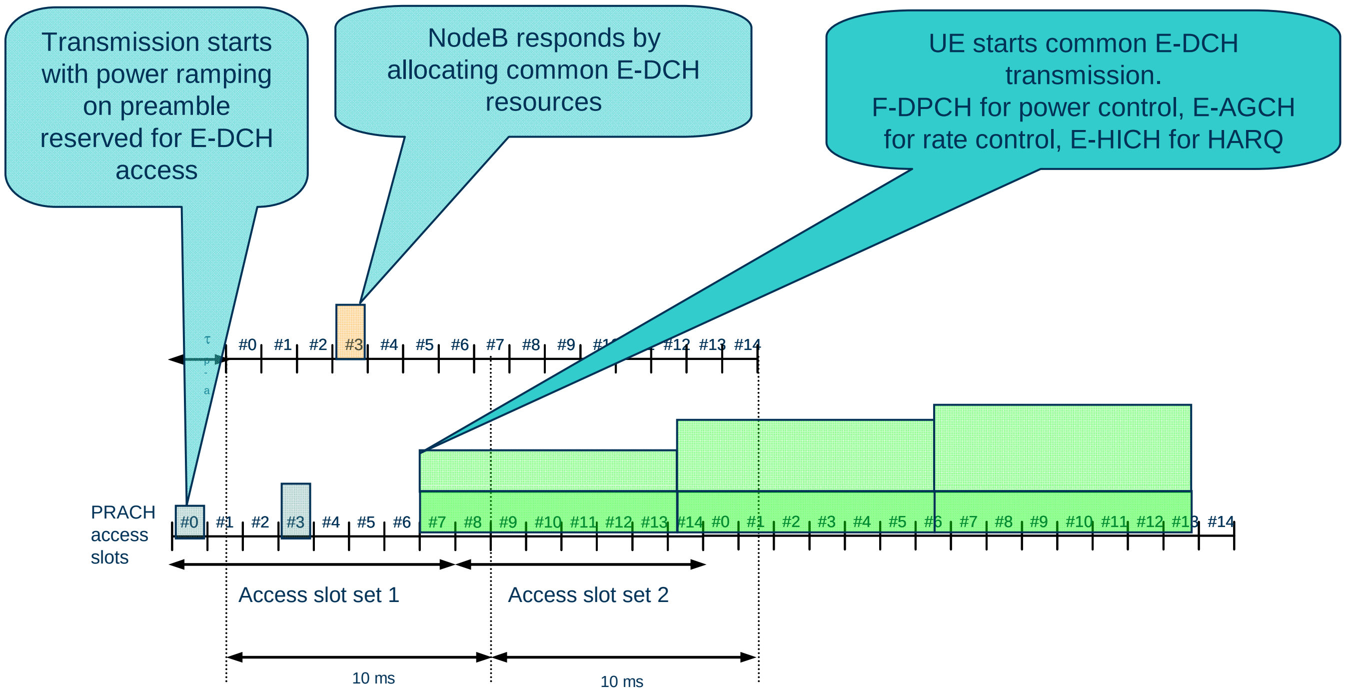
- UEs are not always kept in CELL_DCH state, eventually fall back to CELL_PCH/URA_PCH
- HSPA+ introduces enhancements to reduce the delay in signaling the transition to CELL_DCH → use of HSDPA in CELL_FACH and URA/CELL_PCH states instead of S-CCPCH
  - Enhanced CELL_FACH
  - Enhanced Paging procedure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



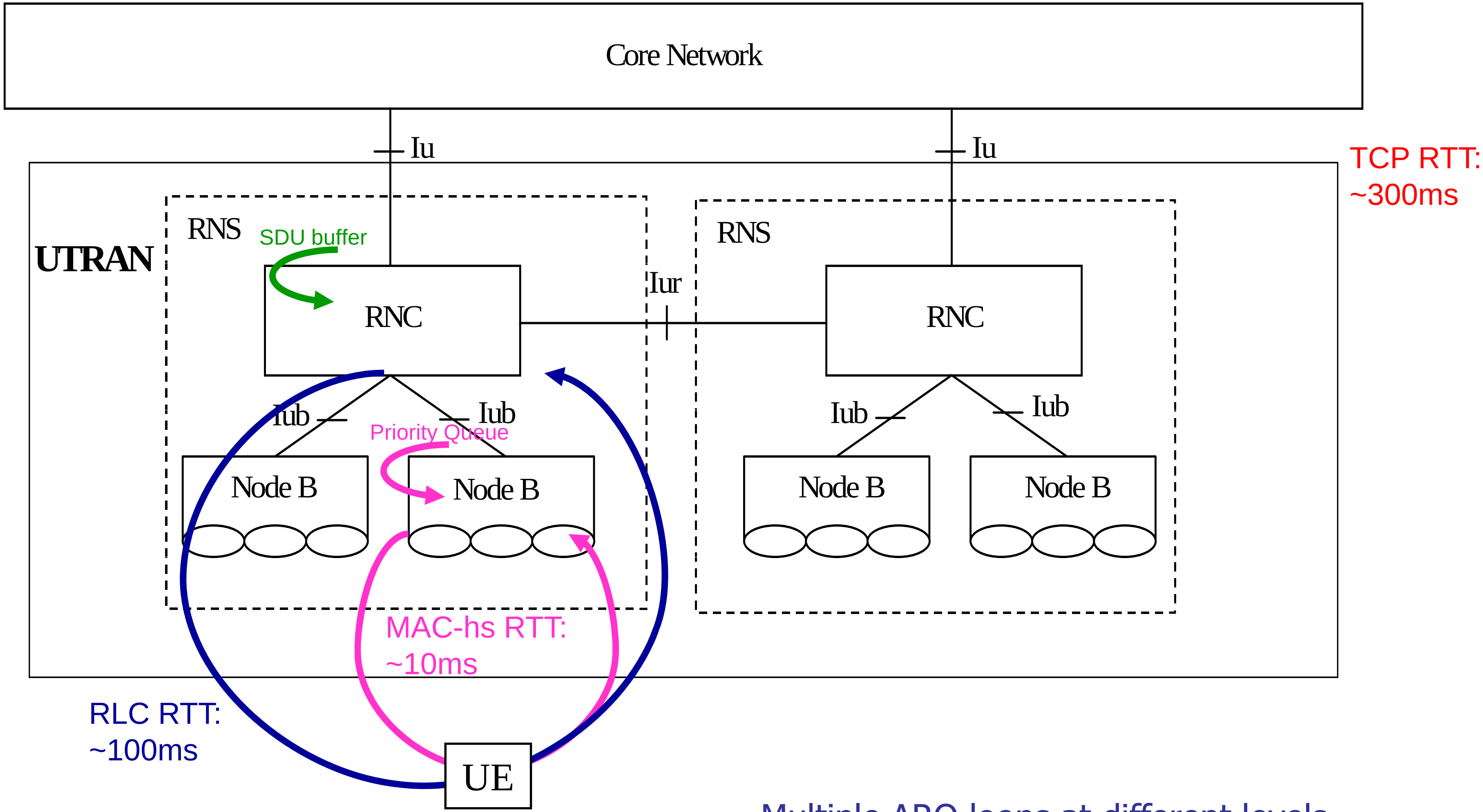
Enhanced CELL_FACH/Paging/RACH reduces setup delay → improves PoC

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

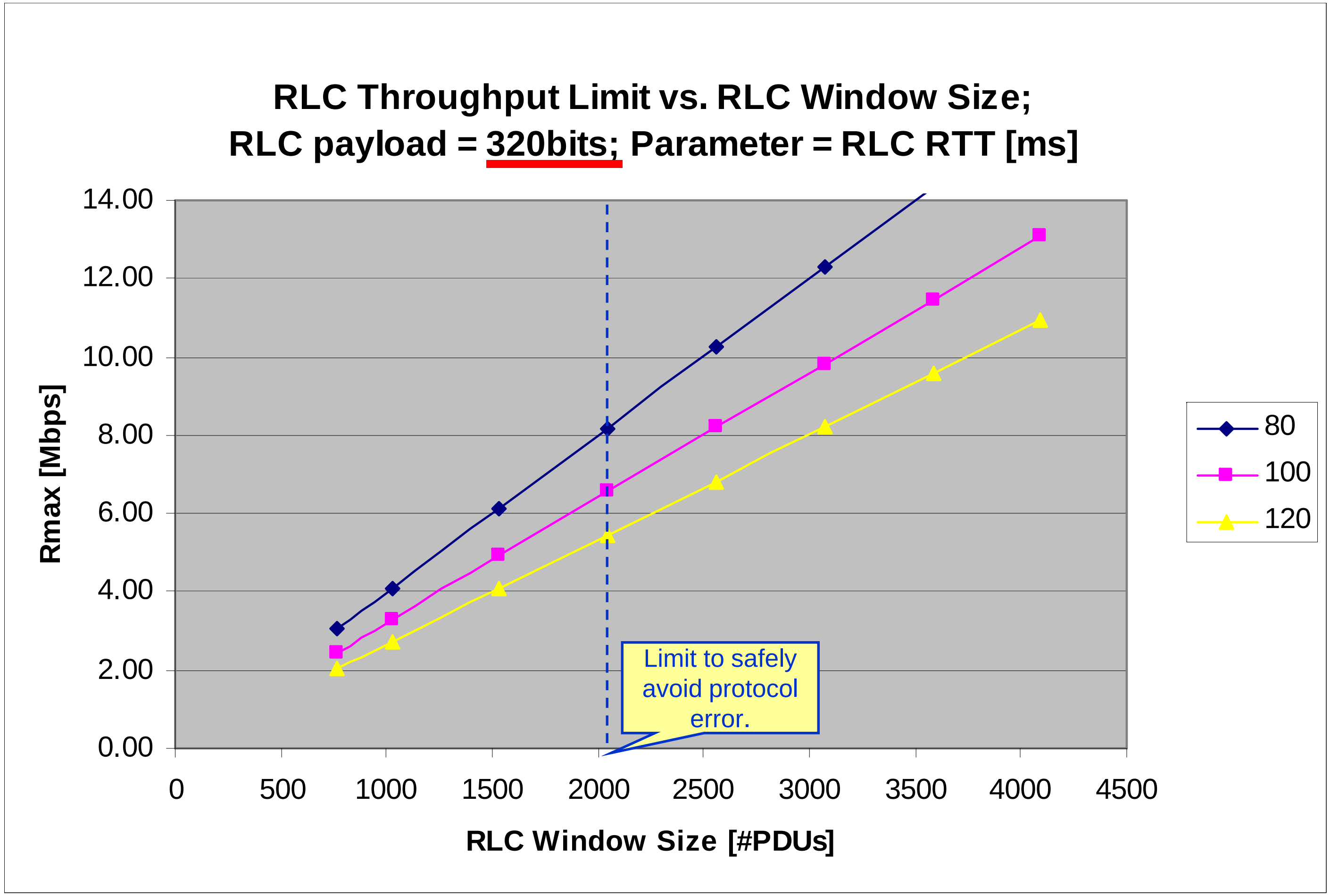


UTRAN Architecture



Multiple ARQ loops at different levels

RLC Throughput Limit vs. RLC Window Size



Theoretical limit:
PHY >> RLC

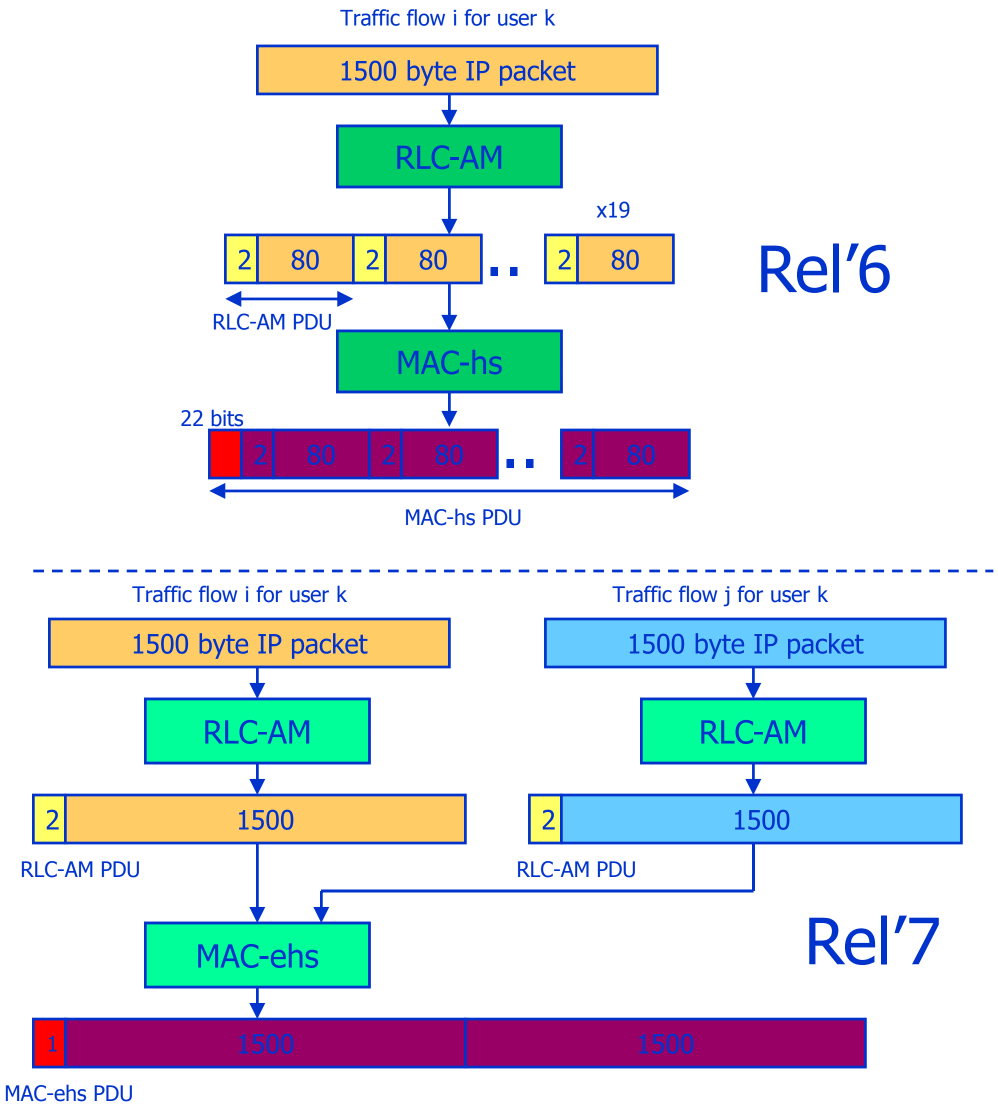
Options to increase data rate

- Increase PDU size/ RLC window
- Reduce RTT

HSDPA increases peak data rate significantly, while it does not reduce RLC RTT equivalently !

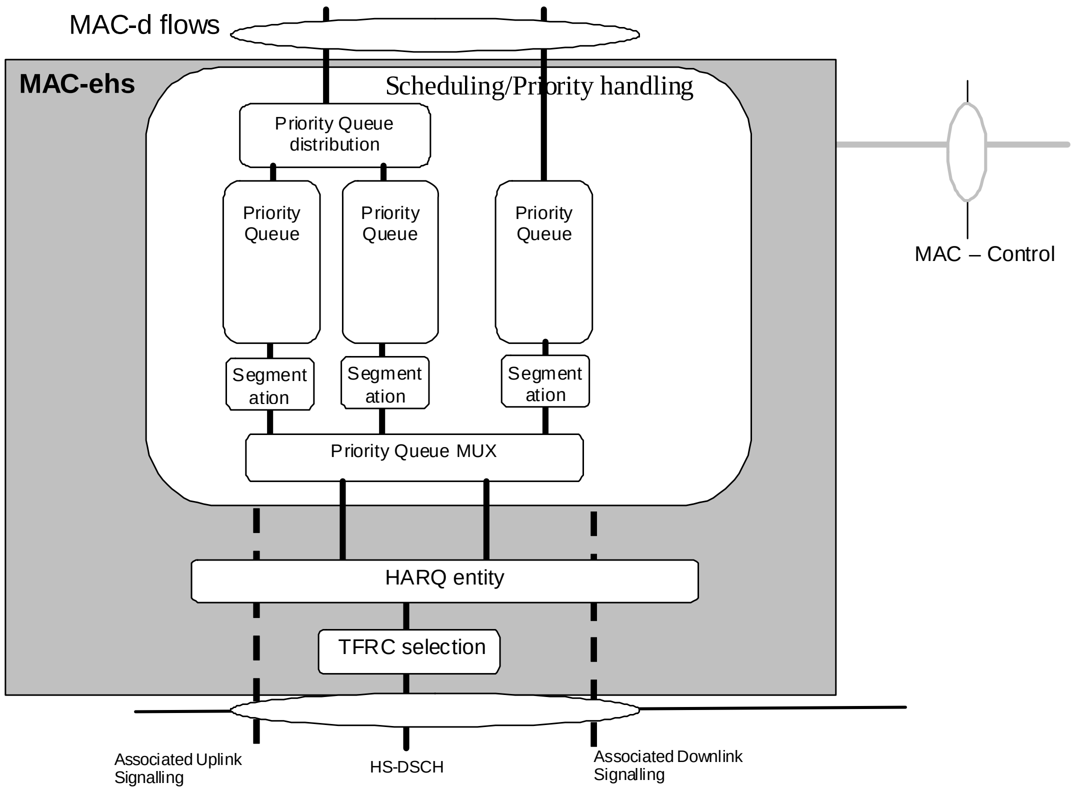
Enhanced Layer-2 Support for High Data Rates

- 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

Evolved HSPA Architecture (1) – Objectives

- Further improve latency and bit rate with limited and controlled hardware and software impacts

- Take advantage of these improvements as soon as today
  - E.g. independently of the availability of the SAE Core

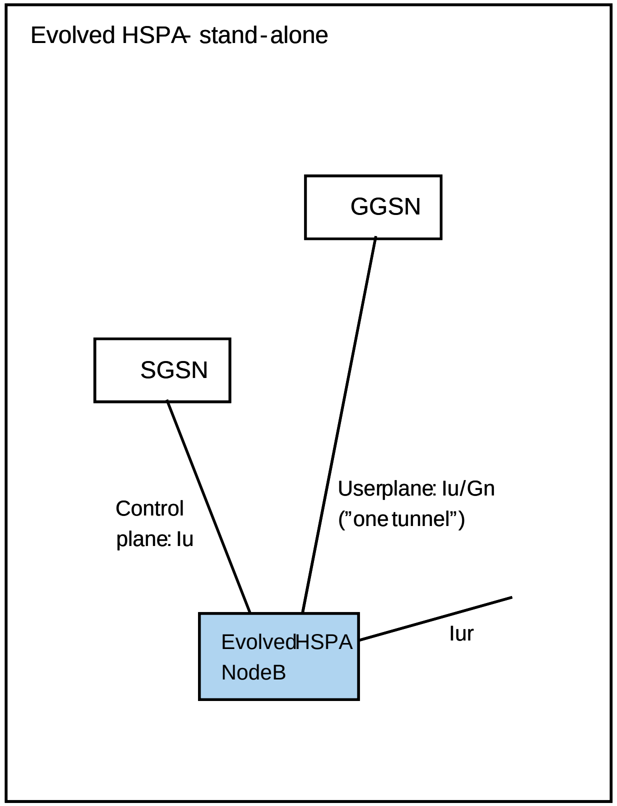
- Operate as a packet-only network based on shared channels only

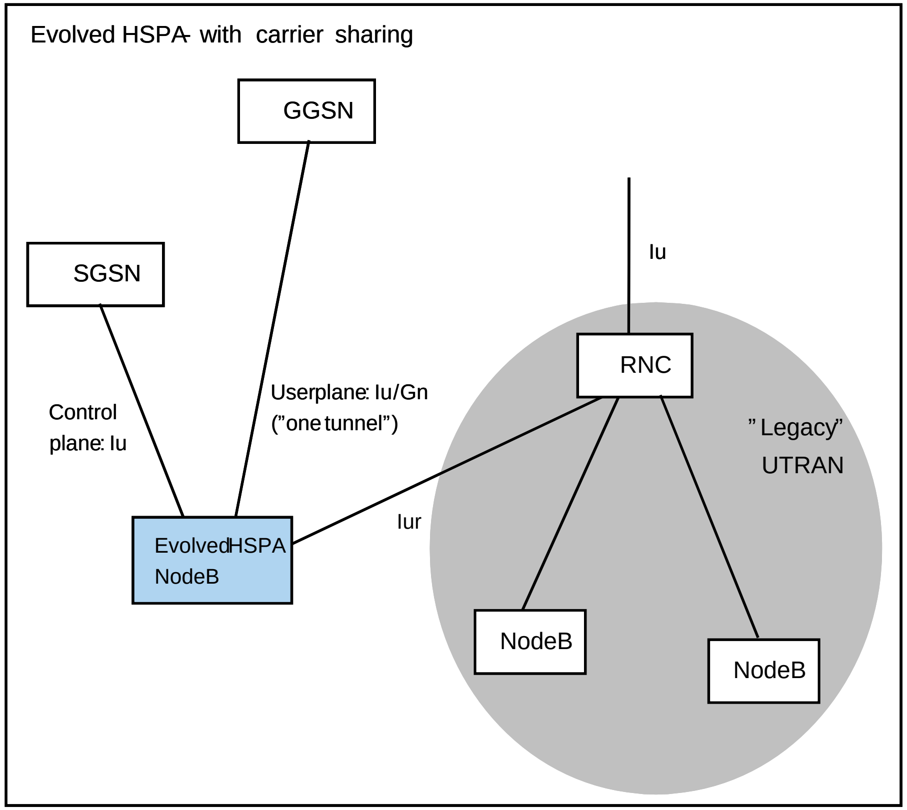
- Backwards compatible with legacy terminals

- Simple upgrade of existing infrastructure (for both hardware, software)

Evolved HSPA Architecture (2) – Full RNC/NodeB collapse

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





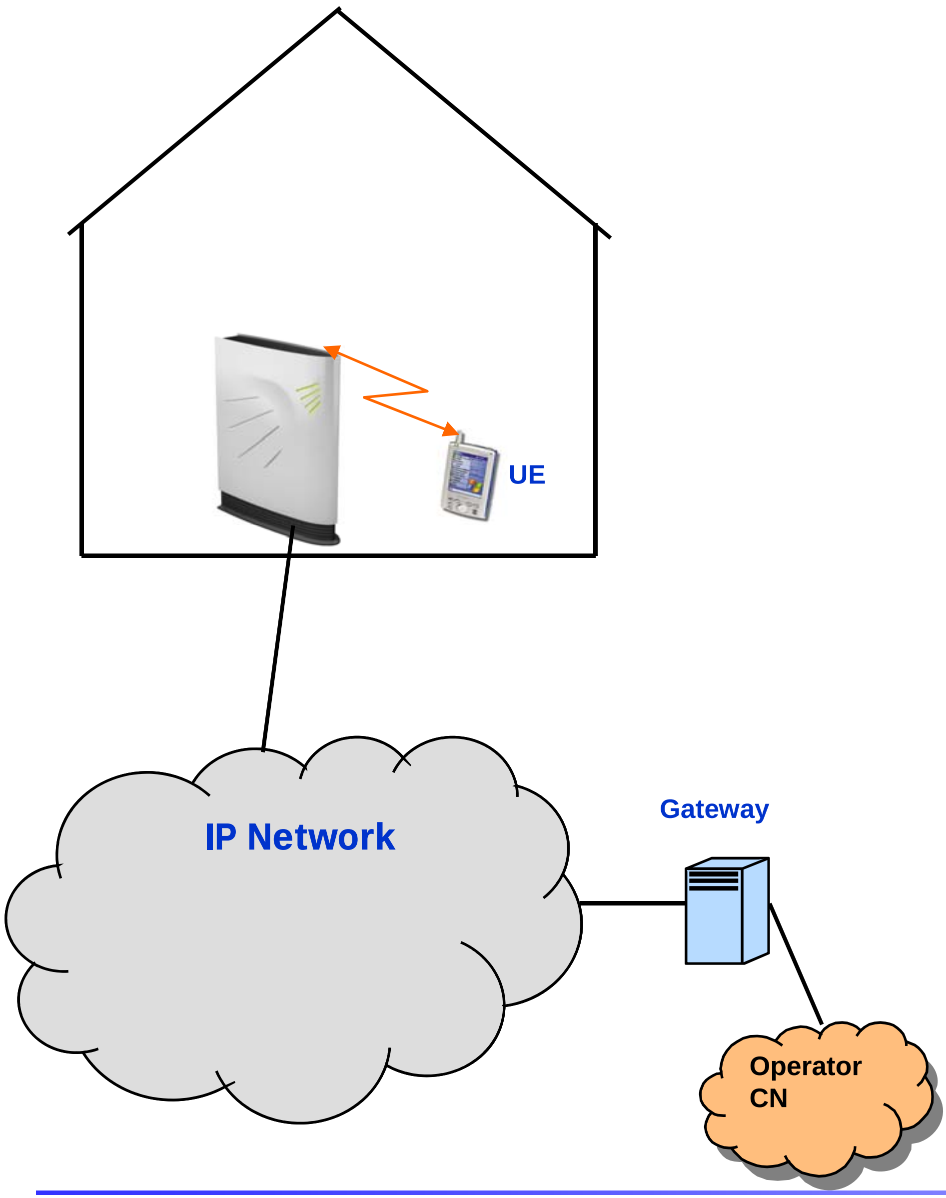
Evolved HSPA Architecture (3): Key features

- Optimal efficiency with all radio functions grouped together (Radio bearer control, RRC, handover control, RLC/MAC)

- Optimisation of resources
  - Central management of common channels

- Synergy with LTE
  - RLC, RRC already in the nodeB+
  - Ciphering and compression already in NodeB+ (with decision of PDCP in LTE eNodeB)

Home NodeB – Background

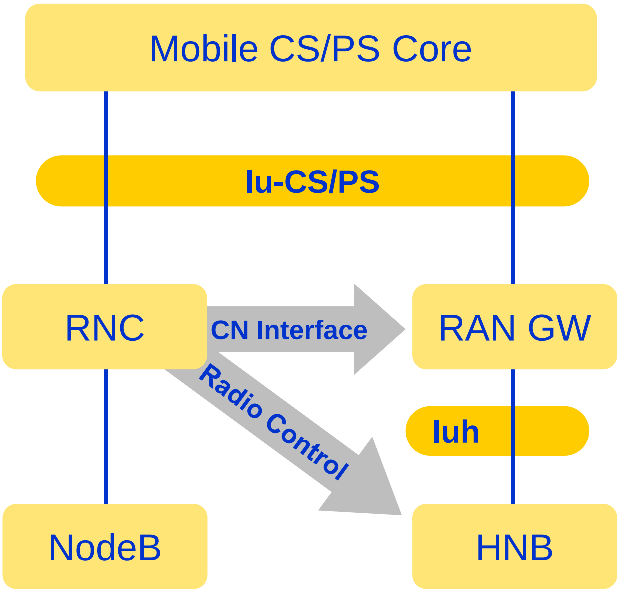


- Home NodeB (aka Femtocell) located at the customers premise
  - Connected via customers fixed line (e.g. DSL)
  - Small power (~100mW) to only provide coverage inside/ close to the building

- 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 suggested for 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)

A Smooth Evolution to HSPA+

2005	2006	2007	2008	2009
W-CDMA	HSDPA	HSUPA	HSPA+	
DL: 2 Mbps UL: 384 kbps	DL: 14.0 Mbps UL: 384 Kbps	DL: 14.0 Mbps UL: 5.74 Mbps	DL: 28.0 Mbps UL: 11.5 Mbps	DL: 42.2 Mbps UL: 11.5 Mbps

HSPA+ IMPLEMENTATION		HSPA+ Key Takeaways
64-QAM DL/16-QAM UL, MIMO, L2 enh., CPC	Higher Bit Rates & Increased Capacity	More than 2x HSPA peak rates, 35-40% improvement in VoIP capacity
Enhanced CELL_FACH/ RACH/ Paging, Architecture Enhancements	Reduced Delay	Saves 100s of ms of setup delay
	Smooth Evolution to HSPA+	Coexistence with Rel99/HSDPA/HSUPA, SW upgrade to support HSPA+, availability expected 2008-2009

Enhanced performance on W-CDMA/HSPA through radio improvements and architecture evolution; smooth migration to LTE

HSDPA References

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  - A. Toskala et al: "High-Speed Packet Access Evolution (HSPA+) in 3GPP," Chapter 15 in Holma/ Toskala: WCDMA for UMTS, Wiley 2007
  - R. Soni et al: "Intelligent Antenna Solutions for UMTS: Algorithms and Simulation Results," Communications Magazine, October 2004, pp. 28–39
- Standards
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  - 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
64QAM	64 (state) Quadrature Amplitude Modulation