

4. QoS Functions in Access Networks

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Outline

- QoS management function in GERA networks
 - Weighted Round Robin (WRR) scheduler
 - Deficit Round Robin (DRR) scheduler
 - Handover and cell reselection in 2G
- QoS management function in (enhanced) UTRA networks
 - Fair Throughput (FT) scheduler with QoS differentiation
 - Fair Resources (FR) scheduler with QoS differentiation
 - HSPA differentiated scheduling
- Differentiated intra-frequency, inter-frequency and inter-RAT handovers, and service performance thereof
- 3GPP-WLAN interworking

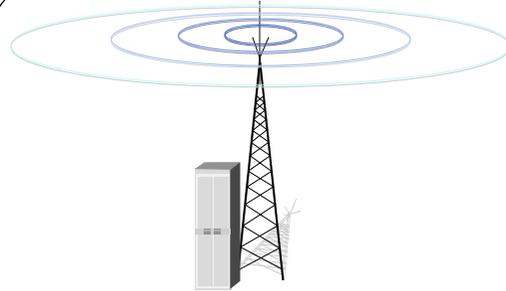


QoS functions in GERAN and UTRAN

MS



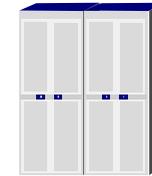
ME + SIM



BTS

- Power control

GERAN



BSC

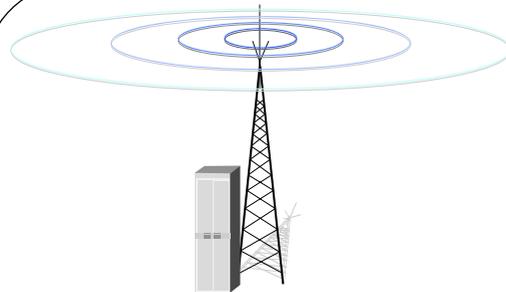
- Handover control
- Packet scheduling
- Admission control

UE



ME + USIM

- Power control



Node B

- Fast power control
- Fast load control
- Fast packet scheduling

Enhanced UTRAN



RNC

- Power control
- Handover control
- Admission control
- Packet scheduling



Territory setting with PS-CS separation

	Not allocated Timeslot		Allocated for circuit switched traffic		Allocated for packet switched traffic		
TRX 1	BCCH	SDCCH	PS-4 PS-2 PS-11	PS-4 PS-2 PS-11	PS-4 PS-2	PS-3 PS-7	PS-3 PS-7 PS-3 PS-7
TRX 2	PS-6 PS-9	PS-6 PS-9	PS-6 PS-10	PS-5 PS-10	PS-5 PS-8	PS-1	PS-1 PS-1
TRX 3	Not used	Not used	Not used	Not used	CS-10	CS-6	CS-12 CS-9
TRX 4	CS-5	CS-11	CS-3	CS-7	CS-8	CS-2	CS-4 CS-1
	TSL 0	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5	TSL 6 TSL 7

Timeslots available for PS traffic

Timeslots available for CS traffic



Territory setting with no PS-CS separation

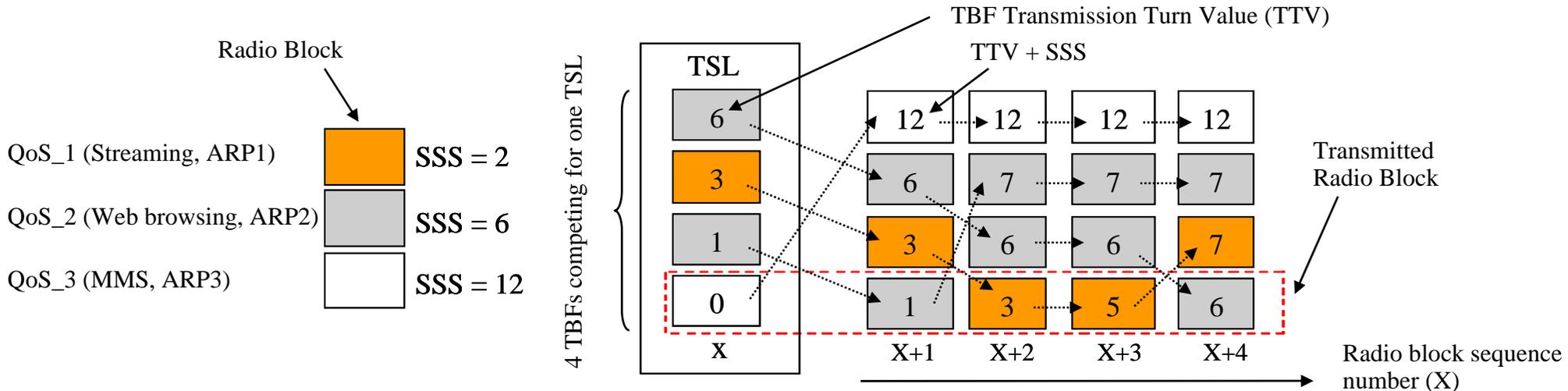
□	Not allocated Timeslot
□	Allocated for circuit switched traffic
□	Allocated for packet switched traffic

TRX 1	BCCH	SDCCH	CS-3	PS-3	CS-5	PS-3	Not used	CS-8
TRX 2	CS-2	PS-6 PS-1	CS-10	Not used	PS-6	CS-1	CS-6	PS-6 PS-1
TRX 3	Not used	PS-5	Not used	PS-5	CS-12	Not used	PS-5	Not used
TRX 4	CS-4	CS-11	PS-4 PS-2	CS-7	PS-4 PS-2 PS-7	CS-9	Not used	PS-4 PS-2 PS-7
	TSL 0	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5	TSL 6	TSL 7



R97/98: QoS differentiation in BSS

- One to one mapping *ARP* (1-3) – *SSS* (*Scheduling Step Size*, 1-12)
- Weighted Round Robin (*WRR*): the lower the *SSS* the higher the priority (= 1/*SSS*)



Throughput R_j experienced by the TBF j in one time slot (TSL)

$$R_j = \frac{SSS_j}{\sum_{i=1}^N \frac{1}{SSS_i}} R_{TSL}$$

R_{TSL} is the average bit rate the TSL in question can offer during the measurement period

Approximation due to:

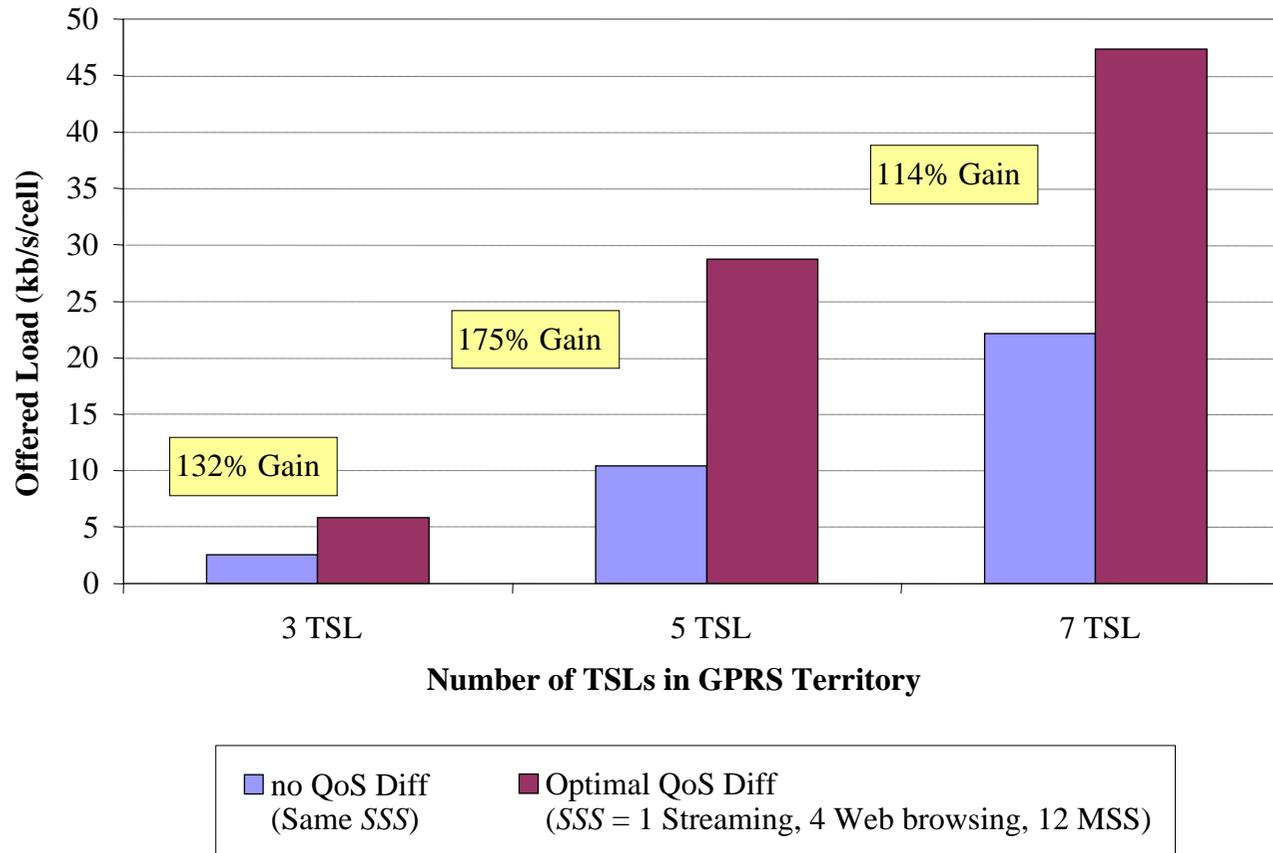
- Different retransmissions and M-CS
- Different number of users per slot

N is the total number of TBFs sharing the same TSL

SSS_i value associated with the TBF i



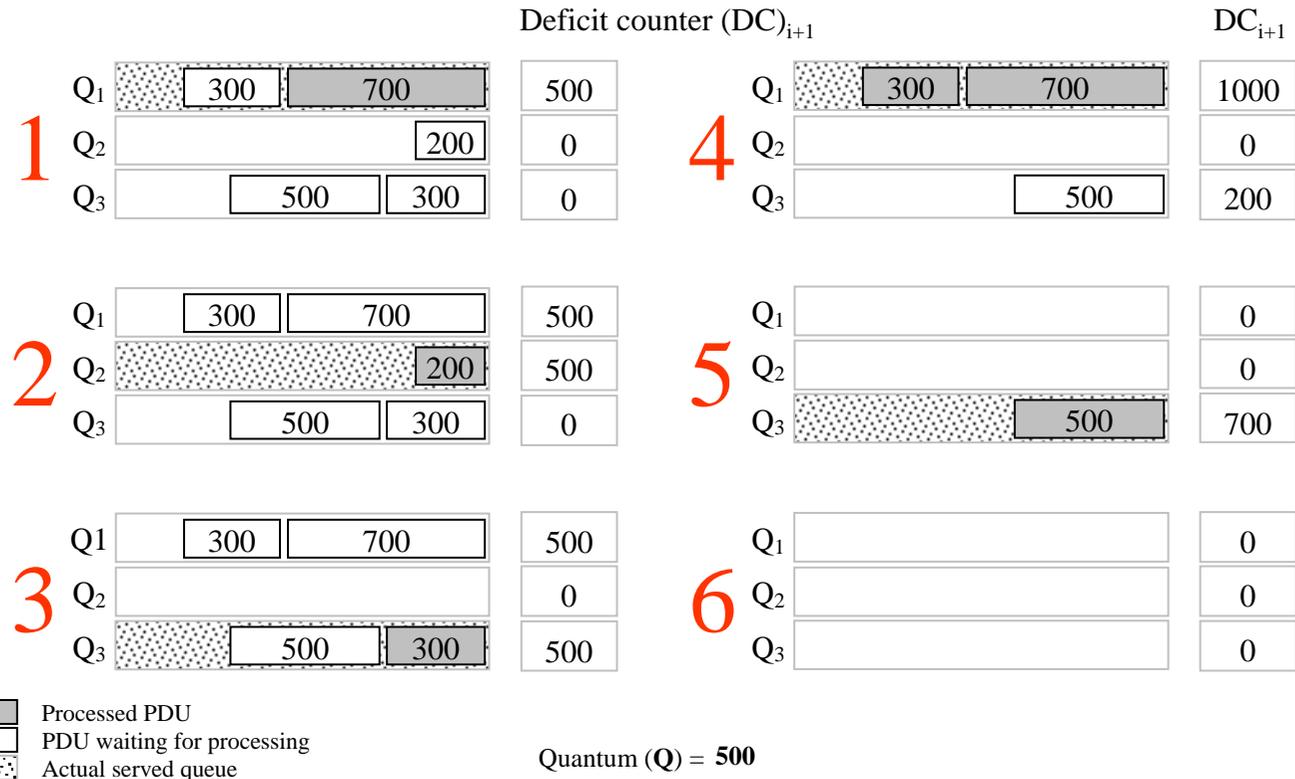
QoS gains provided by WRR



R99: QoS differentiation in BSS

- Deficit Round Robin (DRR): scheduling of packets (not bit rates)

Step = 1



Quantum (Q) = 500

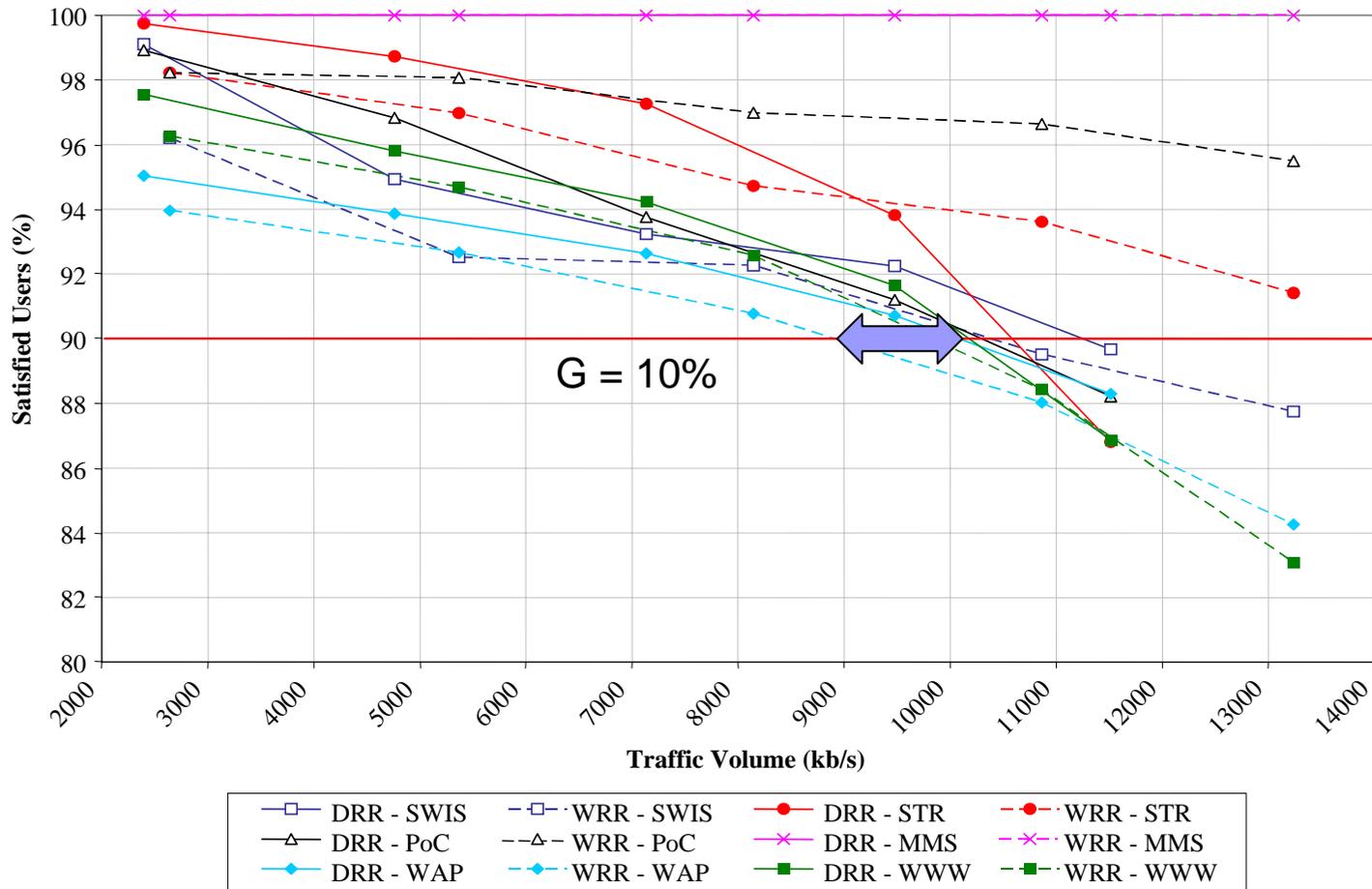
$$\text{Deficit counter } (DC)_{i+1} = DC_i + Q - \text{Tx packets size}$$

Differentiation

- Different priority queues
- Differentiated *Quantum*



Spectral efficiency gains of DRR vs. WRR



2G (CS-Hard) Handovers: MS, BSC, MSC

- Radio resource handovers
 1. Uplink/downlink interference (I_Level)
 2. Uplink/downlink quality (Rx_Qual)
 3. Uplink/downlink signal level (Rx_Level)
 4. Power budget
- Imperative handover
 - Distance between the MS and BTS exceeds a maximum threshold
 - O&M command to empty the cell is issued
 - Rapid field drop is detected; and
 - Serving cell is congested and a directed retry is needed
- Traffic reason handover
 - Steer traffic distribution between cells and/or layers
- Target cell evaluation process
 - Rx level, Quality, Load



2G Cell reselection: MS, BSC, SGSN

■ Normal MS control

- MS performs cell reselection autonomously based on NCL
- New LLC link with SGSN and BSC accordingly informed
- Gaps up to 30 s expected!

■ Network Controlled Cell Reselection (NCCR)

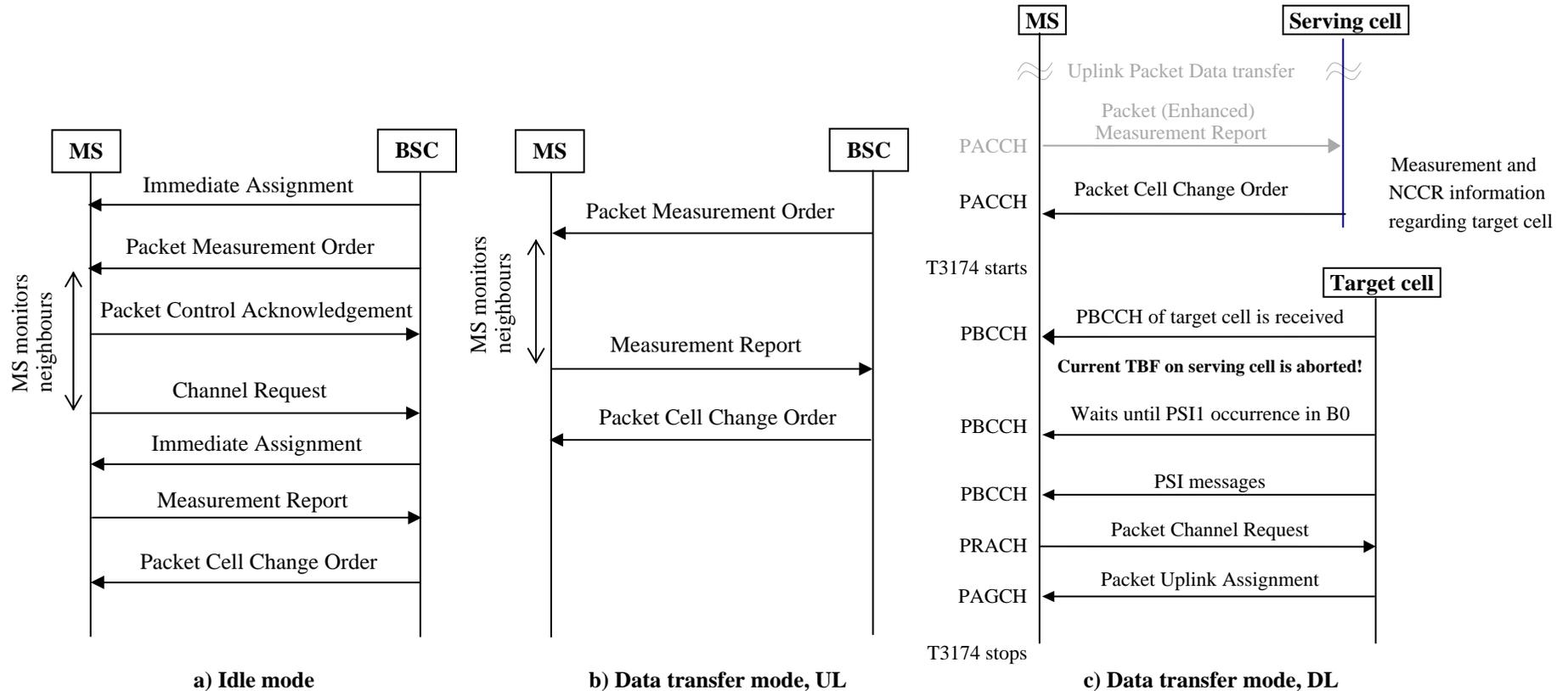
- BSC commands MS to send measurement reports
- MS reports NCL measurements periodically
- BSC order packet cell change (**BCCH frequency, BSIC**)
- Gaps from 2-5 s expected and efficient resource allocation

■ Network Assisted Cell Change (NACC)

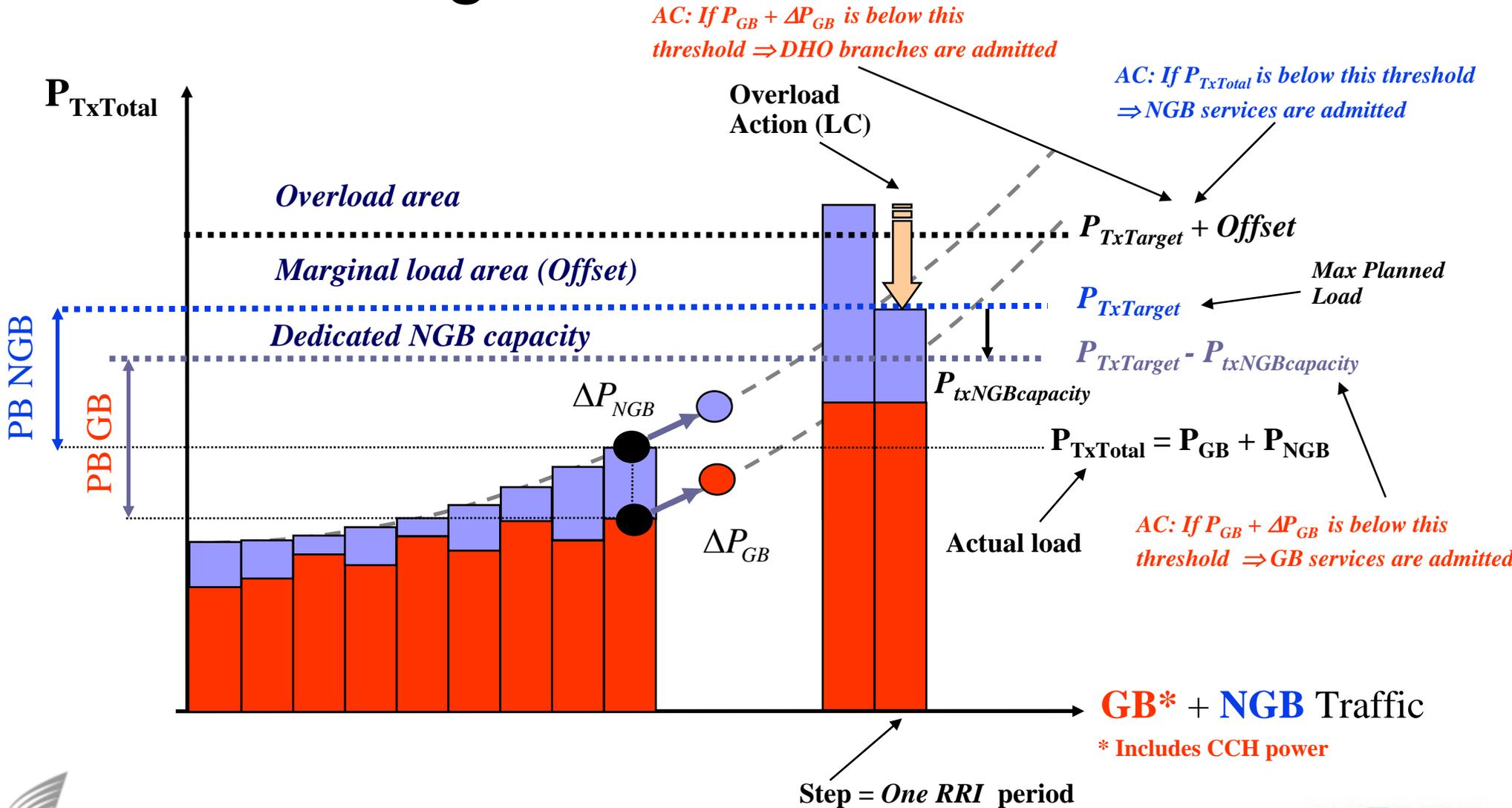
- BSC provides to MS part of target **Packet System Information (PSI)**
- **NCCR & NACC**: Gaps of few 100 ms expected



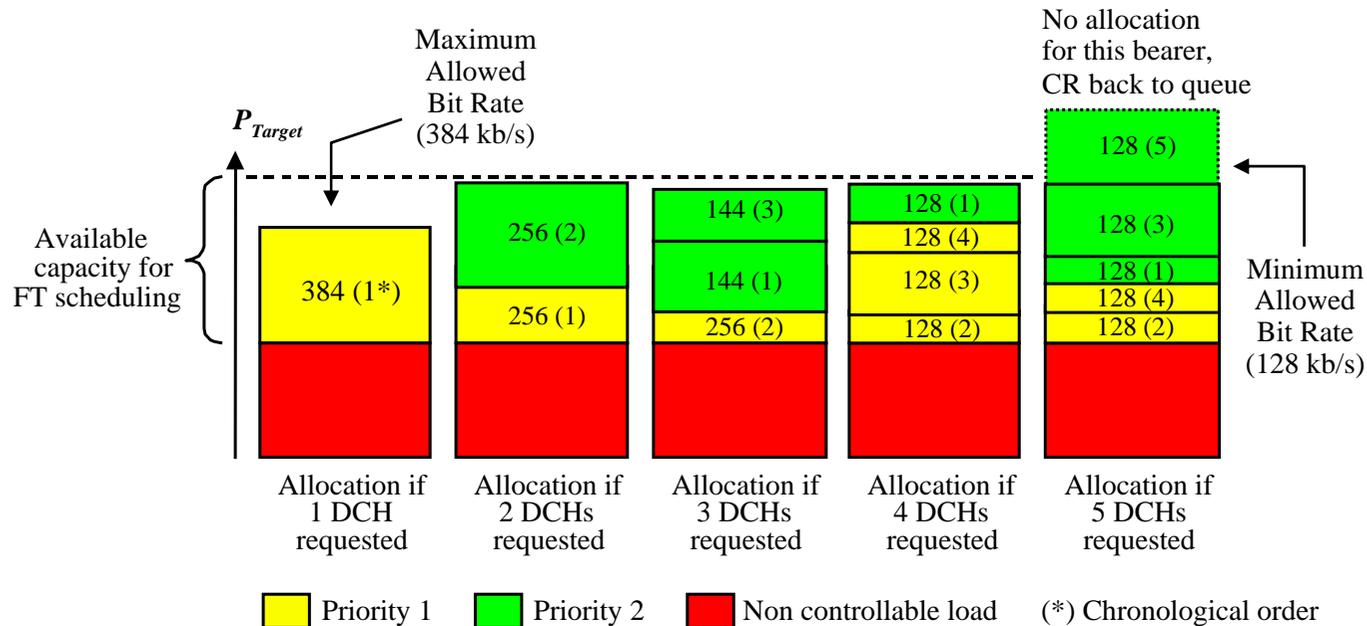
NCCR procedure vs. MS states



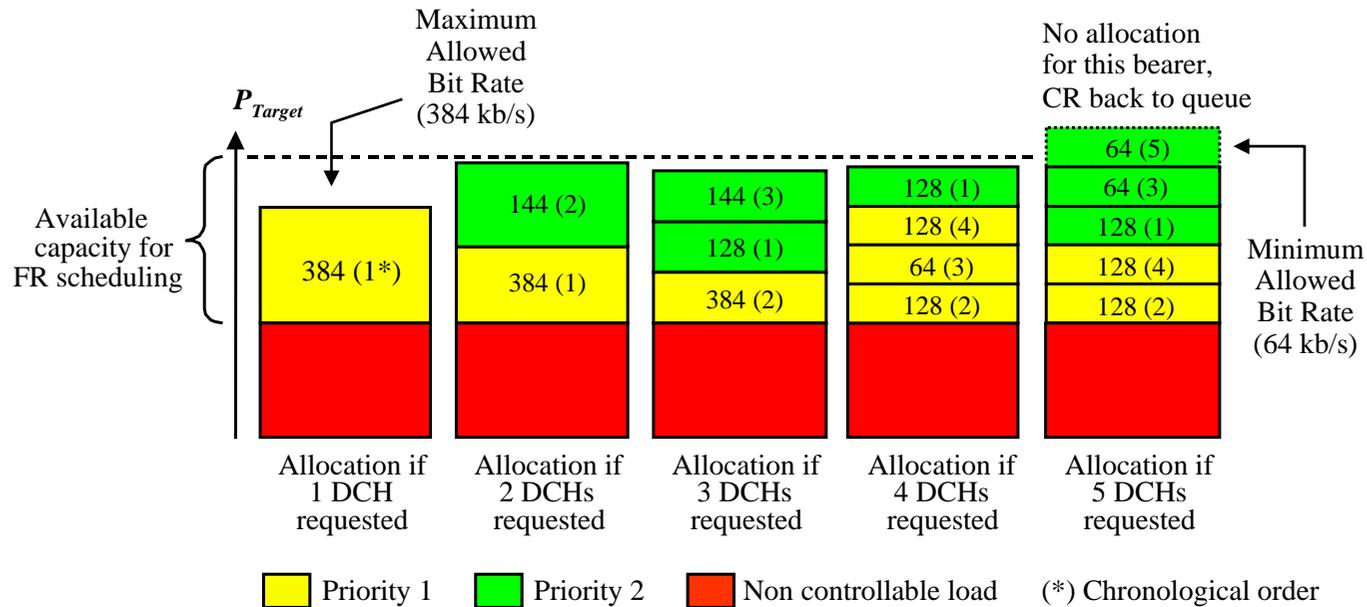
QoS management functions in UTRAN



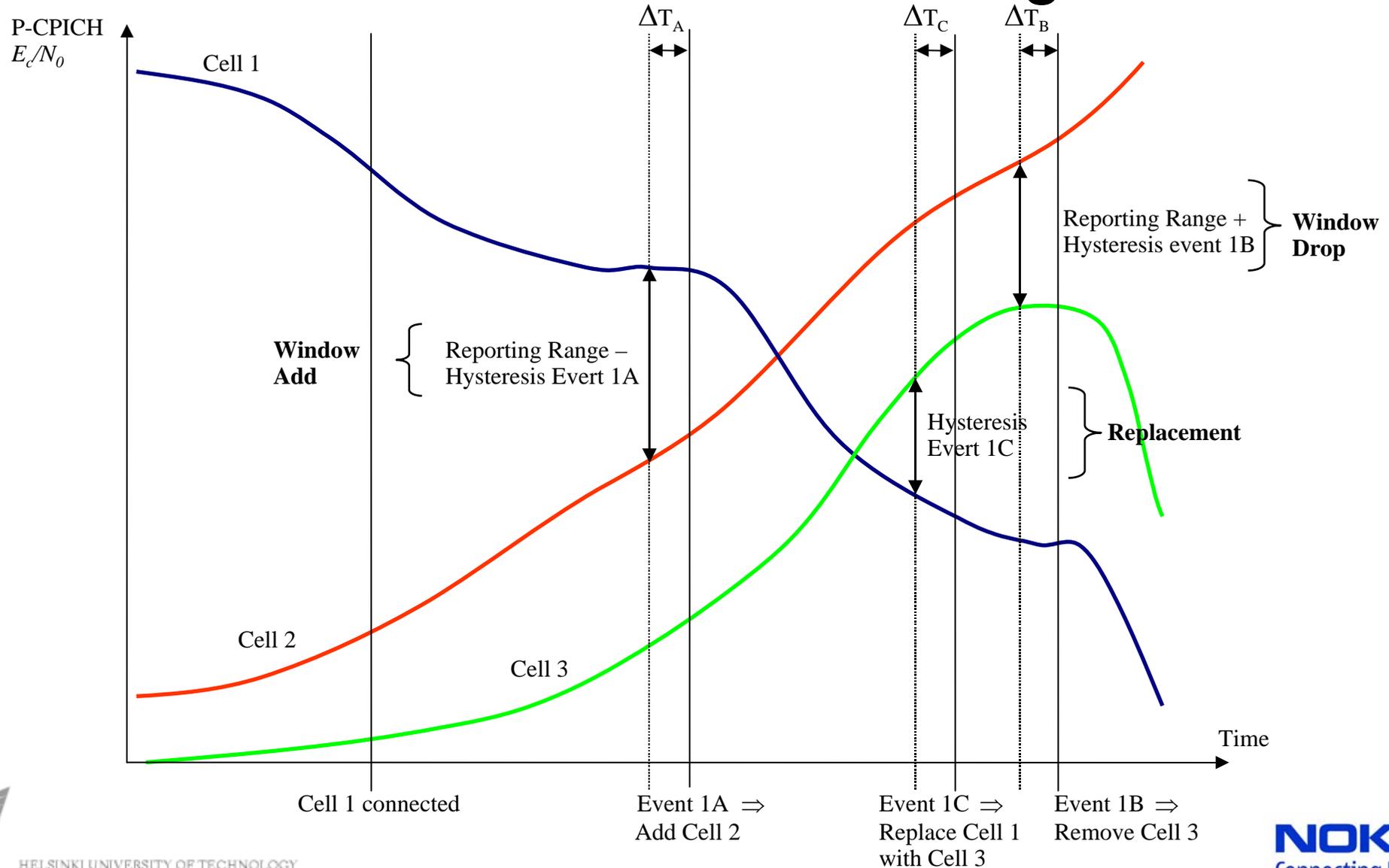
DCH: Fair Throughput (FT) scheduling



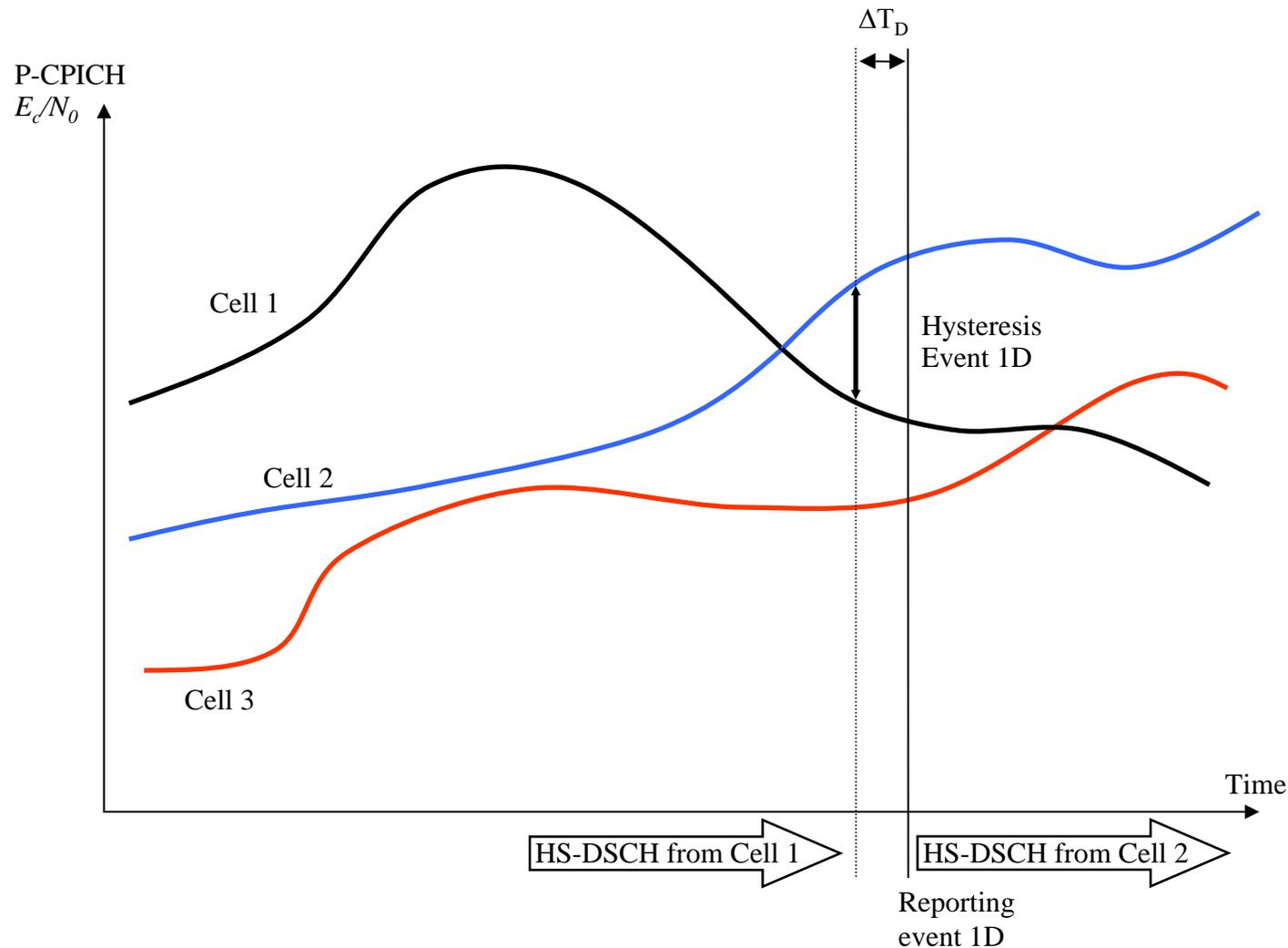
DCH: Fair Resources (FR) scheduling



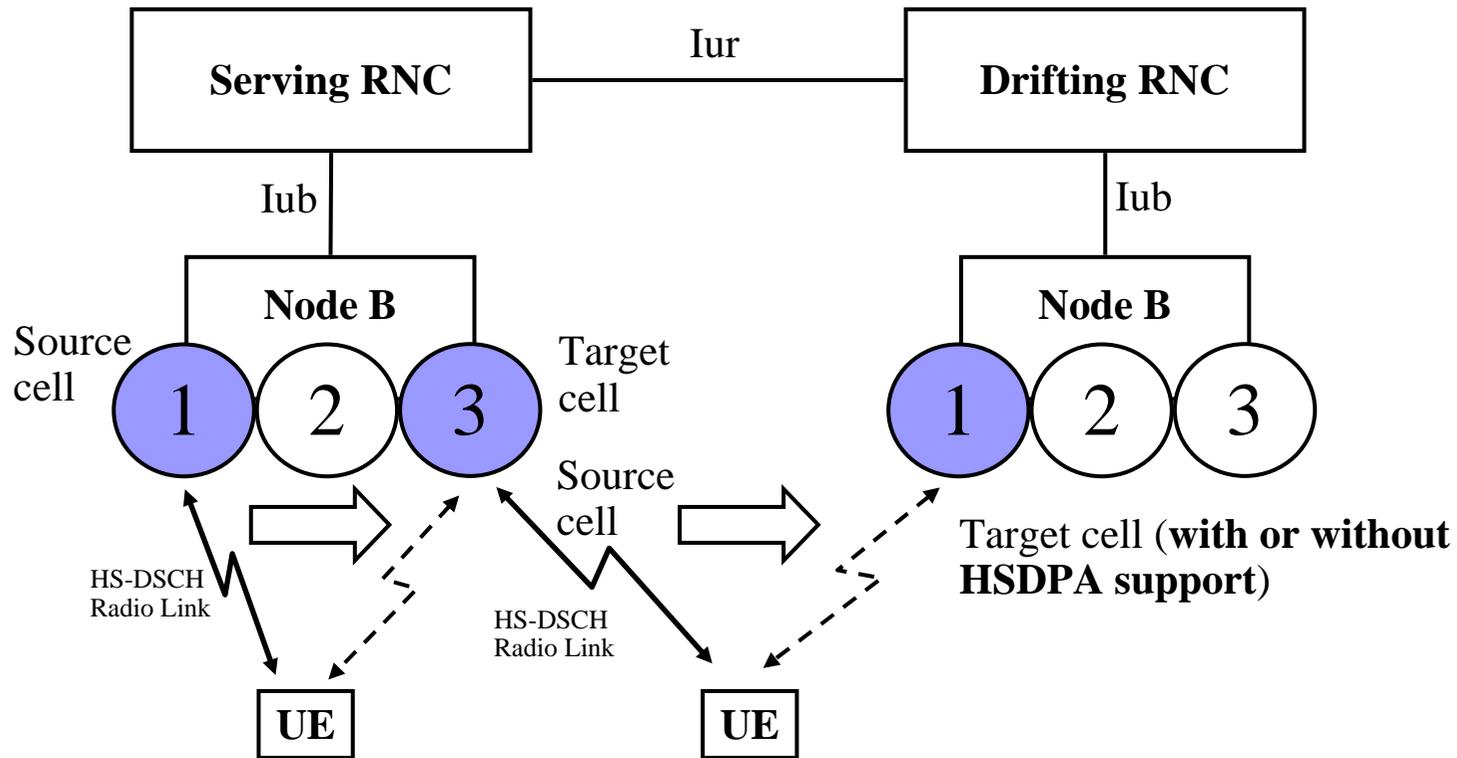
WCDMA soft/softer handover algorithms



Best serving HS-DSCH cell measurements



Serving HS-DSCH/(E-DCH) cell change



The user is moving to another cell



Serving HS-DSCH cell change

■ Triggers for serving HS-DSCH cell change

- Periodical CPICH E_c/N_0 measures
- Periodical UL SIR_{error} measures
- Event 1B: serving HS-DSCH cell is removed from the active
- Event 1C: serving HS-DSCH cell is replaced by another cell
- Failures in serving HS-DSCH radio link: loss of synchronization or time difference
- Serving HS-DSCH radio link is handed over to DRNC

■ Target HSDPA-capable cell (handover path)

- May be selected based on its allocated status, measured uplink SIR_{error} and/or downlink CPICH E_c/N_0

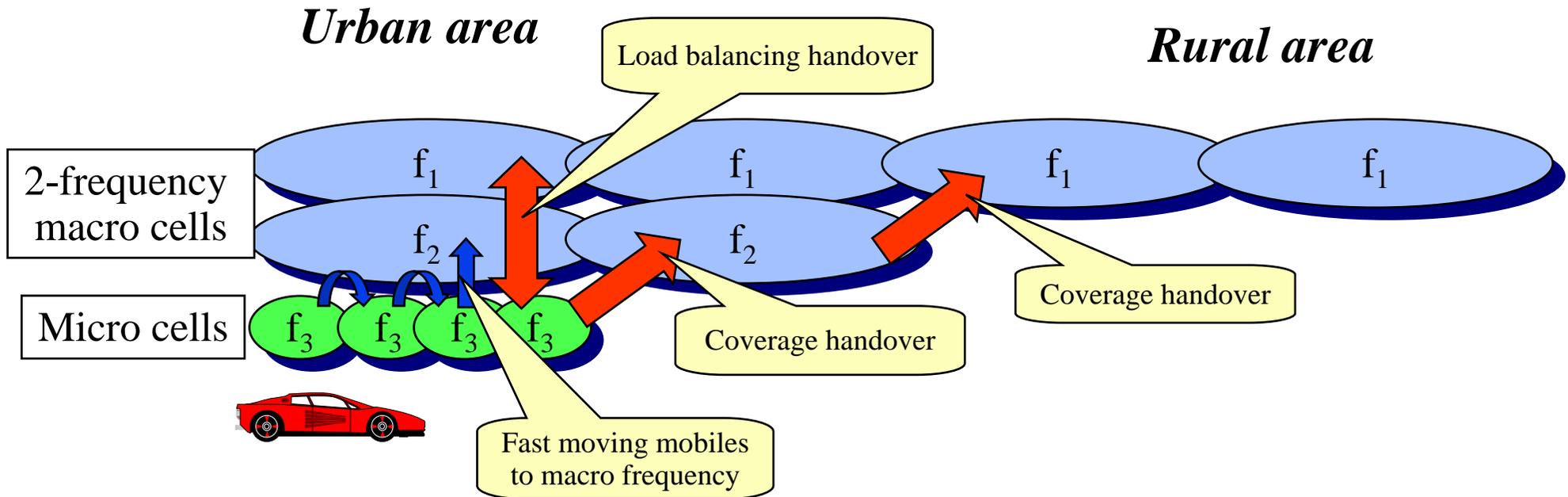


Serving RLS (cell) for E-DCH scheduling

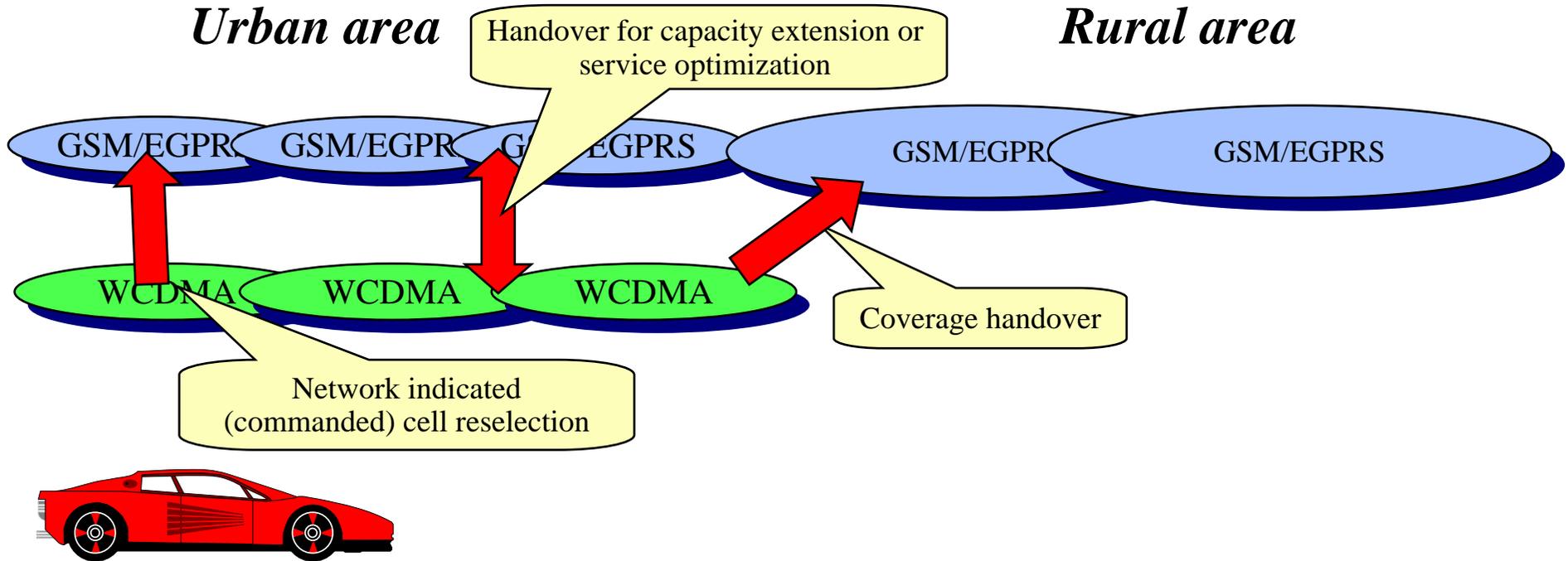
- For the serving RLS, the SRNC may select the RLS with the highest data throughput and, for the serving cell, the cell that provides the best downlink quality
- When an E-DCH serving cell change is triggered, the network updates the serving grant in the UE, and all L2-deactivated processes become active
- Processes can be enabled/disabled via RRC



WCDMA inter-frequency handover



WCDMA inter-RAT handover



Coverage and quality reason handovers

■ Triggers: HC may start inter-freq/RAT measurements

- UE Tx power (Event 6A)
- Uplink DCH quality
- Downlink DPCH power
- CPICH RSCP or E_c/N_0 (Event 1F)

■ Target cell selection

□ Inter-frequency handover path

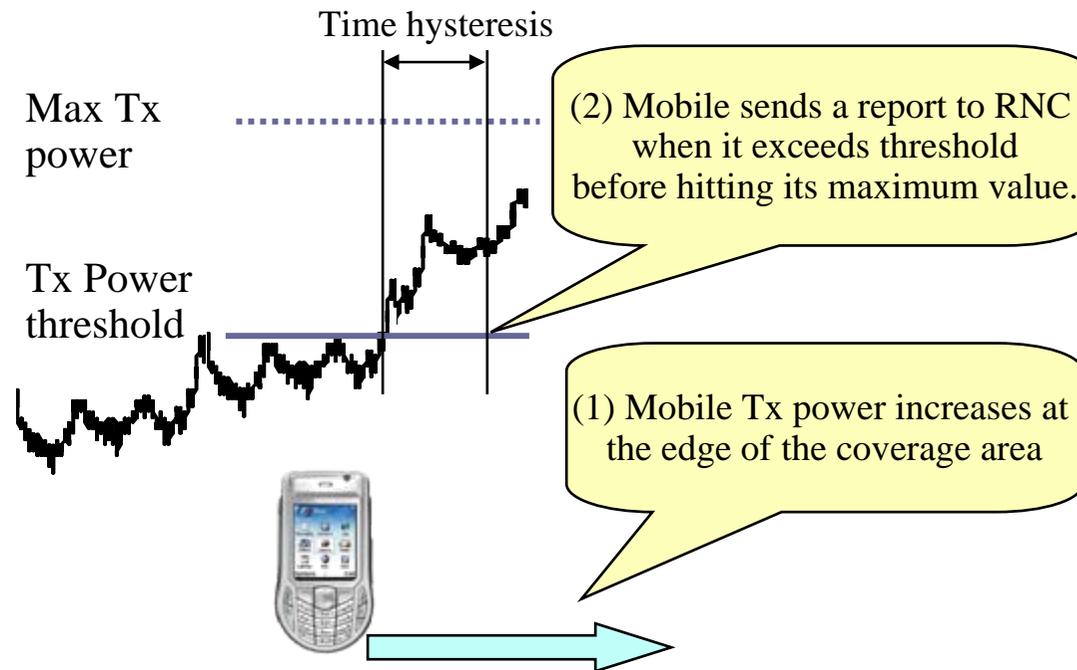
- Based on best CPICH RSCP and E_c/N_0 and relevant RNP parameters
- Based on pre-assigned priority level in the case of the same radio performance

□ Target cell selection: inter-RAT handover path

- Based on best **GSM carrier RSSI values** and relevant RNP parameters
- For CS voice/data services the **BSIC** of the target cell is **always** verified first
- For PS (GB and NGB) services verification should be ordered only in the case of BCCH frequency collision between neighbor cells



WCDMA: Event triggered 6E

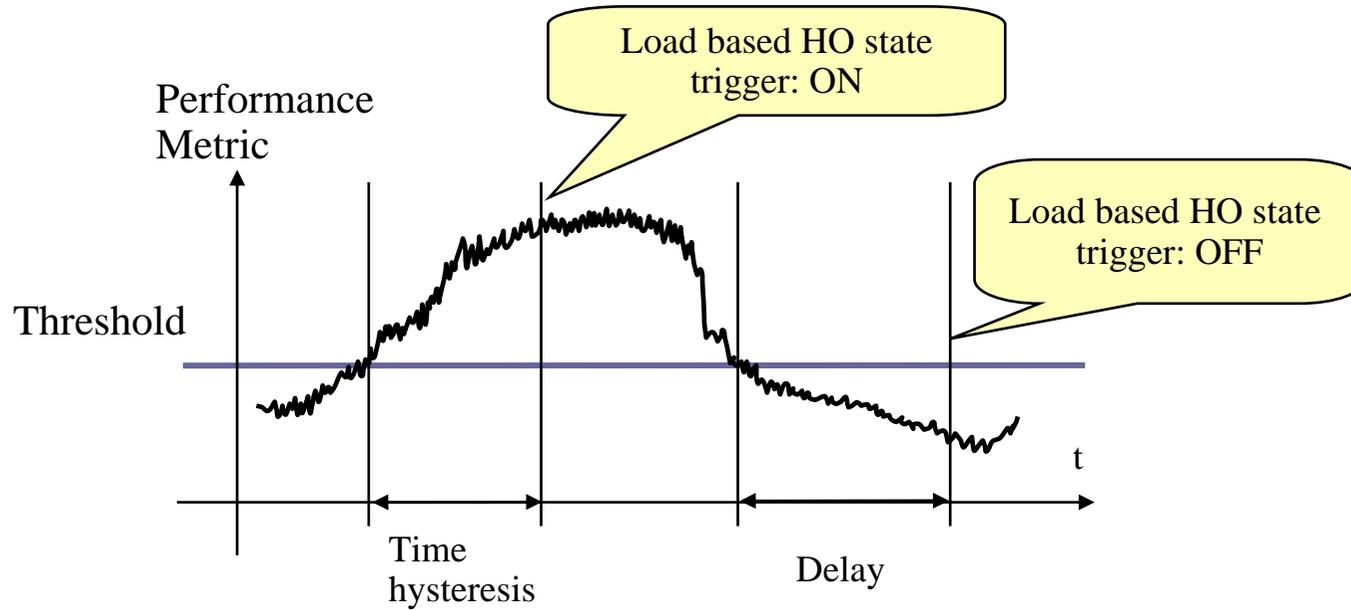


Load based handovers (1/2)

- Used for balancing the traffic (load) between different WCDMA frequency layers or between WCDMA and GSM/GPRS cellular networks
- Triggers, which may be checked periodically
 - Too high uplink or downlink interference
 - The CRRR for NGB traffic is higher than a threshold
 - The cell is running out of downlink spreading codes
 - The cell is hardware- or logical resources limited



Load based handovers (2/2)



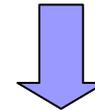
Service based handovers (1/2)

- Service-based handovers are used for directing UEs to preferred RAT or hierarchical WCDMA layers
- Service-based handover actions may be taken periodically, and the checking period is usually a parameter for the operator to set

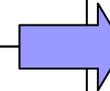
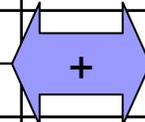


Service based handovers (2/2)

Service type		Target RAT or layer (RNP parameter)
CS Conversational	Speech	E.g. "GSM"
	Transparent data	E.g. "GSM"
PS Conversational	Speech	E.g. "WCDMA"
	Real time data	E.g. "WCDMA"
CS Streaming	Non transparent data	E.g. "WCDMA macro"
PS Streaming	Real time data	E.g. "WCDMA macro"
Interactive	THP1 – NGB data	E.g. "WCDMA micro" or "HSDPA"
	THP2 – NGB data	E.g. "WCDMA micro" or "HSDPA"
	THP3 – NGB data	E.g. "WCDMA micro" or "HSDPA"
Background	NGB data	E.g. "WCDMA micro" or "HSDPA"



Handover Service Priority IE (From CN)	Cell based service priority information (From above table)	Combined service priority list (RNP parameter)
"RAB should be handed over to GSM"	Target RAT or Layer	Target RAT or Layer
"RAB should not be handed over to GSM"	Target RAT or Layer	Target RAT or Layer
"RAB shall not be handed over to GSM"	Target RAT or Layer	Target RAT or Layer
Service Priority IE not available	Target RAT or Layer	Target RAT or Layer

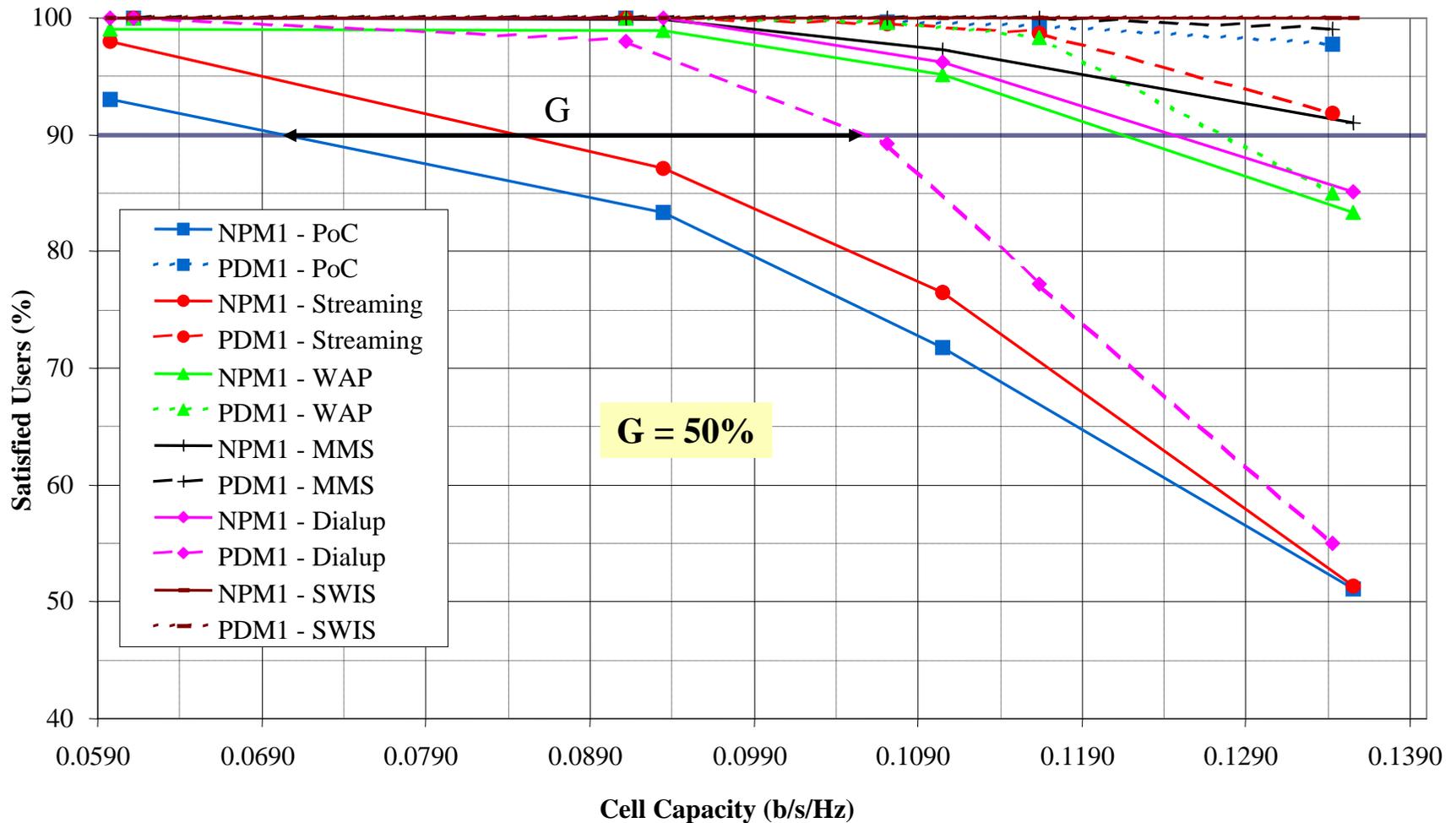


Service and load-based handovers

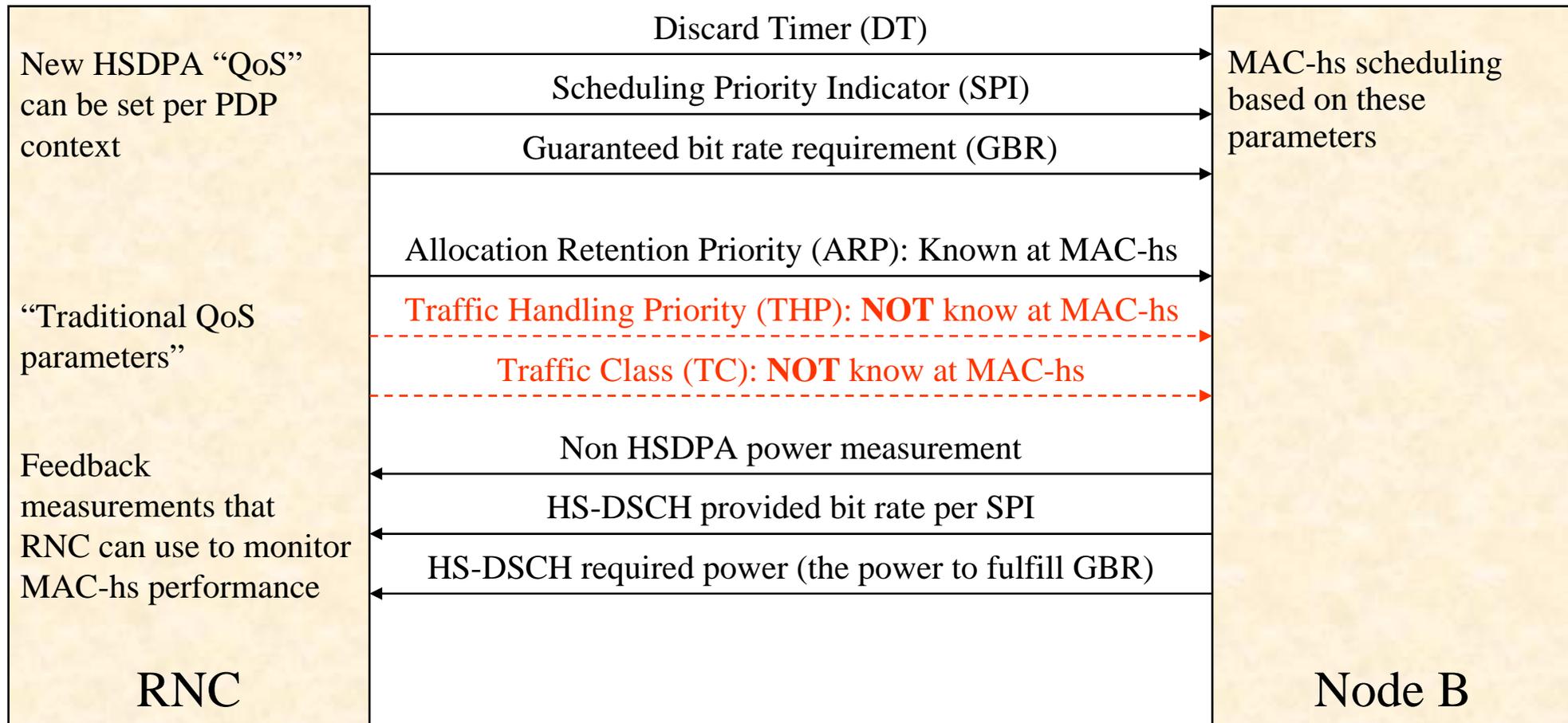
- Not performed for **multi-service connections** where the combined service priority lists are not compatible
- **Handovers or network-controlled cell reselections** (in the case of GPRS) are performed only for those connections that are in **Cell_DCH state**
- **Measurements** as well as the **criteria adopted for the selection of the target layer** are (may be) the ones described for **coverage and quality reasons**



WCDMA: QoS differentiation gains



HSDPA: QoS parameters (1/2)



HSDPA: QoS parameters (2/2)

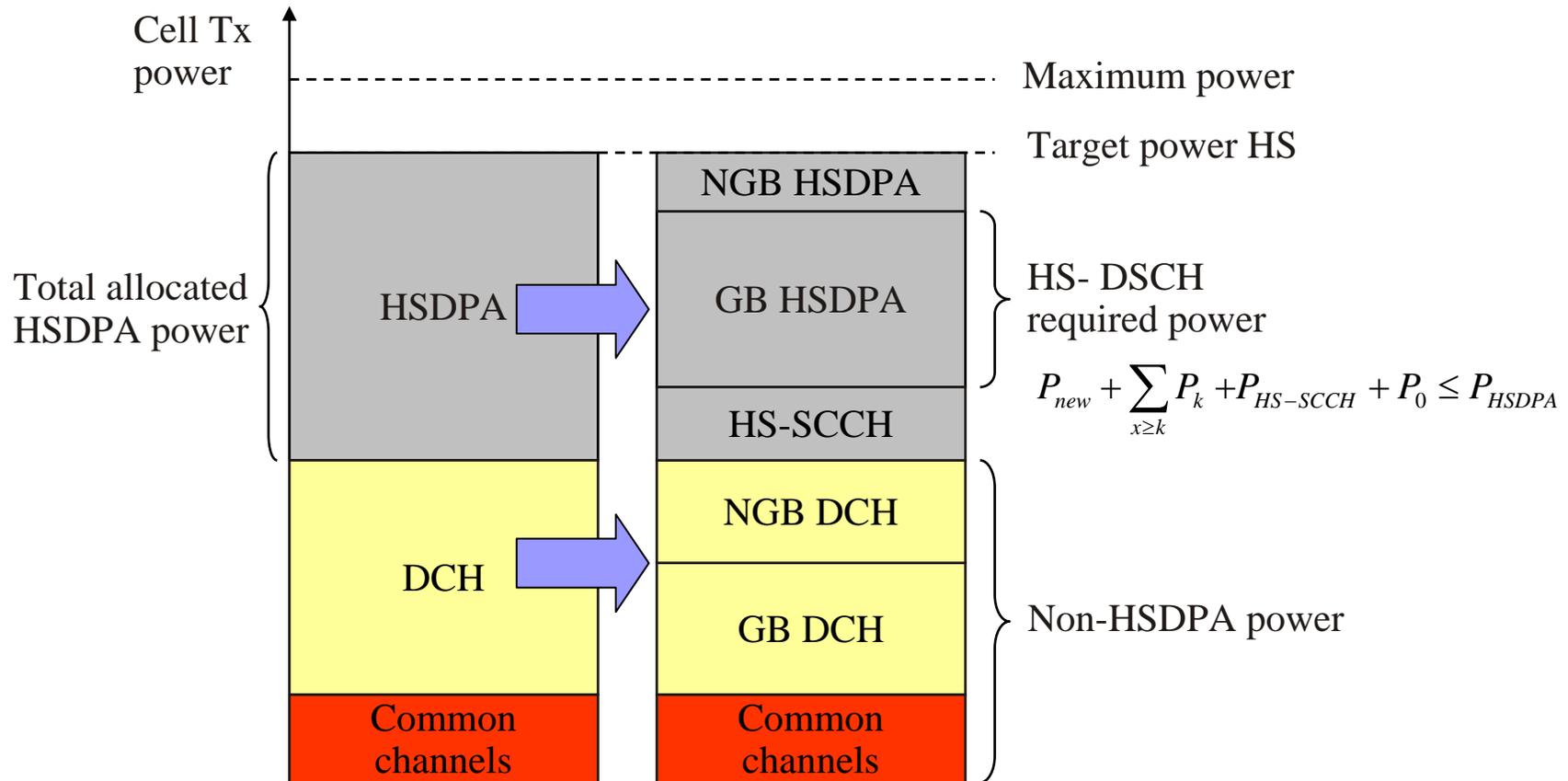
Traffic Class		SPI	MAC-hs GBR (RNP parameter)	Discard Timer (DT) (RNP parameter)
Streaming		4 (high)	$BR_{target_4} = \text{GBR (RAB attribute)}$	Defined as a function of the RAB attribute Transfer Delay
Interactive	THP1	3	BR_{target_3}	DT_3
	THP2	2	BR_{target_2}	DT_2
	THP3	1	BR_{target_1}	DT_1
Background		0 (low)	BR_{target_0}	DT_0

Traffic Class		Allowed to use HS-DSCH (RNP parameter)
Conversational		No
Streaming		Yes
Interactive	THP1	Yes
	THP2	Yes
	THP3	Yes
Background		Yes

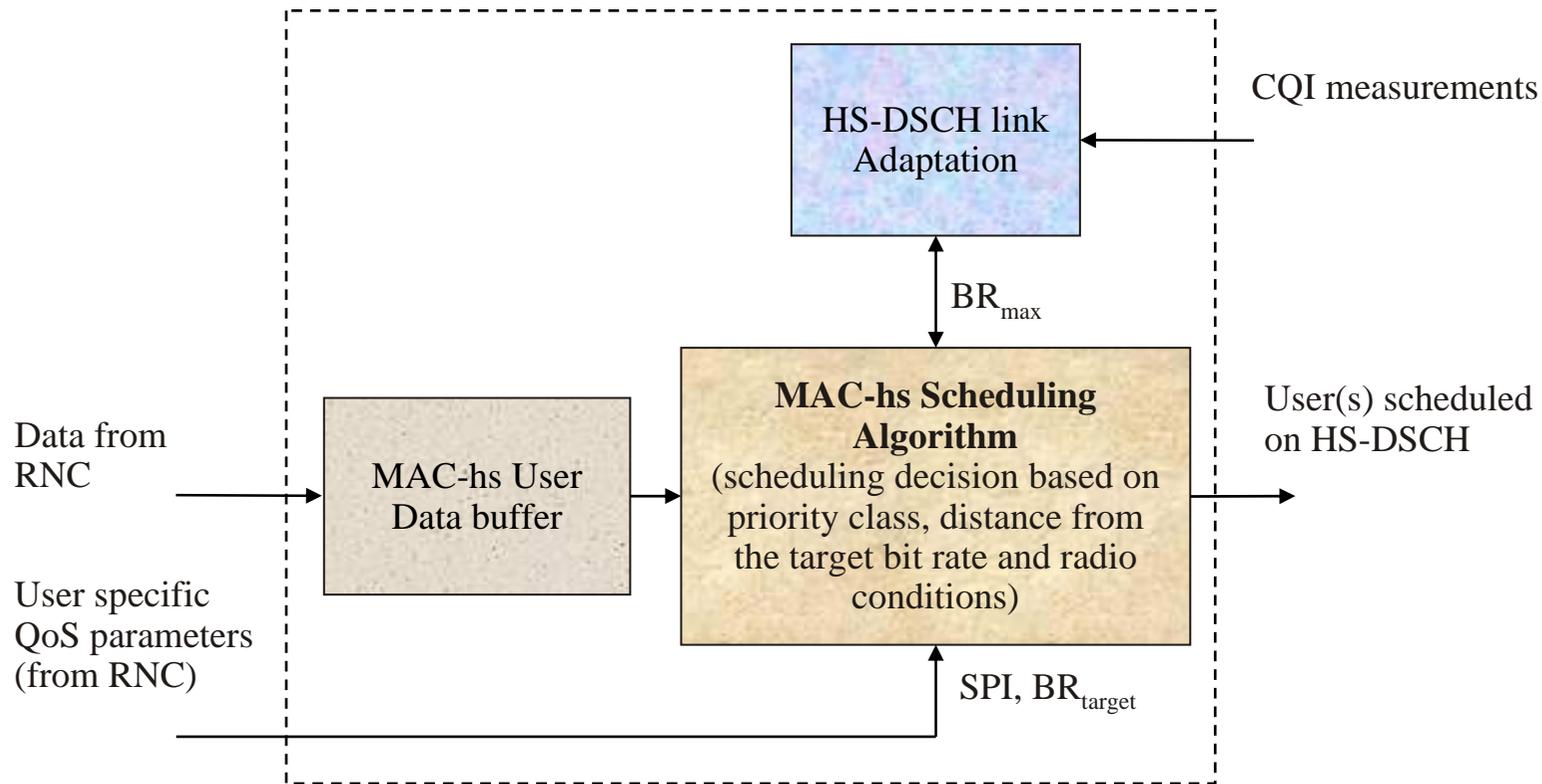
For MAC-hs GBR may also be defined for other traffic classes than Conversational and Streaming



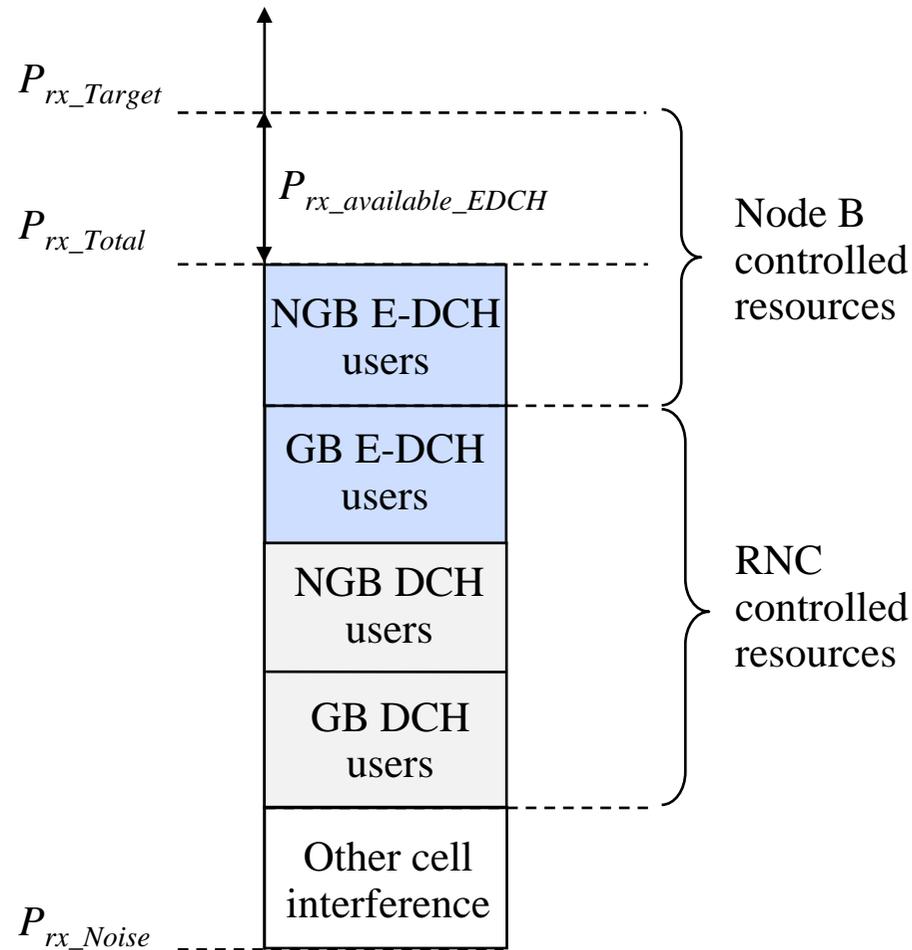
HSDPA power allocation (power budget)



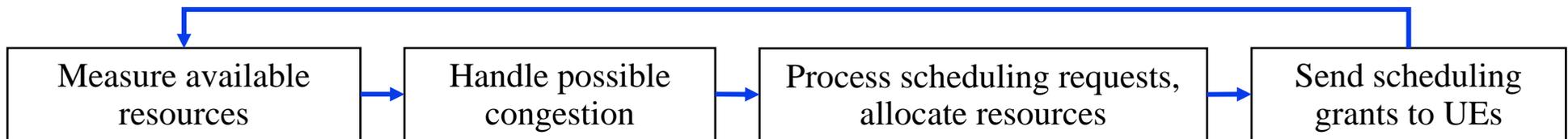
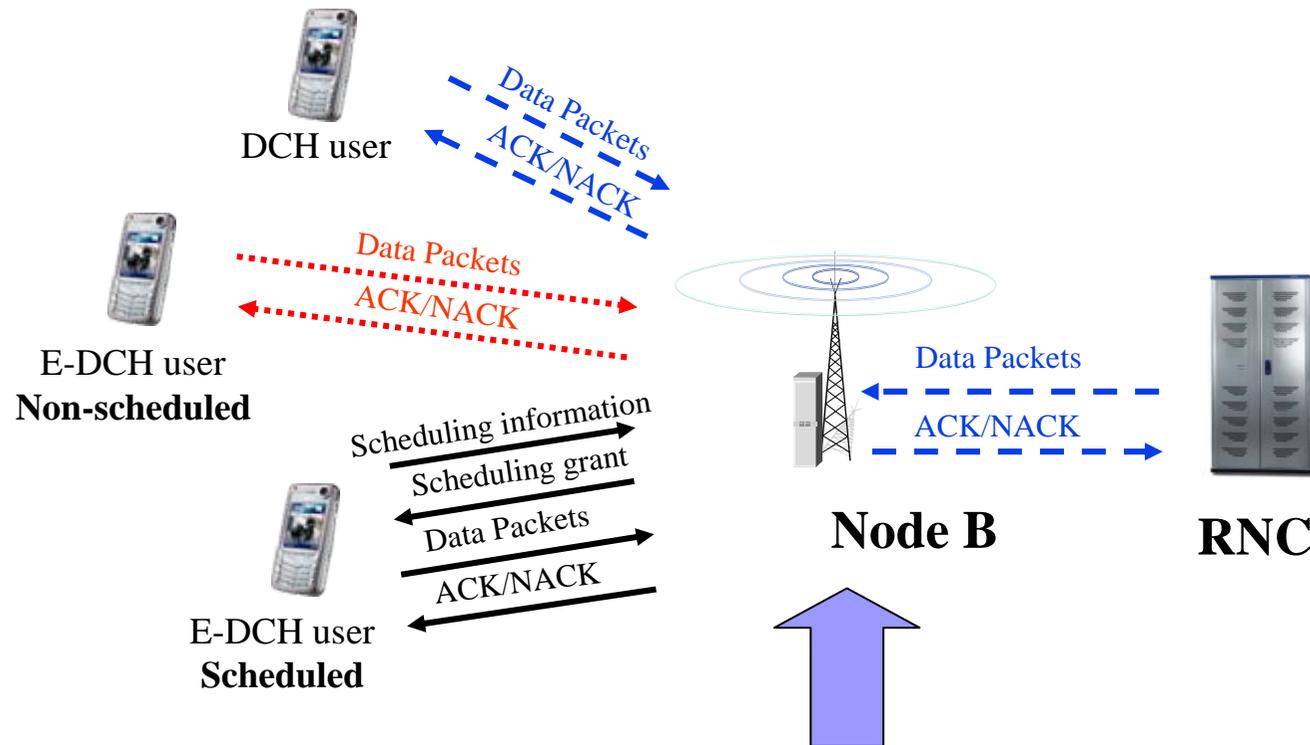
HSDPA: example of MAC-hs scheduler



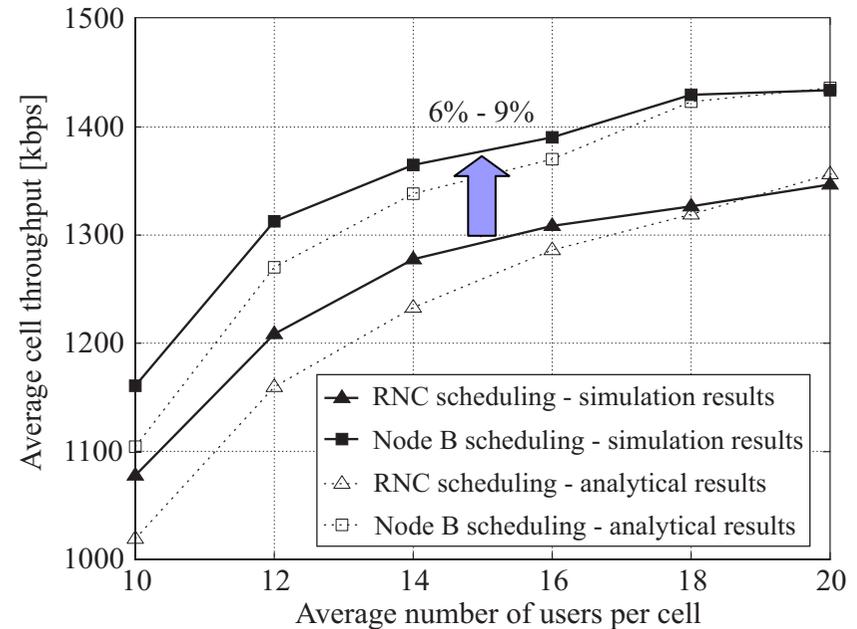
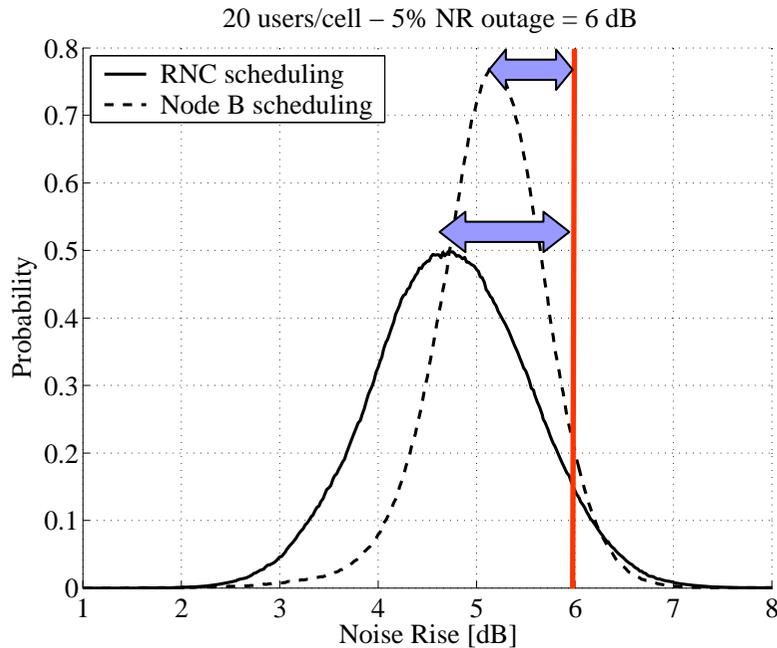
HSUPA power allocation (power budget)



Different uplink transmission mechanisms



RNC vs. Node B packet scheduling

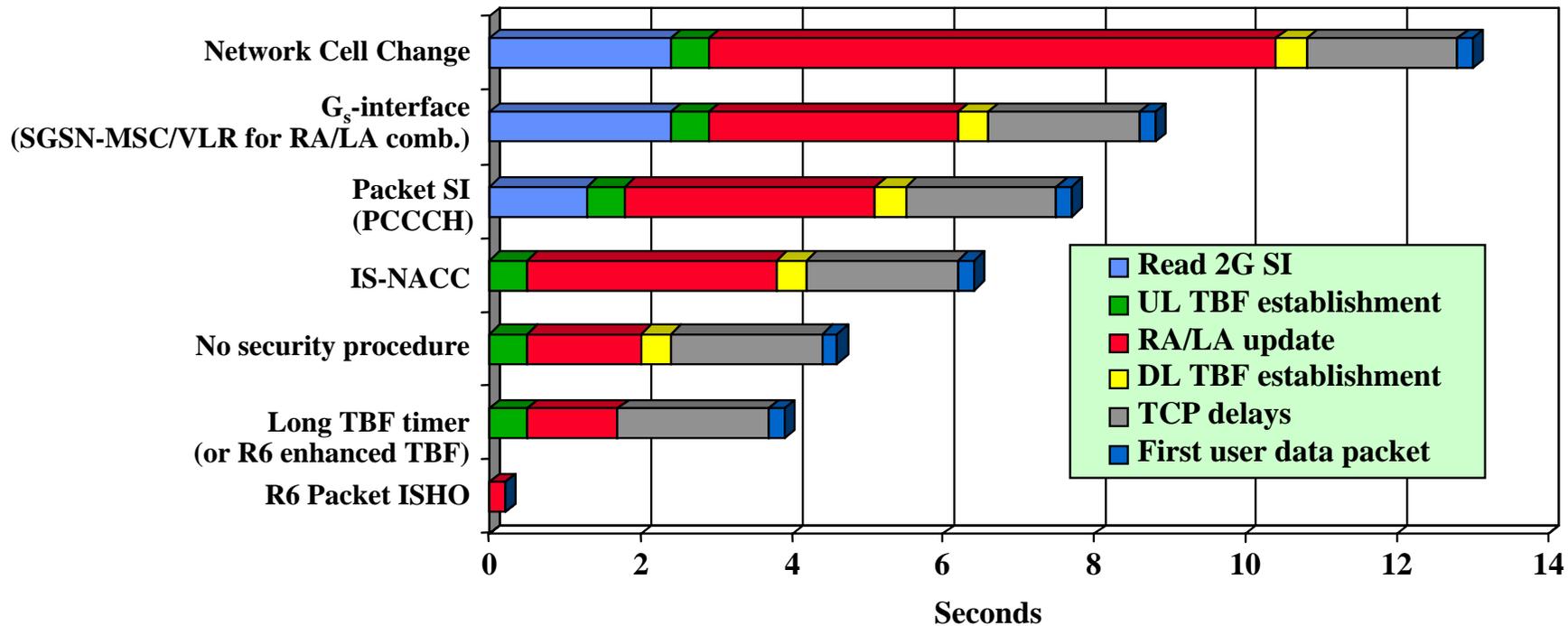


*Reduction of PC headroom ⇒
UL capacity increase at a given QoE*



PS: From UTRAN to GERAN

Service Break from 3G → 2G Access Change



PS: From GERAN to UTRAN

- During cell reselection from GERAN to UTRAN, quite similar procedures have to be performed
 - Gaps about 5 s with some variation depending on whether combined or separated RAU/LAU is performed and which bit rate is used for the SRB signaling bearer in WCDMA (3.4 kb/s or 13.6 kb/s)
- In 3GPP R6, PS handover will be the ultimate feature to get interruption times down to the subsecond area

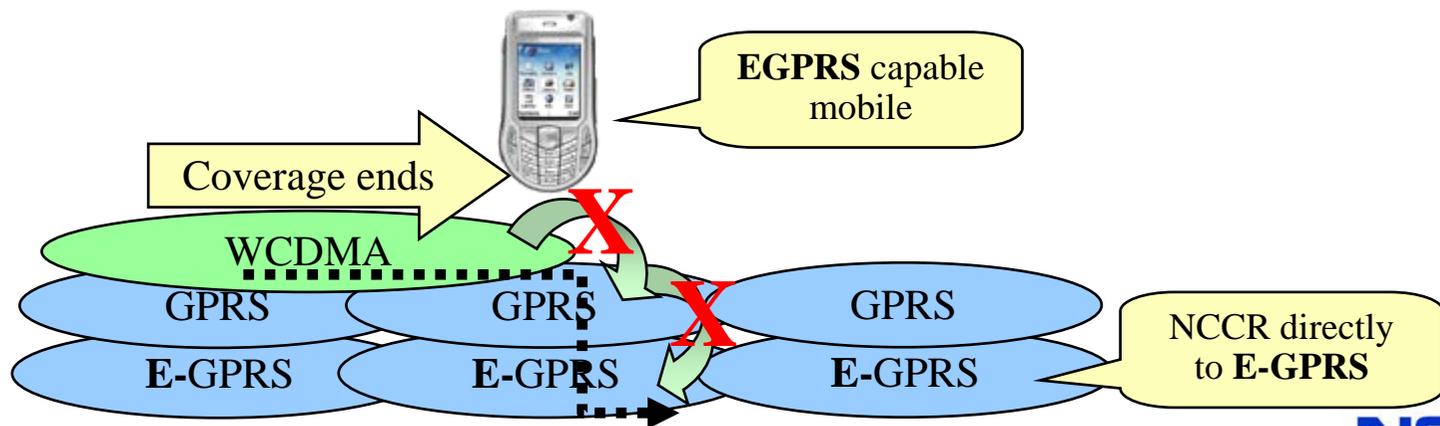
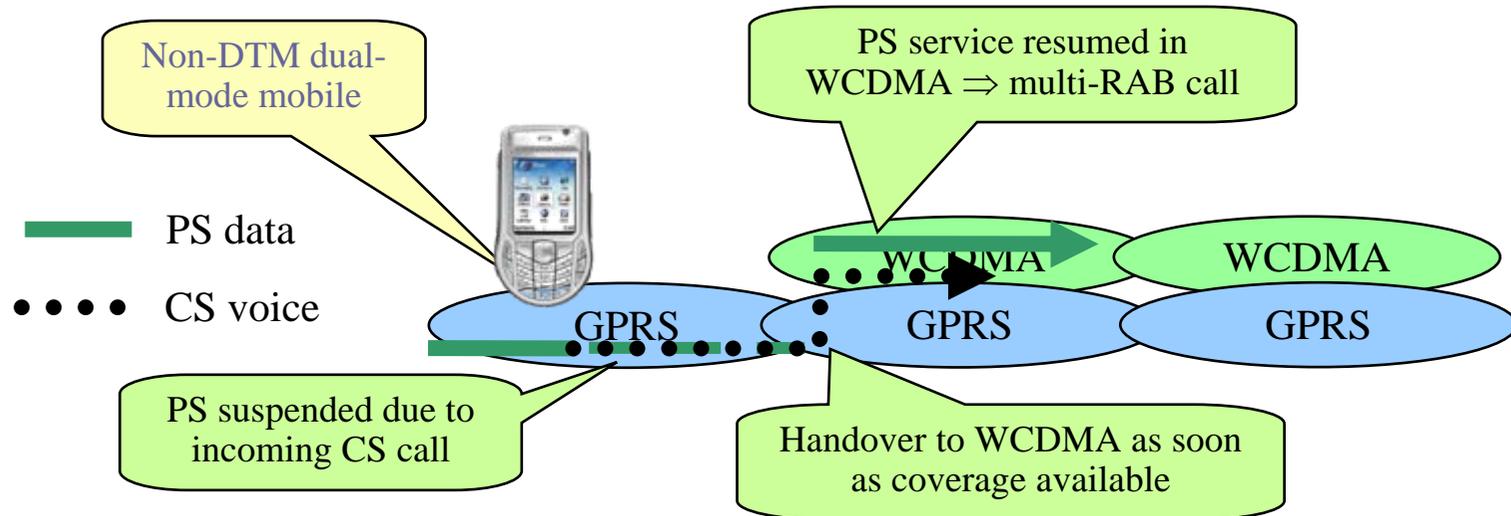


CS: inter-system HO performance

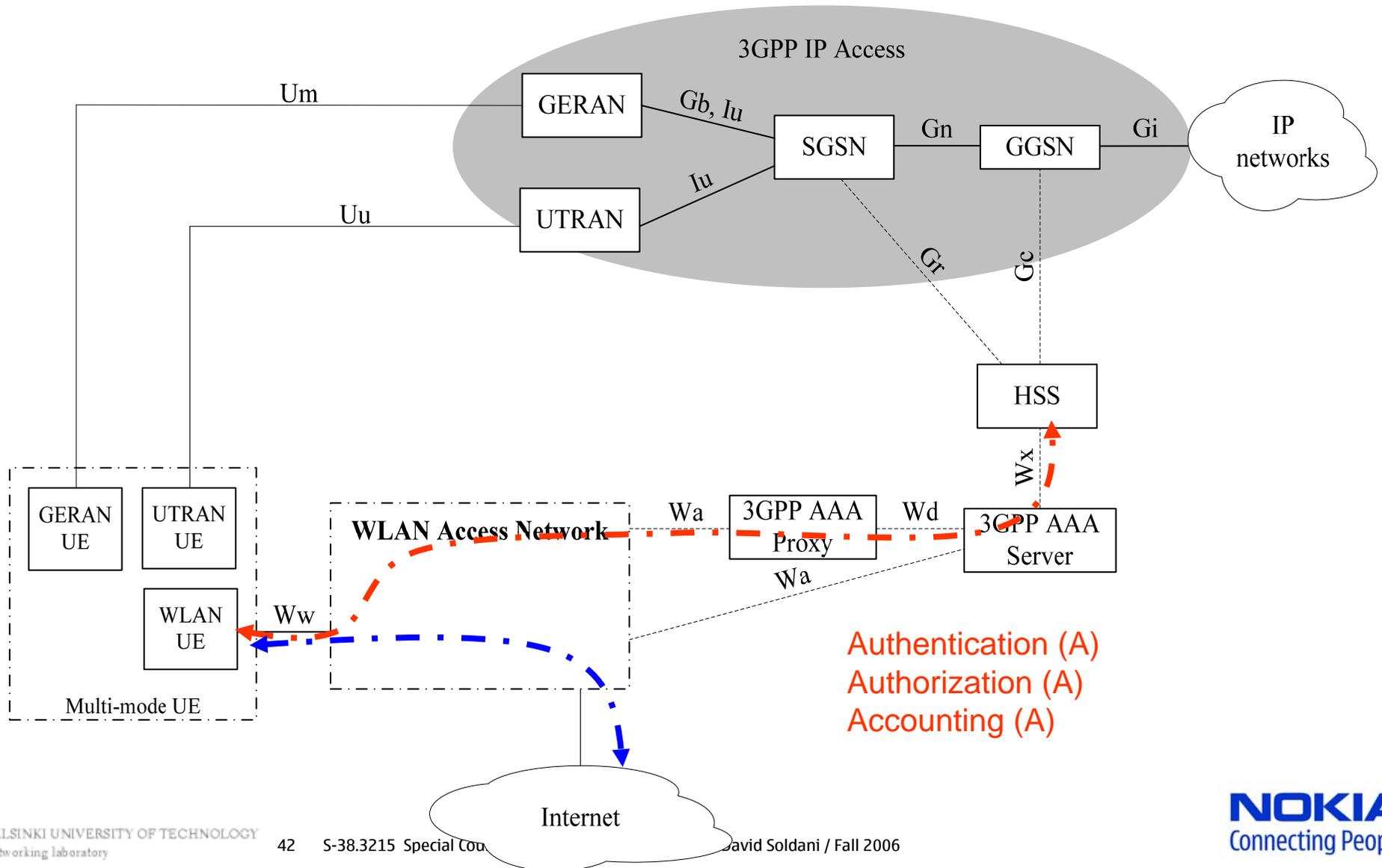
- Service interruption unnoticeable
- WCDMA to GSM direction
 - Gap of about 200 ms
- GSM to WCDMA direction
 - Gap of about 350 ms (due to SFN decoding)



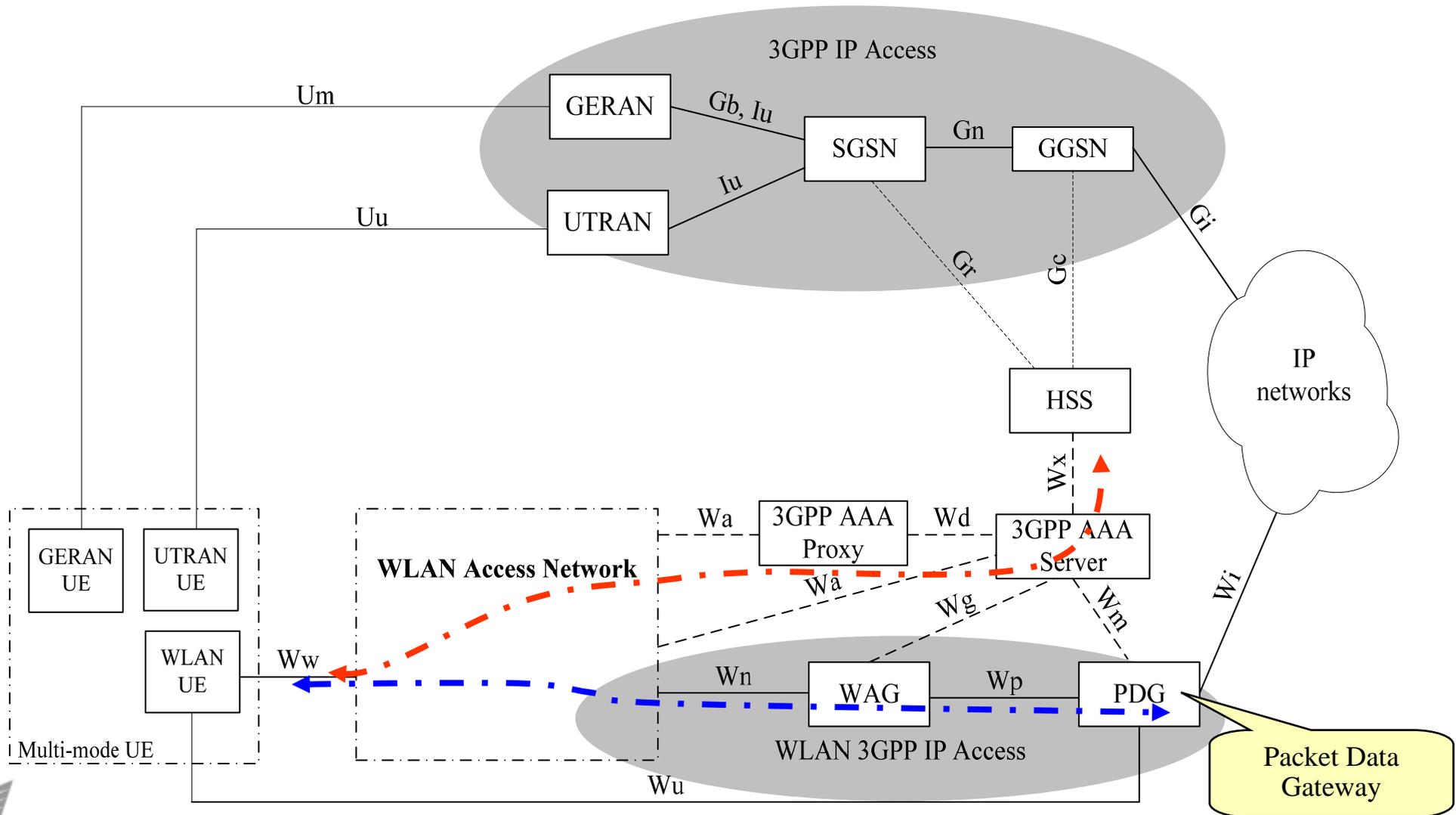
Non-Dual Transfer Mode (DTM) terminals



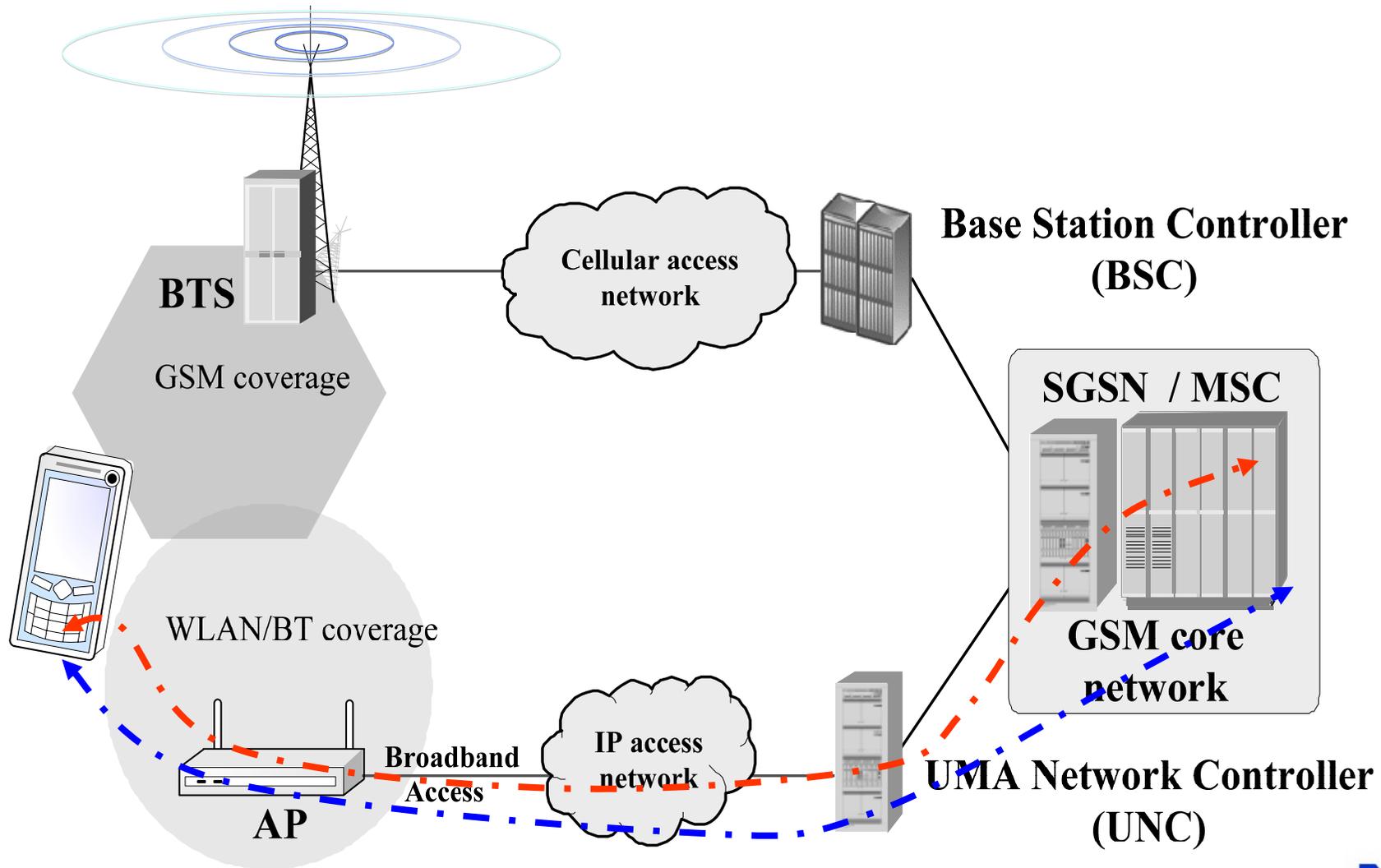
3GPP-WLAN system based AAA



Access to 3GPP IMS PS-based services



Unlicensed Mobile Access (UMA)



References

- D. Soldani, M. Li and R. Cuny (eds.), **QoS and QoE Management in UMTS Cellular Systems**, John Wiley and Sons, June, 2006, 460 pp.
 - <http://eu.wiley.com/WileyCDA/WileyTitle/productCd-0470016396.html>
 - <http://www.connecting.nokia.com/NOKIA/nns.nsf/a/78786C61AB5A7C5AC225718F0026BAA3>
- (Contact Mr. Geoff Farrell @ Wiley gfarrell@wiley.co.uk)

See also:

- <http://lib.tkk.fi/Diss/2005/isbn9512278340/>

