Dimensioning of the Shared Transport Network for Collocated Multiradio: LTE and HSDPA

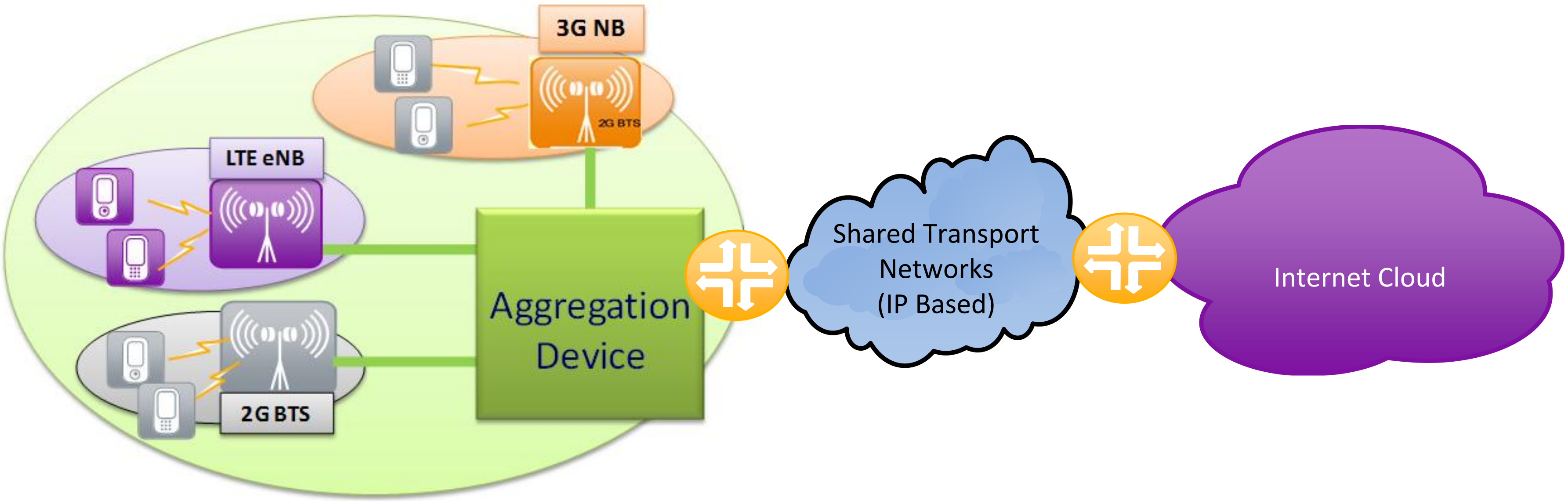
Ming Li, M.Sc.

FFV Workshop 2012-II

October 19th, Hamburg

X. Li, M. Li, U. Toseef, D. Dulas, M. Nowacki, A. Timm-Giel, C. Goerg, R. Ruchala, "Dimensioning of the Shared Transport Network for Collocated Multiradio: LTE and HSDPA" in the WiMob 2012, Barcelona, October, 2012.

Shared Transport Network for Collocated Multiradio



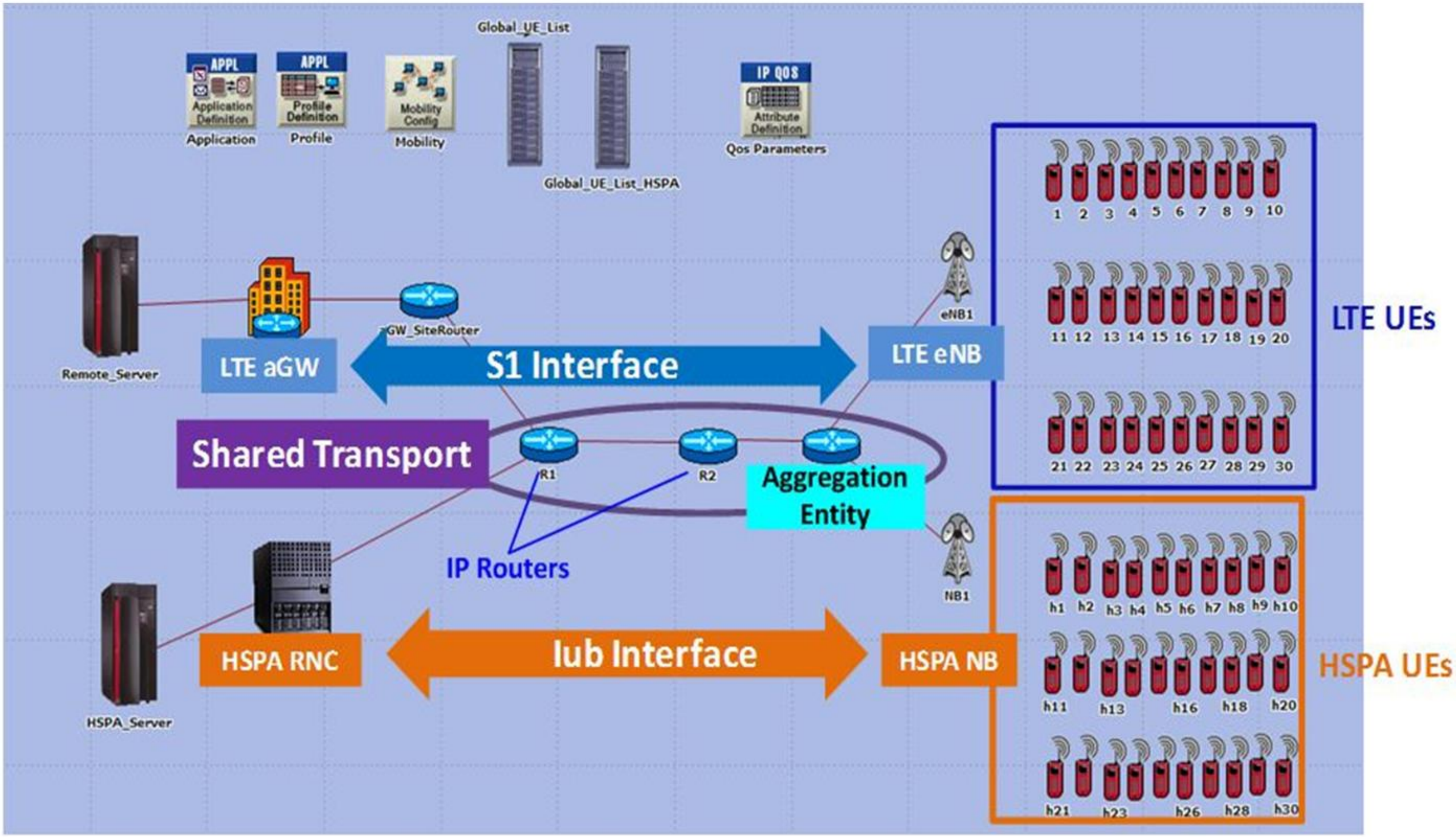
We propose a multiradio shared transport system

- Reduced costs on renting transport resources
- Maximized reuse of existing infrastructure
- Provide smooth migration to new technologies (LTE and LTE-Advanced)

Different radio technologies (2G, 3G, LTE) will still coexist for some time

How to aggregate the traffic?
How much gain do we have?
How to dimension the common link?

Overview of our Simulation Model



Our Focuses and Contributions

- Our Focuses
  - Focus on the elastic traffic (TCP-based traffic)
  - Cover the User-Plane interfaces (LTE: S1; HSPA: Iub)
  - Only the DL direction is considered

- Our Contributions
  - Investigate the shared transport network
    - Proposed a QoS framework
    - Analysis of the achievable sharing gain (bandwidth saving)
  - Propose analytical models to dimension the shared link
    - Reduce the dimensioning time from hours/days to several seconds
    - Portable dimensioning tools are implemented

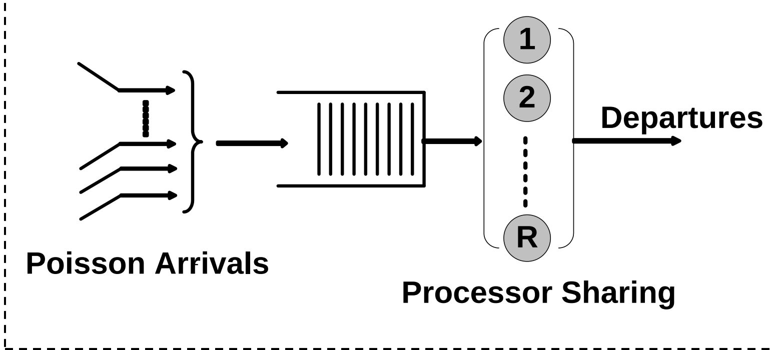
Process Sharing Model for Elastic Traffic

- The dimensioning model for elastic traffic (TCP-based traffic) is based on **M/G/R-PS Model**
  - Due to TCP flow control all TCP flows share the link bandwidth equally → the system can be modeled as a **Processor Sharing** system
  - The M/G/R-PS Model has been used for dimensioning
    - networks, e.g. IP network, ADSL, etc.
    - mobile networks, e.g. UMTS

Assumptions

- Flow arrival follows **Poisson Process**
- **General** file length **distribution**

M/G/R-PS Model



$R = C / r_k$

C: Link capacity

r_k: Flow peak data rate

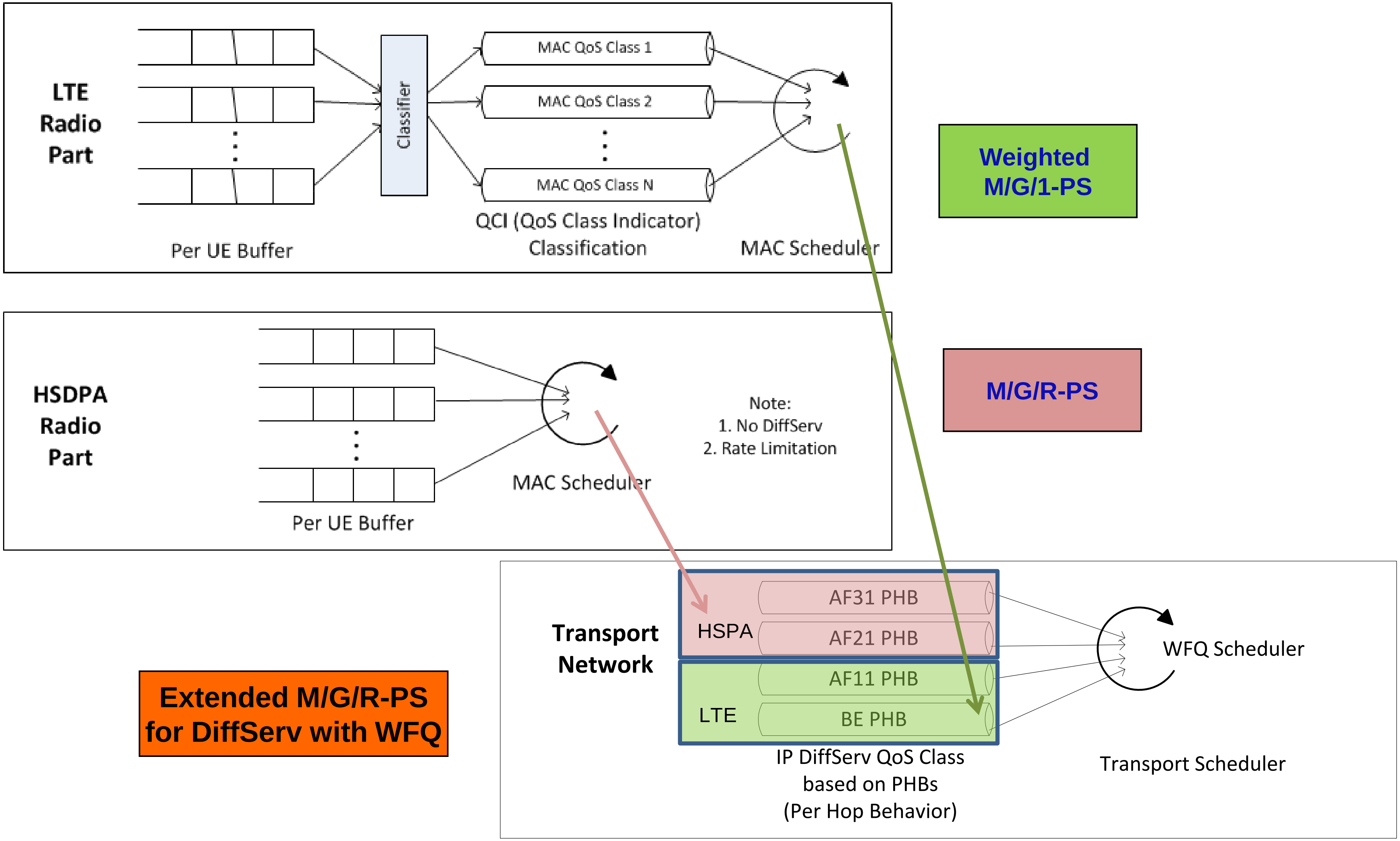
Average File Transfer Delay of QoS class *k*

$$T(x_k) = \frac{x_k}{r_k}\left(1 + \frac{E_2(R_k, R_k\rho_k)}{R_k(1-\rho_k)}\right) = \frac{x_k}{r_k} f_k$$

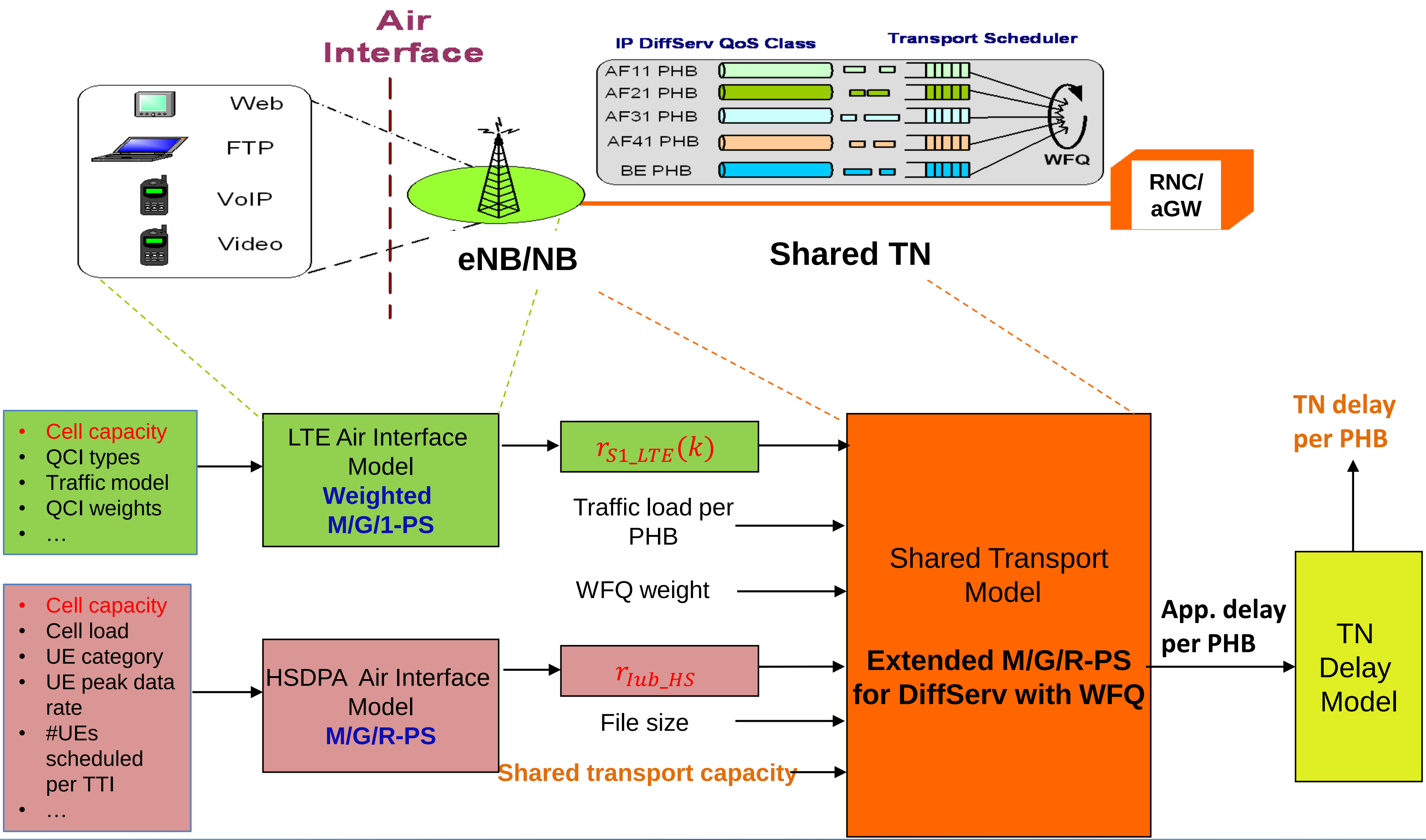
- File length: x_k
- Number of servers: $R = C / r_k$
- Peak data rate: r_k
- Link utilization: ρ_k
- Delay factor: f_k

*Xi Li (PhD thesis): "**Radio Access Network Dimensioning for 3G UMTS**". Vieweg+Teubner Verlag, 2011.*

Dimensioning Models



Dimensioning Framework for Elastic Traffic (nGBR)



Technische Universität Hamburg-Harburg

ComNets

Nokia Siemens Networks

ComNets HH

Modeling the LTE air interface

- Estimate the avg. UE Uu throughput of Elastic traffic (nGBR) with **Weighted M/G/1-PS Model**
  - Model Parameters for elastic traffic
    - Air interface capacity of a LTE cell: C_{Uu_LTE}
    - the defined QCI weight for the QoS class k in LTE MAC scheduler: $W_{QCI}(k)$
    - Mean traffic load of the elastic traffic of QoS class k: $L_{Uu\_LTE}(k)$

a) Step 1: calculate the available cell capacity used for elastic traffic of QCI class k

$$C_{Uu\_LTE}(k) = \max\left\{\left(C_{Uu\_LTE} \cdot \frac{w_{QCI}(k)}{\sum_i w_{QCI}(i)}\right), \left(C_{Uu\_LTE} - \sum_{j \neq k} L_{Uu\_LTE}(j)\right)\right\}$$

b) Step 2: calculate the estimated peak data rate at the LTE S1 interface for each QCI class k

$$r_{S1\_LTE}(k) = C_{Uu\_LTE}(k) - L_{Uu\_LTE}(k)$$

Modeling the HSDPA air interface

- Estimate the avg. UE Uu throughput of Elastic traffic (nGBR) with **M/G/R-PS Model**
  - Model Parameters for elastic traffic
    - Air interface capacity of a HSDPA cell: C_{Uu_HS}
    - Peak data rate (bits/s) of a HSDPA bearer (TCP flow): r_{HS}
    - Mean traffic load of all elastic traffic in a cell: L_{Uu_HS}

a) Step 1: calculate the air interface delay factor

Delay factor | # Servers | Link Utilization

$$f_{Uu\_HS} = \left(1 + \frac{E_2(R_{HS}, R_{HS} \cdot \rho_{HS})}{R_{HS} \cdot (1 - \rho_{HS})}\right)$$

$$where \quad R_{HS} = \left\lfloor \frac{C_{Uu\_HS}}{r_{HS}} \right\rfloor \quad and \quad \rho_{HS} = \frac{L_{Uu\_HS}}{C_{Uu\_HS}}$$

$$E_2(R, A) = \frac{\frac{A^R}{R!} \cdot \frac{R}{R-A}}{\sum_{i=0}^{R-1} \frac{A^i}{i!} + \frac{A^R}{R!} \cdot \frac{R}{R-A}}$$

Erlang's second formula (Erlang C formula)

b) Step 2: calculate the estimated peak data rate on the Iub interface

$$r_{Iub\_HS} = r_{HS} / f_{Uu\_HS}$$

Modeling of the Shared Transport Network

- The dimensioning model for elastic traffic (TCP-based traffic) is based on extended M/G/R-PS Model*

$r_{S1\_LTE}(k)$ or r_{Iub_HS}

$$BW_{TN}(j) = \max\left\{ \left(BW_{TN} \cdot \frac{w_{WFQ}(j)}{\sum_i w_{WFQ}(i)} \right), \left(BW_{TN} - \sum_{i \neq j} L_{TN}(i) \right) \right\} \Rightarrow R_j = \lfloor BW_{TN}(j) / r_{TN}(j) \rfloor$$

$$\rho_{TN}(j) = L_{TN}(j) / BW_{TN}(j)$$

$$T(x_j) = \frac{x_j}{r_{TN}(j)} \left(1 + \frac{E_2(R_j,\ R_j \cdot \rho_{TN}(j))}{R_j(1-\rho_{TN}(j))} \right) = \frac{x_j}{r_{TN}(j)} f_{TN}(j)$$

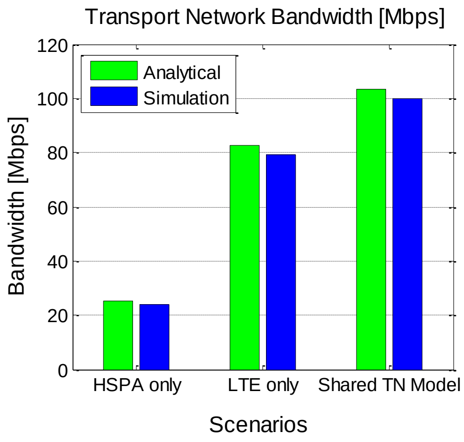
- app. mean delay for PHB class j (sojourn time) → $T(x_j)$
- File Size → x_j
- # Servers → R_j
- Peak data rate → $r_{TN}(j)$
- Link Utilization → $\rho_{TN}(j)$
- Delay factor → $f_{TN}(j)$

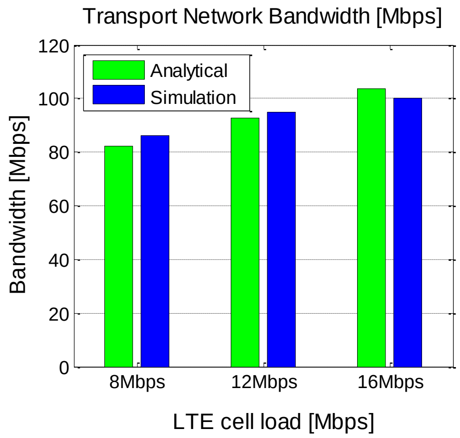
* Extended M/G/R-PS K. Lindberger (1999)

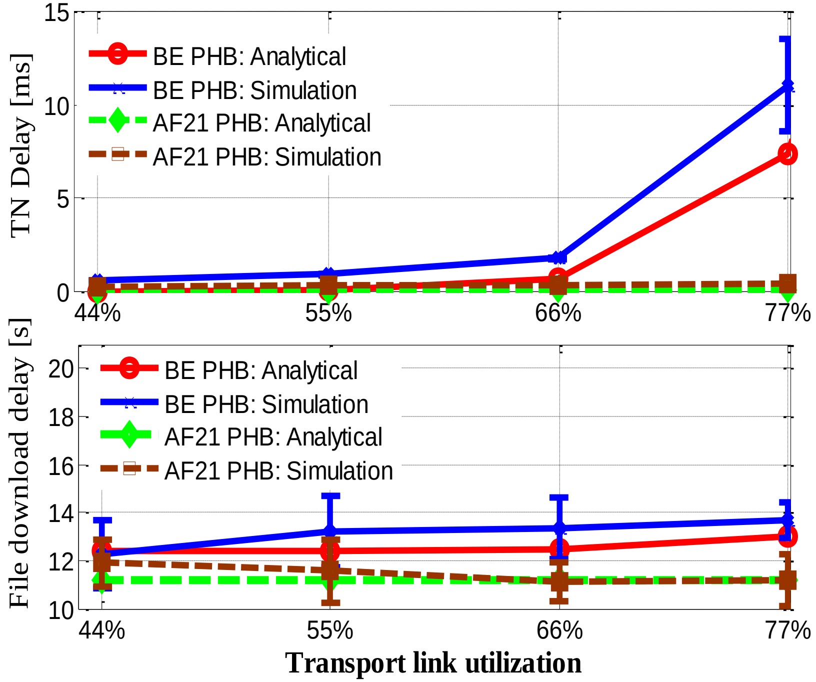
Validation of the Analytical Dimensioning Models

LTE Part, 1GB TCP buffer size, 20MHz cell bandwidth		
Services	Load per cell	PHB (WFQ weight)
FTP (QCI9)	8, 12, 16Mbps	BE (1)
HSDPA Part, 64KB TCP buffer size, 5MHz cell bandwidth		
Services	Load per cell	PHB (WFQ weight)
FTP	6Mbps	AF21 (100)

* Dimensioning target: HSDPA 50ms, LTE 15ms

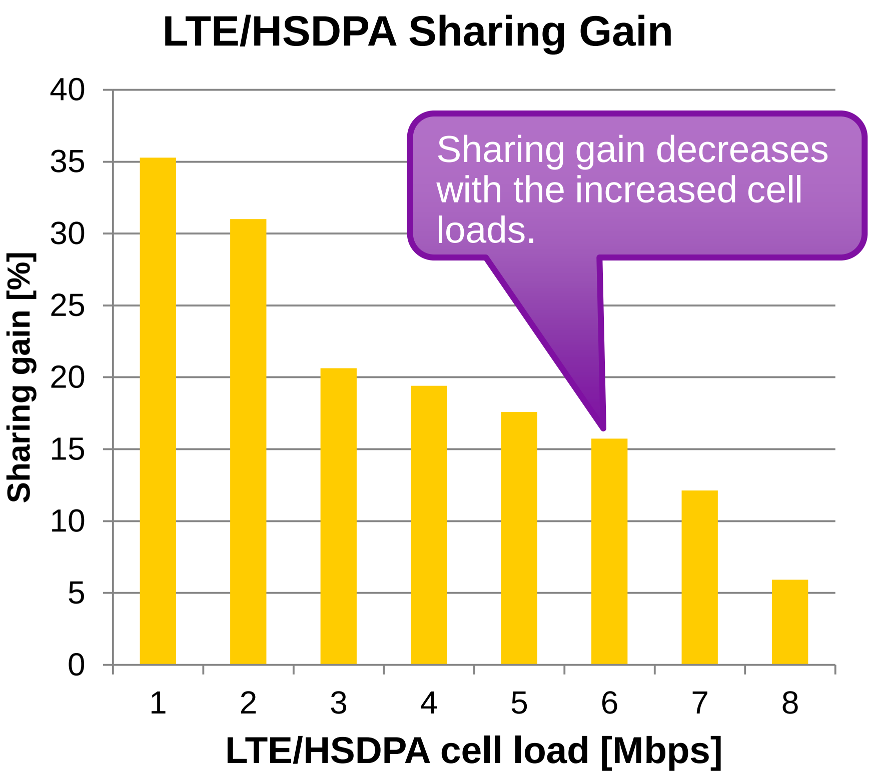


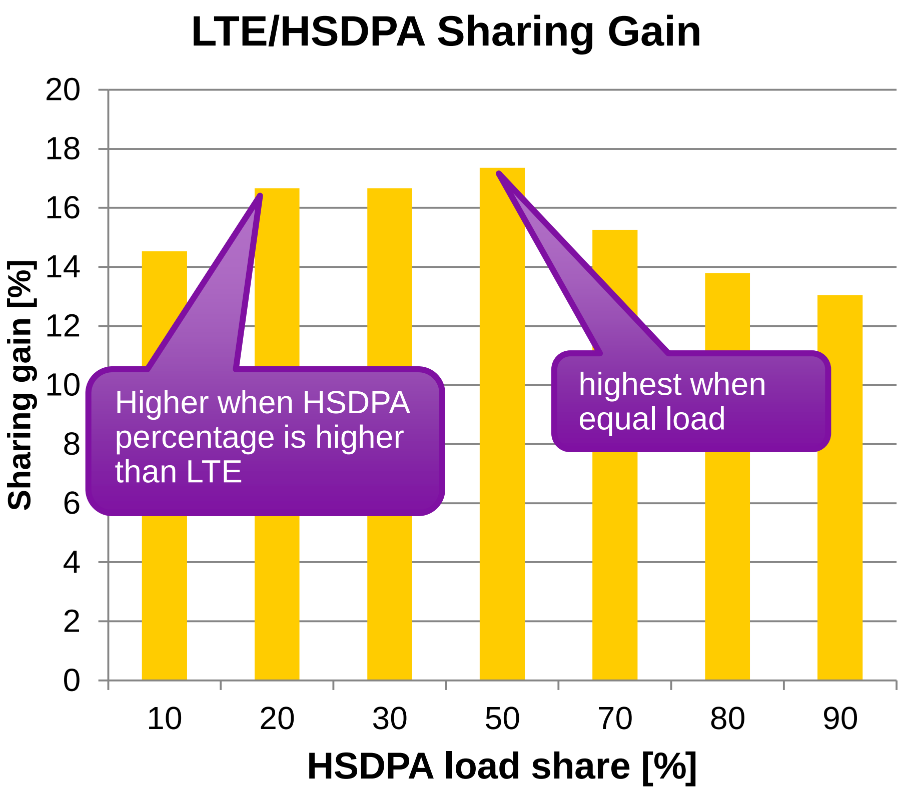




Analysis of the Achievable Sharing Gain

* Dimensioning target: HSDPA 15ms, LTE 15ms





$$Sharing\_G = \left(1 - \frac{BW_{Shared\_TN}}{BW_{HS} + BW_{LTE}}\right) \cdot 100\%$$

Summary

- A multiradio shared transport system is presented, and developed in a system simulation model in OPNET.
  - Both application and Transport network delays are improved
  - Around 20~30% gain on bandwidth saving from the example scenarios
- Propose an analytical framework to dimension the shared transport interface for the elastic traffic based on the extended M/G/R-PS model
  - Modeling the LTE/HSDPA radio interface
  - Modeling the DiffServ QoS scheme in shared transport network
  - Dimension the shared transport network to fulfill the QoE/QoS requirements
- The presented validation results demonstrate the proposed analytical models
  - Can appropriately estimate the application/link level performances of different traffic and priorities
  - Can estimate the achievable LTE/HSDPA sharing gain from sharing the transport

Next Steps

- Extend the dimensioning models for multiple base stations (eNBs, NBs) scenarios, and other traffic types
- Adding other radio technologies like HSUPA, GSM and UMTS Rel'99

Thanks and Any Questions?

Nokia Siemens Networks

ComNets HH

ComNets