LTE system performance optimization by RED based PDCP buffer management

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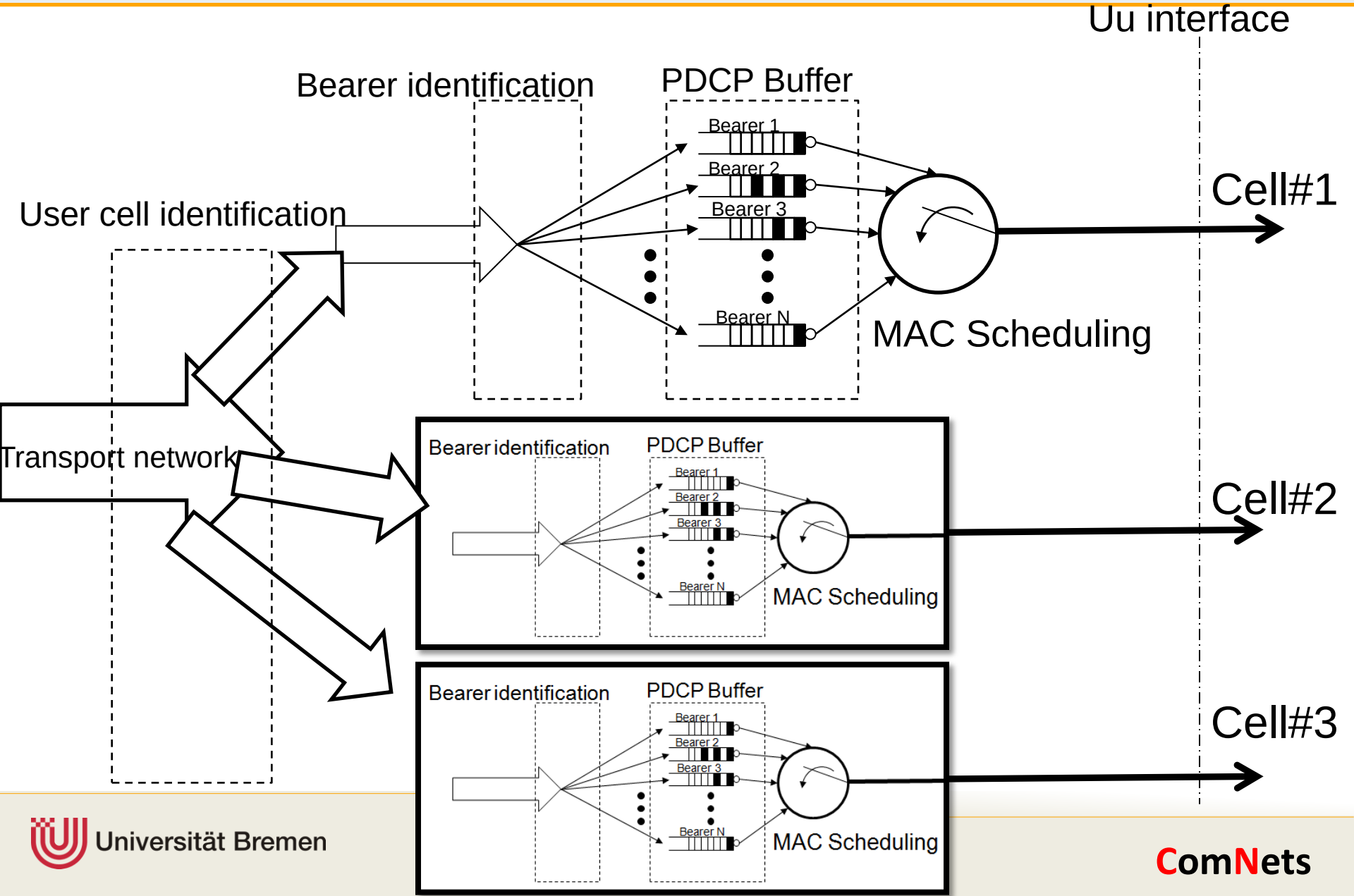
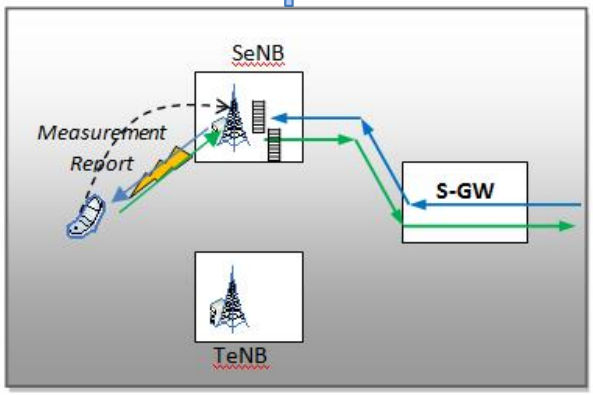
Background – LTE downlink data transmission

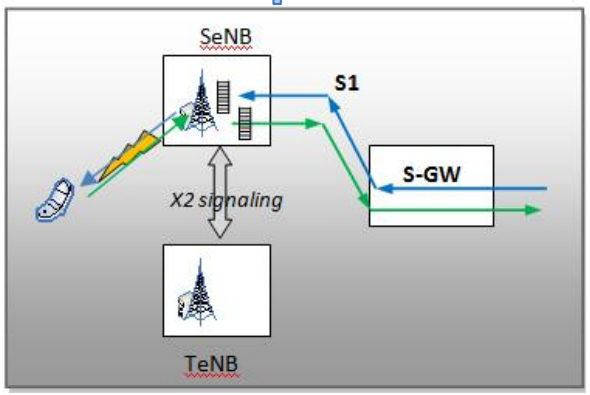


Background – LTE inter-eNB handover procedure

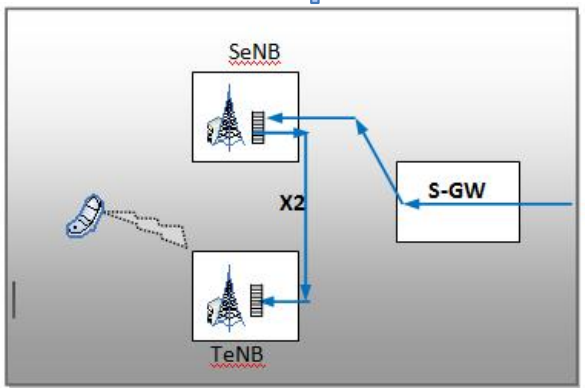
Step 1



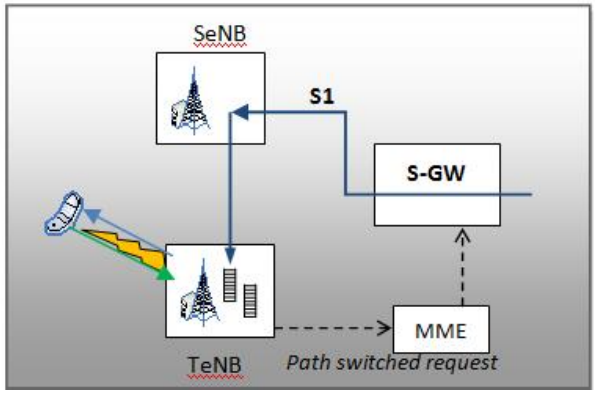
Step 2



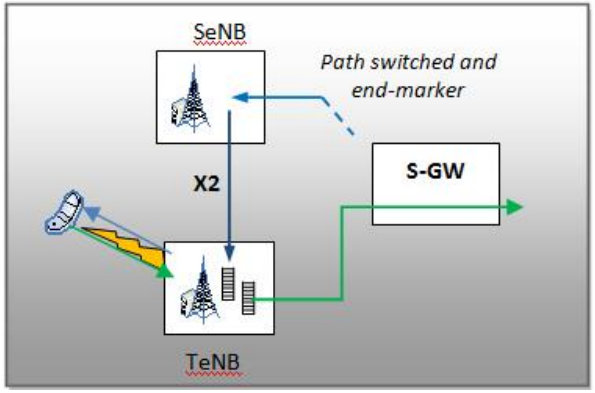
Step 3



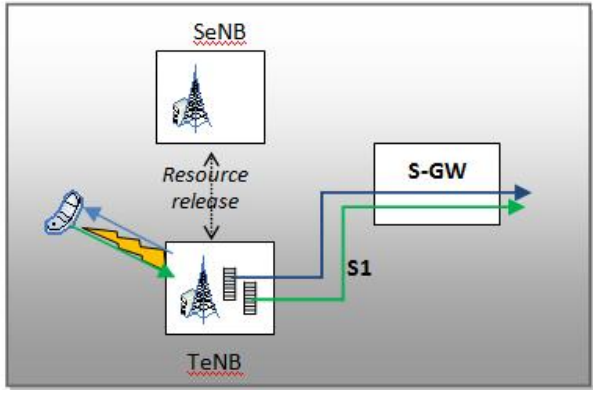
Step 4



Step 5



Step 6



Problem statement

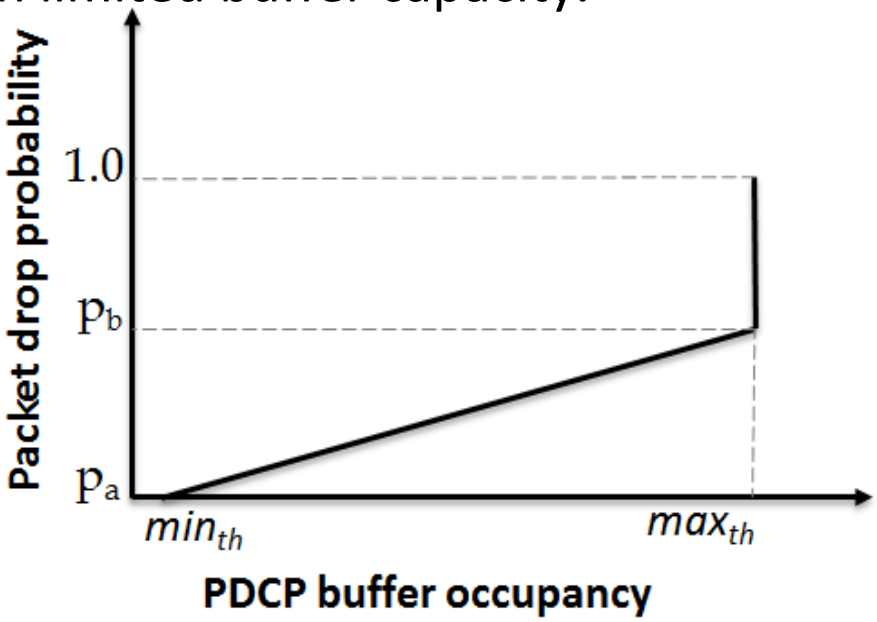
- Per bearer PDCP buffers at eNodeB hold downlink data before it is scheduled by MAC scheduler for transmission over radio interface.
- PDCP buffer occupancy affects X2 data volume and inter-eNB handover completion time
- PDCP buffer occupancy should be kept at minimal required level
  - To reduce X2 traffic volume and save transport network bandwidth
  - To reduce handover completion time during inter-eNB handover
  - To reduce PDCP buffering delay and hence improve packet end-to-end delay
- However reducing PDCP buffer to an arbitrarily small capacity could harm user application performance due to packet drops.

$$\text{TCP throughput} \leq \frac{MSS}{RTT\sqrt{PLR}}$$

- An efficient buffer management scheme is needed to keep PDCP buffer occupancy at an optimum level.

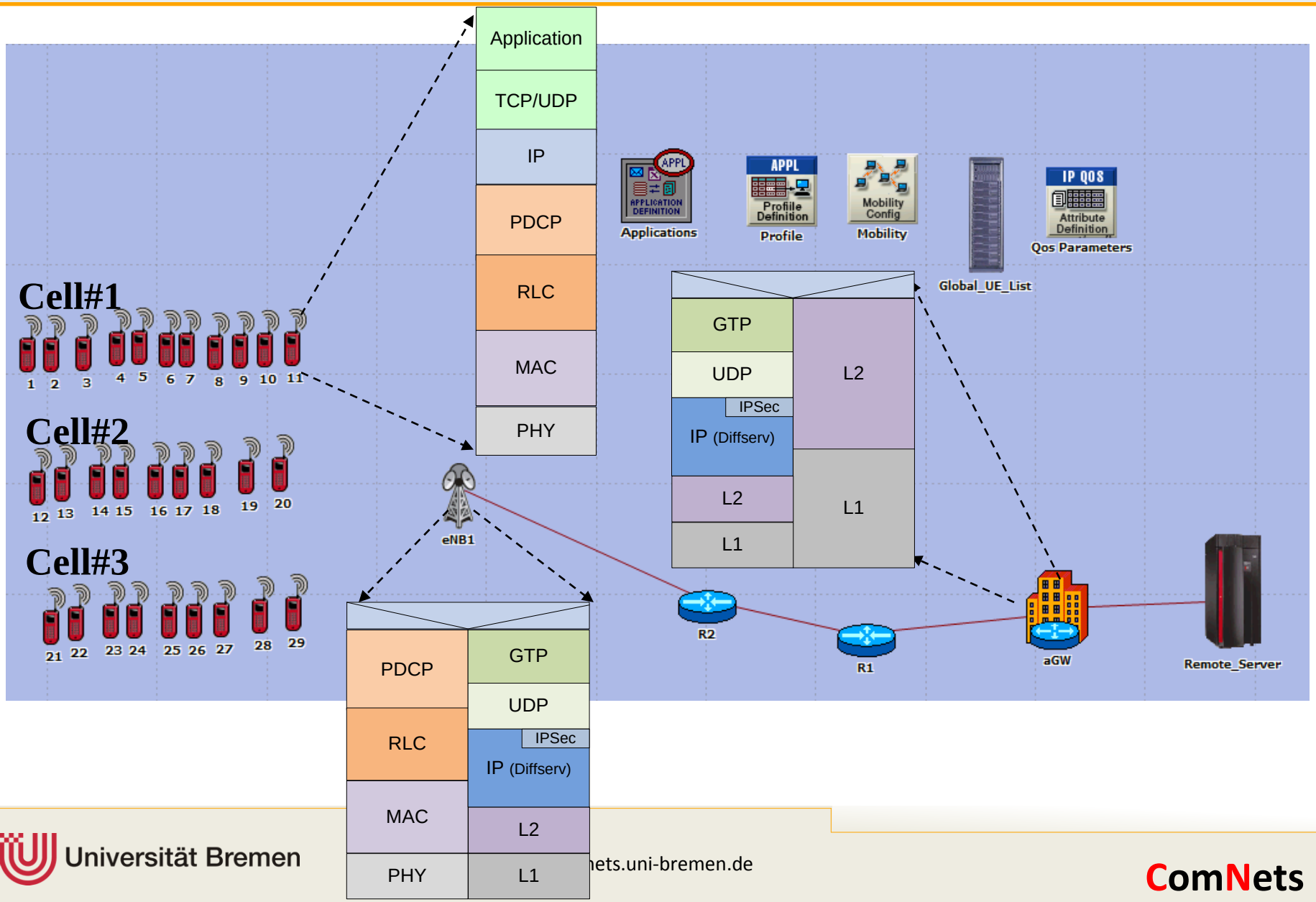
Proposed solution

- Deploy following buffer management scheme and tune the configuration parameters to achieve optimum PDCP buffer occupancy
  - Random Early Detection (RED) based scheme
- Performance of above scheme is compared against simple tail drop scheme with limited buffer capacity.



RED based PDCP buffer management scheme

LTE system level simulator in OPNET



Simulation configuration parameters

User Profile Definition	
Number of active users per cell	60
Number of cells per eNB	1
FTP traffic data	File size: constant 5M Byte
Web (HTTP) traffic data	Number of pages per session: 5 pages Average page size: 100K Bytes Number of objects in a page: 1
VoIP traffic data	GSM EFR codec (12.2 kbps) Silence suppression: off Call length: 90 sec
User Mobility Model	Random Direction (50km/h)
Network Configuration	
Cell Bandwidth	10 MHz
Handover	Disabled
MAC Scheduler	Round Robin
S1 link capacity	100 Mbps (Ethernet 100BaseX)
Per bearer PDCP buffer capacity	Configurable (30KB, 50KB & 100KB)
RED parameters for PDCP buffer management	$threshold_{min}$: 33%, $threshold_{max}$: 100% Pa: 0%, Pb: 5%
Simulation duration	2000 sec

Simulation results and analysis

Case 1: Prioritizing HTTP users over FTP user

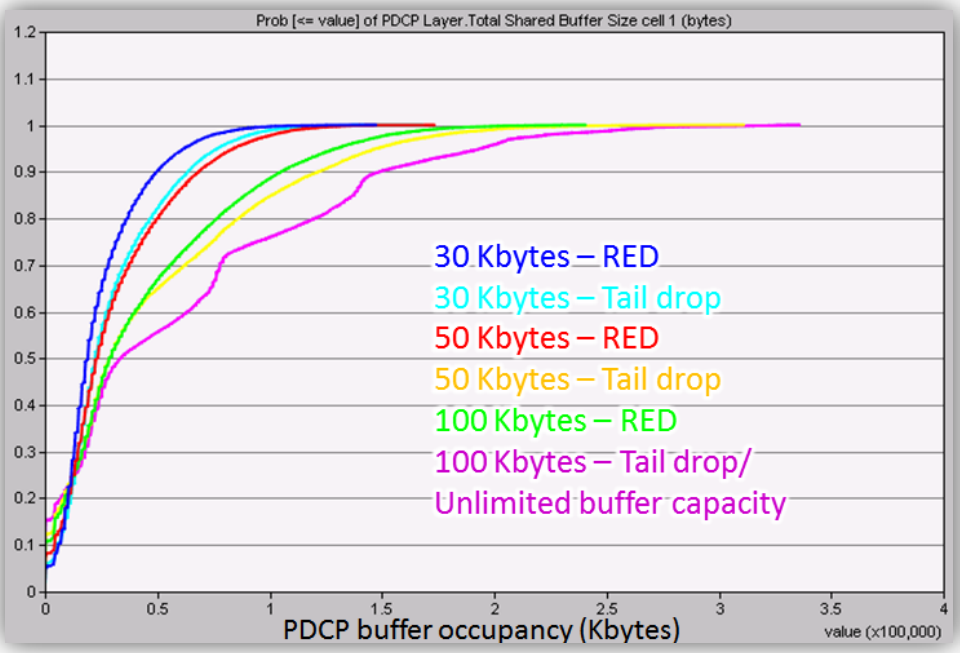
- **Moderate offered traffic load**
- High offered traffic load

Case 2: Mixing HTTP and FTP users in same priority class

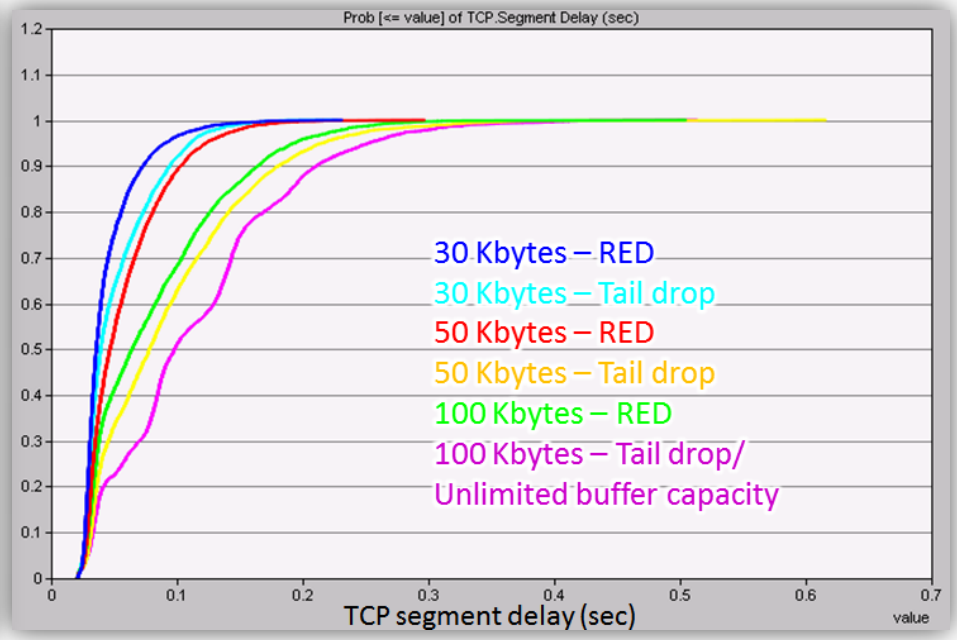
- Moderate offered traffic load
- High offered traffic load

PDCP buffer occupancy & TCP delay – CDF curves

PDCP buffer occupancy



TCP segment delay



Simulation result statistics

Per bearer PDCP buffer capacity (KB)	Mean PDCP buffer space usage (KB)	Total PDCP packet drops	Mean TCP segment delay – FTP DL (msec)	Mean FTP file download time (sec)	Mean HTTP page download time (sec)
unlimited	61.7	0	115	9.41	0.54
			Tail drop		
100	61.7	0	115	9.41	0.54
50	48.0	994	094	10.01	0.54
30	29.5	5,078	051	11.21	0.53
			RED		
100	43.7	653	082	10.10	0.53
50	30.9	2,033	058	11.43	0.56
30	24.1	5,080	044	13.28	0.70

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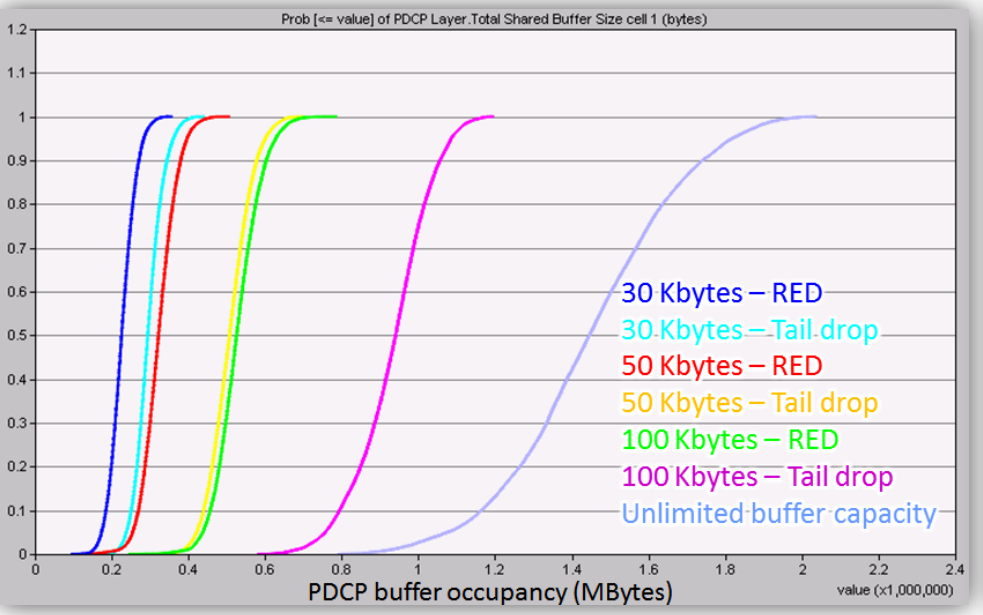
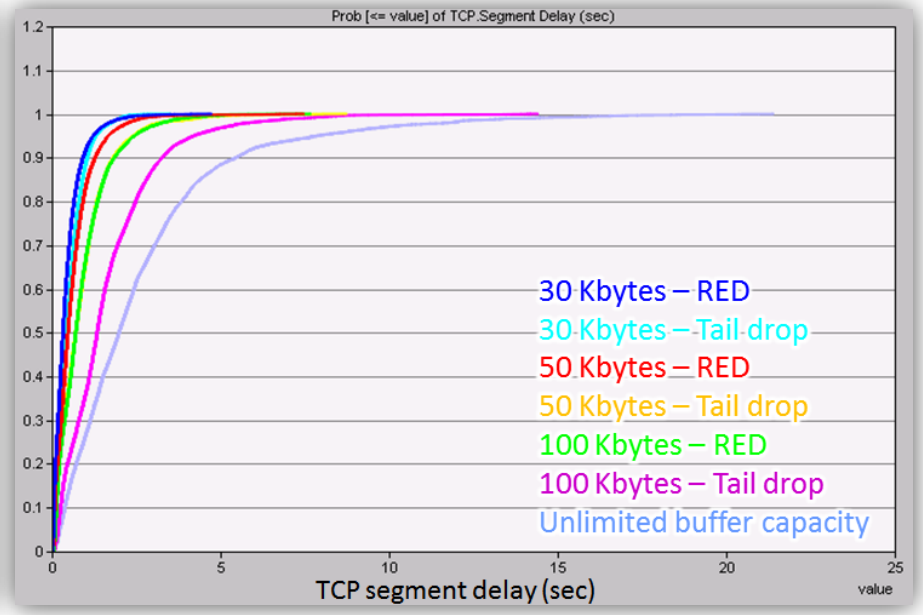


TCP segment delay



Simulation result statistics – Case 1: high load

Per bearer PDCP buffer capacity (KB)	Mean PDCP buffer space usage (KB)	Total PDCP packet drops	Mean TCP segment delay – FTP DL (msec)	Mean FTP file download time (sec)	Mean HTTP page download time (sec)
unlimited	1450	0	2,189	113.17	0.68
		Tail drop			
100	932	4,442	1,342	112.12	0.68
50	508	11,941	763	115.36	0.68
30	296	20,170	475	121.32	0.68
		RED			
100	528	6,754	746	114.21	0.68
50	323	14,810	520	117.28	0.78
30	227	24,673	361	119.56	0.94

Simulation results and analysis

Case 1: Prioritizing HTTP users over FTP user

- Moderate offered traffic load
- High offered traffic load

Case 2: Mixing HTTP and FTP users in same priority class

- **Moderate offered traffic load**
- **High offered traffic load**

Simulation result statistics – Mixed traffic

Per bearer PDCP buffer capacity (Kbytes)	Mean PDCP buffer occupancy (Kbytes)	Total PDCP packet drops	Mean TCP segment delay – FTP QCI9 (msec)	Mean FTP file download time (sec)		Mean HTTP page download time (sec)	
				QCI8	QCI9	QCI8	QCI9
unlimited	619	0	123	9.29	9.45	0.55	0.55
Tail drop							
100	619	0	123	9.29	9.45	0.55	0.55
50	488	1,042	096	9.74	10.79	0.55	0.59
30	312	5,088	056	11.34	11.81	0.54	0.64
RED							
100	389	530	066	8.76	9.62	0.53	0.53
50	325	2,085	064	11.74	11.91	0.59	0.60
30	231	4,865	042	12.44	13.15	0.65	0.74

Moderate offered traffic load

Simulation result statistics – Mixed traffic

Per bearer buffer PDCP capacity (Kbytes)	Mean PDCP buffer occupancy (Kbytes)	Total PDCP packet drops	Mean TCP segment delay – FTP QCI9	Mean FTP file download time (sec)		Mean HTTP page download time (sec)	
				QCI8	QCI9	QCI8	QCI9
unlimited	1,090	0	4.284 sec	20.43	233.6	0.73	6.76
			Tail drop				
100	767	3,782	3.010 sec	21.00	225.2	0.74	6.44
50	494	8,626	2.140 sec	21.17	249.5	0.72	6.69
30	311	22,914	1.251 sec	22.48	245.2	1.09	6.60
			RED				
100	513	4,458	2.124 sec	20.87	214.2	0.71	6.81
50	353	11,030	1.517 sec	21.90	238.8	0.84	6.85
30	251	23,809	0.872 sec	21.77	203.1	1.06	6.91

High offered traffic load

Summary and conclusions

- An optimal PDCP buffer occupancy helps achieving shorter inter eNB handover time and reduced X2 traffic volume
- PDCP buffer with arbitrarily large capacity creates high buffer occupancy
- With the help of a PDCP buffer management scheme e.g. RED, discard timer etc. reduce buffer occupancy up to 60%.
- Proper tuning of parameters of buffer management scheme is required in order to achieve low buffer occupancy without significant loss in user application performance.
- A practical range of tuning parameter values is also proposed to ease the system performance optimization task when using discard timer scheme.
- As a next step more sophisticated queue management scheme will be applied.

Thanks for your attention

- Questions and comments are welcome!