

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

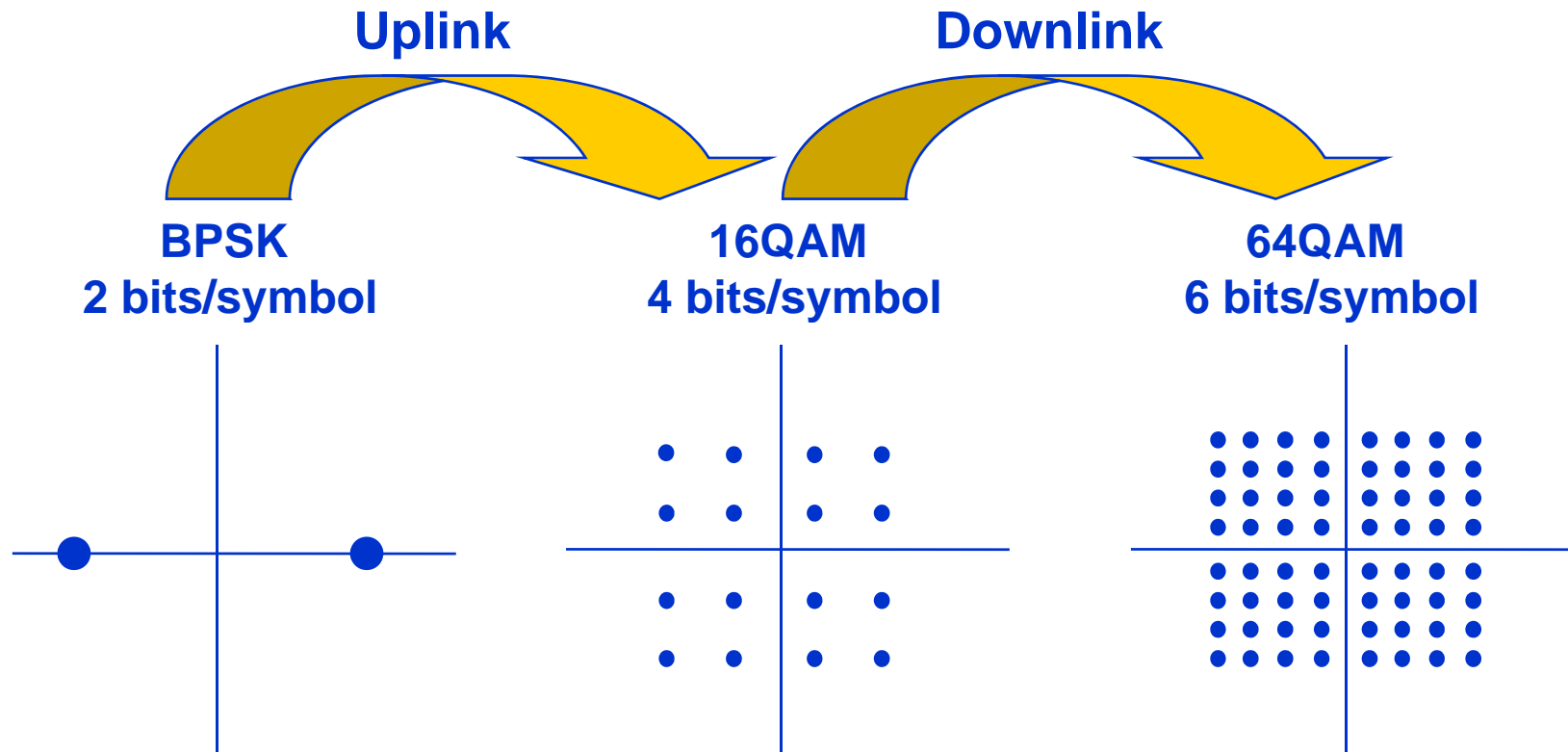
HSPA+ Goals

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

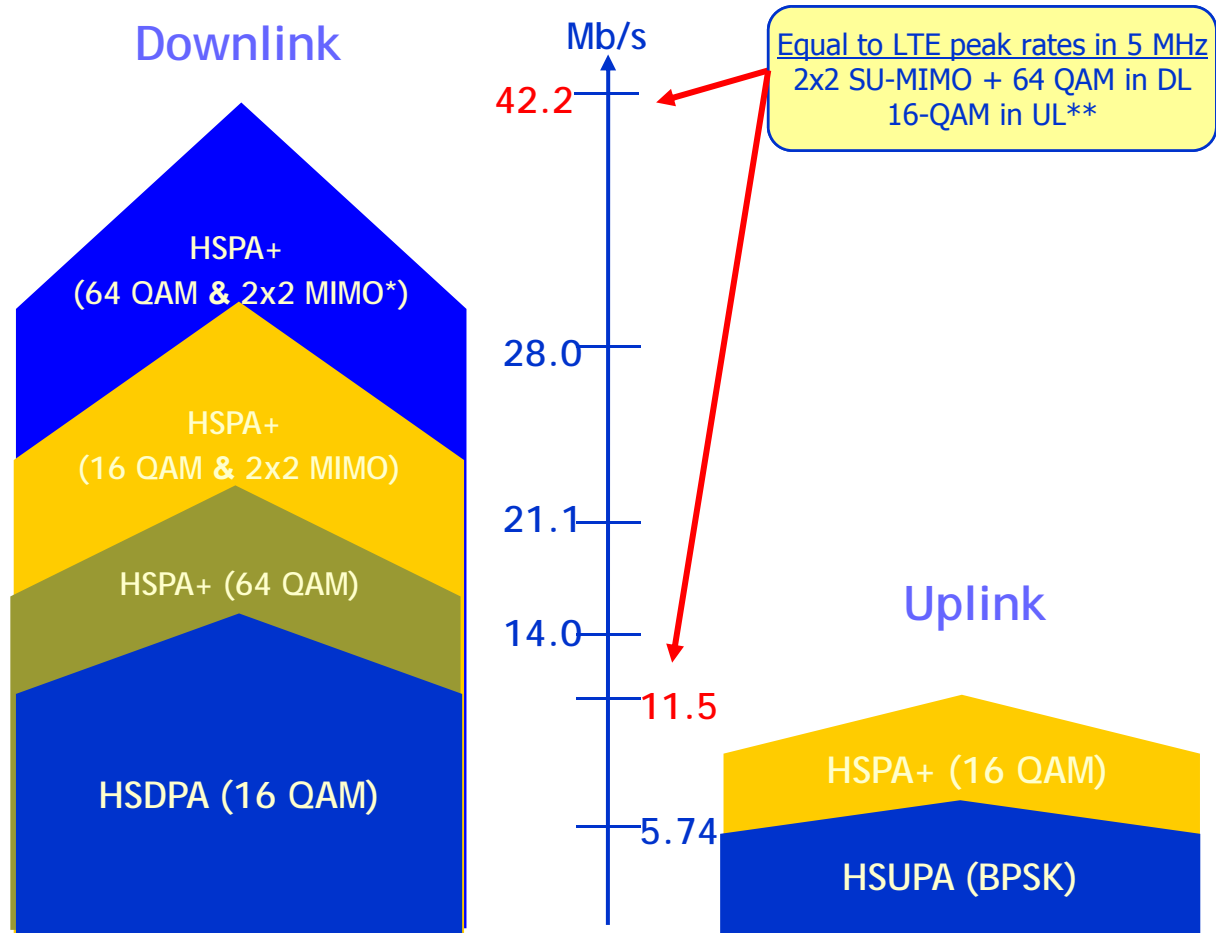
HOMs increase the number of bits/symbols transmitted, thereby increasing the peak rate

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)

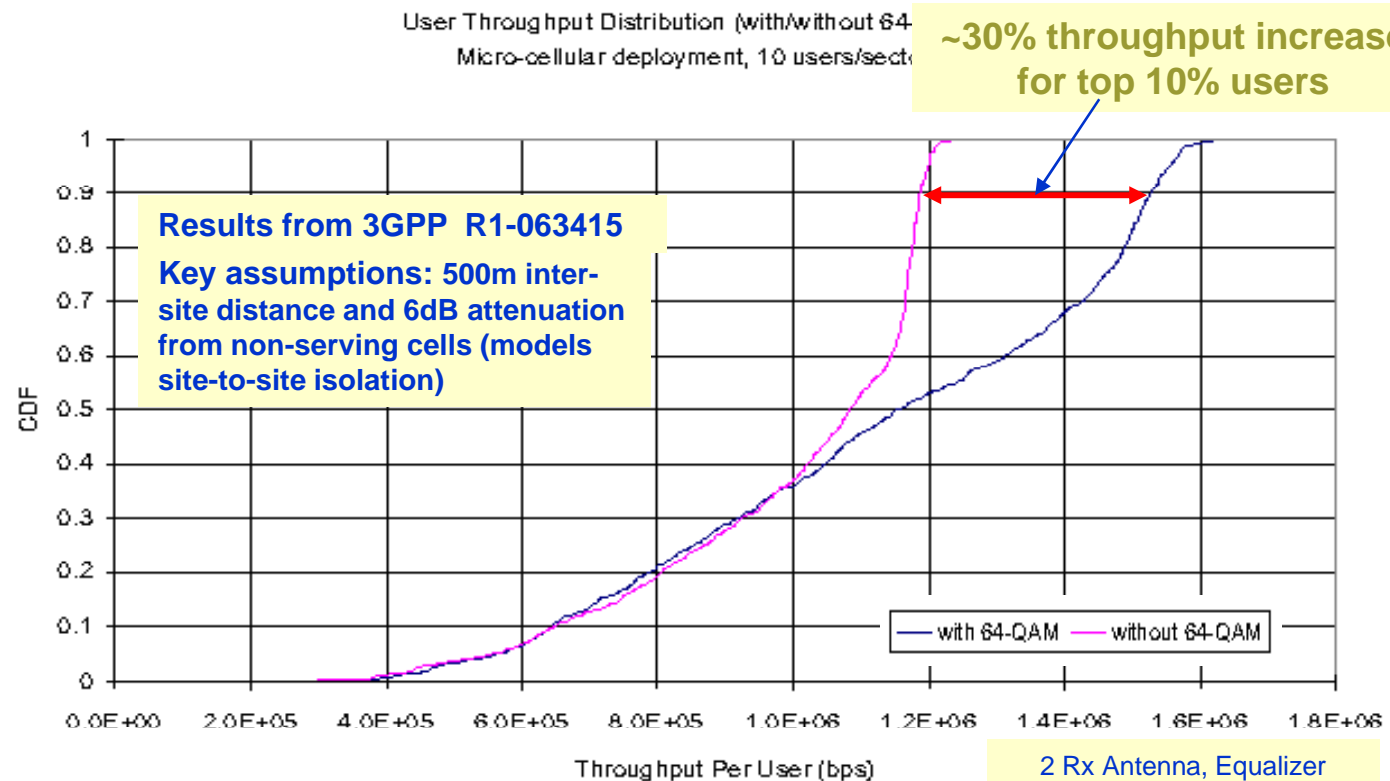
*Part of 3GPP Rel-8



Theoretical Max Peak Rates In Perfect RF Conditions

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

HSDPA 64-QAM – Micro Cell / Hotspot Deployment



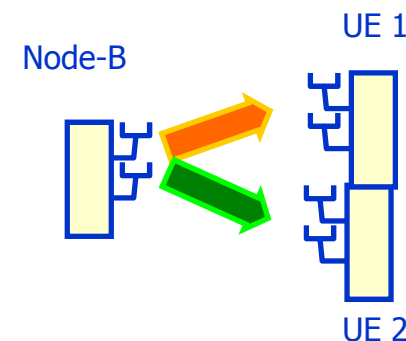
	Without 64-QAM	With 64-QAM	Gain
Sector Throughput	10 Mbit/s	11.3 Mbit/s	13%
90%-tile Throughput (normalized for 1 user per sector)	12 Mbit/s	15.6 Mbit/s	30%

HOMs provide significant improvements for “hot spot” deployments

Multiple Antenna Techniques

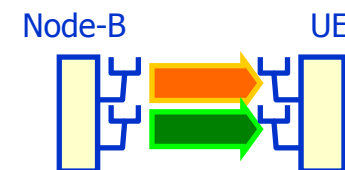
- **Spatial Division Multiple Access (SDMA) or Beamforming**

- 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



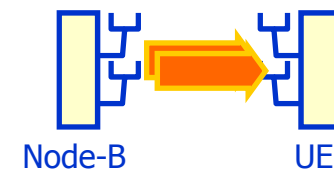
- **Spatial Multiplexing (SM) → SU-MIMO**

- 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**

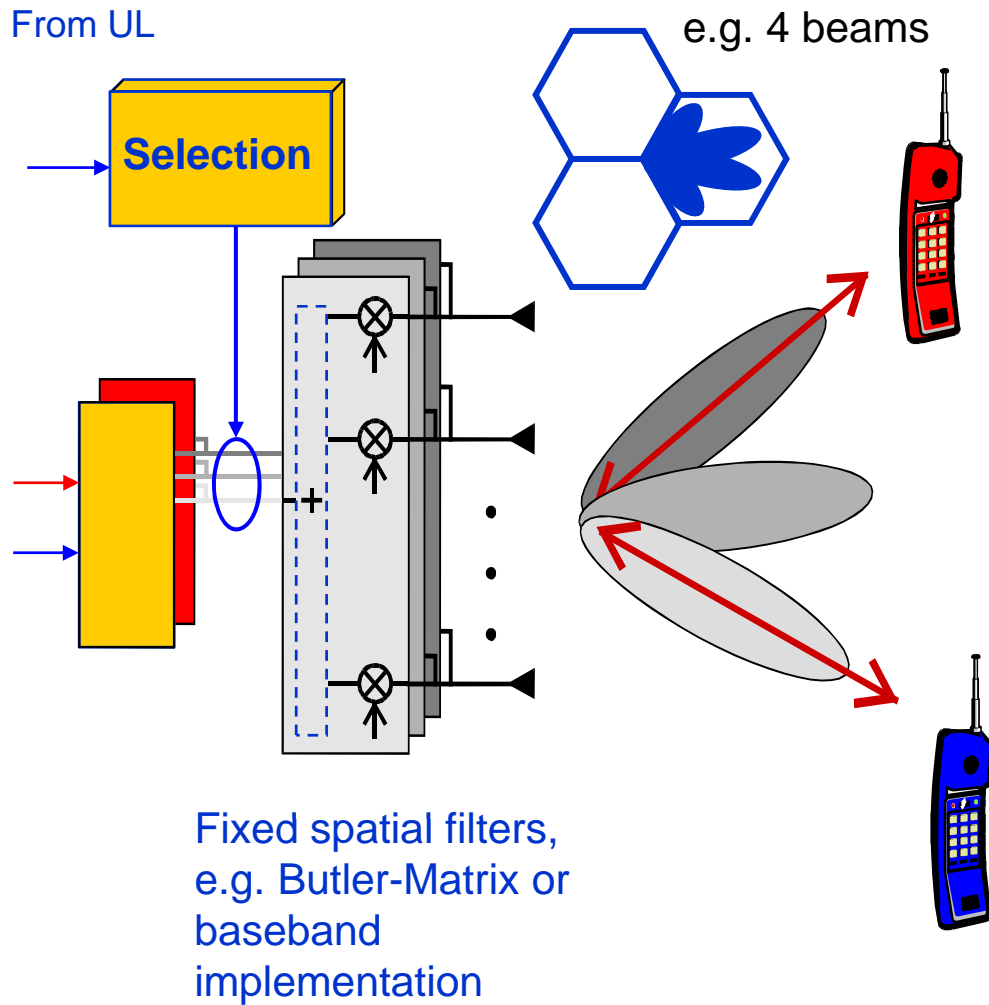


- **Closed Loop Transmit Diversity (CLTD)**

- Improves reliability on a single data stream
- Fall back scheme if channel conditions do not allow SM

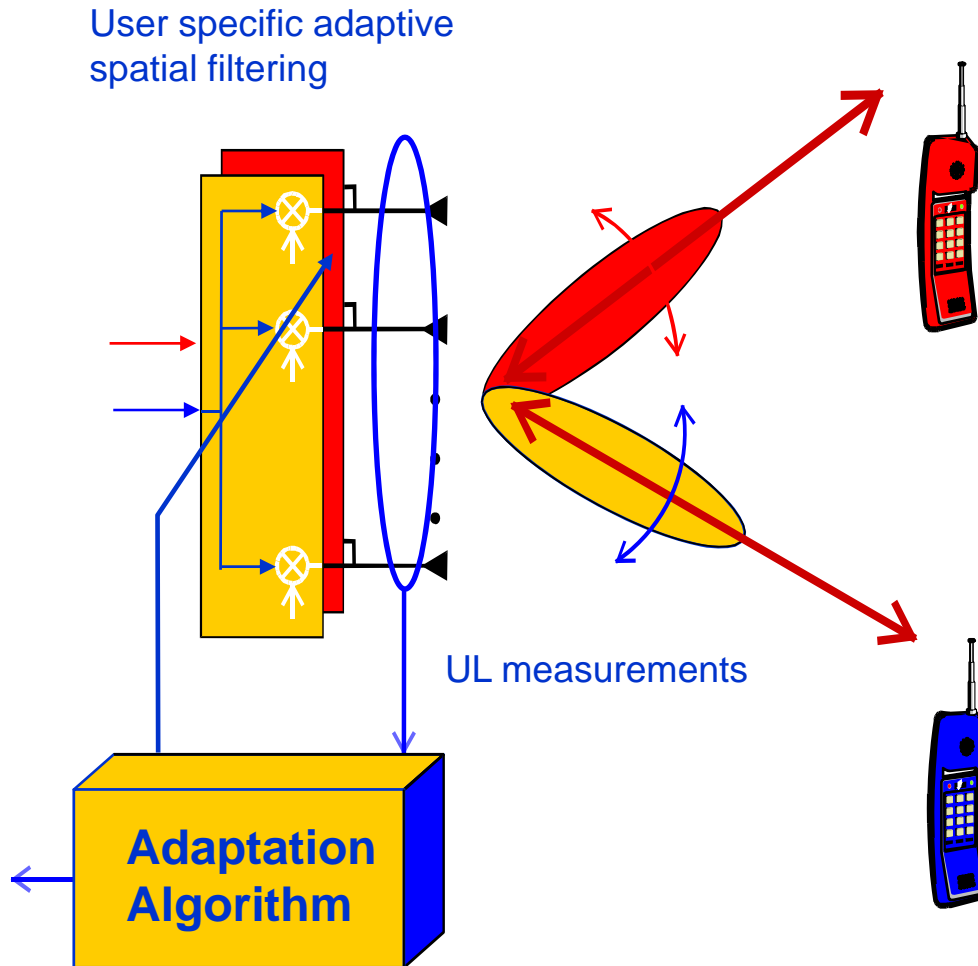


Fixed Beam Switching (FBS)



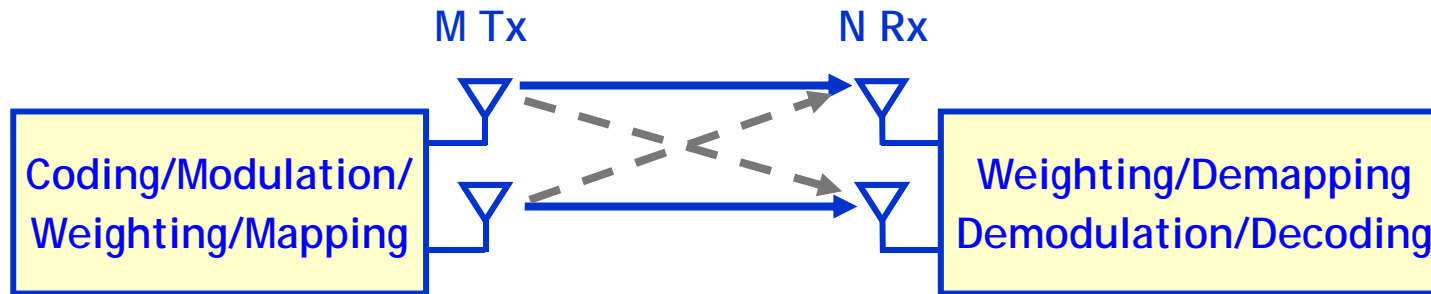
- Spatial partitioning of the sector area by help of a fixed number of beams
- S-CPICH (per beam) is introduced for improving UE channel estimation
- Beam specific secondary scrambling codes can be applied → code limitation preventable

Adaptive Beamforming/ Beam Pointing (BP)



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

Basic MIMO Channel



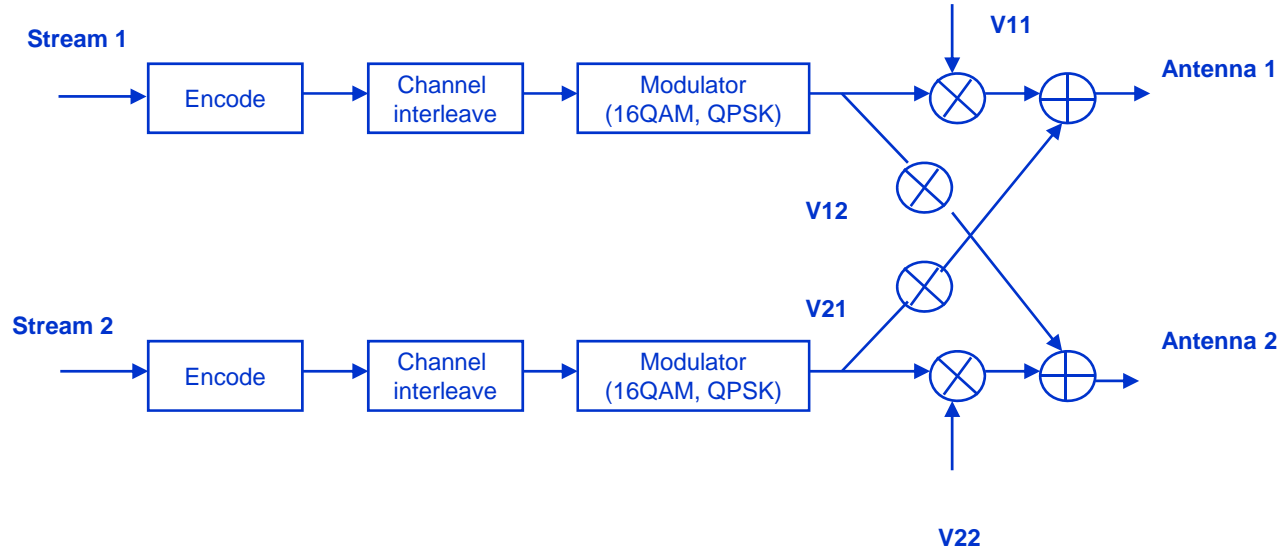
- The MIMO channel consists of M Tx and N Rx antennas
- Each Tx antenna transmits a different signal
- The signal from Tx antenna j is received at all Rx antennas i
- Channel capacity can increase linearly

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

MIMO in HSPA+

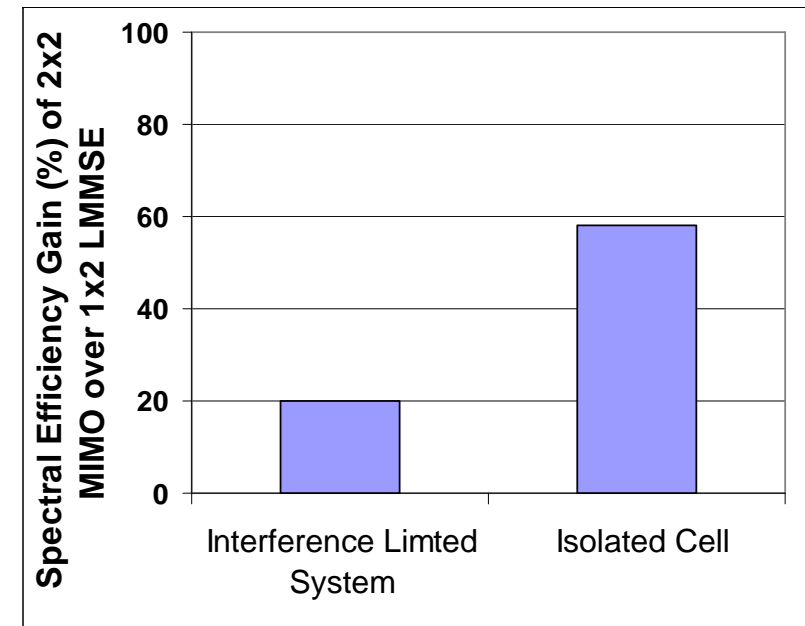
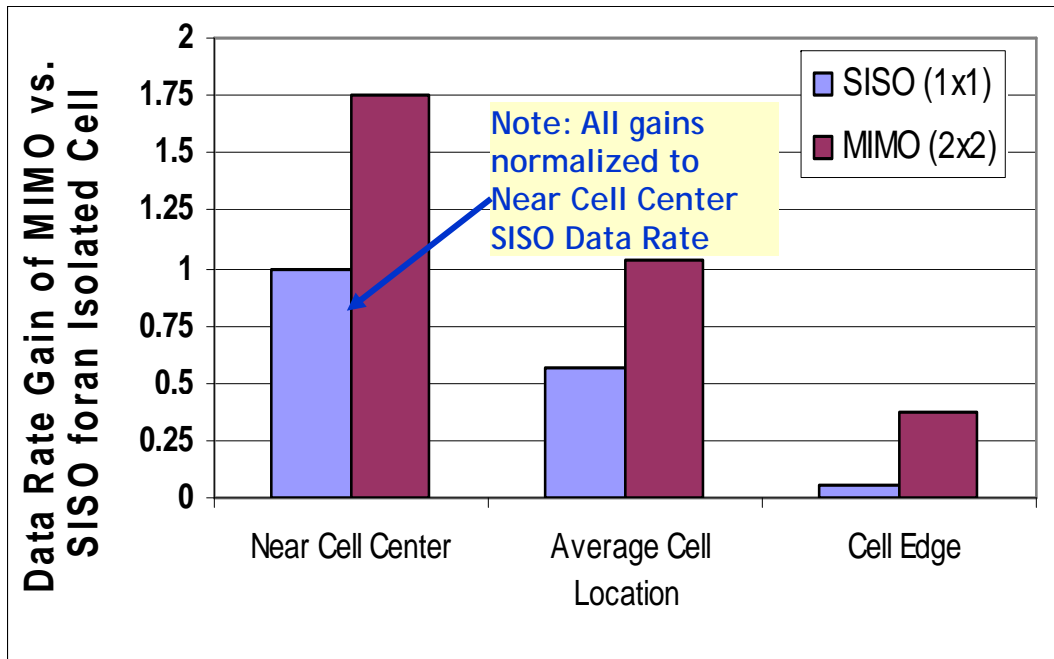
Release 7 MIMO for HSDPA

- ◆ 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

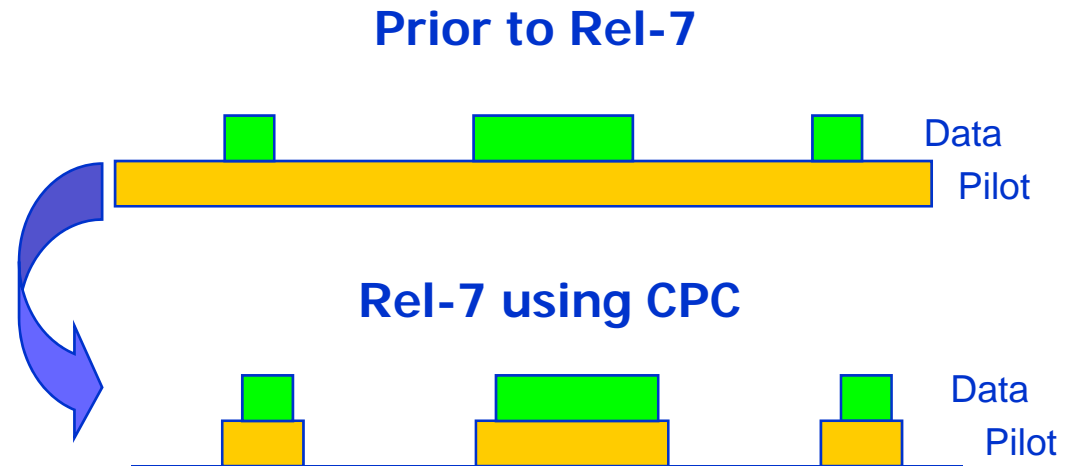
NOTE 1: When 4 codes are transmitted in parallel, two codes shall be transmitted with SF2 and two codes with SF4

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

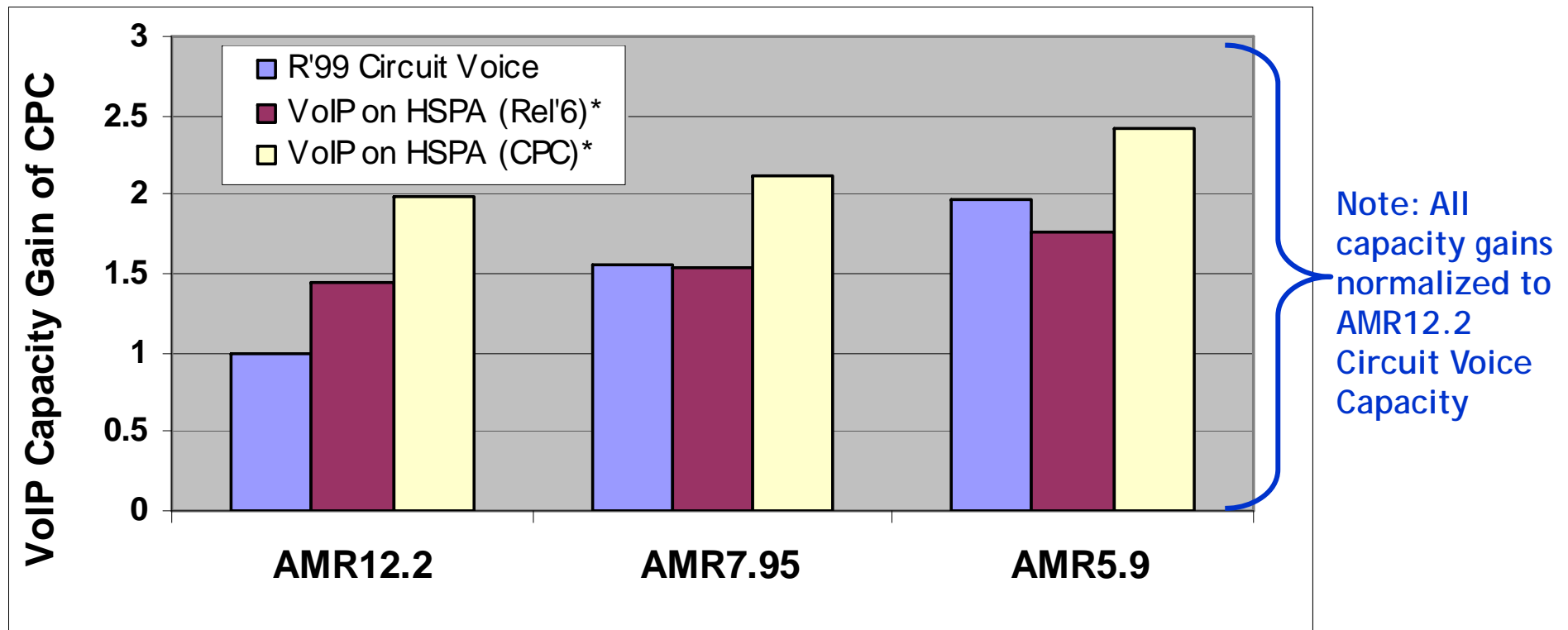


- ◆ **HS-SCCH-less transmission** introduced to reduce signaling bottleneck for real-time-services on HSDPA

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

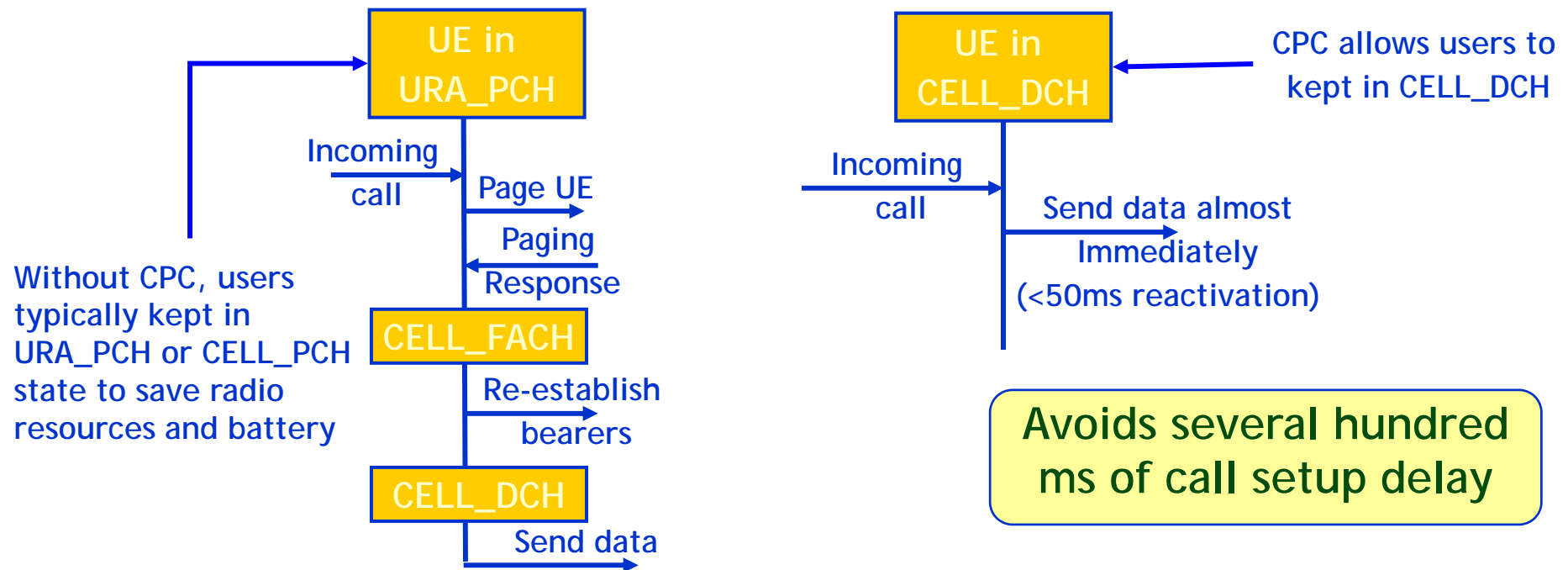


CPC provides significant VoIP on HSPA capacity benefits

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

“Always On” Enhancement of CPC

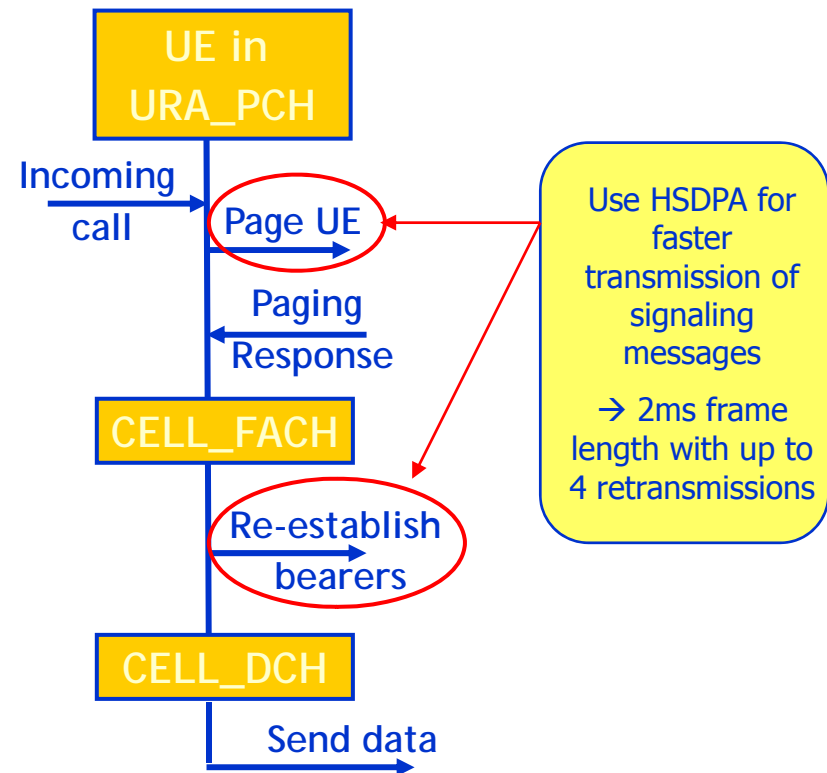
- ◆ CPC allows UEs in CELL_DCH to “sleep” during periods of inactivity
 - ◆ Reduces signaling load and battery consumption (in combination with DRX)
- ◆ Allows users to be kept in CELL_DCH with HSPA bearers configured
- ◆ Need to page and re-establish bearers leads to call set up delay



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

Enhanced CELL_FACH & Enhanced Paging Procedure

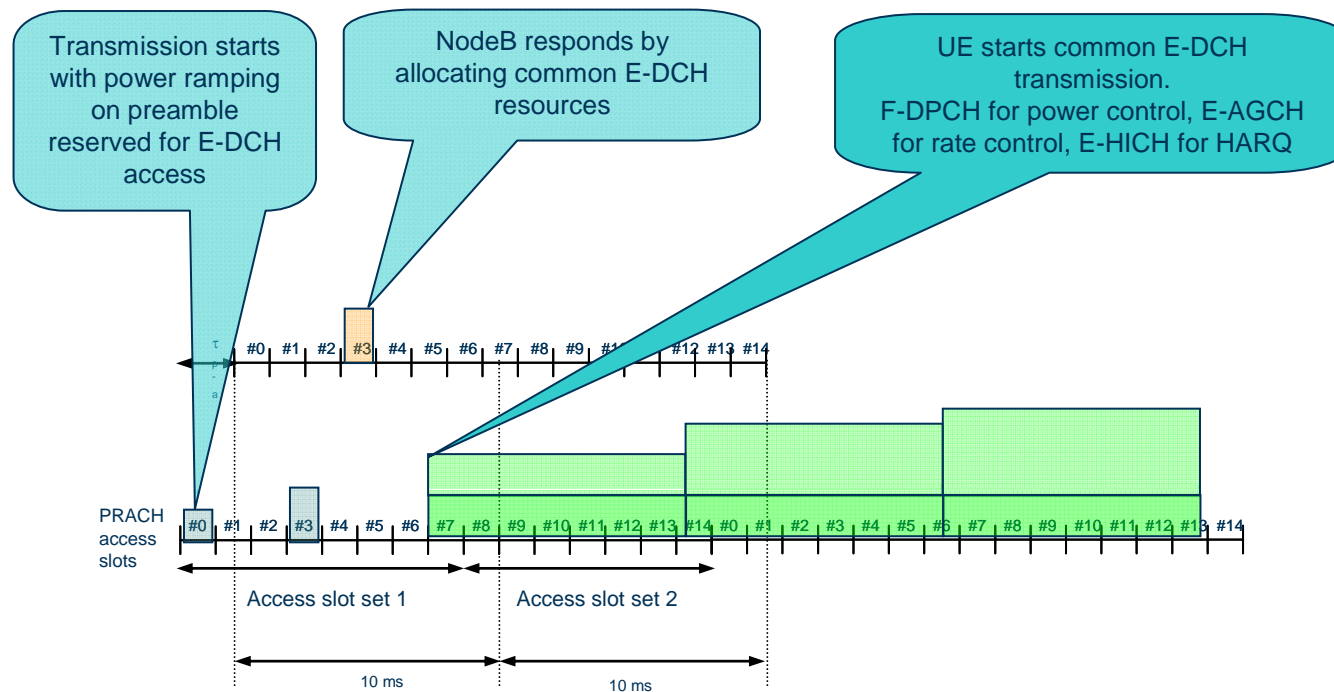
- ◆ UEs are not always kept in CELL_DCH state, eventually fall back to CELL_PCH/URA_PCH
- ◆ HSPA+ introduces enhancements to reduce the delay in signaling the transition to CELL_DCH → use of HSDPA in CELL_FACH and URA/CELL_PCH states instead of S-CCPCH
 - ◆ Enhanced CELL_FACH
 - ◆ Enhanced Paging procedure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



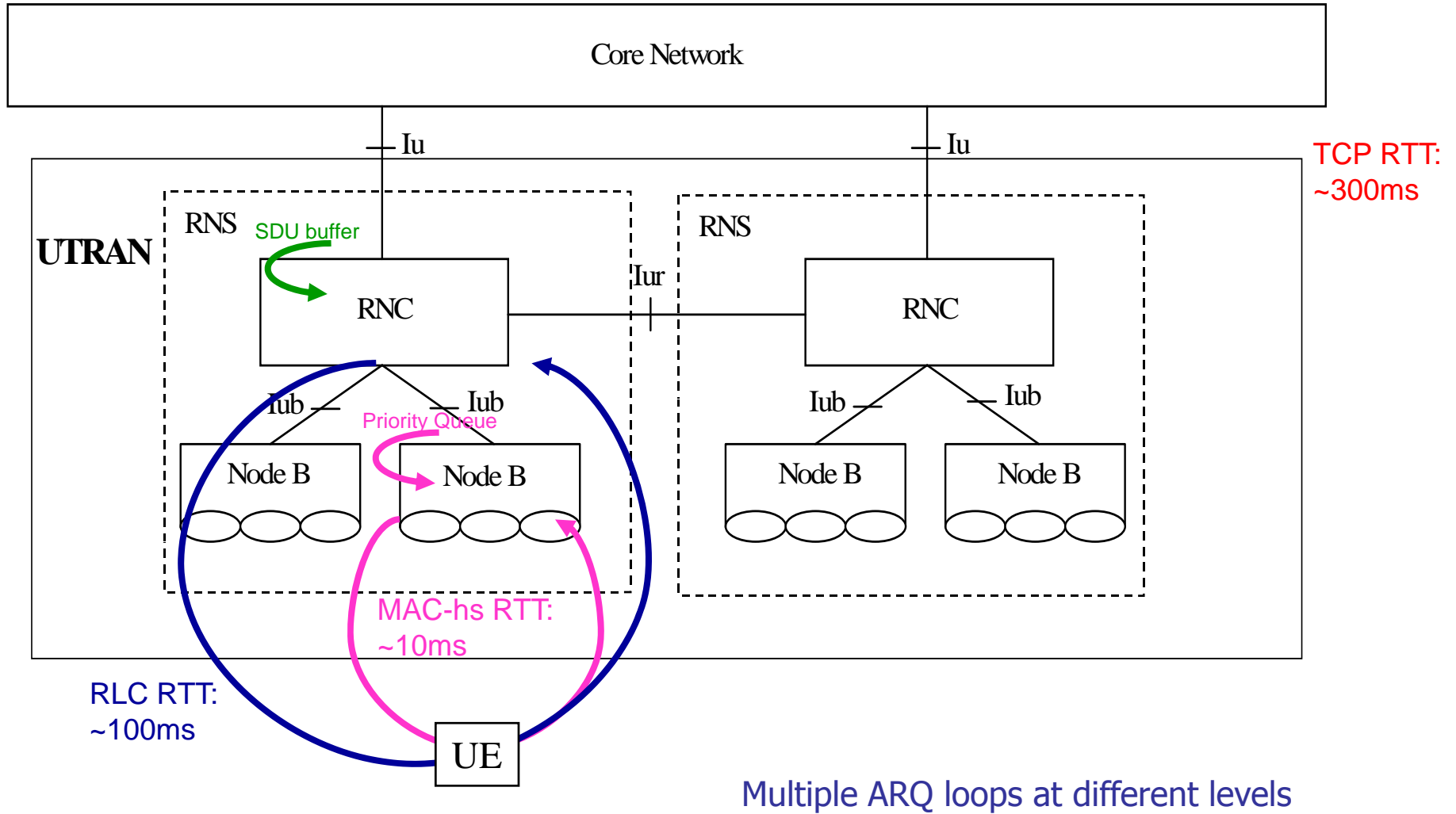
Enhanced CELL_FACH/Paging/RACH reduces setup delay → improves PoC

E-RACH – High level description

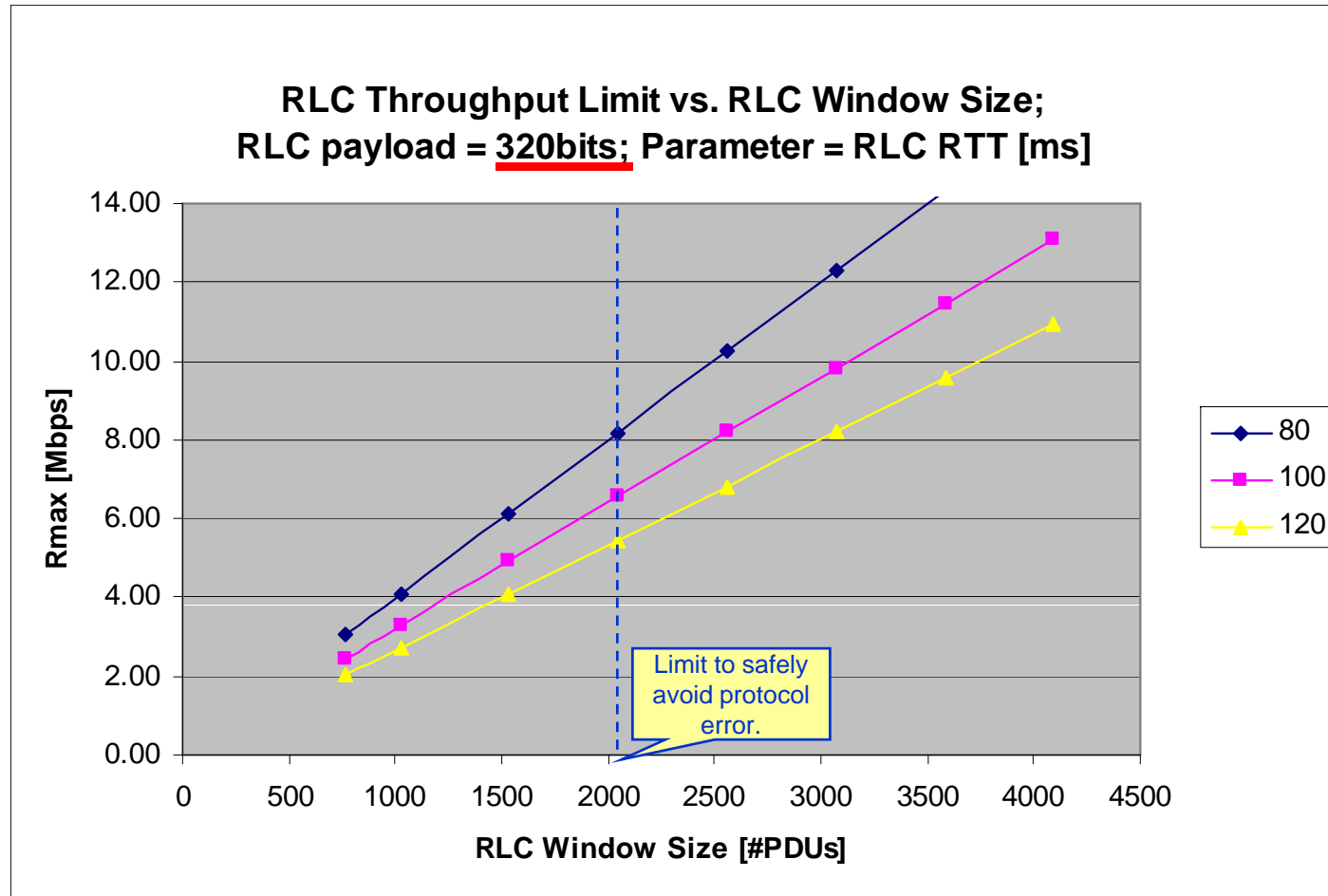
- ◆ RACH preamble ramping as in R'99 with AICH/E-AICH acknowledgement
- ◆ Transition to E-DCH transmission in CELL_FACH
 - ◆ Possibility to seamlessly transfer to Cell_DCH
- ◆ NodeB can control common E-DCH resource in CELL_FACH
 - ◆ Resource assignment indicated from NodeB to UE



UTRAN Architecture



RLC Throughput Limit vs. RLC Window Size



Theoretical limit:
PHY >> RLC

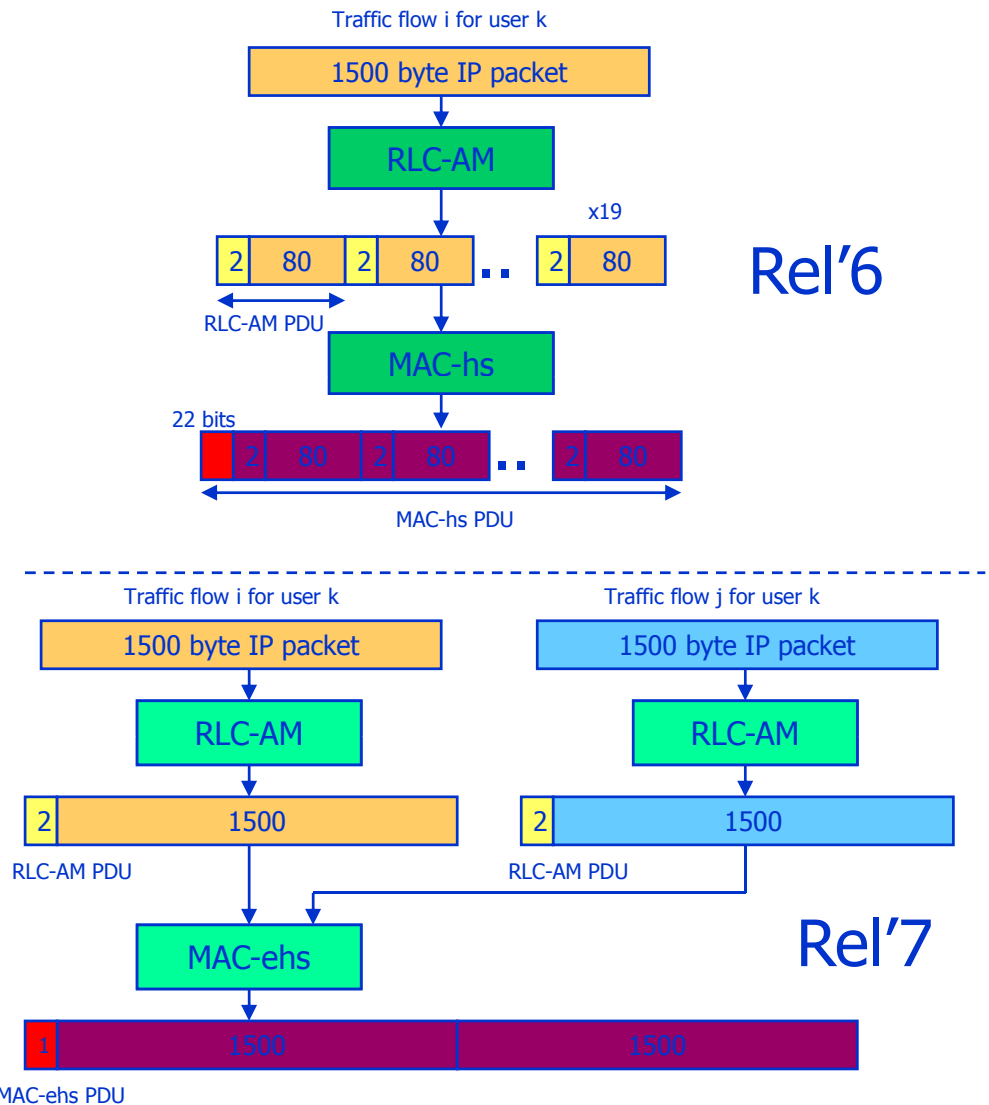
Options to increase
data rate

- ◆ Increase PDU size/
RLC window
- ◆ Reduce RTT

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

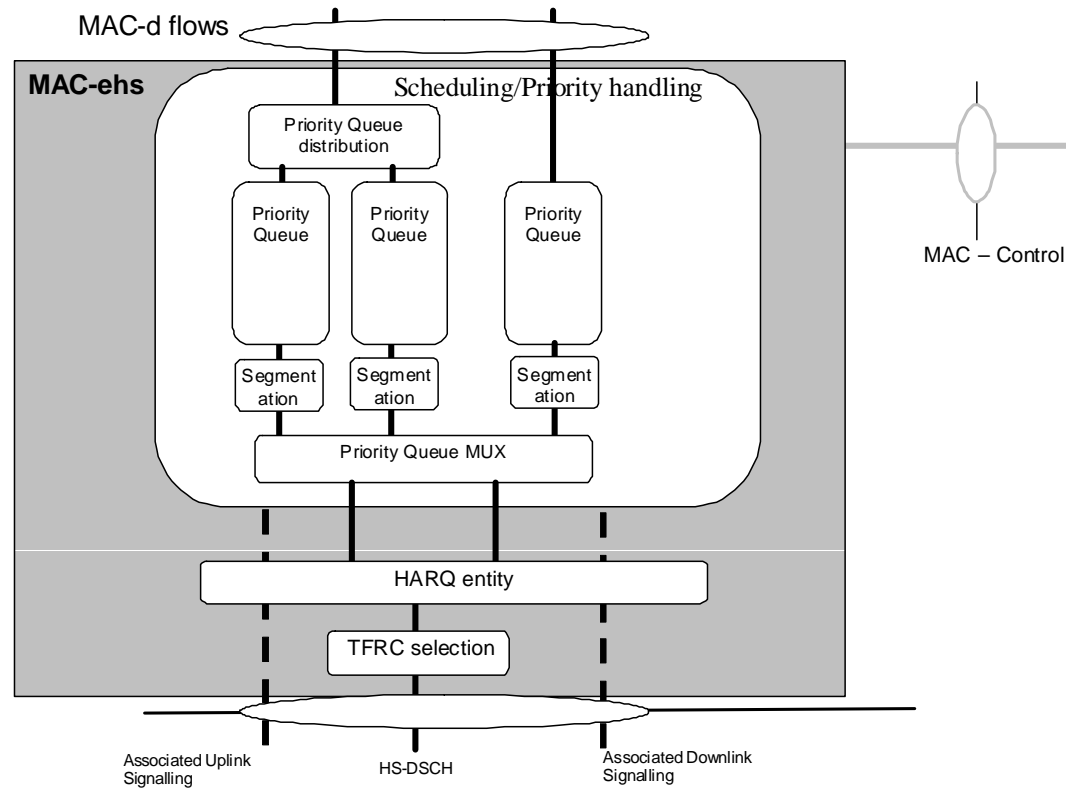
Enhanced Layer-2 Support for High Data Rates

- ◆ 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)

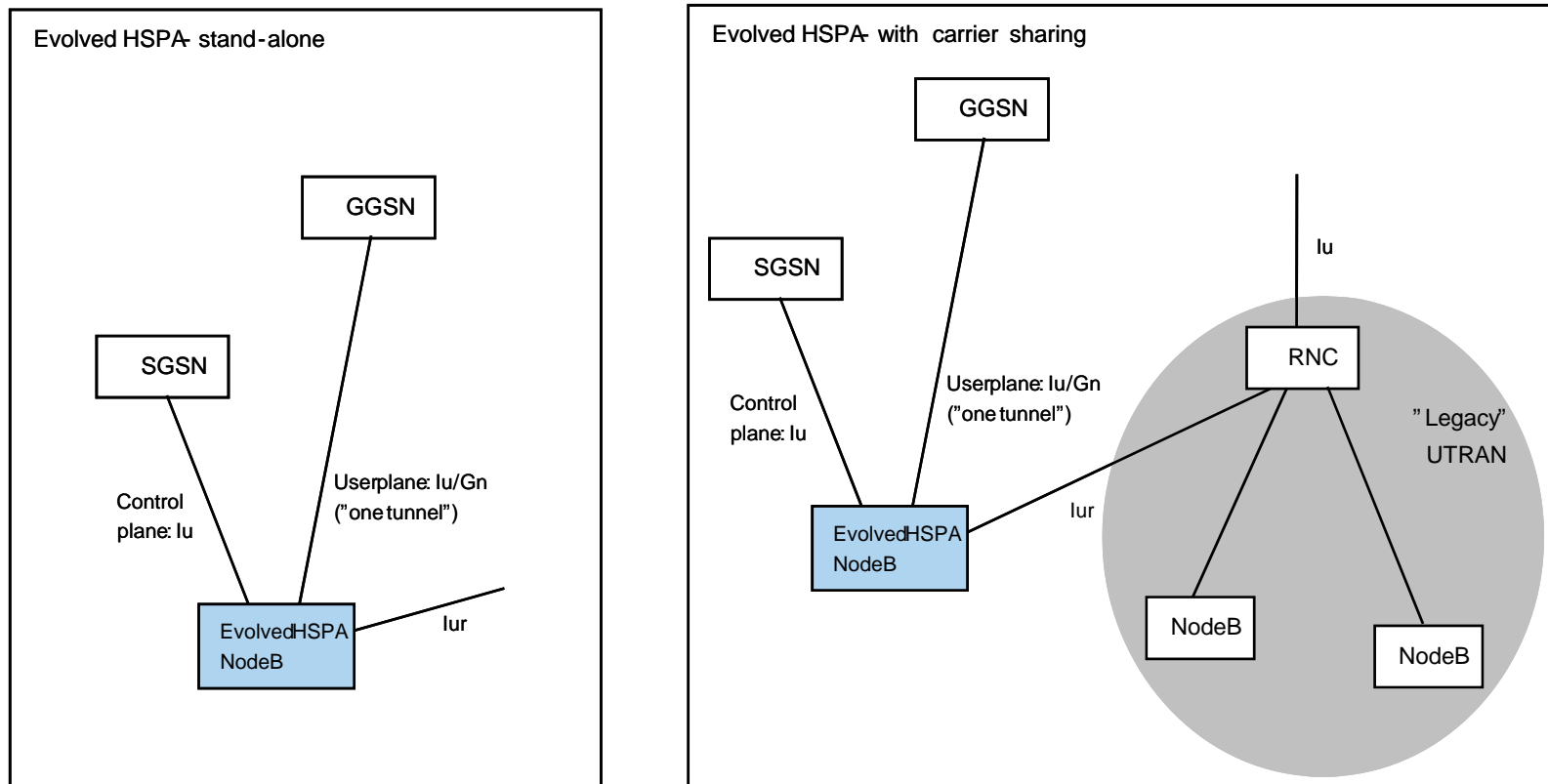
- ◆ Flow Control
- ◆ Scheduling/ Priority handling
- ◆ HARQ handling
- ◆ TFRC Selection
- ◆ Priority Queue Mux
- ◆ Segmentation

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

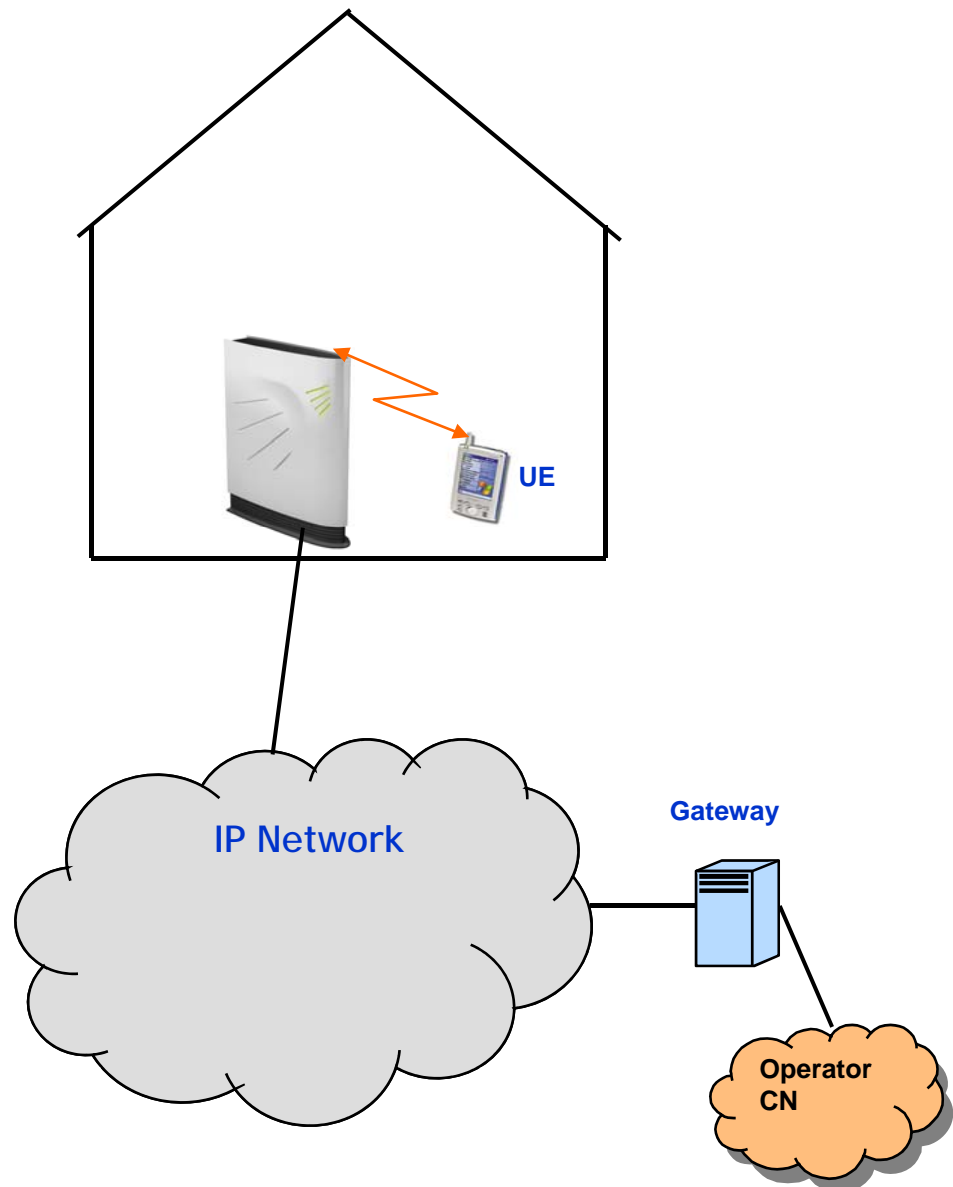
- ◆ 2 deployment scenarios: standalone UTRAN or carrier sharing with "legacy"UTRAN



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)

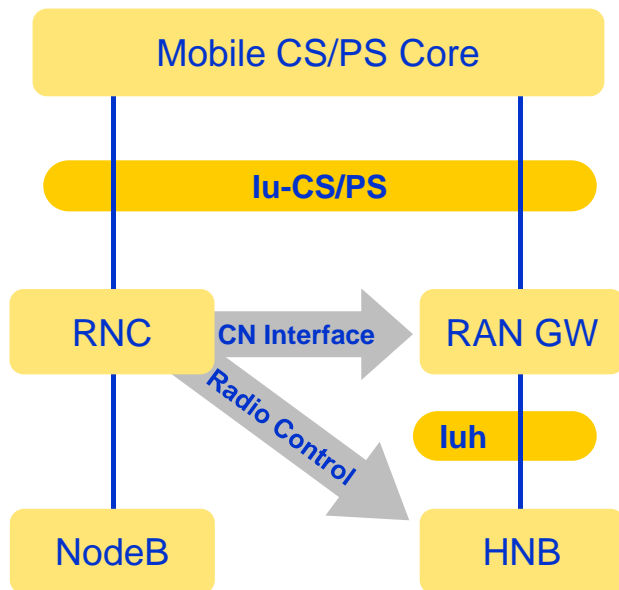
Home NodeB – Background



- ◆ Home NodeB (aka Femtocell) located at the customers premise
 - ◆ Connected via customers fixed line (e.g. DSL)
 - ◆ Small power ($\sim 100\text{mW}$) 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
- ◆ FMS interface

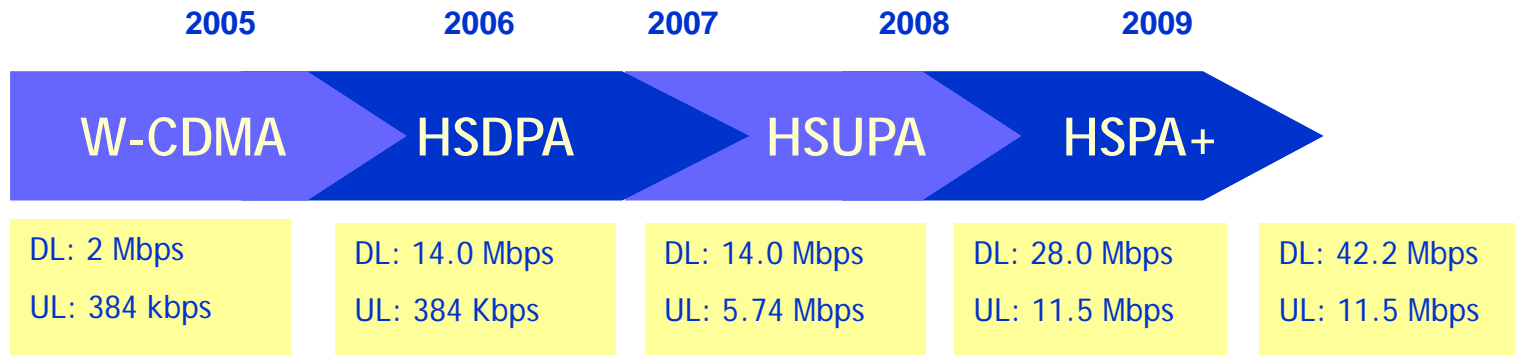
Summary

- ◆ 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+



HSPA+ IMPLEMENTATION

64-QAM DL/16-QAM UL, MIMO, L2 enh., CPC

Enhanced CELL_FACH/RACH/ Paging, Architecture Enhancements

Higher Bit Rates & Increased Capacity

Reduced Delay

Smooth Evolution to HSPA+

HSPA+ Key Takeaways

More than 2x HSPA peak rates, 35-40% improvement in VoIP capacity

Saves 100s of ms of setup delay

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

◆ Papers:

- ◆ 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

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