6. Radio Network Dimensioning and Planning

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S-38.3215 Special Course on Networking Technology for Ph.D. students at TKK

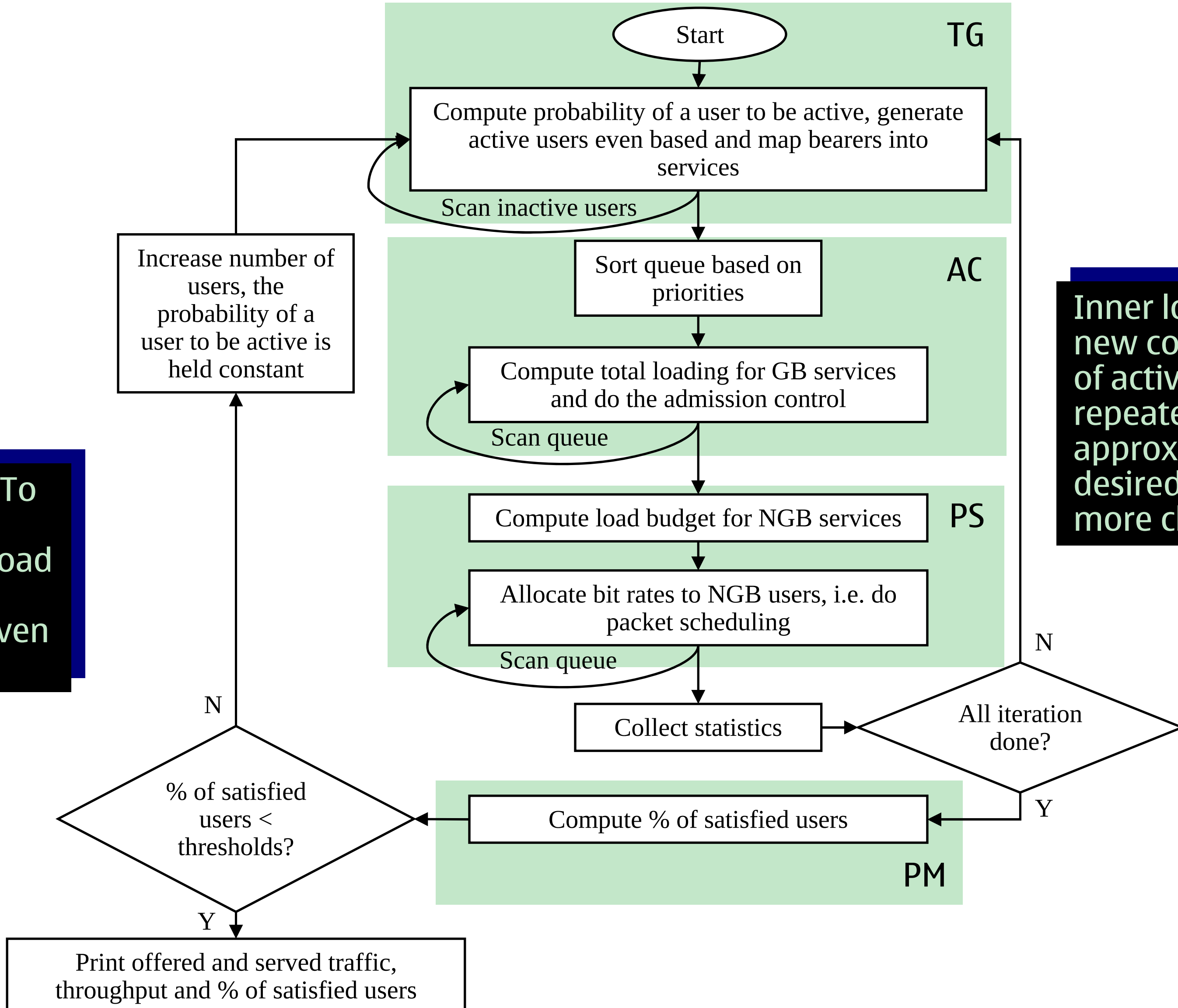
Outline

- WCDMA radio dimensioning and planning
  - Radio dimensioning aspects for UTRAN FDD
  - A virtual time simulator for UTRAN FDD
  - HSDPA dimensioning
- (E)GPRS dimensioning
  - Procedure for CS and PS traffic
  - Dimensioning with capacity and bite guarantees
  - Dimensioning with QoS guarantees

Dimensioning aspects for UTRAN FDD

- **3GPP leaves the engineering process**, as planning and dimensioning aspects, **to convert traffic demand into needed resources to vendors' and operators' choice**
- Hence, due to the complexity of the system and related expenditures, **any practical realization and deployment of new application services needs to be validated a priori** by means of analytical approaches, or simulations, depending on the desired level of accuracy
- **None of the published analytical methods and tools showed enough flexibility** for an efficient and effective WCDMA radio interface dimensioning
- **We propose plain methods for radio interface dimensioning an a simple tool**, which supports models for packet and circuit switched services, and processes snapshots of the system status, upon which performance statistics are derived
- **The proposed solution is used to analyze the deployment of PoC (Push to talk over Cellular)** by means of several case studies

Simulator structure



Inner loop: The new configuration of active users is repeated to approximate the desired result more closely

Outer loop: To derive the maximum load the cell can offer at a given QoS

Call generator

- **Supported traffic models**
  - CS speech and video calls
  - PS SWIS, PoC, streaming, MMS, WAP and dialup connections
- **Service (*i*) based parameters**
  - QoS Profile: TC, THP, bit rates, ARP
  - Mean service time (s): T_i
  - Mean arrival rate (s): A_i
  - Share of subscription (%): S_i
- **Probability P_i for service *i* to be used is:** $P_i = \frac{T_i}{A_i} \frac{S_i}{100}$
- **Group factor for PoC in P_i computation**
  - Geometric distribution
  - Min =1, Max = 25, Mean =4
- **Inner loop: Conditional probability for a user to make other calls**
- **Offered traffic in number of subscriptions N_i is estimated as:** $N_i = U_i \cdot \frac{A_i}{T_i}$
  - U_i = average number of active bearers carrying the service *i*

RRM and load estimates

- GB is blocked if either one of the following in-equation is satisfied:

$$L_{Total} = L_{NGB} + L_{GB} > L_{Target} + Offset$$

$$L_{GB} + \Delta L_{GB} > L_{\mathrm{Target}} - L_{NBGBcapacity}$$

- NGB traffic is always admitted, and bit rate allocated based on

$$PB_{NGB} = L_{Target} - (L_{NGB} + L_{GB})$$

- The load estimates are based on the fractional load equations

$$\eta_{DL}^{k} = \frac{1+SHO}{W}\rho_k R_k v_k \left((1-\alpha)+i_{Dl}\right)$$

where

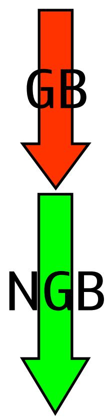
$$L_{Total} = \sum_k \eta_{DL}^{k} = P_{TxTotal} / P_{TxMax}$$

Performance monitoring

- **User satisfaction criteria**
  - GB services: Speech, video and SWIS calls are satisfied if they do not get blocked
  - NGB services: PoC, streaming, MMS, Dialup and WAP users are satisfied if are not blocked and the average bit rate during the iterations (inner loop) is $\geq$ to 8 (or 16), 64, 32, 64 and 32 kb/s, respectively
- **Method 1 (maximum offered load)**:
  - At a given traffic mix, the offered load is increased till at least one of the following conditions results true:
    - Less than **70%** of MMS or WAP users are satisfied
    - Less than **50%** of dialup users are satisfied
    - Less than **90%** of users of any of other services are satisfied
- **Method 2 (impact of a new service on the existing subscribers satisfaction)**:
  - The subscription level is increased gradually for the new service while keeping the input load of the other services constant

Simulation Assumptions (1/2)

Parameter	Value			
Number of iterations (inner loop)	1000			
Downlink Load target	70%			
Overload offset	10%			
Orthogonality (α)	0.5 (ITU Vehicular A)			
Soft handover overhead (*SHO*)	20%			
Other-to-own cell interference ratio (*i*)	0.55			
Chip rate (*W*)	3.84 Mchip/s			
Offered services - Traffic class	**DL DCH bit rates (kb/s)**	**Priority**	**E_b/N_0 (dB)**	**Activity Factor (ν)**
Speech - CS Conversational (GB)	12.2	1	7	0.67
Video - CS Conversational (GB)	64	2	6	1
SWIS - Streaming (GB)	64	3	6	1
PoC - Interactive THP1 (NGB)	0, 8, 16	4	6	1
Streaming - Interactive THP2 (NGB)	0, 64	5	7	0.6
WAP/MMS - Interactive THP3 (NGB)	0, 64, 128, 144, 256, 384	6	5/5.5	1/0.6
Dialup – Background (NGB)	0, 64, 128, 144, 256, 384	7	5.5	0.8



Simulation Assumptions (2/2)

Offered service	Share of Subscriptions (%)	Mean service time (s)	Mean arrival intensity (Hz)
Speech (CS)	100	90	1/4800
Video (CS)	3	120	1/24000
Streaming	10	600	1/(5*3600)
MMS	10	10	1/(2*3600)
SWIS (RTVS)	3	180	1/(2*3600)
Dialup	1	1200	1/(2*3600)
WAP browsing	20	600	1/(4*3600)
PoC	Varies*	60	1/(2*3600)

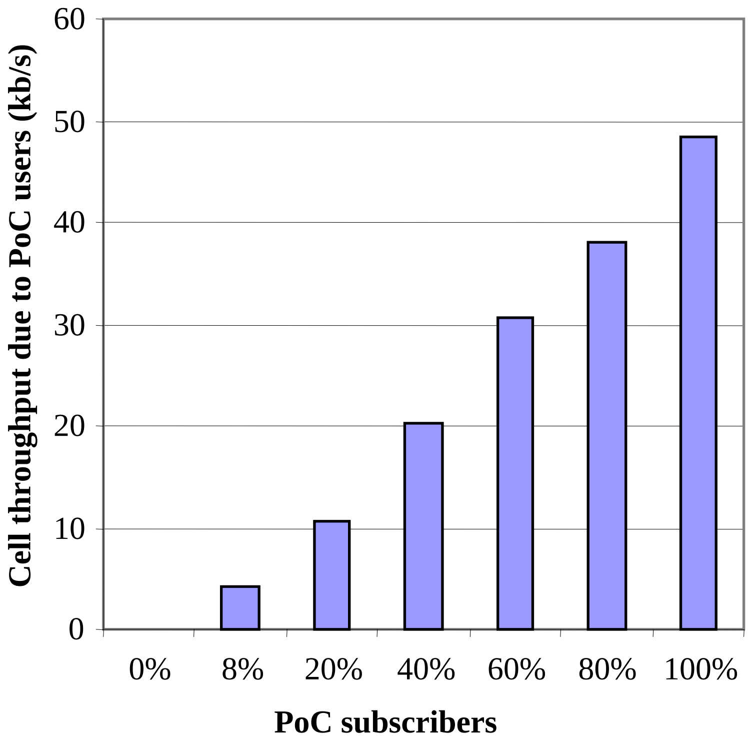
* The volume is increased from 0 to 100%, whereas the average PoC group size is held constant: 1 user in Case 1 and Case 2, 4 users in Case 3 and Case 4.

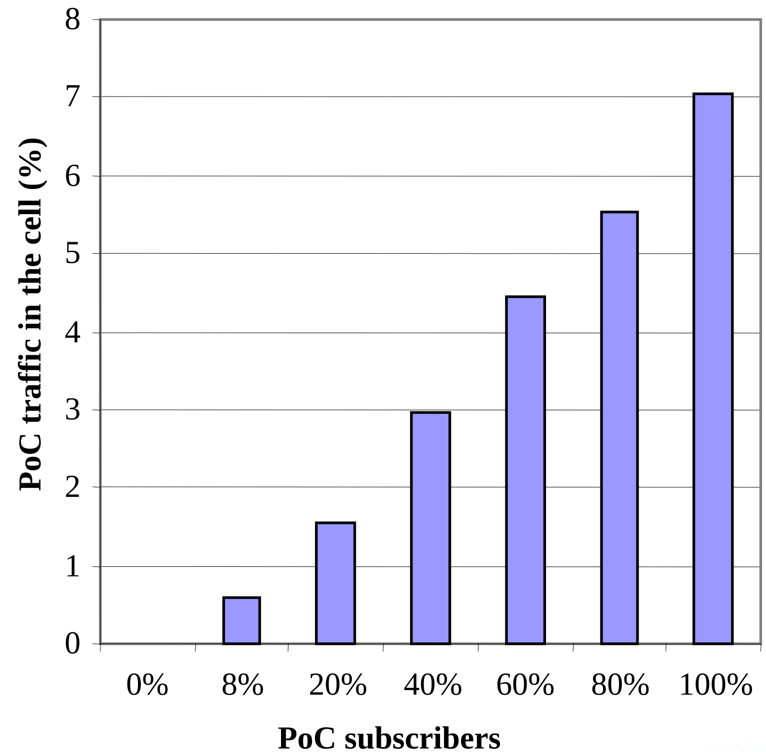
Case studies on PoC deployment

- **Case 1**
  - Maximum allocated bit rate = 8 kb/s
  - Average PoC group size = 1 (one to one communication)
  - Only different priorities are allocated to distinct services
  - **Method 1**
- **Case 2**
  - Maximum allocated bit rate = 16 kb/s
  - All other settings as in Case 1
  - **Method 1**
- **Case 3**
  - PoC av. group size in the same cell = 4
  - All other settings as in Case 2
  - **Method 1**
- **Case 4**
  - **Method 2**
  - 500 non-PoC users (held constant)
  - All other settings as in Case 3

Case 1: Simulation results (1/2)

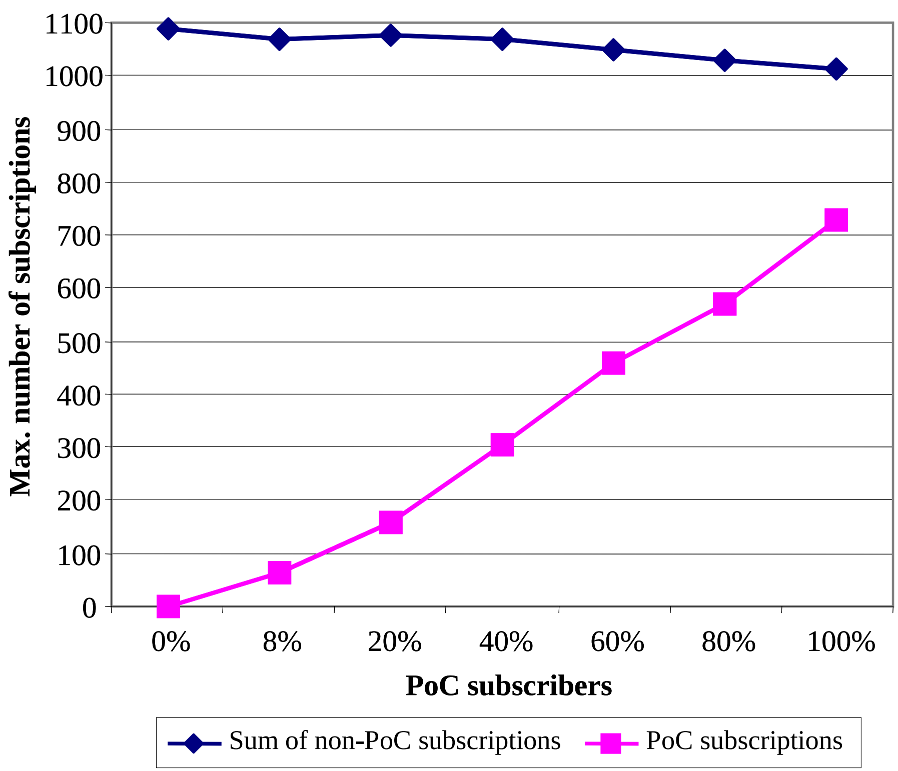
- **Served PoC traffic as a function of PoC subscriptions**
  - Average PoC cell throughput < 50 kb/s
  - ≤ 7% of the total traffic in the cell

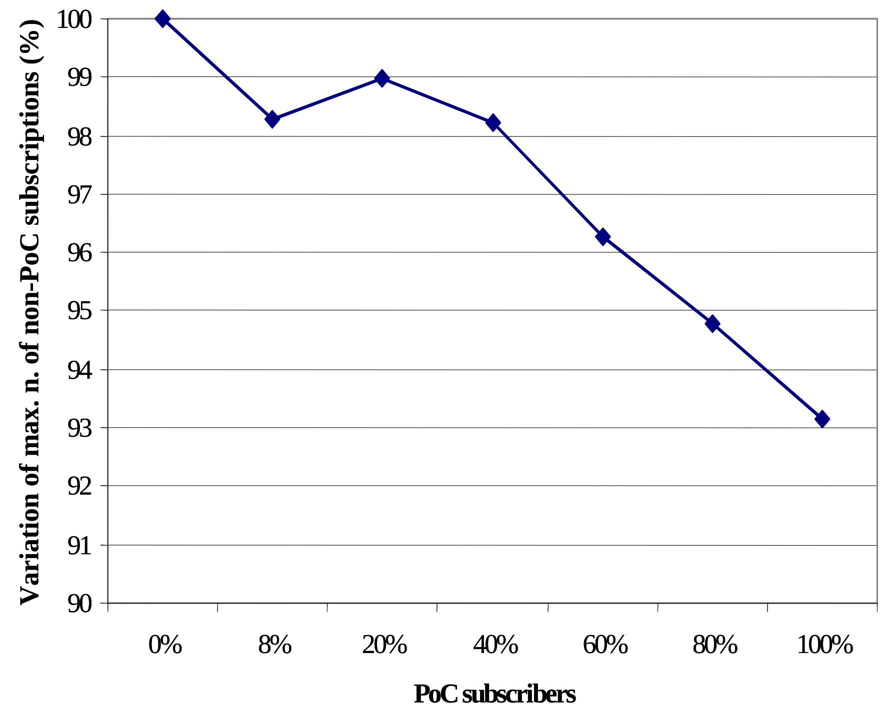




Case 1: Simulation results (2/2)

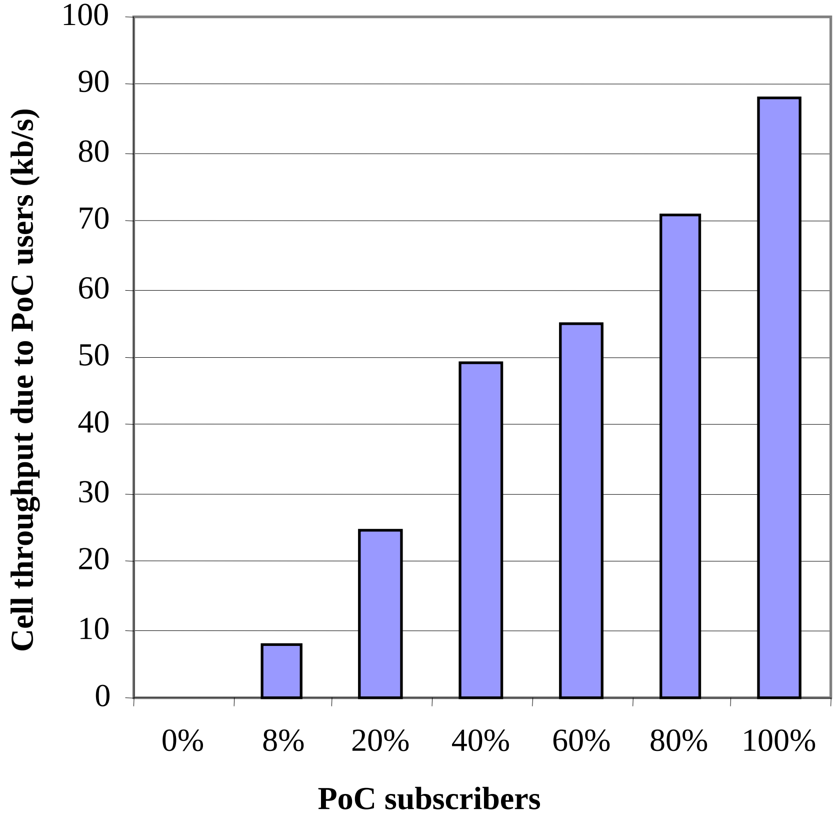
- **Impact of PoC traffic on other services**
  - Insignificant: Only 7% of the other services would be not satisfactory if all the end users subscribed to PoC

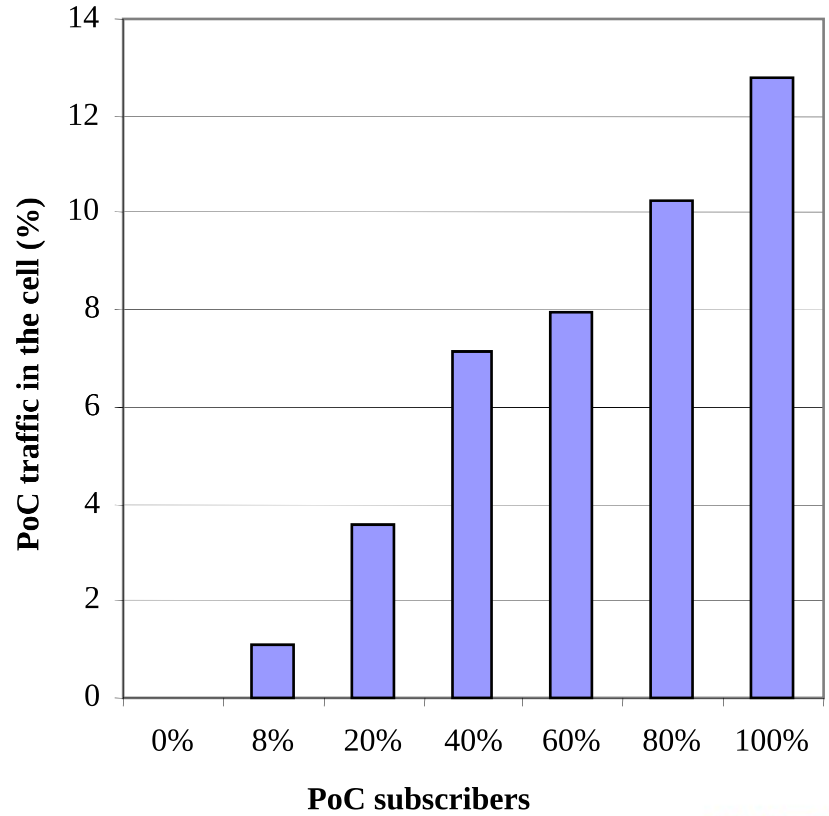




Case 2: Simulation results (1/2)

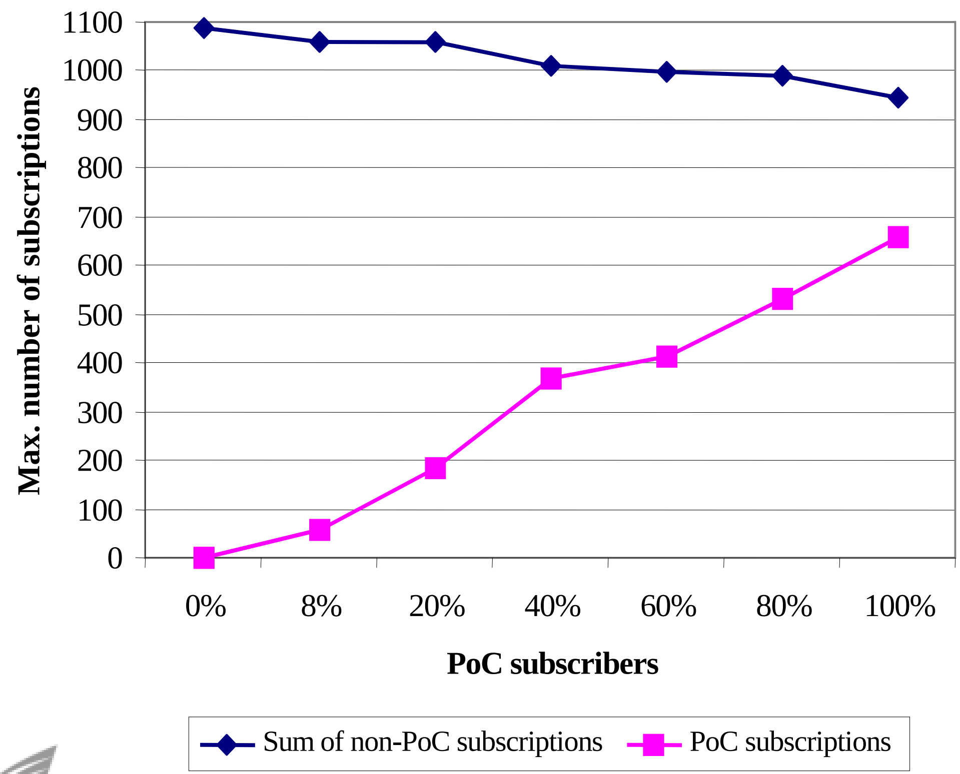
- **Served PoC traffic as a function of PoC subscriptions**
  - Average PoC cell throughput < 90 kb/s
  - ≤ 13% of the total traffic in the cell

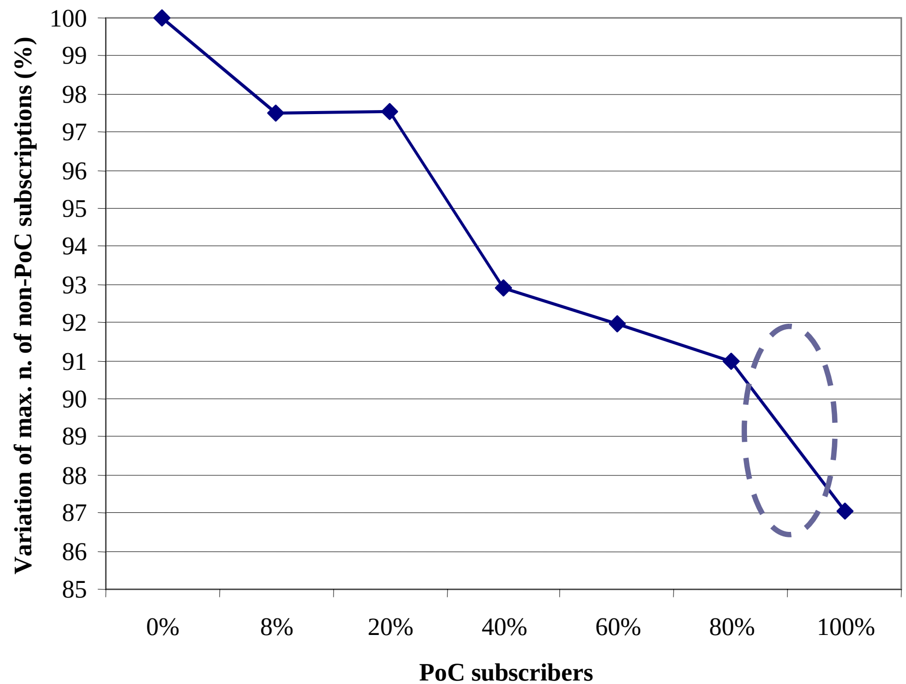




Case 2: Simulation results (2/2)

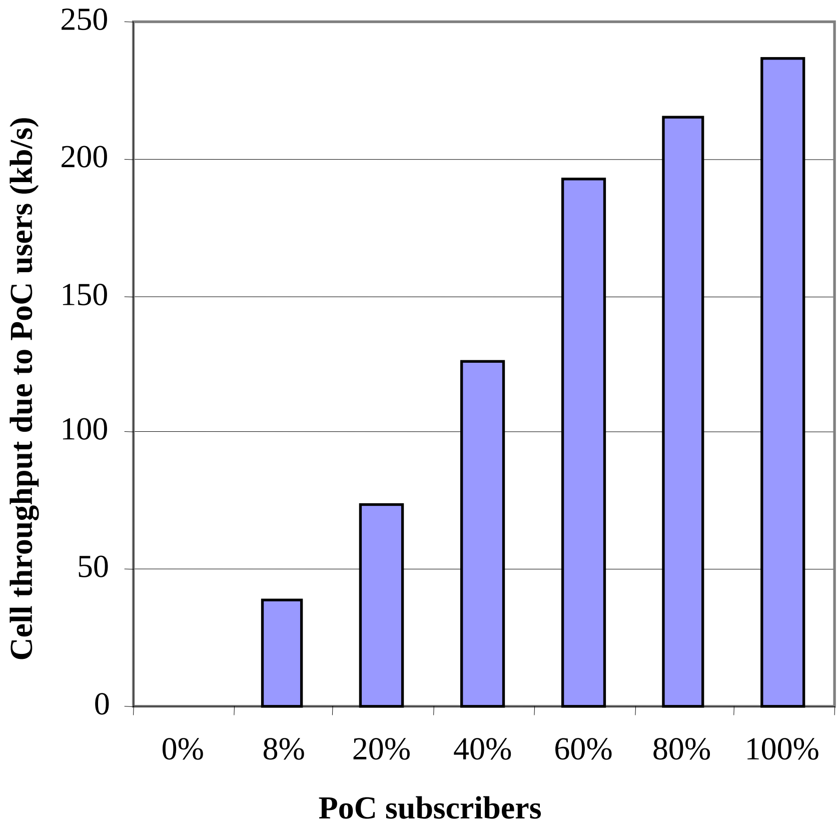
- **Impact of PoC traffic on other services**
  - More significant than in Case 1: about 13% of the other services would be not satisfactory if all the end users subscribed to PoC

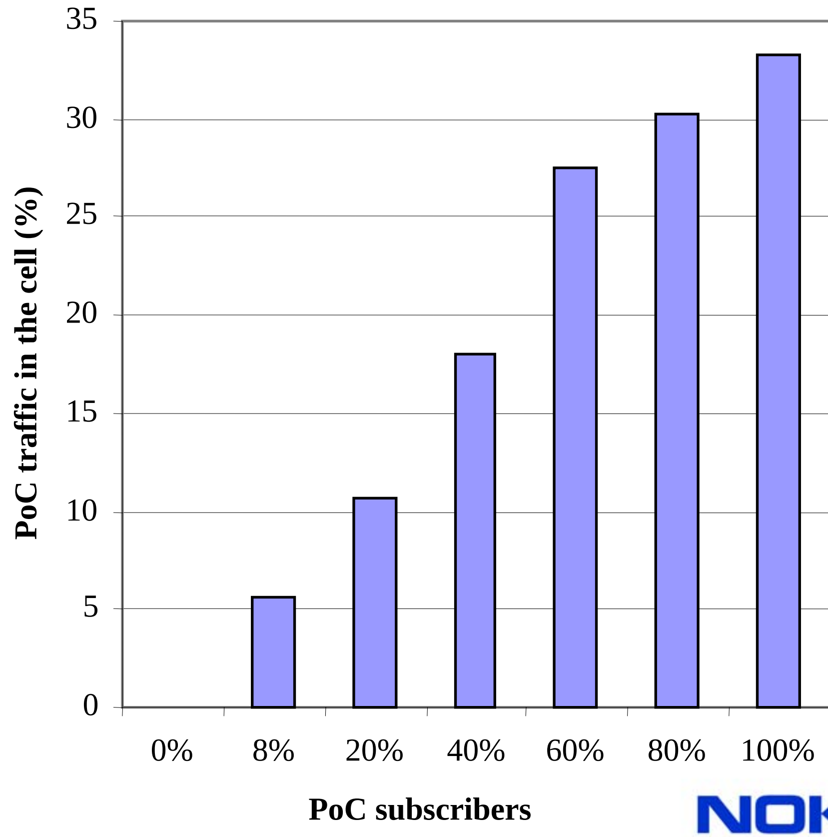




Case 3: Simulation results (1/2)

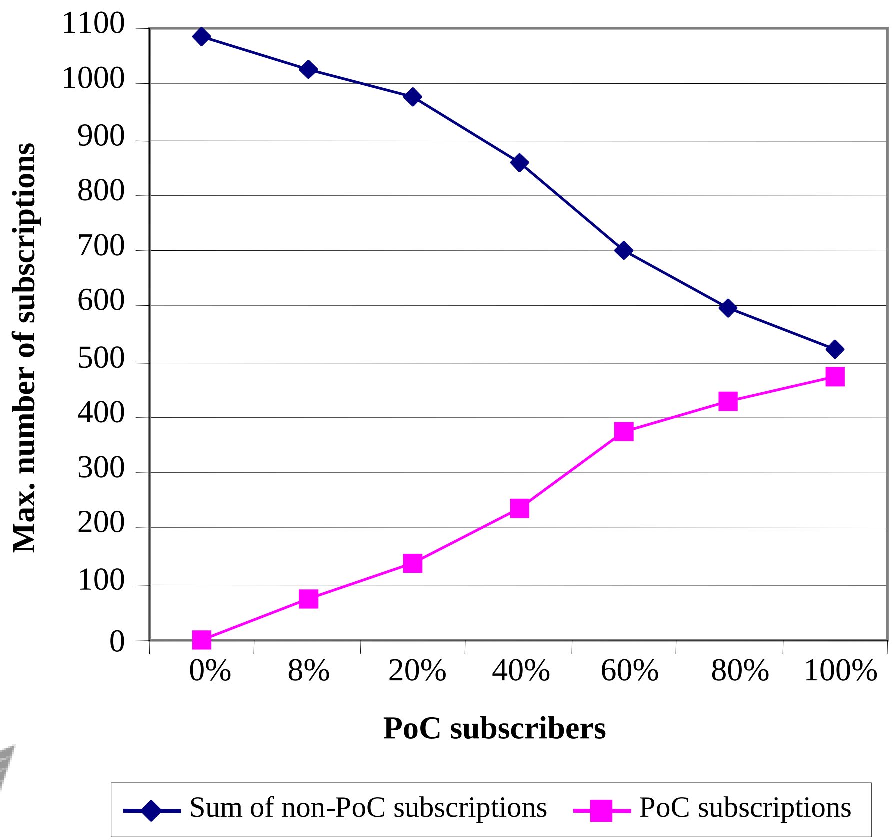
- **Served PoC traffic as a function of PoC subscriptions**
  - Average PoC cell throughput < 250 kb/s
  - ≤ 1/3 of the total traffic in the cell

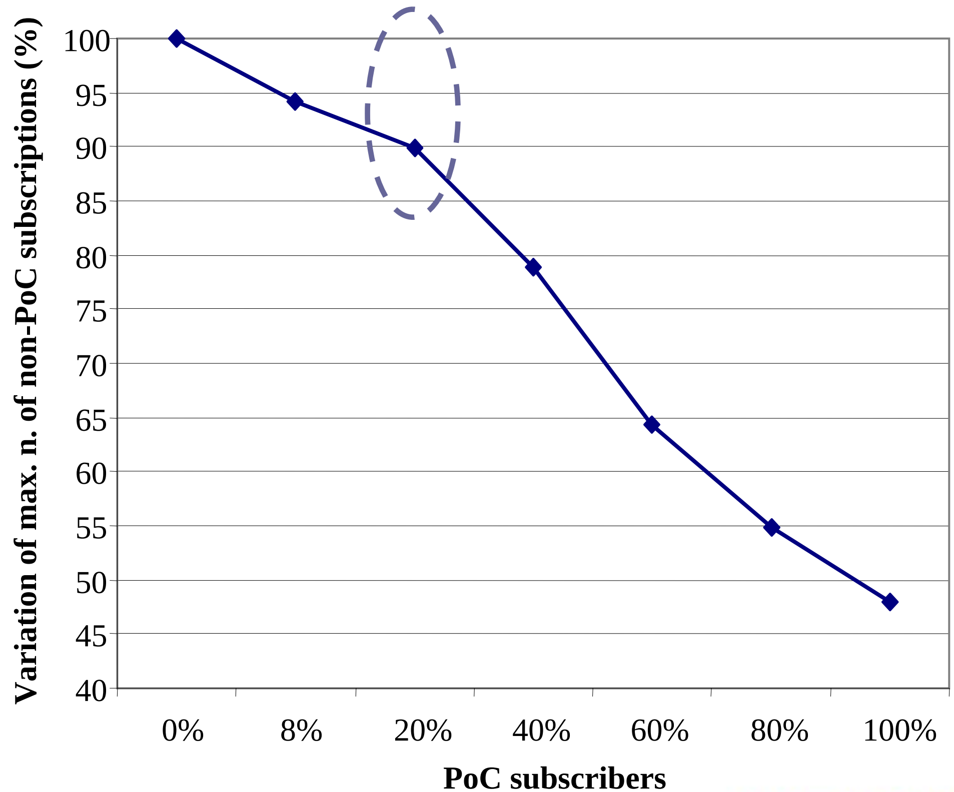




Case 3: Simulation results (2/2)

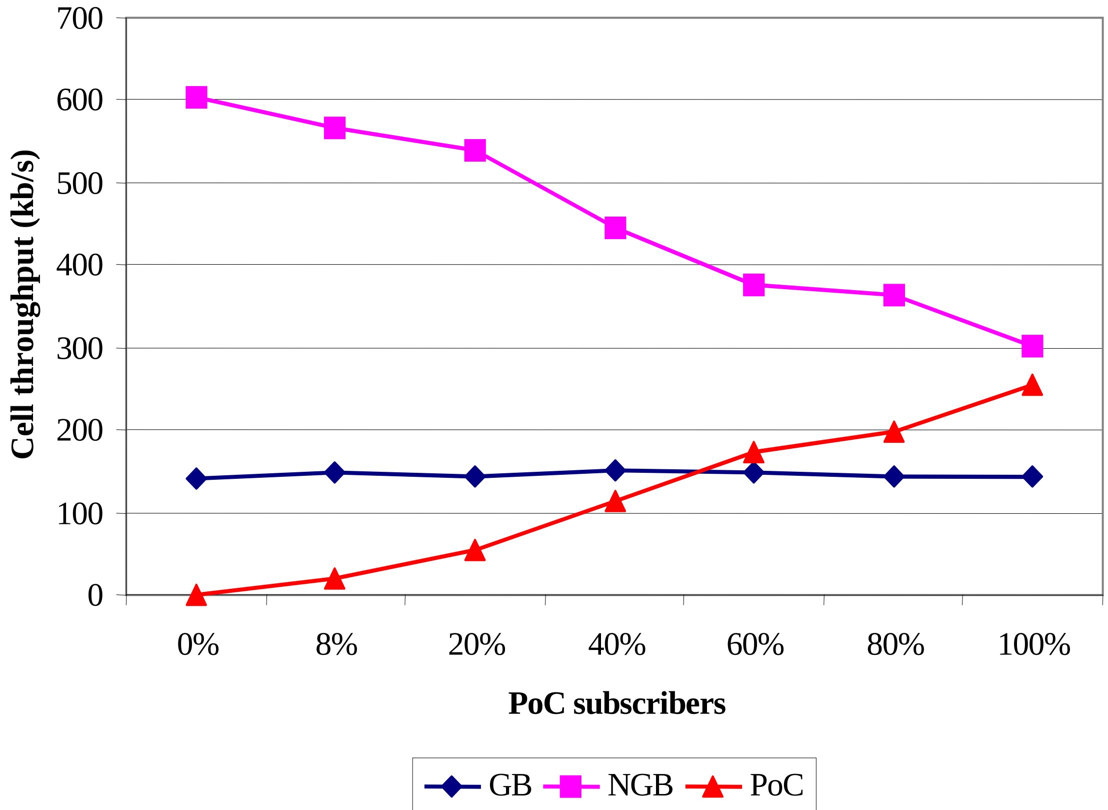
- **Impact of PoC traffic on other services**
  - Worst case: Significant deterioration of the performance of other services if more than 20% of the end users subscribed to PoC





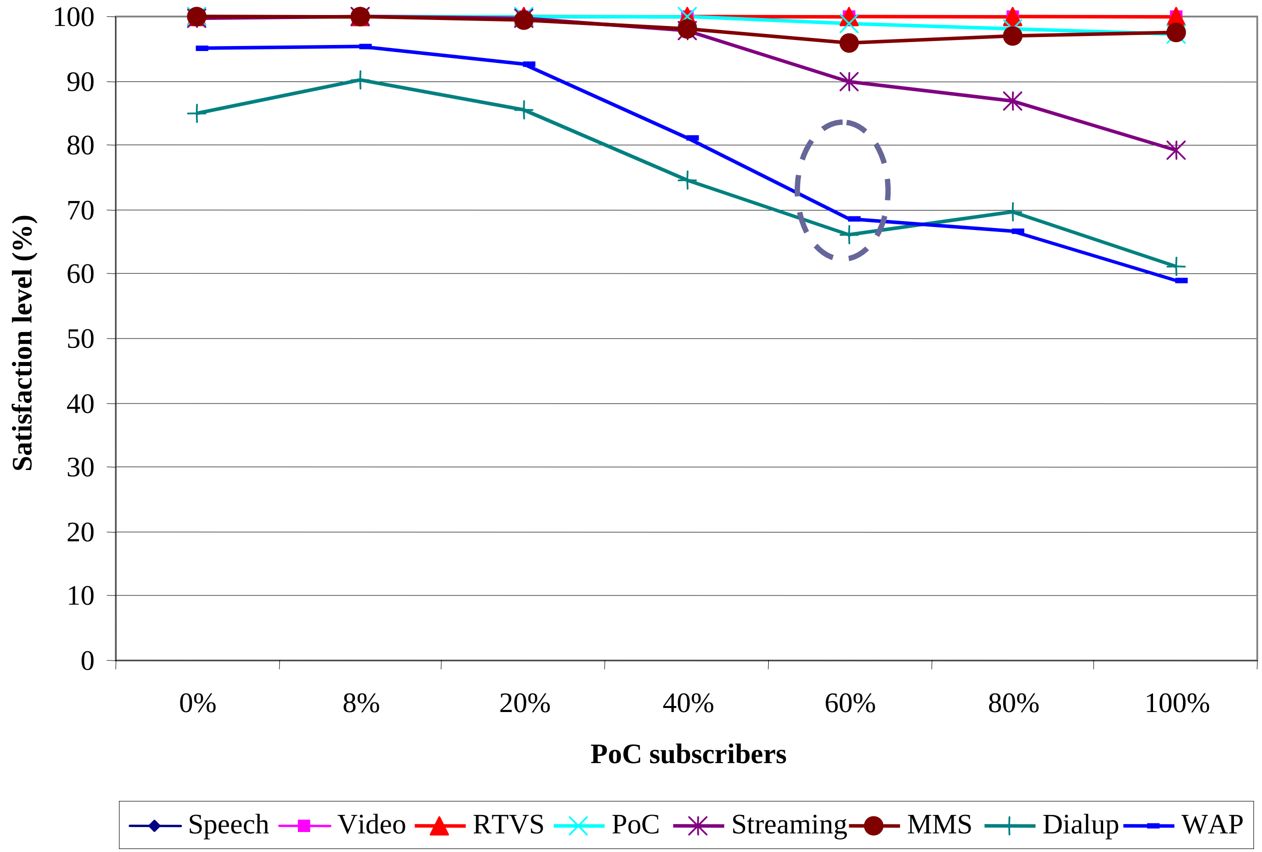
Case 4: Simulation results (1/2)

- **Average cell throughput as a function of PoC subscriptions**
  - As expected, when the PoC traffic increases the NGB load decreases (PoC has higher priority), whereas the load due to GB services remains constant (PoC has no means to affect the AC of GB services)



Case 4: Simulation results (2/2)

- **Impact of PoC traffic on other services**
  - Significant deterioration of WAP performance if more than 50% of the end users subscribed to PoC: Extra capacity needed in the cell



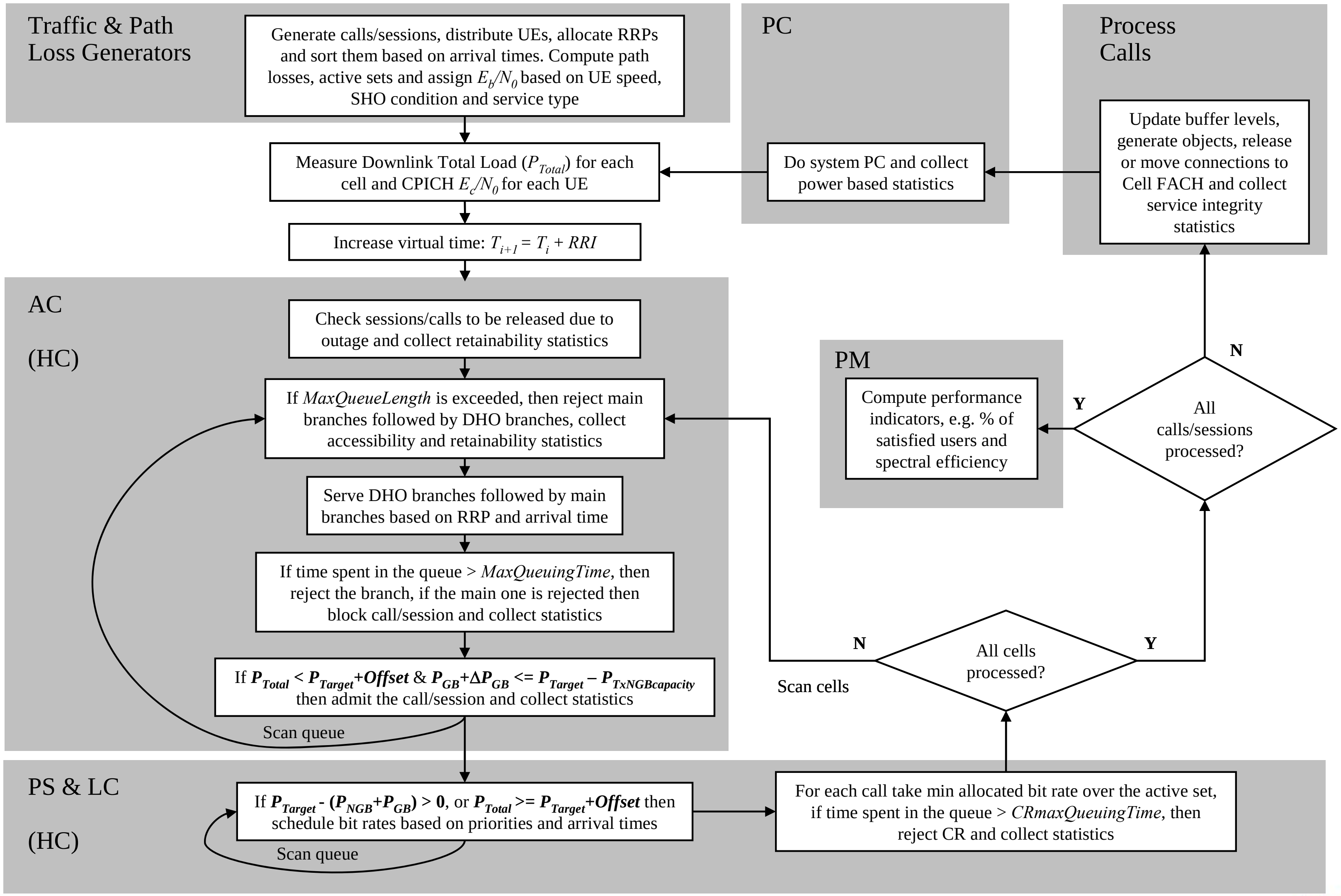
Virtual time simulator for UTRAN FDD

- **In UMTS only a layered bearer service architecture and QoS attributes are defined**: Implementation and planning aspects of the actual QoS management functions are left to vendors' and operators' choice
- Due to the complexity of the system and infrastructure costs, **any practical deployment of radio resources management (RRM) algorithms and offered services in UTRAN needs to be validated a priori** by means of static or dynamic simulations, depending on the desired level of time resolution and accuracy
- **We present a virtual time simulator that overcomes the limitations** (snap shot of the system status only) **and complexity** (far too high time resolution) **of static and dynamic system level simulators**

Simulator structure

- **Modular structure with clear interfaces**: Each module is implemented independently so that each entity may be straightforwardly replaced by an alternative solution
- **Supported functions**: Traffic and path loss generators, Admission Control (AC), Load Control (LC), Packet Scheduler (PS), Power Control (PC), Process Calls (PrC) and Performance Monitoring (PM)
- **Mobility effects and SHO gains:** may be taken into account by e.g. speed dependent Eb/N0 requirements and SHO condition
- DHO branches are processed first followed by the main branches, the bit rate assigned to the radio link set (UE) is the minimum of the bit rates allocated separately (for each cell) to all radio links of the active set
- The maximum resolution of the tool is one radio resource indication period (RRI), i.e. the time needed to receive the power levels from the base stations

Simulation flow chart

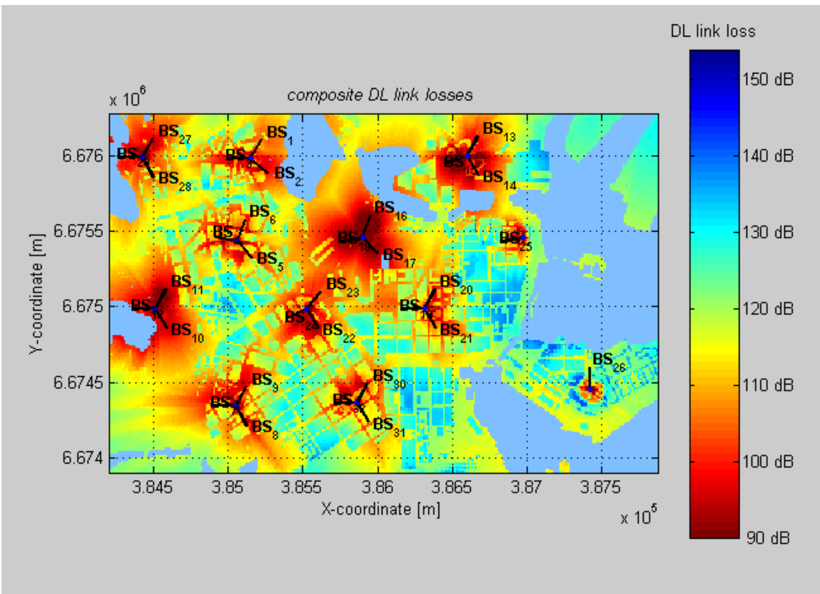


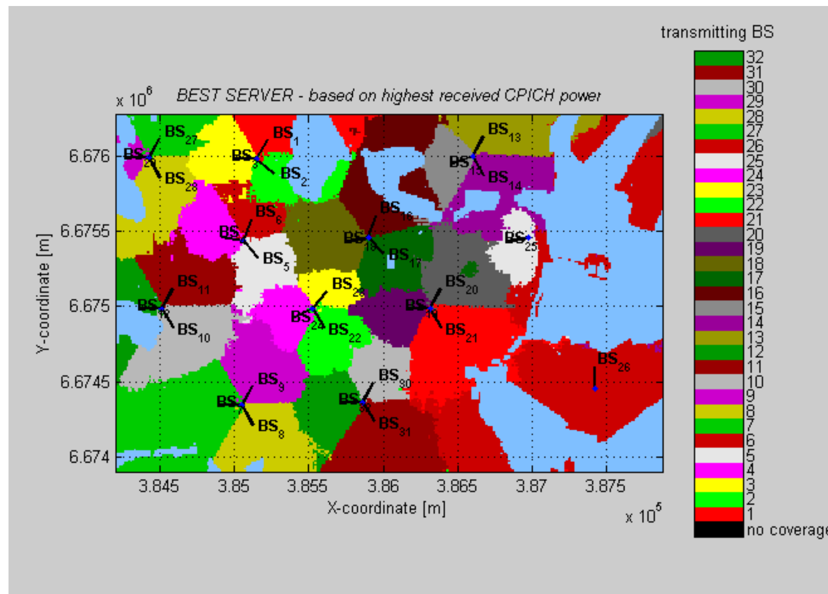
Traffic models

- **Call and session arrivals are generated following a Poisson process**, and mapped onto the appropriate QoS profiles, depending on the carried type of traffic
- **Circuit switched (CS) speech and video calls** are held for an exponentially distributed service time, and their inter-arrival periods follow exactly the same type of distribution
- **Packet switched services** are implemented as an ON/OFF process with truncated distributions
- All calls/sessions (generated at the beginning of each simulation) are subsequently processed (played back) taking into account the corresponding arrival times, service activities and priorities, *hence the name **virtual time simulator***

Path loss generator

- For each mobile location, the received power levels from all cells are calculated first and then the cells satisfying the SHO conditions are assigned as active
- **Path loss calculations**: Imported from other tools or using formulas available in the literature, e.g. Okumura-Hata model

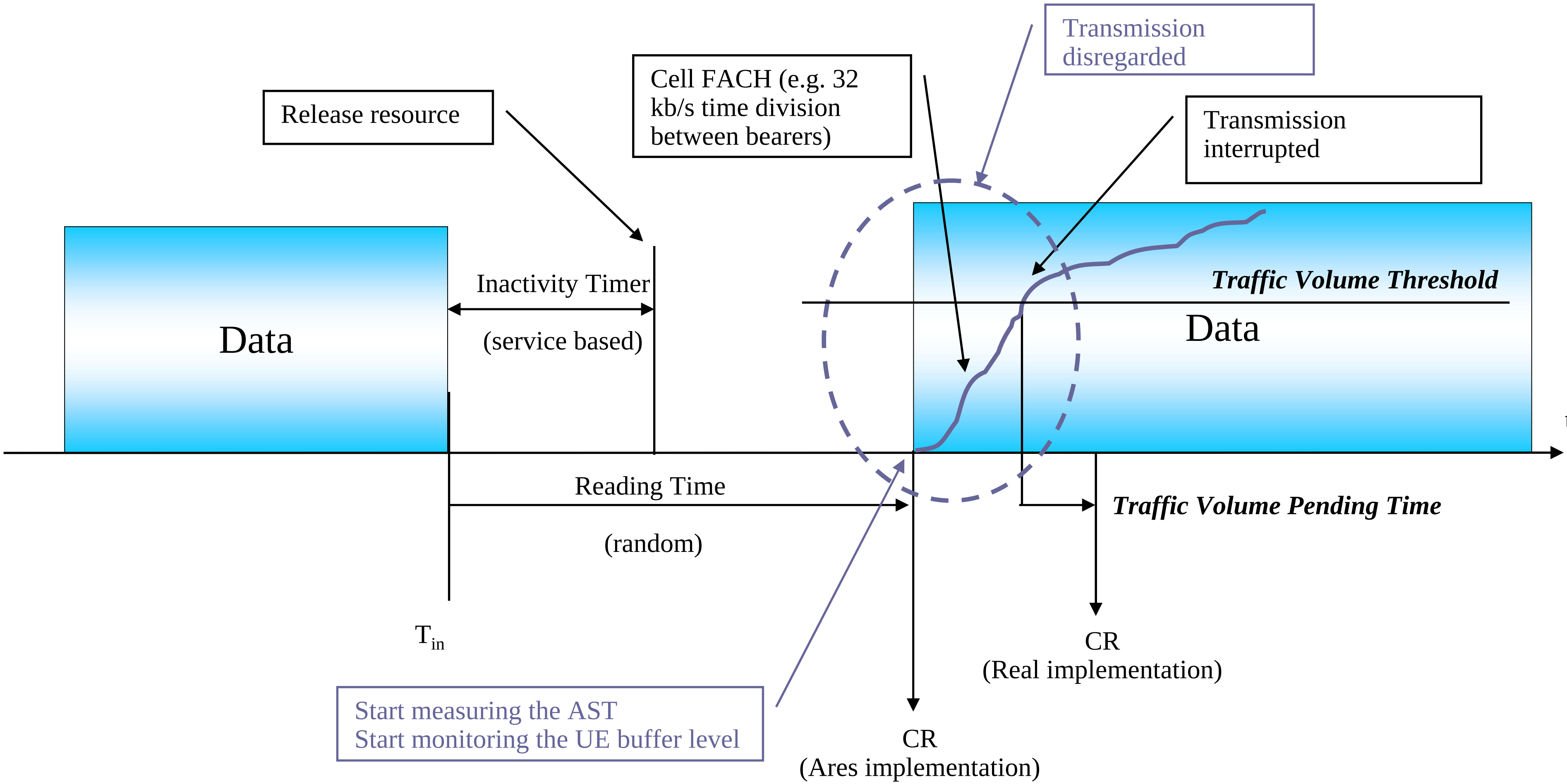




Supported RRM functions

- AC, PS and LC with QoS differentiation
  - See Chapter 5 or Lecture 4
- HC
  - Included in PS and AC functions
  - Terminals not moving
- PC
  - System based

From Cell_DCH to Cell_FACH



<u>Note:</u>

- FACH bit rate = 32 kb/s
- No transmission allowed when the CR is sent

Process calls function

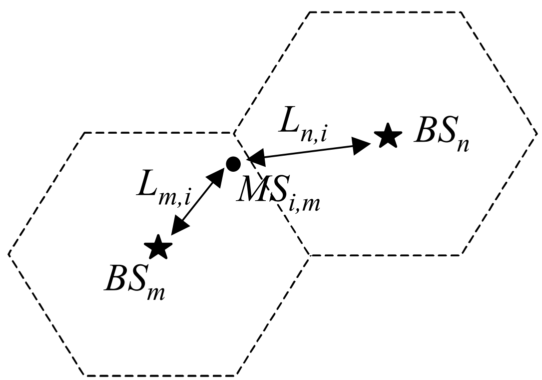
- **All active calls in the system are processed at once** each radio resource indication period
- If the **ongoing connection is CS**, the simulator collects its throughput, and releases the call in the case it lasted longer then the corresponding call duration period
- For **packet switched connections**, the ON/OFF state of each session is handled separately: Throughput is collected only if there is data to transmit, and inactive connections are moved to Cell FACH state

Power control function

- For each connection during each RRI, we derive the transmission power to attain the required E_b/N_0 for sufficient quality, i.e.

?

$$\begin{cases} \dfrac{W p_{i_m} / L_{m,i_m}}{R_{i_m} P_m / L_{m,i_m} (1-\alpha_{i_m}) + \sum_{n,n\neq m} P_n / L_{n,i_m} + N_{i_m}} = \rho_{i_m}, \\ i_m \in I(m), \quad m = 1,\ldots,M \\ P_m = \sum_{i_m \in I(m)} p_{i_m} + p_{c,m} \end{cases}$$



Symbol	Explanation
i_m	Index of a UE served by BS m
m,n	Indices of BSs
$I(m)$	Set of UE indices served by BS m
M	Number of cells
p_{i_m}	BS transmitted power for UE i_m
P_m, P_n	Total transmit power of BS m and BS n
L_{m,i_m}	Pathloss from BS m to UE i_m served by BS m
L_{n,i_m}	Pathloss from BS n to UE i_m served by BS m
R_{i_m}	Bit rate used by UE i_m
α_{i_m}	Orthogonality factor for UE i_m
N_{i_m}	Noise power (thermal plus equipment) of UE i_m
ρ_{i_m}	Required E_b/N_0 for UE i_m

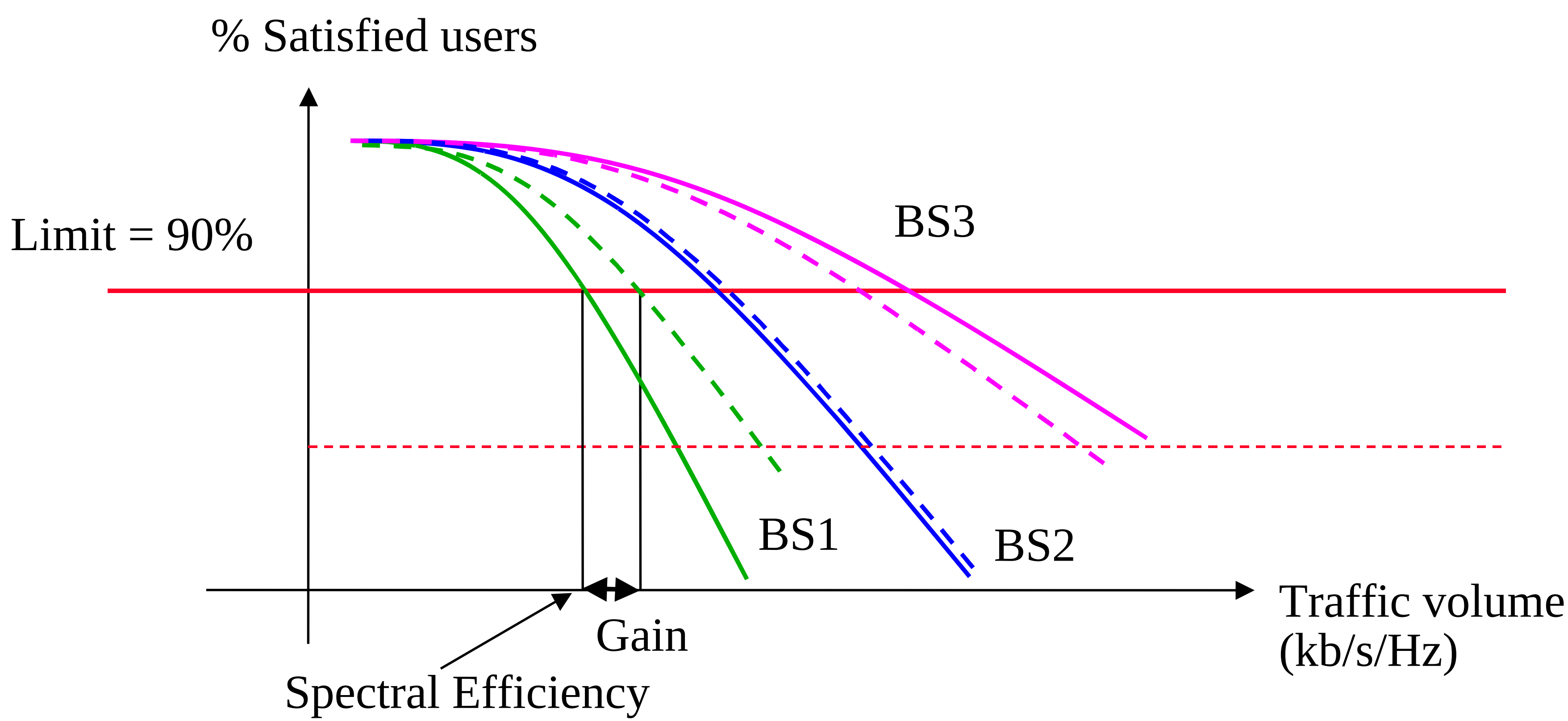
- Multi-path fading and SHO effects are taken into account in the service E_b/N_0 requirement

QoS and QoE monitoring function

- **Performance monitoring**
  - % of satisfied users for each service
  - Spectral efficiency for mixed service scenario
  - Link and cell based powers and E_c/N_0 measurements
- **QoE performance indicators for each service**
  - Call block ratio (%)
  - Call drop ratio (%)
  - Capacity request rejection ration (%)
  - Active session throughput (kb/s)
  - Object transfer delay (s)
  - UE buffer level for Streaming, SWIS, and PoC services
  - Results available on the map

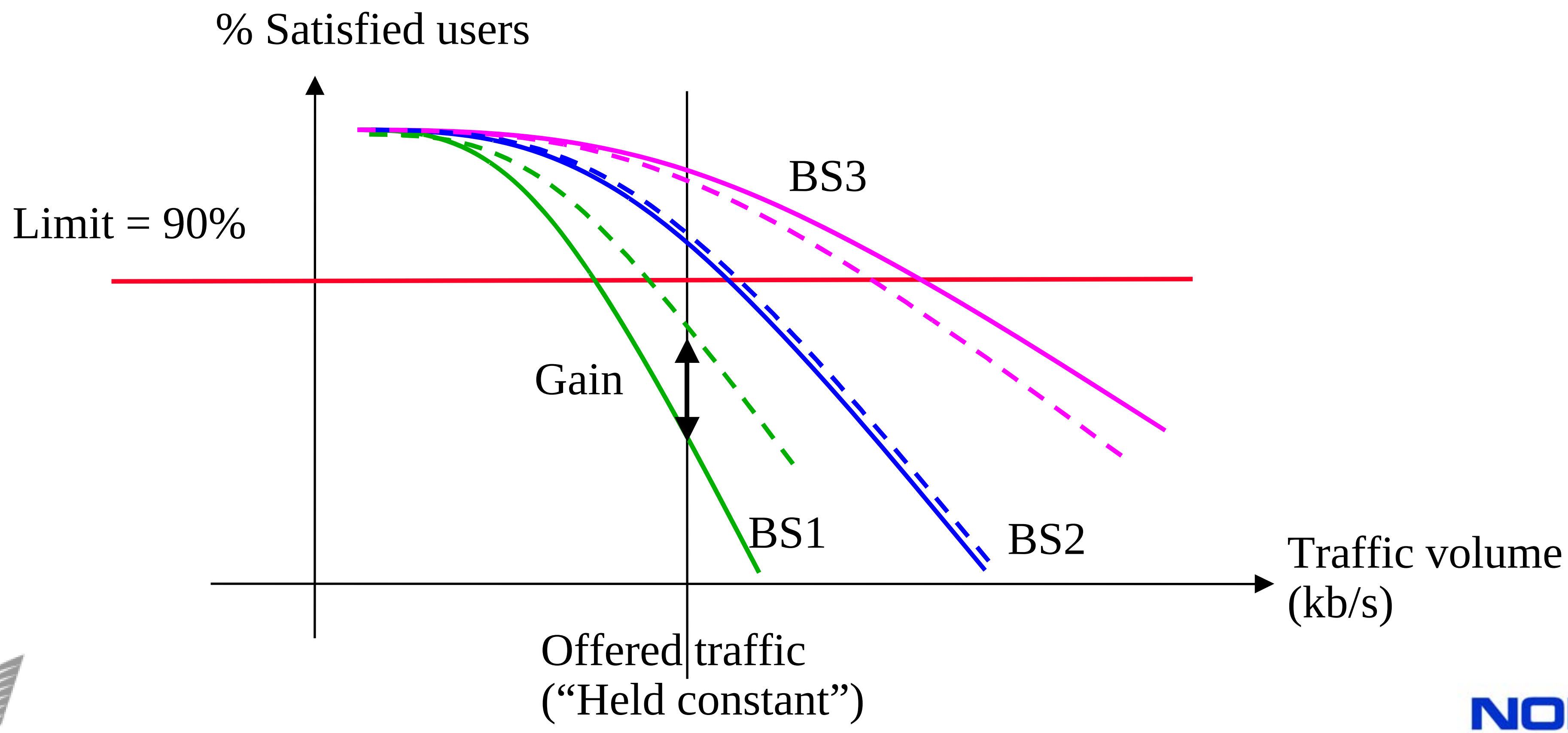
Gains in terms of Spectral Efficiency

- Difference between system loads (average cell throughput divided by the bandwidth) where 90% of users of the worse performing service are satisfied



Gains in terms of % of satisfied users

- Collect the % of satisfied users for each service: The more users that can be satisfied, at a given offered traffic volume, the more efficiently the spectrum is utilized by the operator



Simulation assumptions (1/2)

- The simulation was performed over a period of **2 hours** using a time **step of 200 ms** (RRI period)
- The **traffic mix and the traffic intensity were held constant**, i.e. 2 call/session attempts per second. The corresponding offered traffic was about **750 users per cell over the all simulated time**
- Differentiated parameter vales:

QoS Profile	Service	Bit Rate (kb/s)	RRP	Min. All. Bit Rate (kb/s)	AC Max. Queuing Time (s)	Granted Min. DCH Alloc. Time (s)	Granted Min. DCH Alloc.Time in Overload (s)	Buffering Delay (s)	Inactivity Timer (s)	CR Max. Queuing Time (s)
CS-conv.	Speech	12.2	1	GB	5	-	-	-	-	-
	Video	64	2	GB	10	-	-	-	-	-
PS-stream.	SWIS	64	3	GB	10	-	-	5	-	-
PS-int. THP1	PoC	0, 8	4	8	15	15	10	4	60	4
THP2	Streaming	0, 64	5	64	15	10	5	16	5	10
THP3	WAP/MMS	0, 16, 32, 64, 128, 144, 256, 384	6	32	15	5	0.2	-	10	10
PS-backg.	Dialup	0, 16, 32, 64, 128, 144, 256, 384	7	16	15	1	0.2	-	5	5

Simulation assumptions (2/2)

- Most important system based parameters

Parameter	Value
Call/session mean arrival rate	0.5 s
Radio resource indication period (*RRI*)	0.2 s
Simulation time (s)	7200 s
Power target for DL AC	3 dB below BTS total power
Overload offset for DL AC	1 dB above power target
Orthogonality (α)	0.5
Period for load control actions	0.2 s (1 RRI)
Period for Packet Scheduling	0.2 s (1 RRI)
E_b/N_0 requirements	
Speech	7 dB
SWIS	6 dB
Streaming	6 dB
PoC	7 dB
MMS/WAP	5/5.5 dB
Dialup	5.5 dB
Maximum BTS Tx power	43 dBm
P-CPICH Tx power	33 dBm
Sum of all other CCH Tx powers	30 dBm
Length of AC queue	10 Radio bearers
Dedicated NGB capacity	0 dB, i.e. not used
Power weight for inactive NGB traffic (*k*)	0.5

Adopted traffic models and mix

Service	Data rate (kb/s)	Buffer size (s)	Object size (kB)	Off time (s)	Session length (Objects)	Mix (%)
PoC	8	1	Exponential 6 mean, 0.5 min, 40 max	Exponential 60 mean, 1 min, 1200 max	Geometric 8 mean, 1 min, 30 max	18
Streaming	64	8	Uniform 160 min, 3200 max	-	1	12
MMS	Best Effort	-	Exponential 20 mean, 3 min, 200 max	-	1	5
Dialup	Best Effort	-	Log-normal (μ=5, σ=1.8) 0.1 min, 20000 max	Pareto (k=2, α=1) 2 min, 3600 max	Inv. Gaussian (μ=3.8, λ=6) 1 min, 50 max	15
SWIS	64	1	Exponential 80 mean, 32 min, 2400 max	-	1	10
WAP	Best Effort	-	Log-normal (μ=2, σ=1) 0.1 min, 50 max	Exponential 20 mean, 1 min, 600 max	Geometric 3 mean, 1 min, 50 max	13
Speech	12.3	-	-	-	Exponential 90 s	20
Video	64	-	-	-	Exponential 120 s	7

Mapping of services onto QoS profiles

- Radio Resource Priority / Guaranteed Bit Rate values

GB

QoS Class		RRP/BitRate
Signalling		9/3.4 kbps
Emergency call		1/12.2kbps
CS – Conversational	Speech	2/12.2kbps
	T Data	3/64kbps
CS - Streaming	NT Data	

GB: Guaranteed Bit Rate

NGB: Non Guaranteed Bit Rate

NGB

QoS Class		ARP=1	ARP=2	ARP=3
PS - Conversational				
PS - Streaming		4 (SWIS)		
PS - Interactive	THP1	5 (PoC)		
	THP2		6 (Streaming)	
	THP3			7 (WAP+MMS)
PS - Background				8 (Dialup)

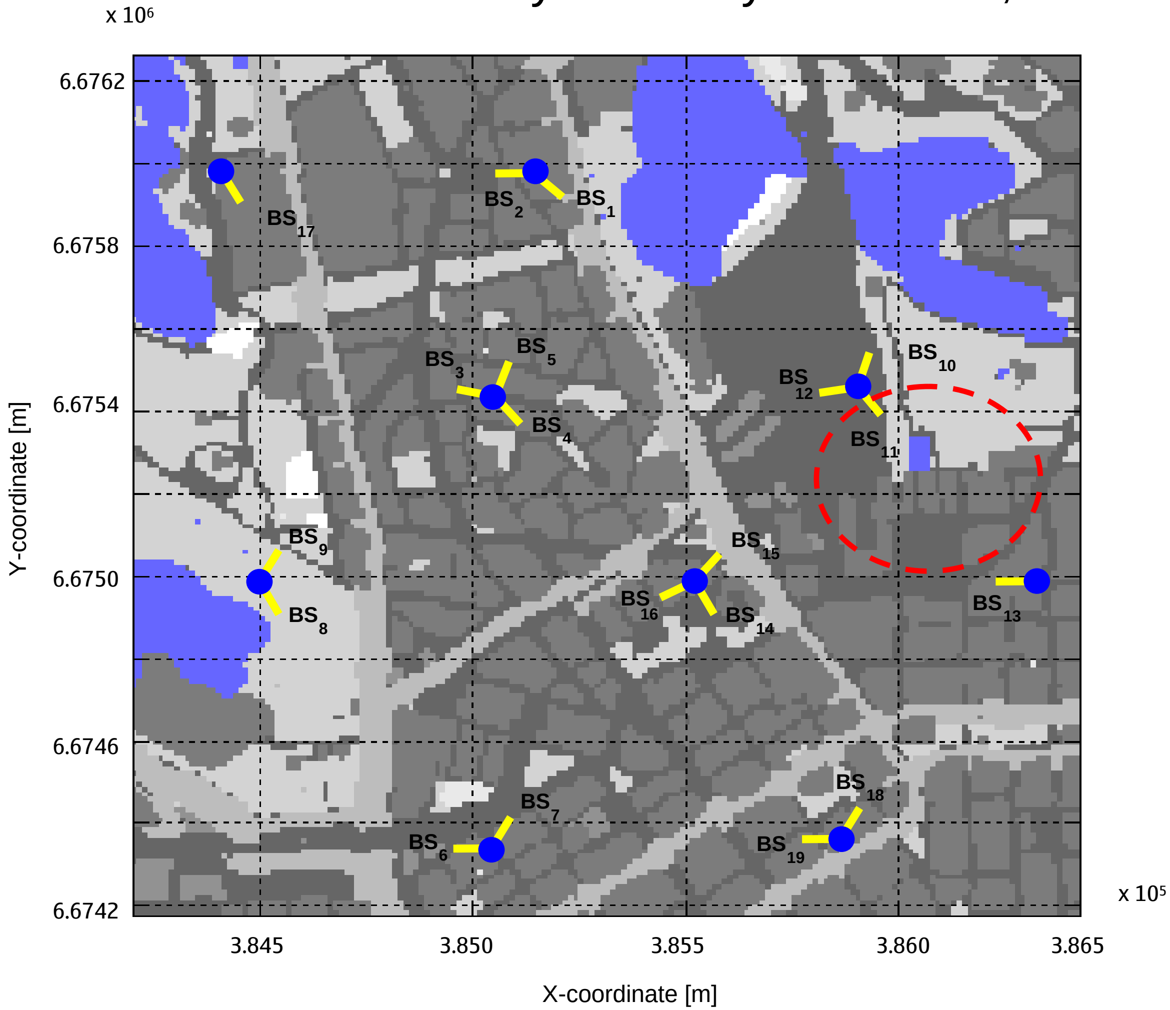
Bearer services

User satisfaction: Definition

- **Speech calls and video calls (GB)**
  - The user does not get neither blocked nor dropped
- **SWIS (GB)**
  - The user does not get neither blocked nor dropped
  - No re-buffering occur during the session
- **PoC (NGB)**
  - The user does not get neither blocked nor dropped
  - No re-buffering occur during the session
- **Streaming (GB and NGB)**
  - The user does not get neither blocked nor dropped
  - No re-buffering occur during the session
- **Dialup (http, emails, ftp) (NGB)**
  - The user does not get neither blocked nor dropped
  - Active session throughput >= 64 kb/s
- **WAP (NGB)**
  - The user does not get neither blocked nor dropped
  - Active session throughput >= 32 kb/s
- **MMS (NGB)**
  - The user does not get neither blocked nor dropped
  - Active session throughput >= 8 kb/s

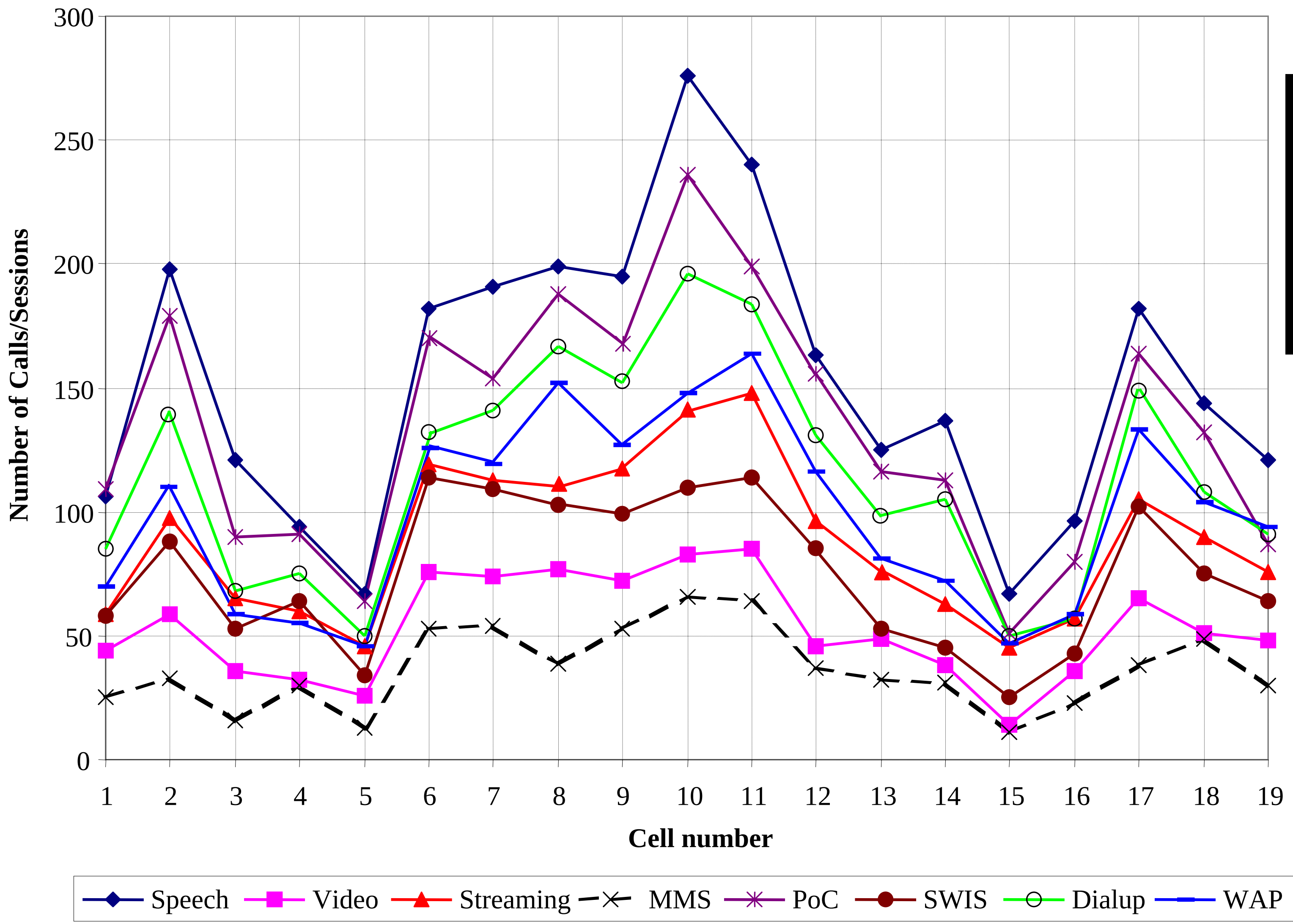
Simulated environment

- Helsinki 19 cells: Terminals uniformly randomly distributed, but not on the water



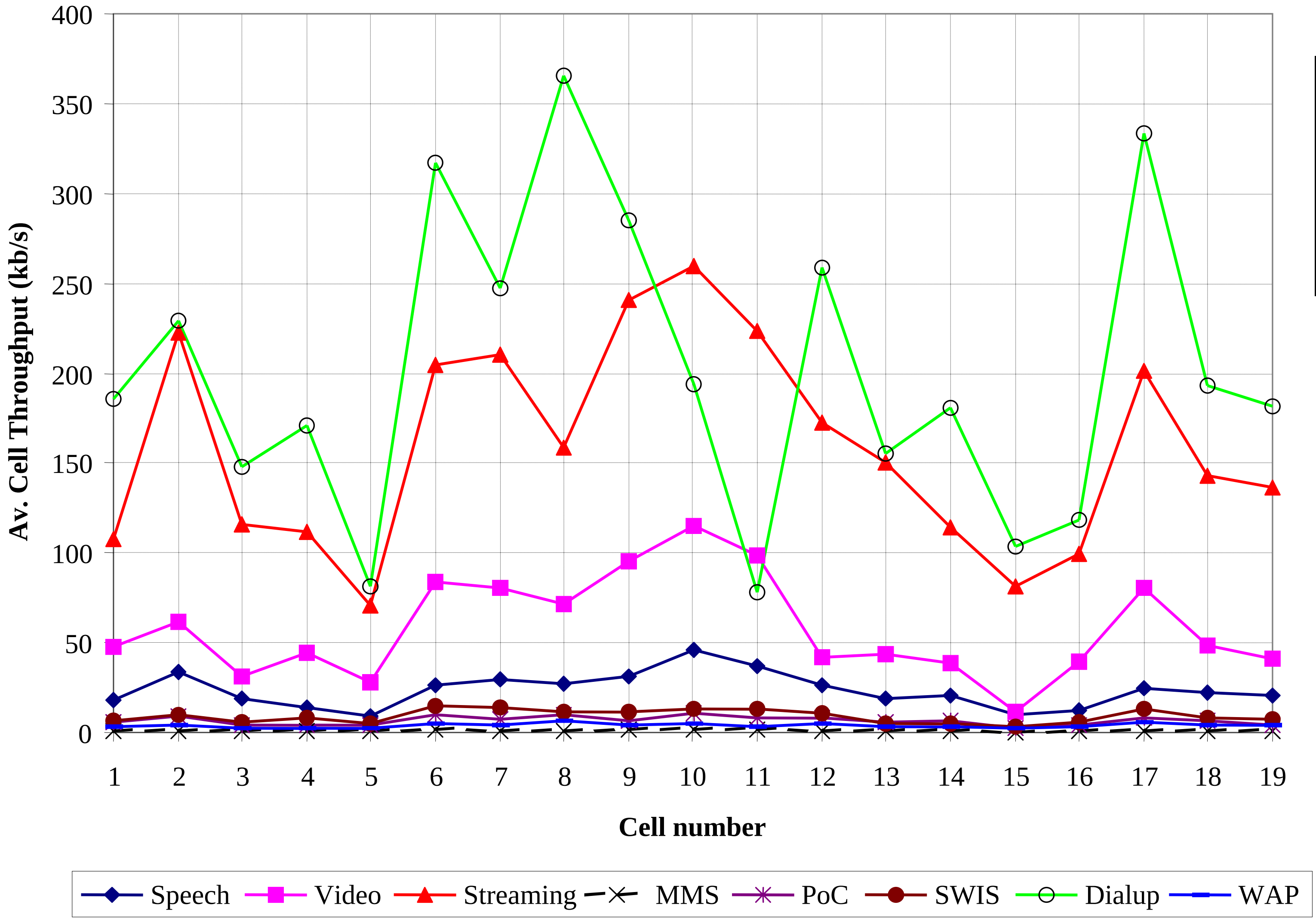
The status of Cell 11 is also investigated separately

Traffic distribution: Offered load in call arrivals



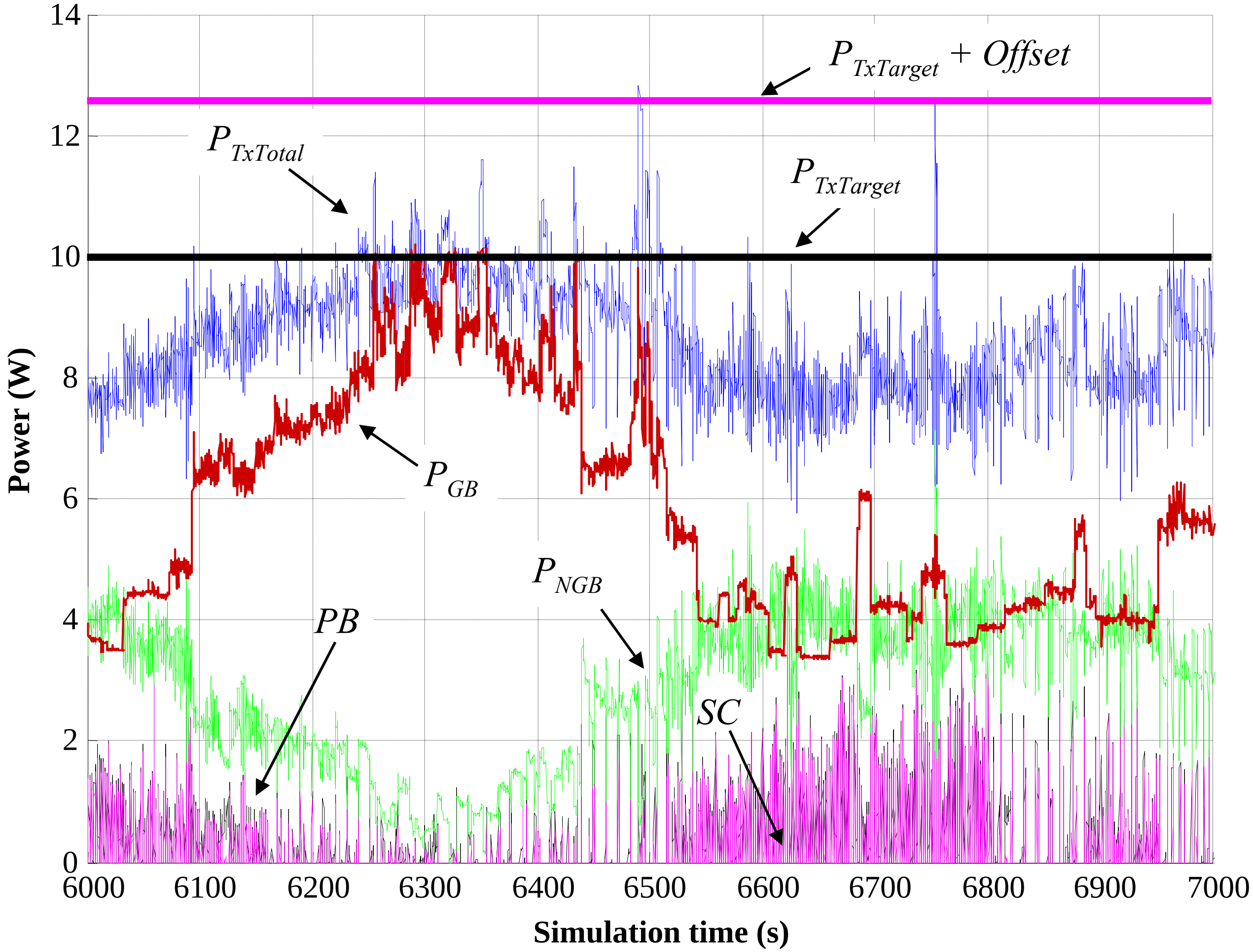
The offered load complies with the input traffic mix

Traffic distribution: Average cell throughputs



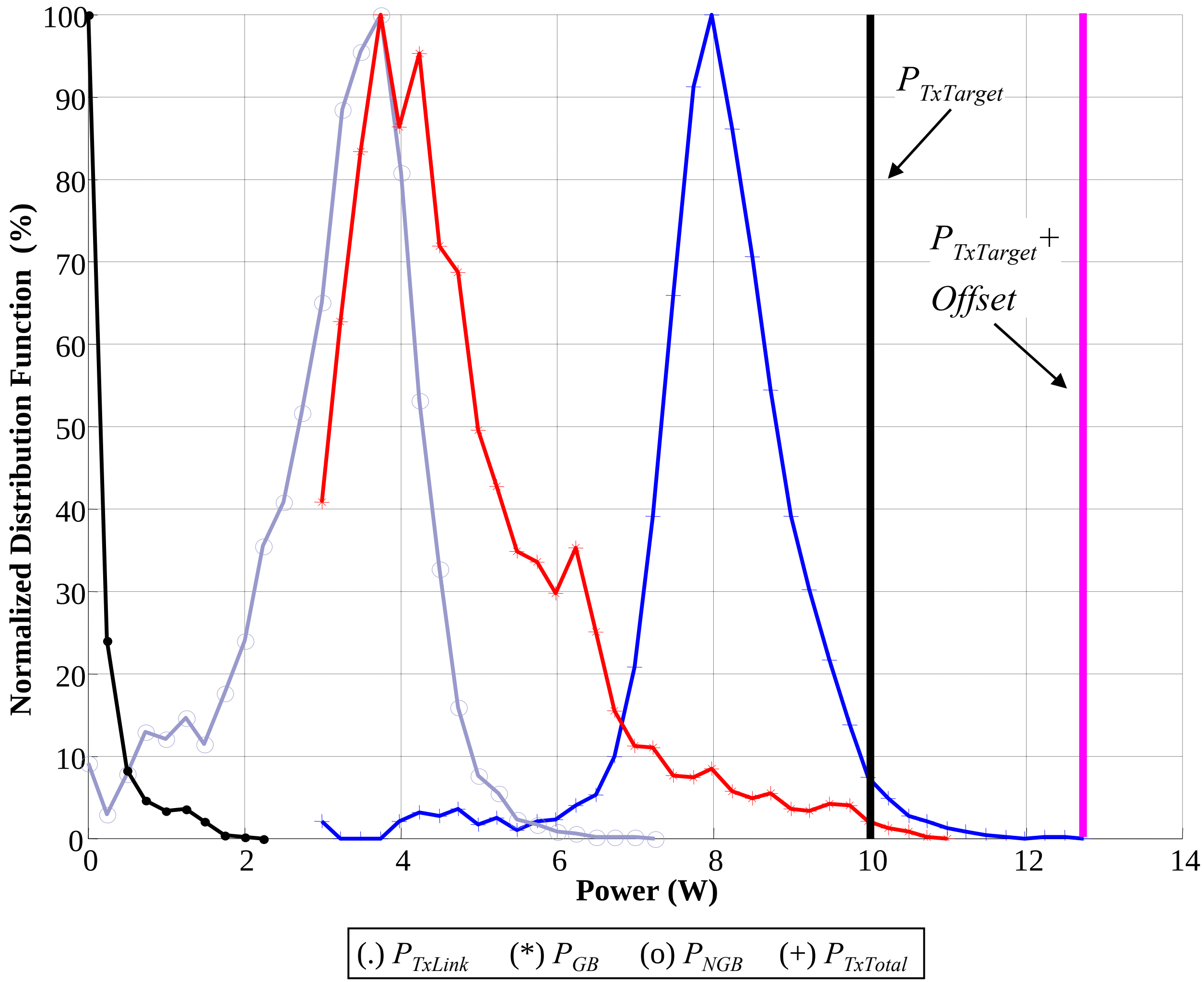
The served load reflects the input traffic mix and models

Cell 11: Snapshot of the simulation period



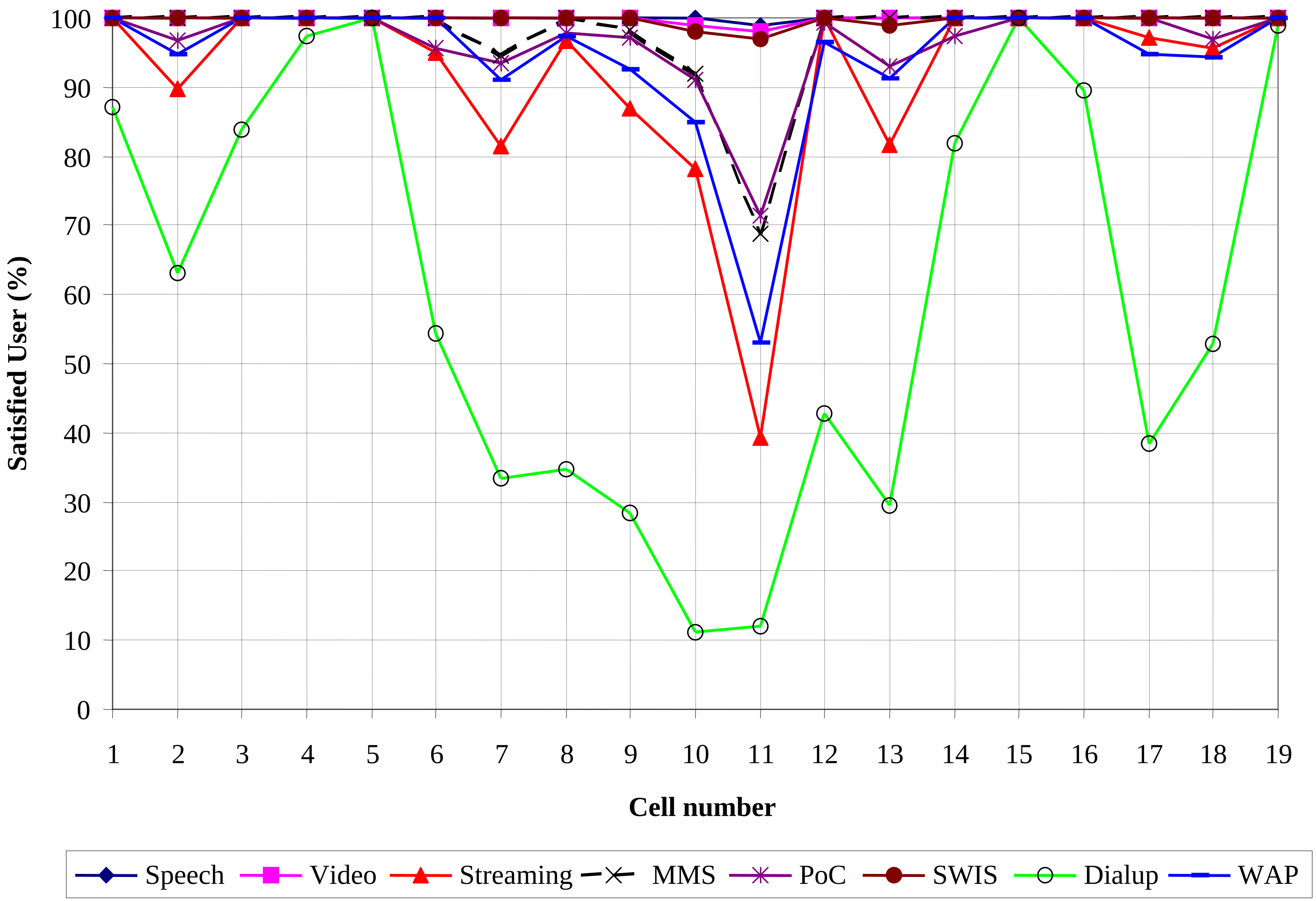
PS, AC, LC, PC work as intended, and power estimates are sufficiently accurate

Cell 11: Power distribution functions



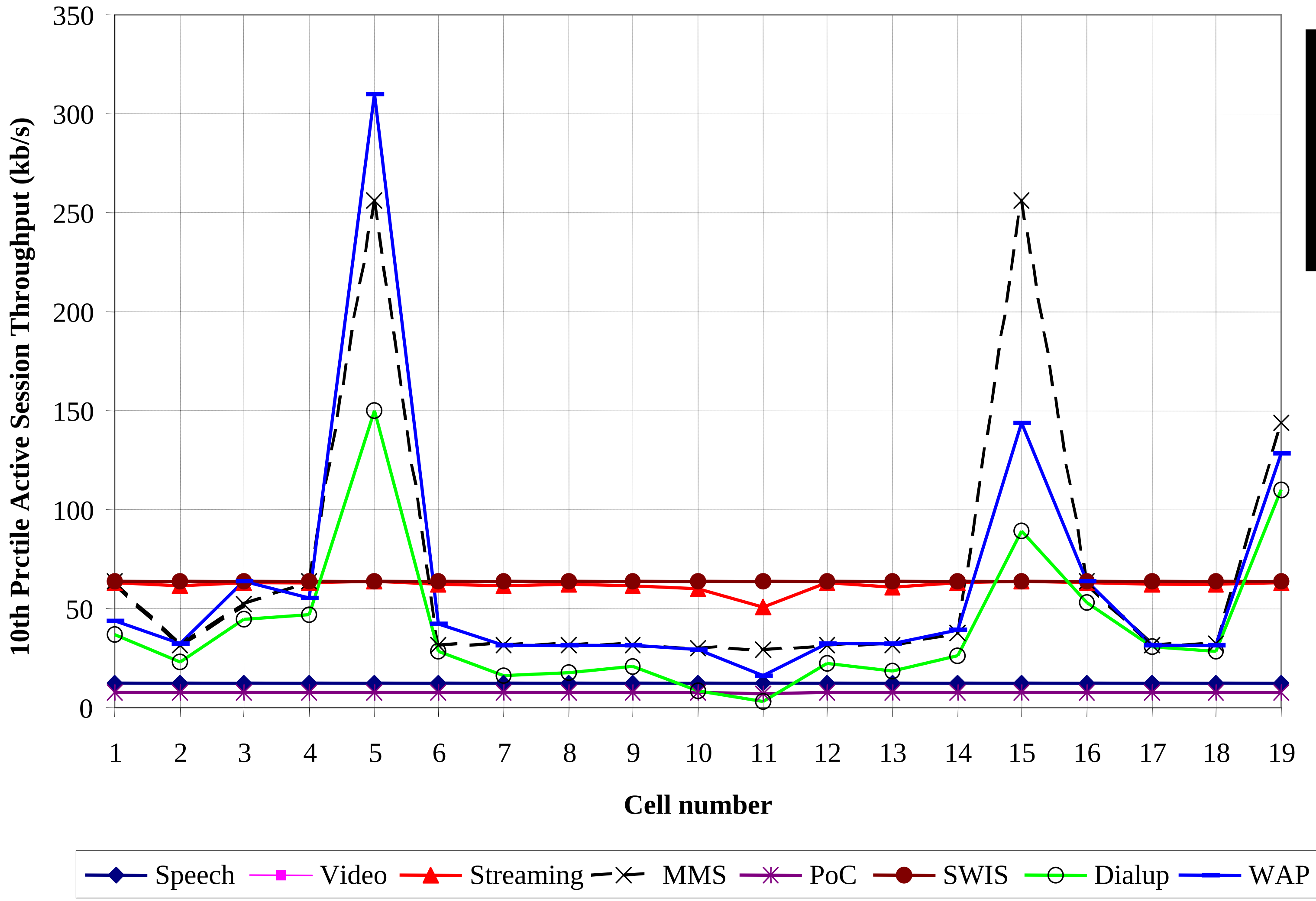
The distributions comply with the input parameter values and load status in the cell

Service based indicators for each of the simulated cells: Percentage of satisfied users



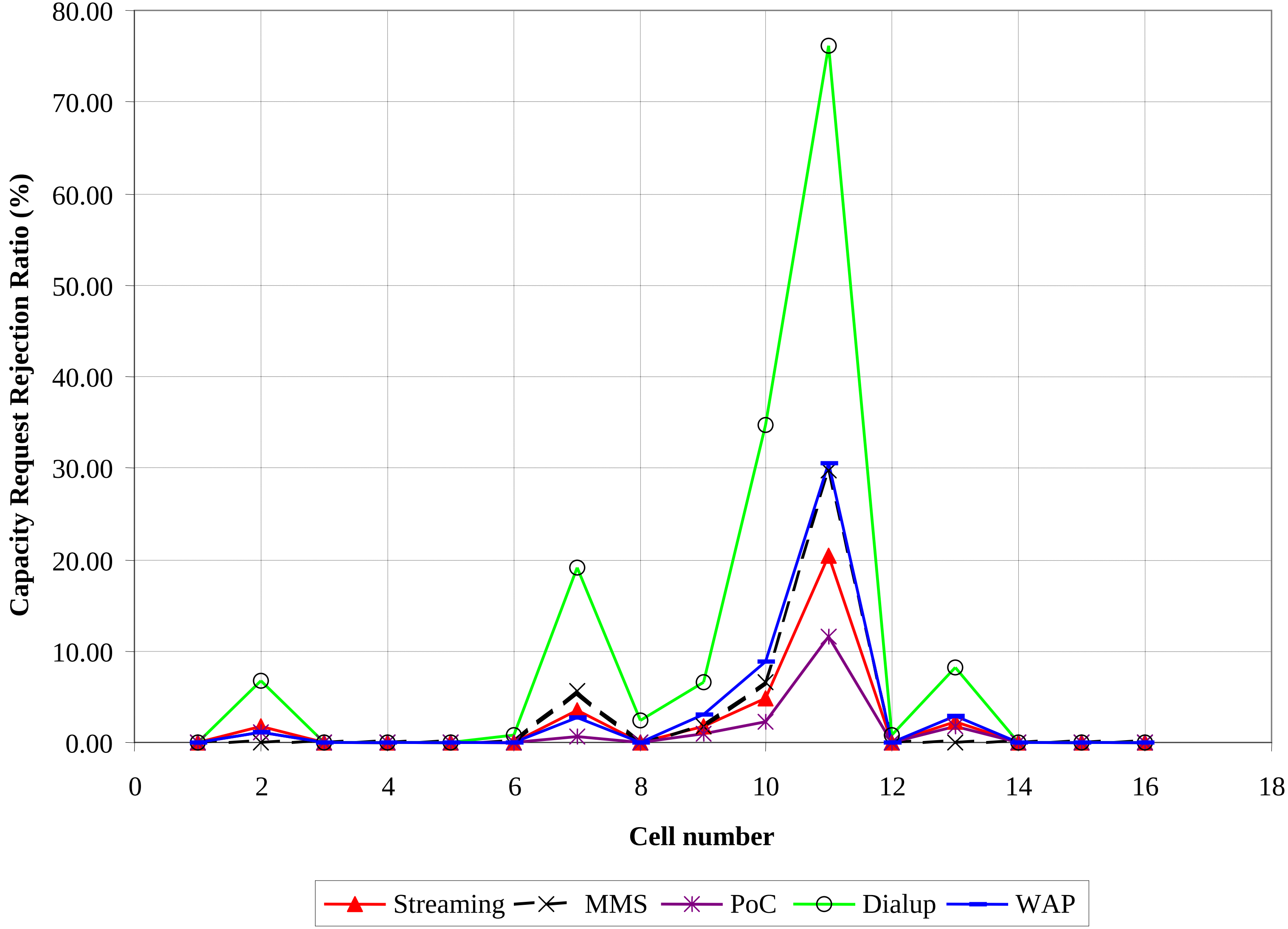
The % of satisfied users reflects exactly the provisioned discrimination between GB and NGB services

10th percentile of the average active session throughput during the simulated time



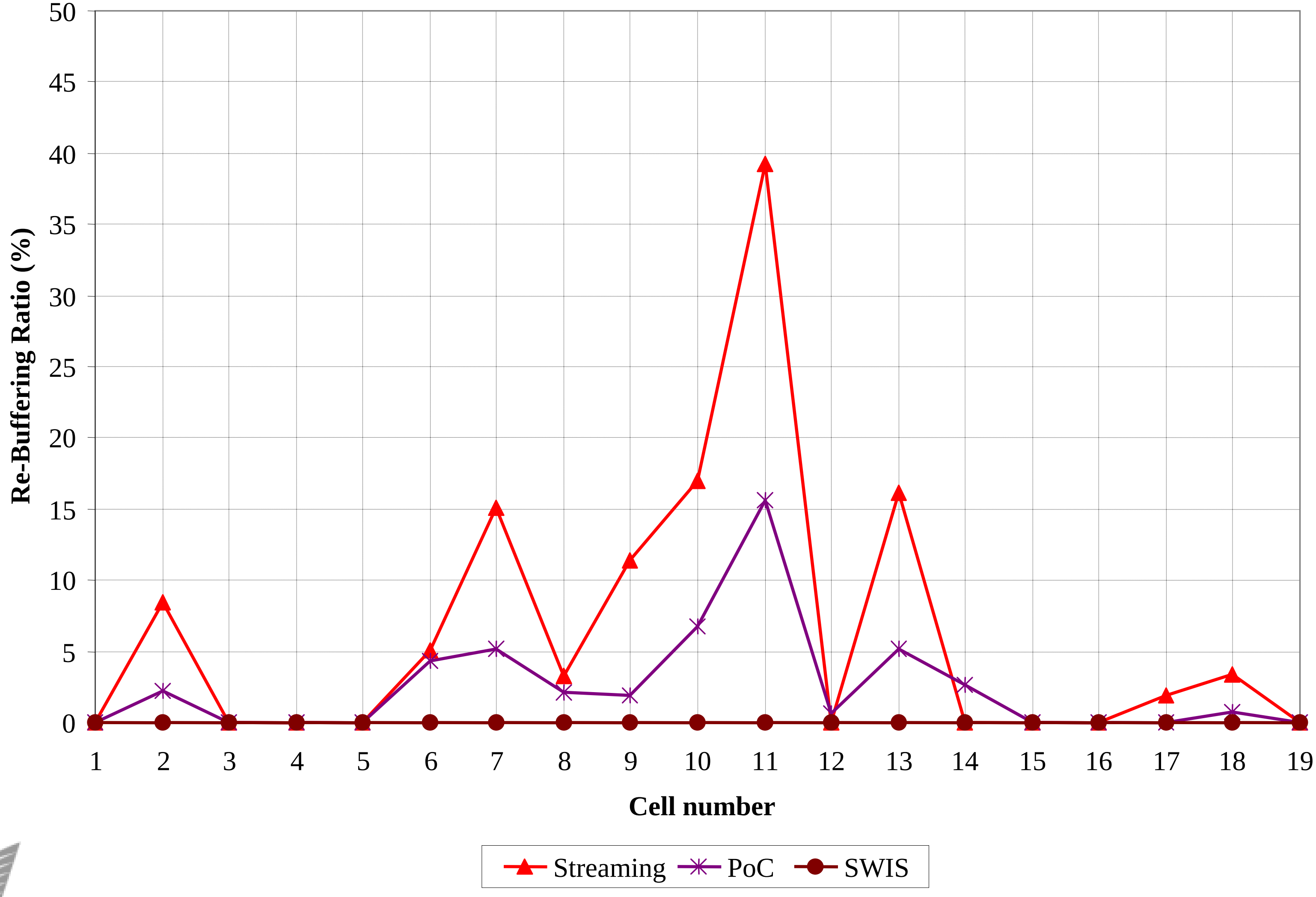
The monitored AST reflects exactly the NGB service differentiation

Service based performance indicators: Capacity request rejection ratio



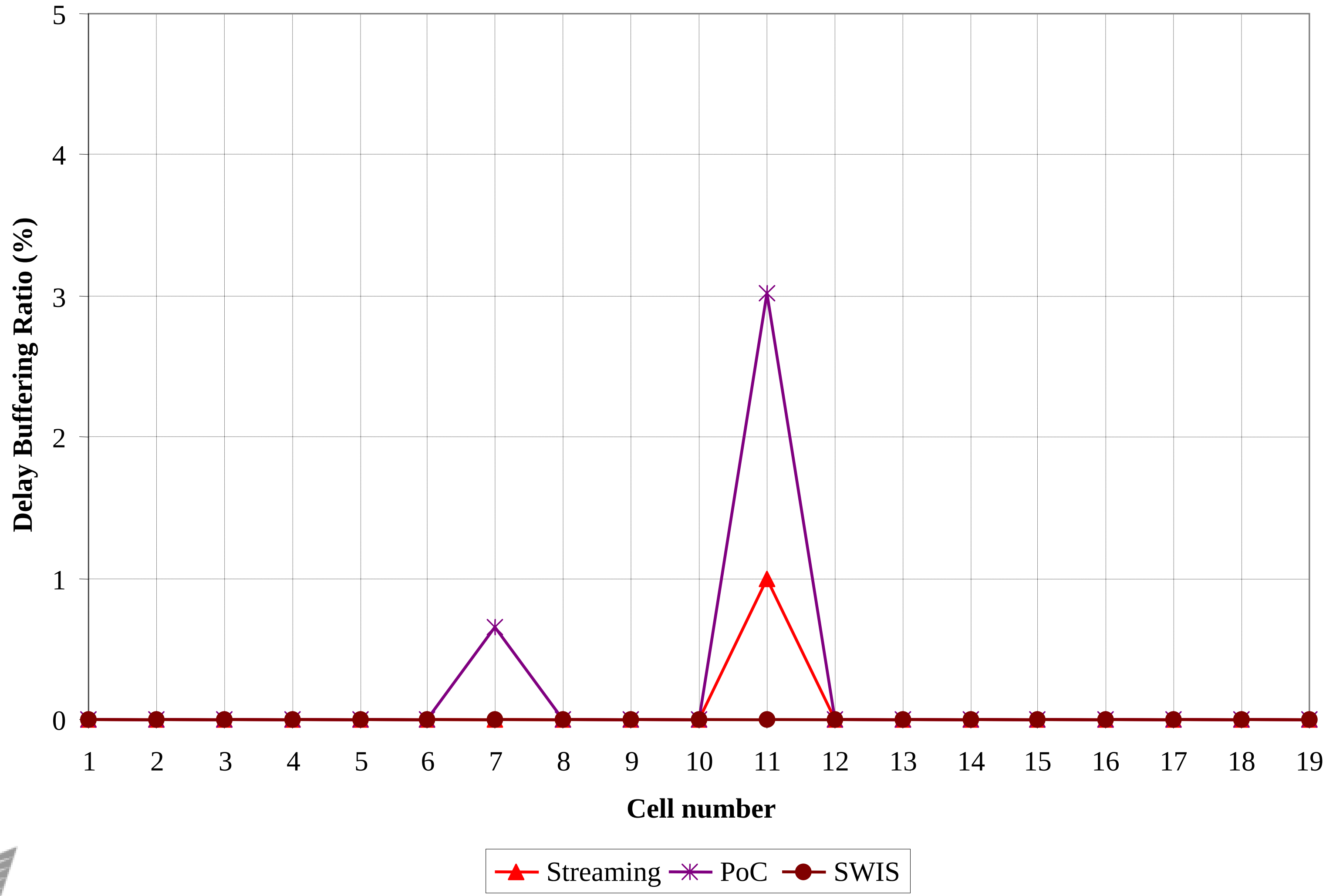
The monitored CRRR reflects exactly the NGB service differentiation

Service based performance indicators: Re-buffering ratio



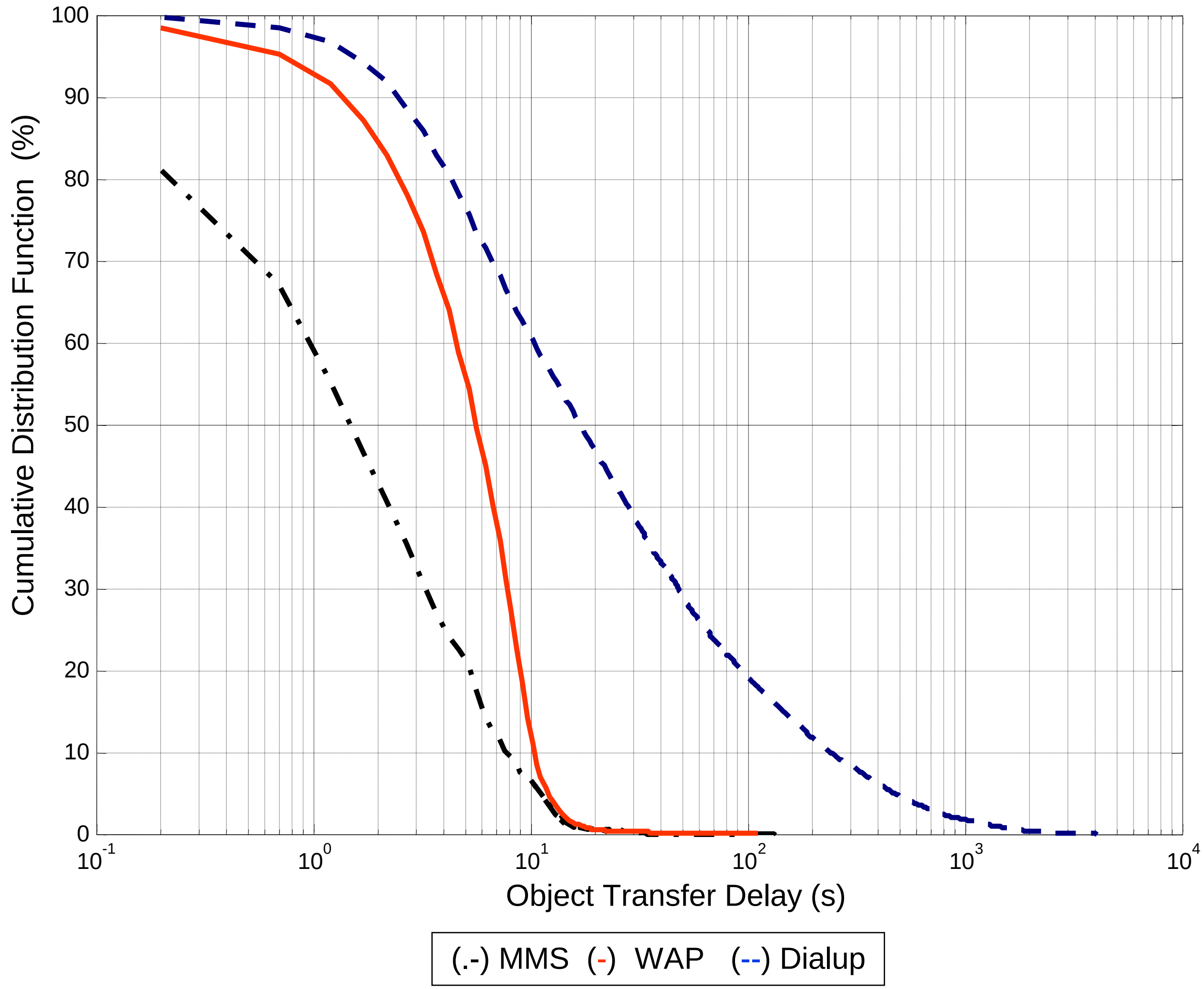
The re-buffering ratio is correctly higher for streaming

Service based performance indicators: Too long time needed for re-buffering ratio



The tolerance of streaming users is higher than for PoC

MMS, WAP and Dialup object transfer delays (system based statistics upon all simulated time)



The measured metrics reflect exactly the calculated object delays from the median of AST and object size, hence PrC and PM functions work as intended

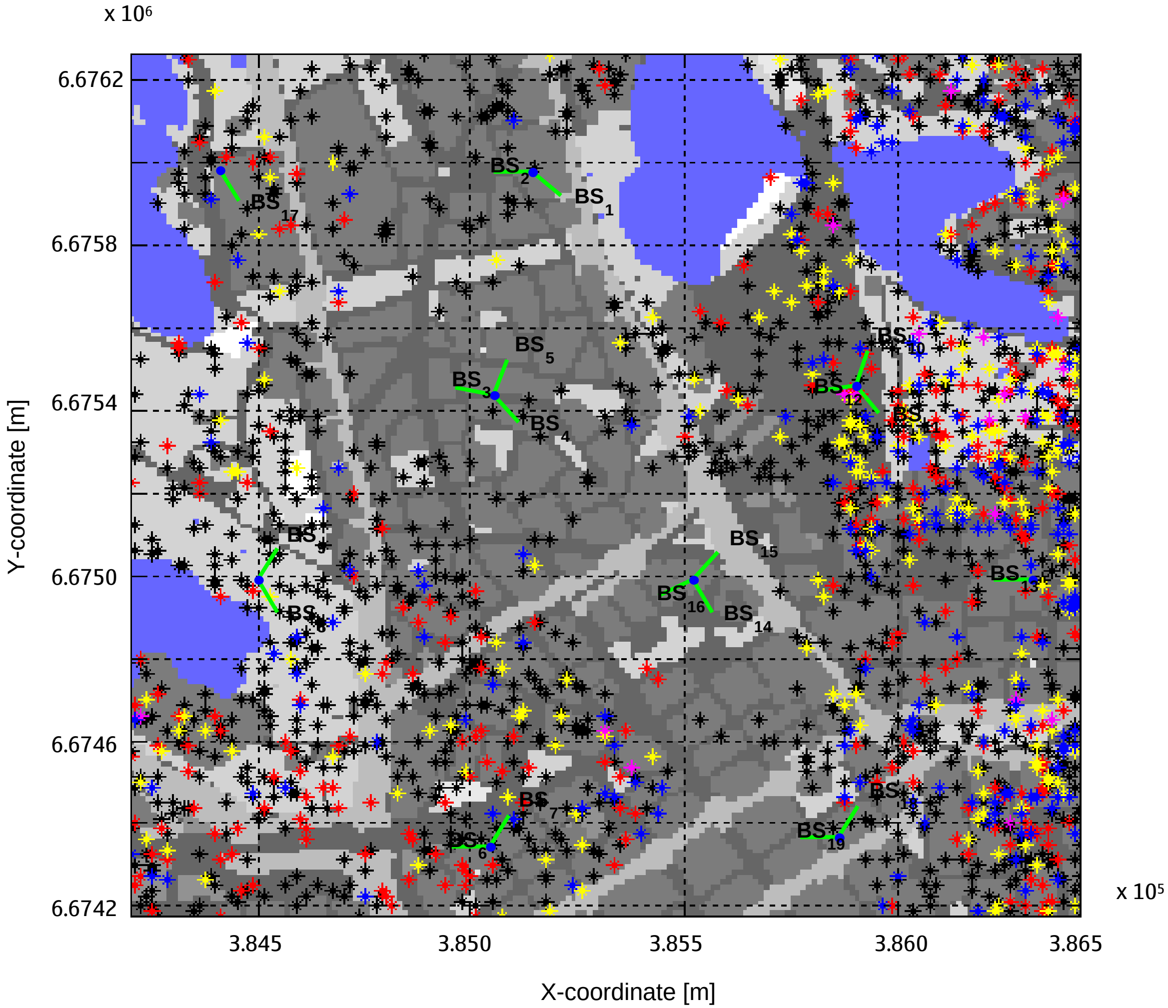
System based measurement results (1/2)

Service type	CBR (%)	CDR (%)	CRRR (%)	RBR (%)	DBR (%)	Median AST (kb/s)	Median Object Size (kB)	Calculated Object Delay (s)	SU (%)
Speech	0.05	0.00	-	-	-	12.2	-	-	99.95
Video	0.16	0.00	-	-	-	64.0	-	-	99.84
Streaming	0.00	0.00	1.93	6.35	0.05	63.4	1682	212.2	91.67
MMS	0.00	0.00	2.29	-	-	70.5	15	1.7	97.55
PoC	0.00	0.03	1.08	2.49	0.19	8.0	4	4.0	96.31
SWIS	0.32	0.00	-	0.00	0.00	64.0	89	11.1	99.68
Dialup	0.00	0.00	8.44	-	-	51.4	120	18.7	59.94
WAP	0.00	0.05	2.57	-	-	66.0	48	5.8	94.24

Note: RBR = Re-Buffering Ratio, DBR = Delay Buffering Ratio; SU = Satisfied Users

Consistent with the provisioned QoS for each of the deployed services

System based measurement results (2/2)

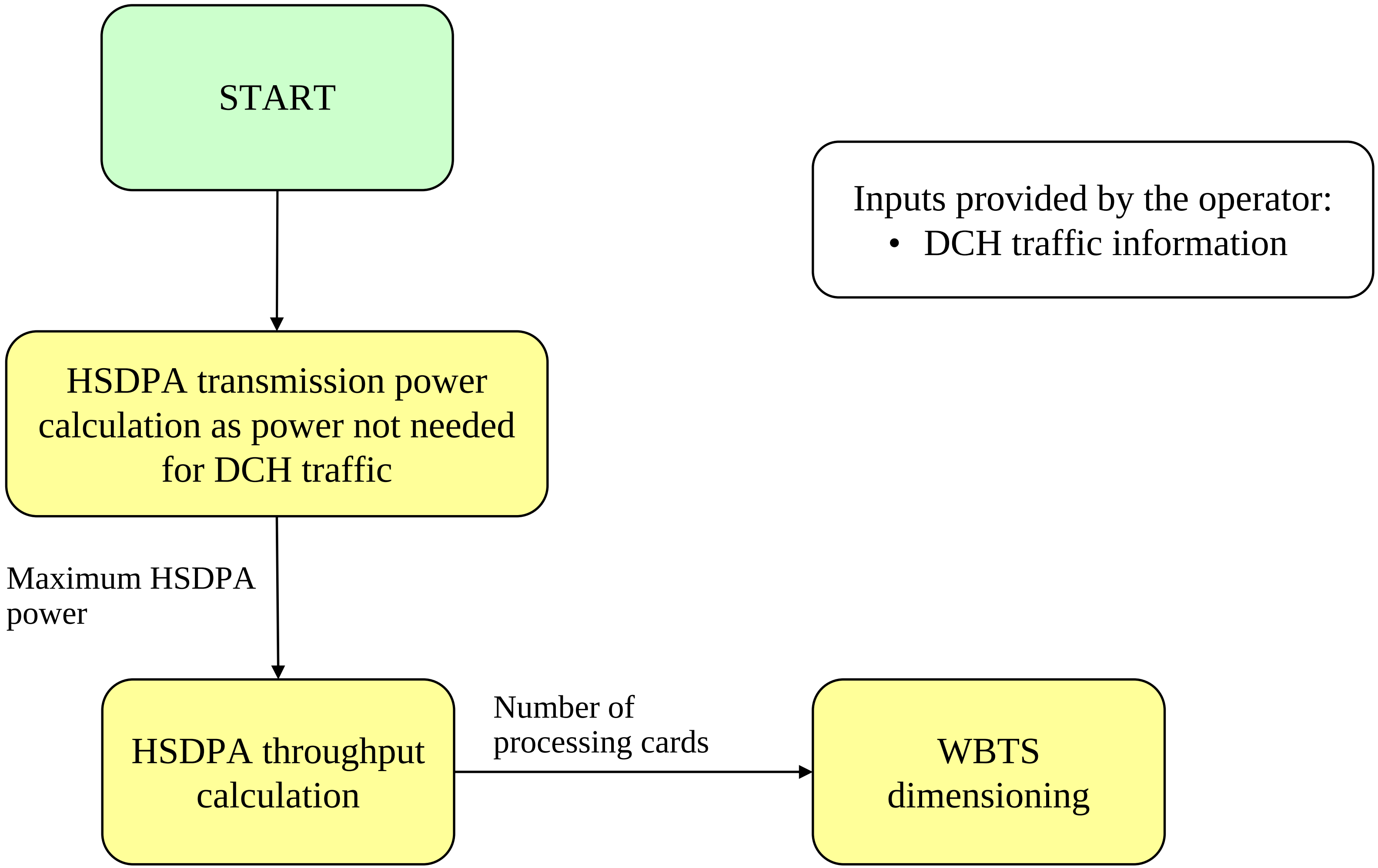


Dissatisfied users: (*) Dialup, (*) PoC, (*) WAP, (*) Streaming, (*) MMS

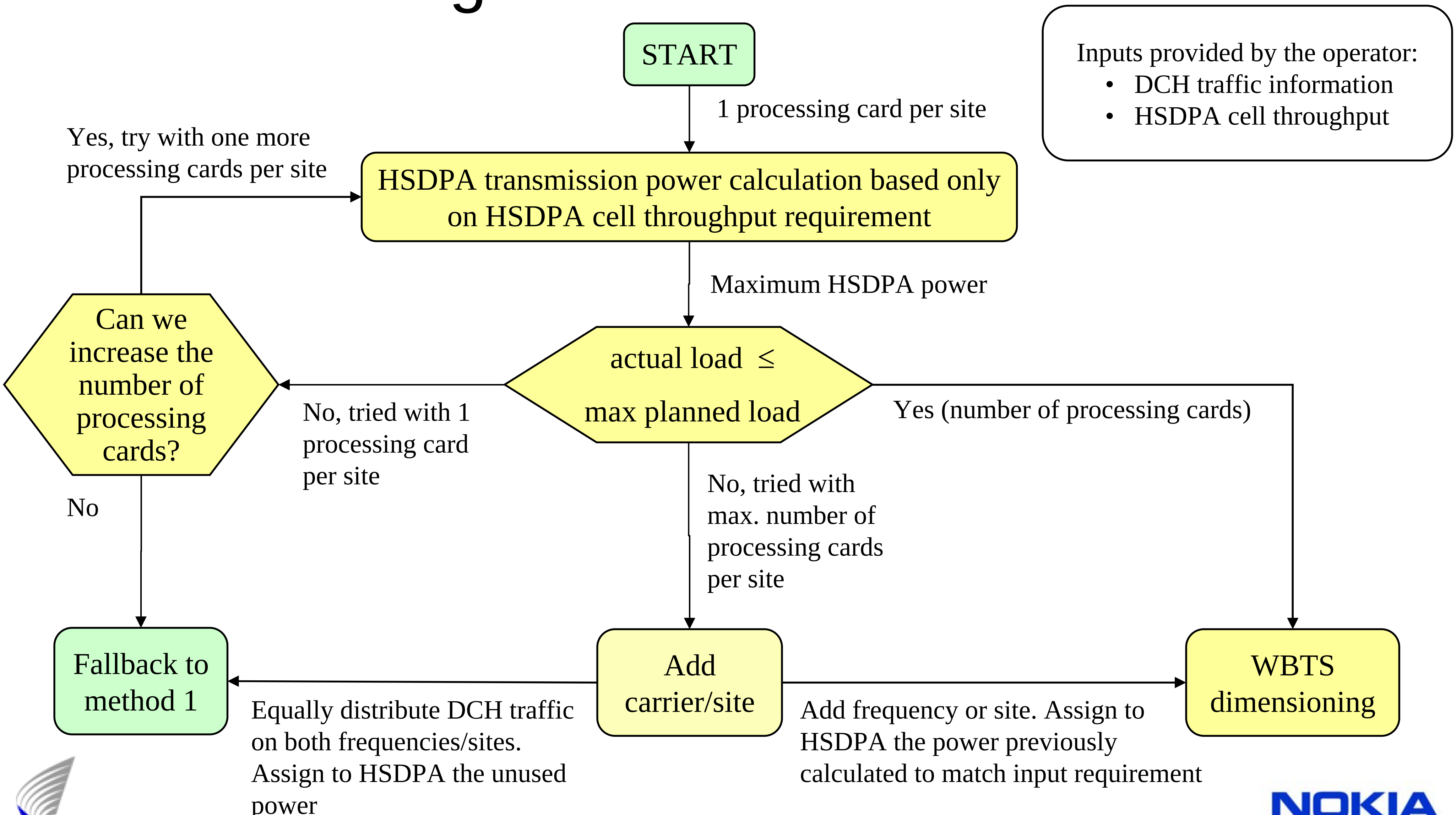
HSDPA dimensioning

- **DL radio dimensioning issue that arises from the introduction of HSDPA in an existing operating WCDMA network**
- **Derives the maximum HSDPA throughput**, or the HSDPA power, if the throughput is provided as an input, as a function of the actual cell load (due to dedicated and common channels), admission and congestion control thresholds
- Also, the results of this process can be used to find out whether **resources already allocated for WCDMA are sufficient for a satisfactory HSDPA service, or it is necessary to add new carriers or sites**
- **Effects on coverage** can be estimated using the proposed changes to the radio link power budget calculation

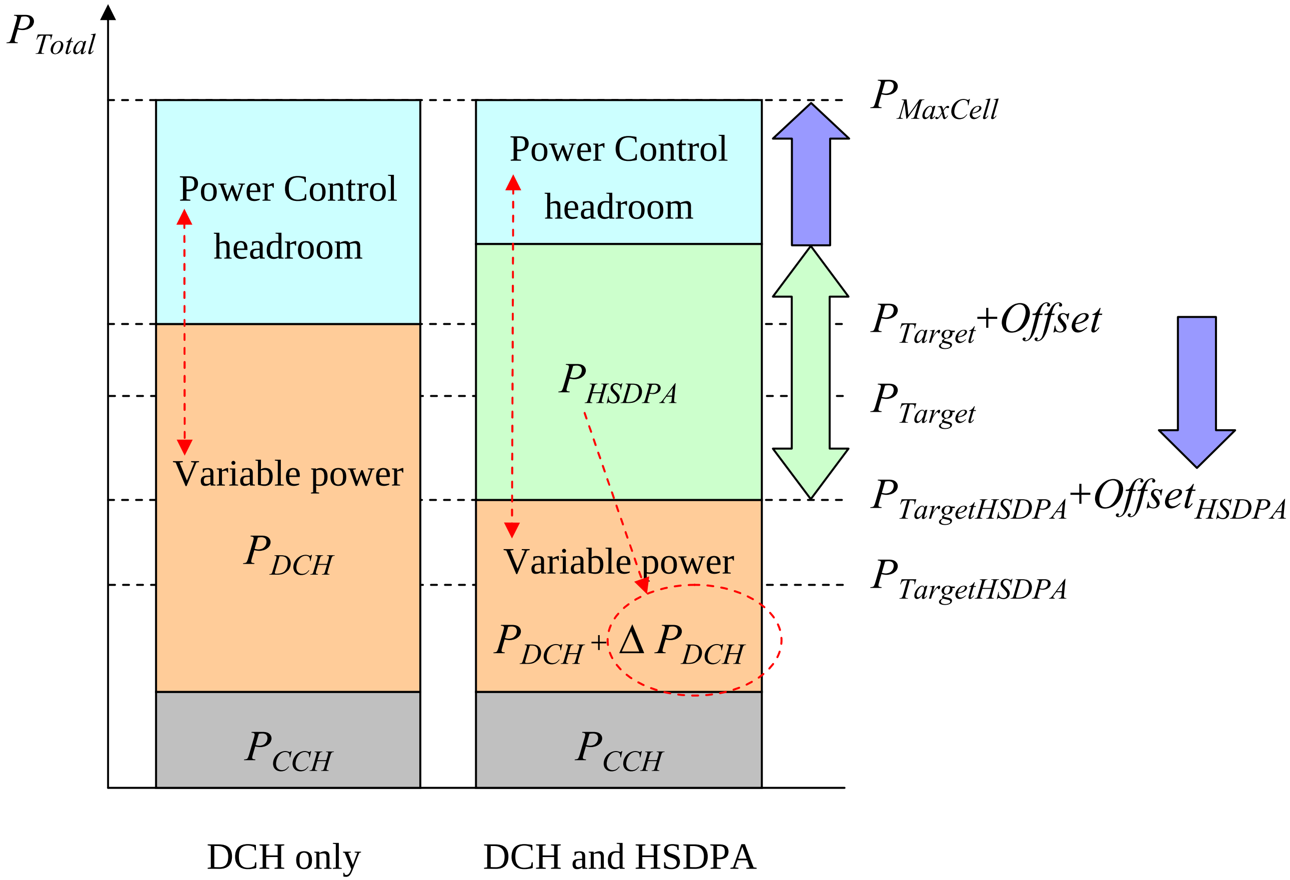
Dimensioning: Method 1



Dimensioning: Method 2



Downlink Power Budget



Mathematical background

- **Maximum utilisation of resources**

Maximum DL load factor with DCH only

Dedicated Channels power*

$$P_{HSDPA} = \frac{\eta_{DCH\max} - \dfrac{P_{DCH} + P_{CCH}}{P_{MaxCell}}}{\dfrac{1}{P_{MaxCell} - P_{DCH}} - \dfrac{1-\eta_{DCH\max}}{P_{MaxCell} - P_{CCH}}}$$

Maximum Cell transmission power

(e.g. 43 dBm = 20 W)

Common Channels power

(e.g. 33 dBm = 2 W)

- **Relationship between HSDPA power and signal quality (SINR)**

Spreading Factor of the HS Dedicated Shared Channel

Total allocated HSDPA power

HS Shared Control Channel power

$$SINR = SF_{HS-PDSCH} \cdot \frac{C}{I} = SF_{HS-PDSCH} \cdot \frac{P_{HSDPA} - P_{HS-SCCH}}{P_{Total} \cdot \left(1 - \alpha + \dfrac{1}{G}\right)}$$

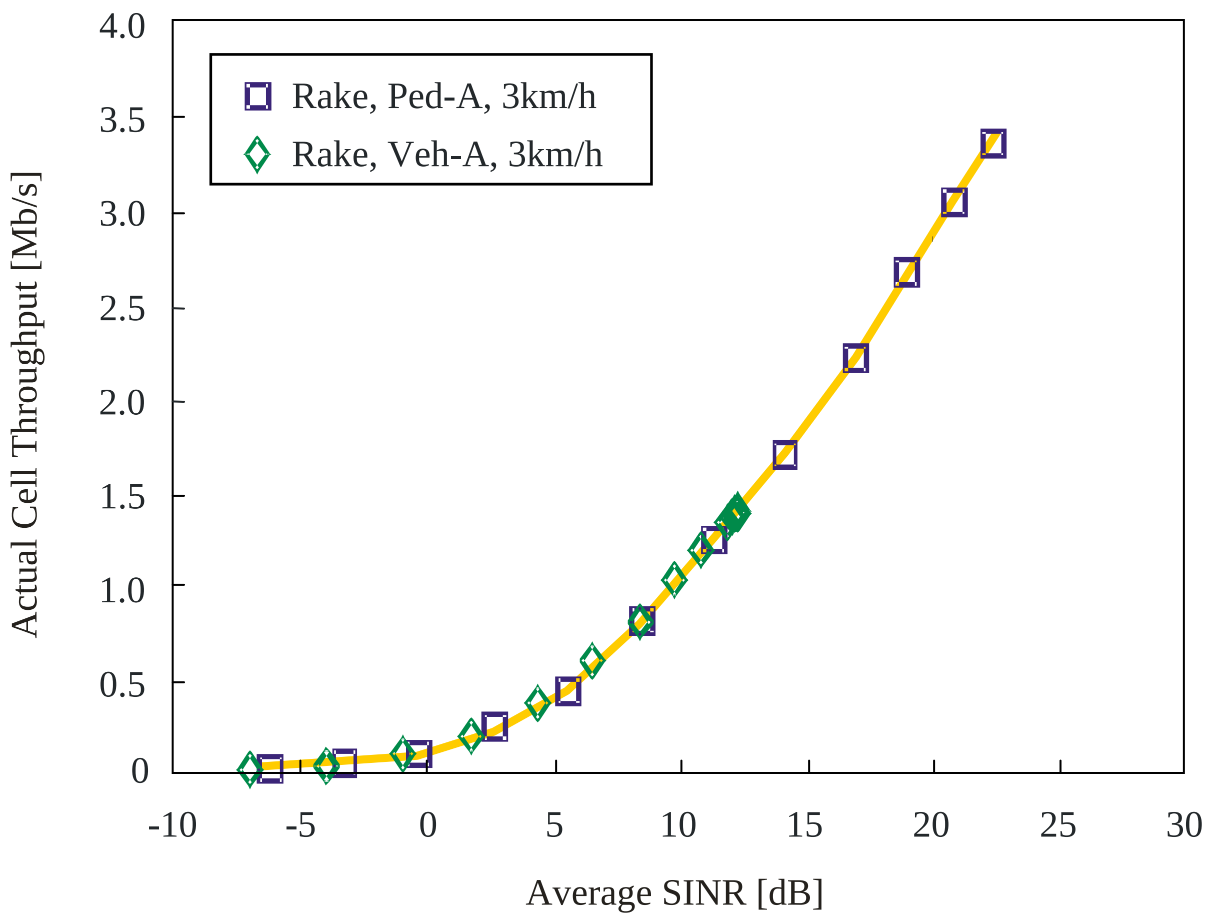
Total Cell transmission power

Orthogonality factor

Geometry factor (*G*), for user position

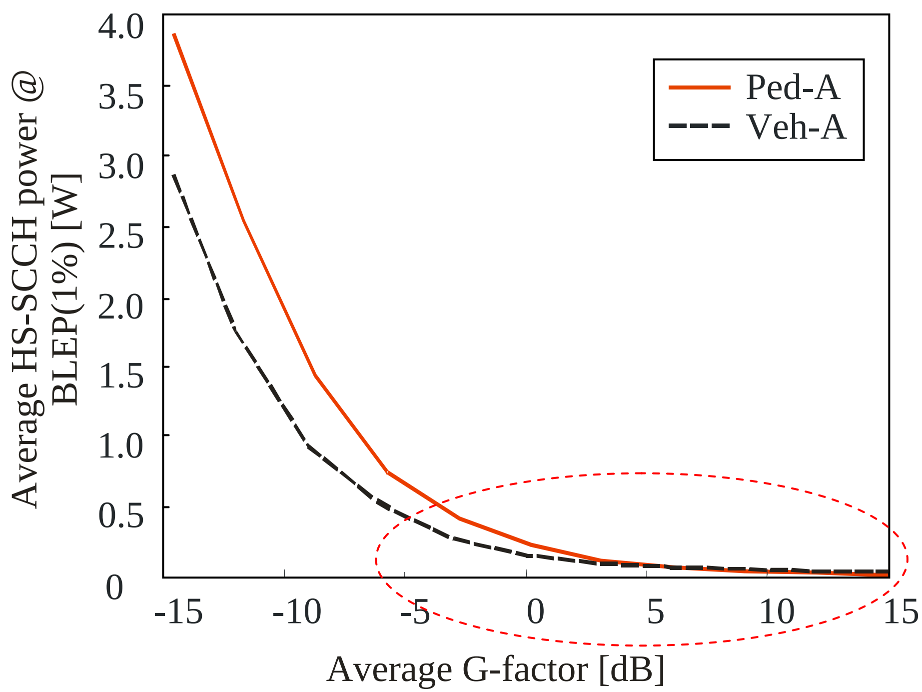
* This may be derived from DCH throughput (see page 6)

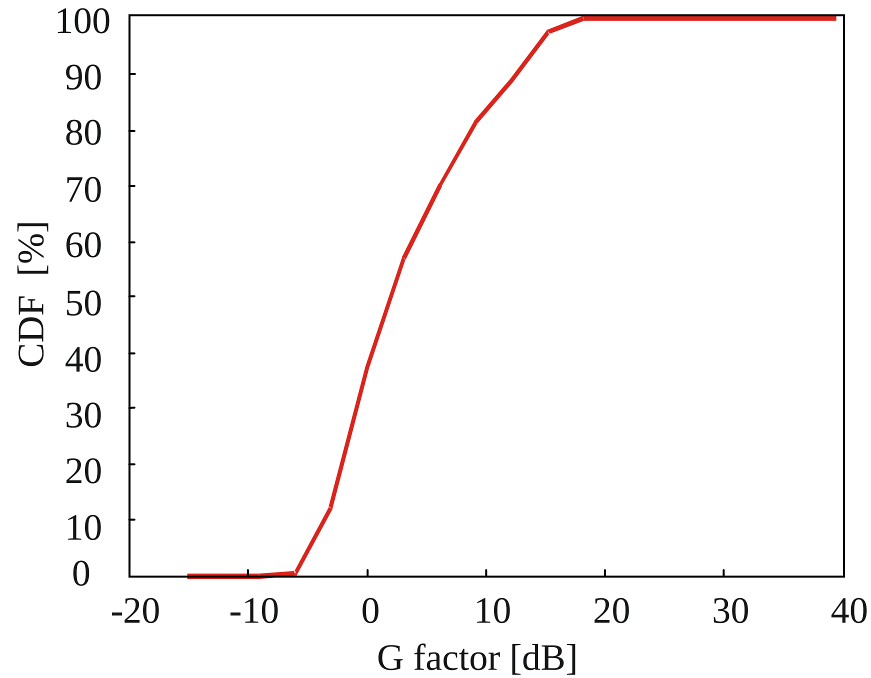
Cell Throughput vs. Average SINR



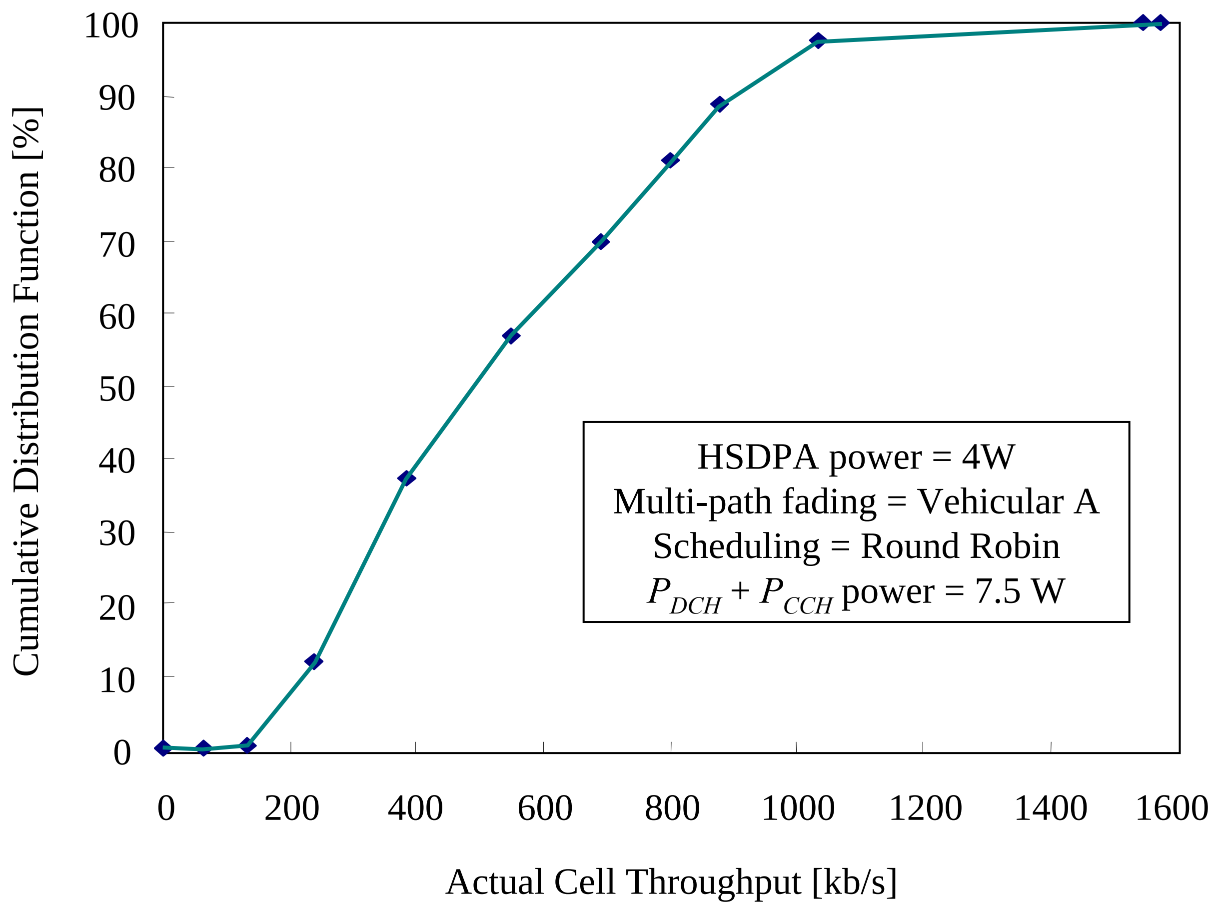
- Performance results attained for five HS-PDSCH codes using a link-level simulator, where the HS-DSCH was 100% utilised
- When more HSDPA users are active in the cell, the throughput per connection depends e.g. on the packet data transfer activity factor and scheduling algorithm
- In case of RR scheduling the average cell throughput shown in the figure is equally divided among the active users

HS-SCCH Power and User Location



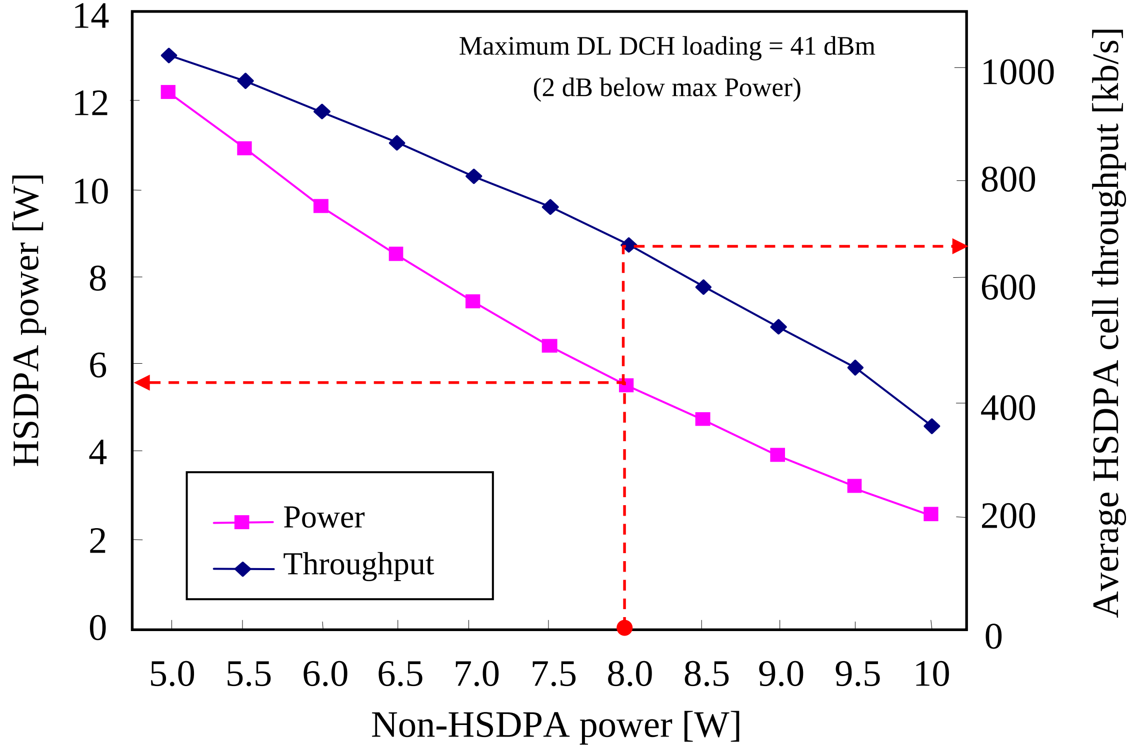


CDF of the Actual Throughput



Case 1: No Requirements on HSDPA

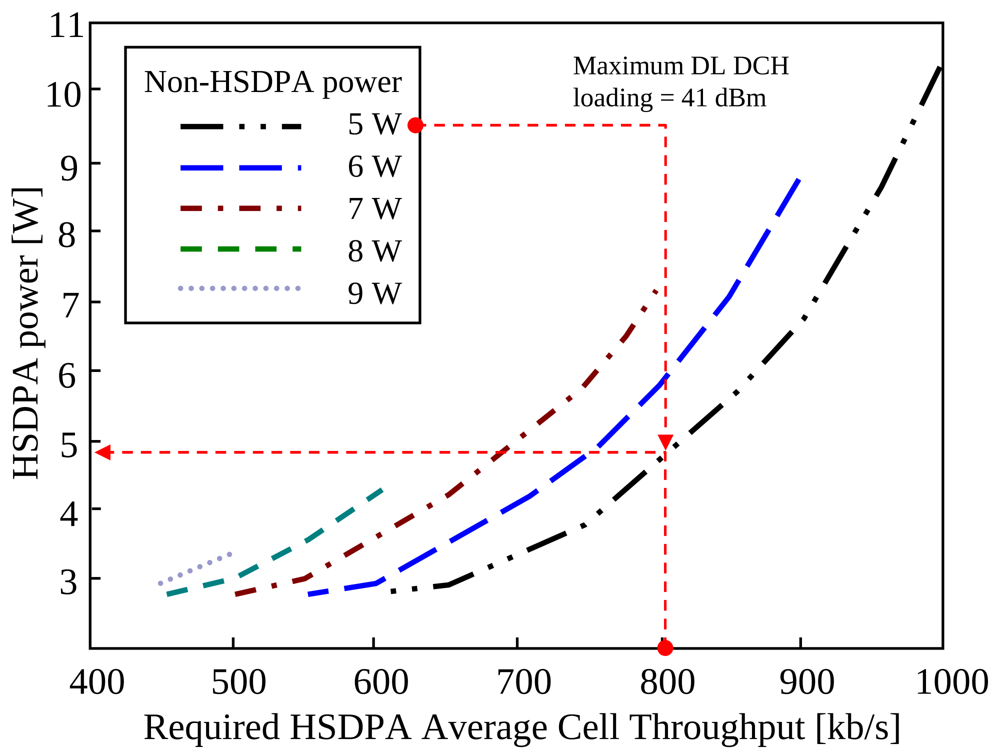
- **Inputs:**
  - Non-HSDPA power (P_{DCH}+P_{CCH})*
  - Maximum DL DCH loading
  - *G* Cumulative Distribution Function
- **Parameters:**
  - Orthogonality Factor (α)
- **Outputs:**
  - HSDPA power
  - Available Average HSDPA Throughput



* For converting DCH throughput value into DCH power setting see pag.6

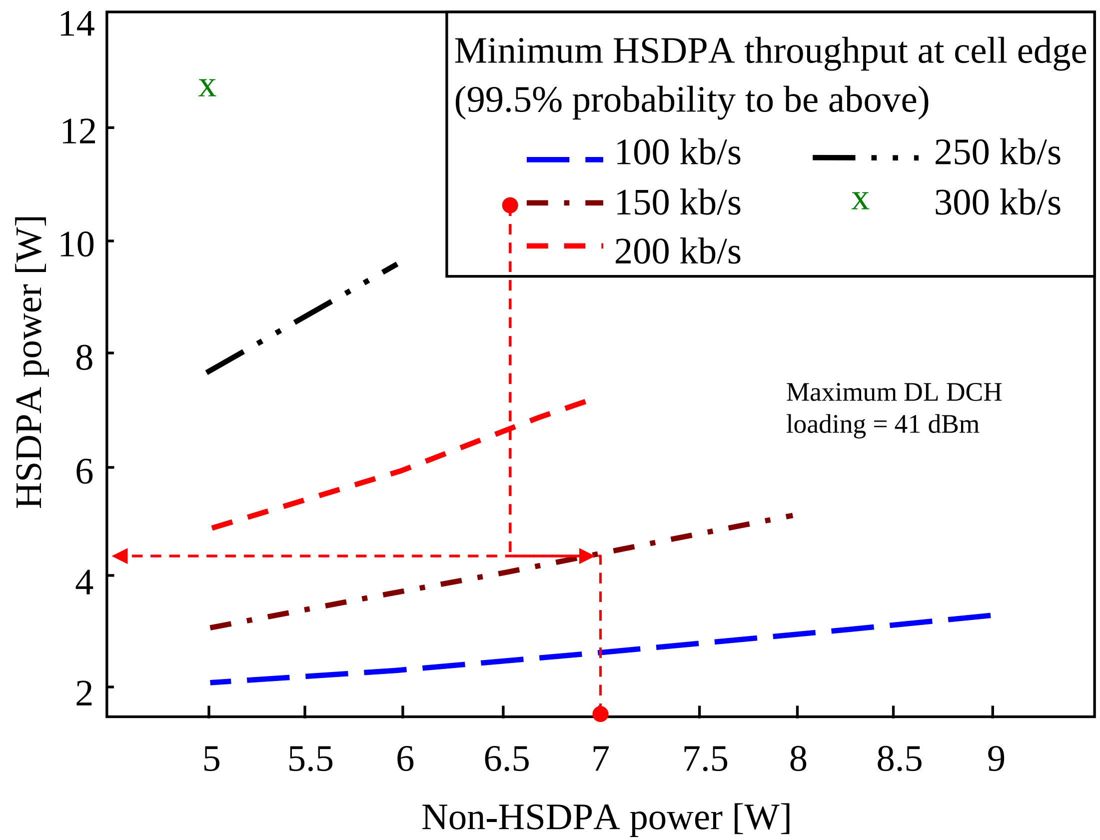
Case 2: Average HSDPA Cell Throughput

- **Inputs:**
  - Average HSDPA cell Throughput
  - Non-HSDPA power (all codes)
  - Maximum DL DCH loading
  - *G* Cumulative Distribution Function
- **Parameters:**
  - Orthogonality Factor (α)
- **Outputs:**
  - HSDPA power



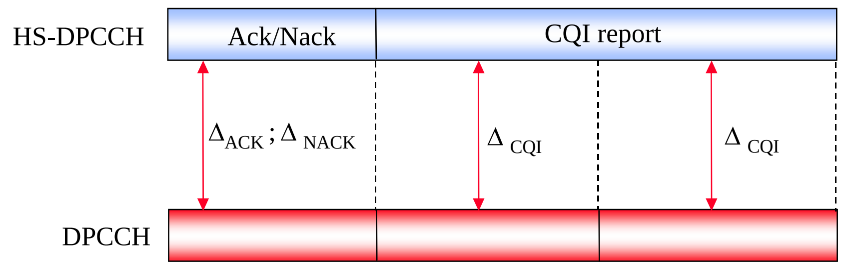
Case 3: Min HSDPA throughput at cell edge

- **Inputs:**
  - Minimum HSDPA Throughput at cell edge
  - Non-HSDPA power (all codes)
  - Maximum DL DCH loading
  - *G* Cumulative Distribution Function
- **Parameters:**
  - Orthogonality Factor (α)
- **Outputs:**
  - HSDPA power



Impact on Uplink Radio Link Budget

Service	Speech	CS Data	PS Data	
Service Rate	12.2	64	64	kb/s
Transmitter - Handset				
Max Tx Power	21	21	21	dBm
Tx Antenna Gain	0	0	0	dBi
Body Loss	3	0	0	dB
HS-DPCCH Offset	0	0	1	dB
EIRP	18	21	20	dBm
Receiver - Node B				
Node B Noise Figure	3			dB
DAS Loss	0			dB
Thermal Noise	-174			dBm/Hz
Uplink Load	50			%
Interference Margin	3.0			dB
Interference Floor	-102.1			
Service Eb/No	4.4	2	2	dB
Service PG	25.0	17.8	17.8	dB
Rx Antenna Gain	18.0	18.0	18.0	dBi
Receiver Sensitivity	-140.7	-135.9	-135.9	dB
UL Fast Fade Margin	3	3	1.8	dB
UL Soft Handover Gain	2	2	0	dB
Slow Fade Margin	0	0	0	dB
Max. Path Loss	**157.7**	**155.9**	**154.1**	dB



- HS-DPCCH introduces an overhead that can be taken into account as an offset to be added to the target DCH E_b/N_0, i.e.

$$\left(\frac{E_b}{N_0}\right)_{HSDPA} = \left(1 + \frac{\Delta_{ACK} \cdot r^2}{1 + r^2}\right) \cdot \left(\frac{E_b}{N_0}\right)_{DCH}$$

where $r = \beta_c / \beta_d$ and Δ_{ACK} is as in the following table

DCH service	Δ_{ACK} and Δ_{NACK}	Δ_{CQI}
64/128 kbps	2	0
384 kbps	0	-2

Impact on Downlink Radio Link Budget

Service	HSDPA	
Transmitter – Node B		
Max Tx Power (HSDPA)	6.5	W
Max Tx Power (HSDPA)	38.1	dBm
Tx Antenna Gain	18	dBi
Cable Loss	4	dB
EIRP	52.1	dBm
Receiver - Handset		
Handset Noise Figure	8	dB
Thermal Noise	-108	dBm
Background RSSI	-100	dBm
Planned DL load	87	%
Interference Margin	8.9	dB
Interference Floor	-91.1	dBm
SINR	2.1	dB
Service processing gain	12.0	dB
Rx Antenna Gain	0	dBi
Body Loss	0	dB
Receiver Sensitivity	-101.1	dB
DL Fast Fade Margin	0	dB
DL Soft Handover Gain	0	dB
Max. Path Loss	153.2	dB

- The estimation of the path loss is derived as in the case of DCH taking into account that:
  - Maximum Tx Power is HSDPA power, not the Total transmission power (e.g. 43 dBm)
  - SHO gain is equal to zero
  - Planned E_b/N_0 is replaced by the SINR calculated at the cell border, i.e. G = – 5 dB
  - Processing gain is $10*\log_{10}(SF_{HS\text{-}PDSCH})$ = 12 dB

(E)GPRS dimensioning

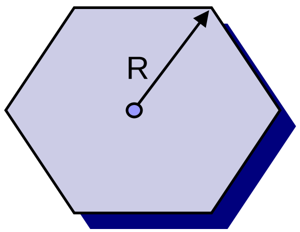
- Inputs
  - CS traffic to be supported during the busy hour (Erlangs)
  - PS traffic to be supported during the busy hour (throughput, kb/s/cell)
  - (E)GPRS layer characteristics: BCCH (frequency reuse), non-hopping (frequency reuse) or hopping layer (number off frequencies per BTS)
  - Average MS time slot capability (maximum number of TSLs an MS can support in the uplink and downlink)
- Dimensioning targets
  - Number of TSLs (TRXs) needed for CS and PS traffic
  - Average PS load supported (kb/s/cell)
  - Maximum possible PS load supported (without CS load, kb/s/cell)
  - Minimum guaranteed PS traffic (kb/s/cell)
  - PS average throughput per MS (kb/s)
  - Throughput (kb/s) for 90% of user connection time in poor radio link conditions (at the border of the cell)

CS traffic dimensioning

- Assumption during the busy hours
  - Arrivals follows a Poisson distribution with no queuing
  - Blocking probability (*BP*), e.g. 2% at Um
  - mErl (erlangs per user, e.g. 25 mErl voice, 5 mErl video)
  - Population density (P) and cell coverage area (C)
- Calculations
  - Traffic per cell (BTS) = mErl * P * C
  - N_{CS} (number of TSLs) = InvErlangB (*BP*, *Traffic per cell*)

Hexagons & Clusters ...

- Use hexagons only for explanation purposes, but never in real planning !

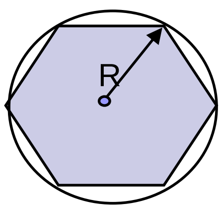


hexagon area : $A = \dfrac{3\sqrt{3}\,R^2}{2}$

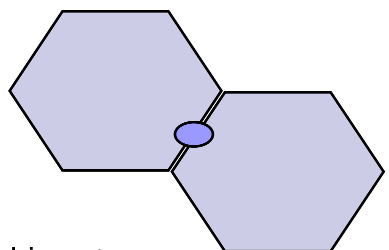
cluster re-use distance : D/R = sqrt(3) *K

cluster numbers : $K = (i+j)^2 - i*j$ = 1, 3, 4, 7, 9, 12, 13, ...
(i, j = 0...N)

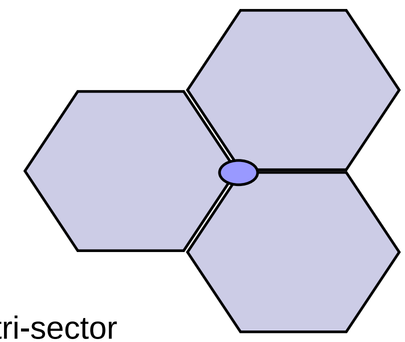
- Typical site configurations



Omni
$A = 2{,}6\ R^2$



bi-sector
area = 1,3 A



tri-sector
area = 1,95 A

Channels (Traffic, BP)

		Blocking probability									
		1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
Erlangs	1	5	4	4	4	4	4	3	3	3	3
	2	7	6	6	5	5	5	5	5	5	4
	3	8	8	7	7	7	6	6	6	6	6
	4	10	9	9	8	8	8	7	7	7	7
	5	11	10	10	9	9	9	9	8	8	8
	6	13	12	11	11	10	10	10	9	9	9
	7	14	13	12	12	11	11	11	10	10	10
	8	15	14	14	13	13	12	12	12	11	11
	9	17	15	15	14	14	13	13	13	12	12
	10	18	17	16	15	15	14	14	14	13	13
	11	19	18	17	16	16	15	15	15	14	14
	12	20	19	18	18	17	17	16	16	15	15
	13	22	20	19	19	18	18	17	17	16	16
	14	23	21	21	20	19	19	18	18	17	17
	15	24	23	22	21	20	20	19	19	18	18
	16	25	24	23	22	21	21	20	20	19	19
	17	27	25	24	23	22	22	21	21	20	20
	18	28	26	25	24	23	23	22	22	21	21
	19	29	27	26	25	24	24	23	23	22	22
	20	30	28	27	26	26	25	24	24	23	23
	21	31	29	28	27	27	26	25	25	24	24
	22	32	31	29	28	28	27	26	26	25	25
	23	34	32	30	29	29	28	27	27	26	26
	24	35	33	32	31	30	29	28	28	27	27
	25	36	34	33	32	31	30	29	29	28	28
	26	37	35	34	33	32	31	30	30	29	29
	27	38	36	35	34	33	32	31	31	30	29
	28	39	37	36	35	34	33	32	32	31	30
	29	40	38	37	36	35	34	33	33	32	31
	30	42	39	38	37	36	35	34	34	33	32
	31	43	41	39	38	37	36	35	35	34	33
	32	44	42	40	39	38	37	36	35	35	34
	33	45	43	41	40	39	38	37	36	36	35
	34	46	44	42	41	40	39	38	37	37	36
	35	47	45	43	42	41	40	39	38	38	37
	36	48	46	44	43	42	41	40	39	39	38
	37	49	47	45	44	43	42	41	40	40	39
	38	51	48	46	45	44	43	42	41	40	40
	39	52	49	47	46	45	44	43	42	41	41
	40	53	50	48	47	46	45	44	43	42	42
	41	54	51	50	48	47	46	45	44	43	43
	42	55	52	51	49	48	47	46	45	44	43
	43	56	53	52	50	49	48	47	46	45	44
	44	57	55	53	51	50	49	48	47	46	45
	45	58	56	54	52	51	50	49	48	47	46
	46	59	57	55	53	52	51	50	49	48	47
	47	61	58	56	54	53	52	51	50	49	48
	48	62	59	57	55	54	53	52	51	50	49
	49	63	60	58	56	55	54	53	52	51	50
	50	64	61	59	57	56	55	54	53	52	51

PS traffic dimensioning

- Assumption during the busy hours
  - Throughput per cell (T_{PS}) in kb/s
  - Time Slot Capacity (*TSLC*) in kb/s
- Calculations
  - N_{PS} (number of TSLs) = roundup (T_{PS} / TSLC)

  Where the *TSLC* estimate depends on
    - EGPRS/GPRS layer(s): BCCH, Hopping and Non-Hopping
    - CS traffic presence
    - DL power control

Typical values for TSLC

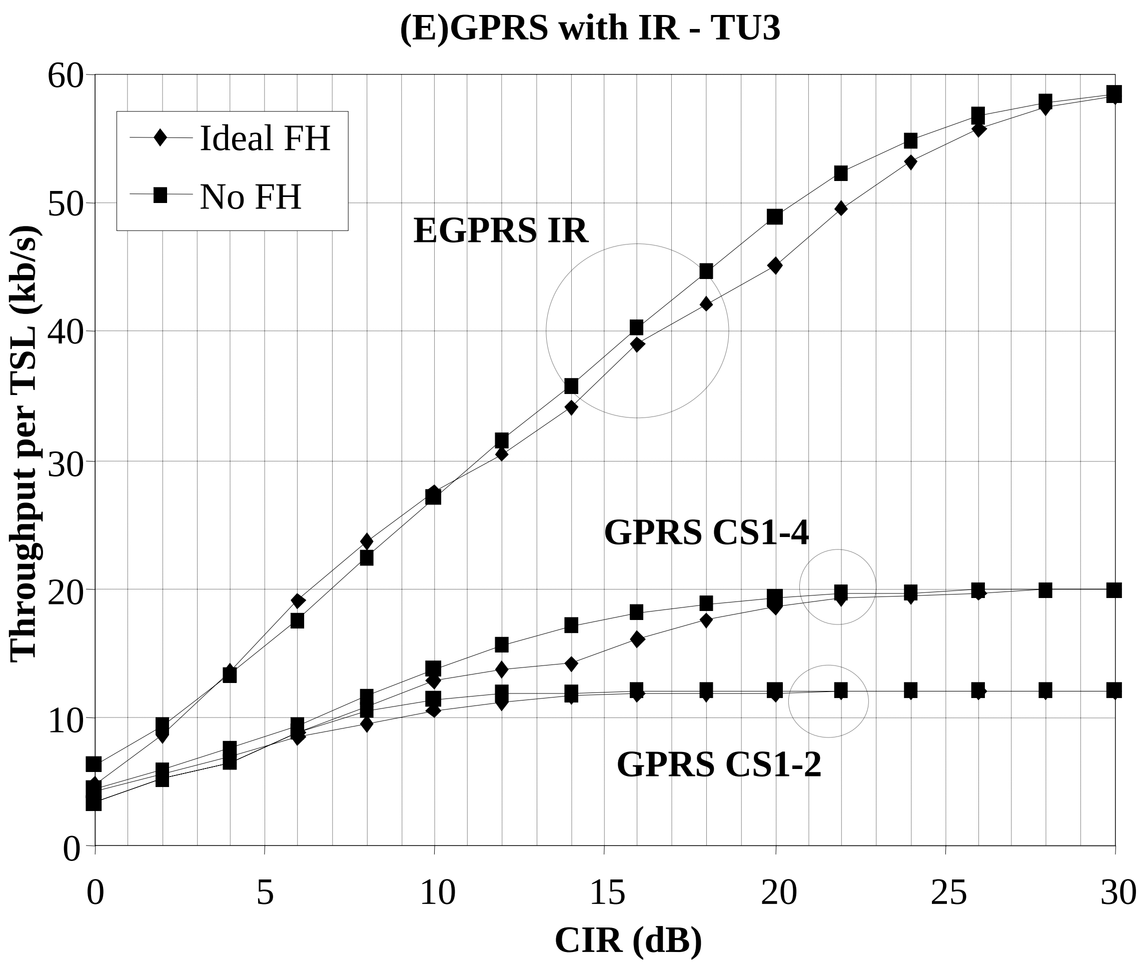
- On average

Layer	GPRS (CS1-2) (kb/s)	GPRS (CS1-4) (kb/s)	EGPRS (MCS1-9) (kb/s)
BCCH	11	20	45
Non hopping	11-10	20-14	40-20
Hopping	12-10	10-18	55-20

- At cell border

Layer	GPRS (CS1-2)	GPRS (CS1-4)	EGPRS (MCS1-9)
Any	10 kb/s	12 kb/s	25 kb/s

TLSC at a given CIR and technology



(E)GPRS dimensioning results

- $TotalTSL = N_{CS} + GuardTSL + (N_{PS} - DedicatedTSL) + DedicatedTSL$

  Where *GuardTSL* is safety guard between CS and PS traffic and *DedicatedTSL* is the territory size dedicated to PS traffic

- $TotalTRX = TotalTSL / N_{of\ TSLs\ per\ TRX}$

  Where 1 TRX (BCCH) = 7 TSLs, otherwise 7.5 slots assumed on average

Performance estimates

- *Max possible PS load* = $(N_{CS} + N_{PS}) * TSLC$
- *Average supported PS load* = $N_{PS} * TSLC$
- *Min supported PS load = DedicatedTSL * TSLC*
- *Mean user throughput = AverageMScapability * ReductionFactor * TSLC*
- *Min user throughput = AverageMScapability * ReductionFactor * min TSLC*

(E)GPRS dimensioning with QoS

For GB and NBR services

- $RadioCapacity_{jt}$ = (1 + $ACMargin$) * $BSforService_j$ / $TSLC_t$
- $TSL_{service}$ = U_{Total} * Sum_j ($S_{ActiveBHj}$ * Sum_t ($RadioCapacity_{jt}$ * Share MS_t))

For BE services

- $UserBH$ = $BH\ Usage$ * $MonthlyUserData$ / 30
- $TotalThroughput$ = U_{Total} * Sum_j ($ServicePenetration_j$ * $UserDataBH_j$ * $Size_j$) / 3600
- $TSL_{service'}$ = $TotalThroughput$ / $TSCL$

$$N_{PS} = TSL_{service} + TSL_{service'}$$

Example: input parameters (1/2)

- Assumptions on the user profile
  - 1000 users in the cluster (denoted by U_{Total})
  - 10% active streaming users during the BH ($S_{ActiveBH}$)
  - 20% active PoC users during the BH
- Assumption on MS capability:
  - Average EGPRS MS capability: 2 DL + 1 UL
  - 60 % EGPRS-capable MSs
  - Average GPRS MS capability: 3 DL + 1 UL
  - 40% GPRS-capable MSs

Example: input parameters (2/2)

- Traffic mix and QoS requirements

Application	Traffic class	Bit rate	Penetration
Video streaming:	Streaming	GB = 32 kb/s	
PoC:	Int. THP1	NBR = 8 kb/s	
Browsing:	Int. THP 2	NBR = 0 kbps	50%
WAP	Int. THP 3	NBR = 0 kbps	70%
MMS	Int. THP 3	NBR = 0 kbps	80%
Email	Background	NBR = 0 kbps	50%
Downloads	Background	NBR = 0 kbps	50%

- Average CIR per cluster provides a *TLSC* of 25 kb/s and 12 kb/s for EGPRS and GPRS respectively
- *AC margin* = 10%

Solution (1/2)

Streaming

- Radio capacity (EGPRS) = (1+0.1)*32/25 = 1.4 TSL / MS
- Radio capacity (GPRS) = (1+0.1)*32/12 = 2.7 TSL / MS
- $TSL_{streaming}$ = 1000 * 0.1 *(1.4 * 60% + 2.7 * 40%) = 192 TSL /Cluster

PoC

- Radio capacity (EGPRS) = (1+0.1)*8/25 = 0.4 TSL / MS
- Radio capacity (GPRS) = (1+0.1)*8/12 = 0.7 TSL / MS
- $TSL_{streaming}$ = 1000 * 0.2 *(0.4 * 60% + 0.7 * 40%) = 104 TSL /Cluster

$TSL_{service}$ = 296 TSL /Cluster

Solution (2/2)

Services	Monthly User Data (amount of events per user per month) <u>Input</u>	Service penetration (%) <u>Input</u>	User BH data (events per user in BH)	Total data volume in BH all users (MB)	Bit rate all Users BH (kb/s)	Size per event (kB) <u>Input</u>	Units
MMS	50	80	0.28	13.6	30.22	60	MMS
Email	100	50	0.57	5.67	12.59	20	Email
Itneractive WWW	62.5	50	0.35	21.25	47.22	120	Web page download
Media services download	50	50	0.28	14.17	31.48	100	Media file download
WAP	750	70	5	175	388.89	50	WAP pages
Total				**229.68**	**510.41**		

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

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See also:

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