ISTITUTO DI TECNOLOGIE DELLA COMUNICAZIONE, DELL'INFORMAZIONE E DELLA PERCEZIONE

Scuola Superiore Sant'Anna

Requirements for 5G Fronthaul

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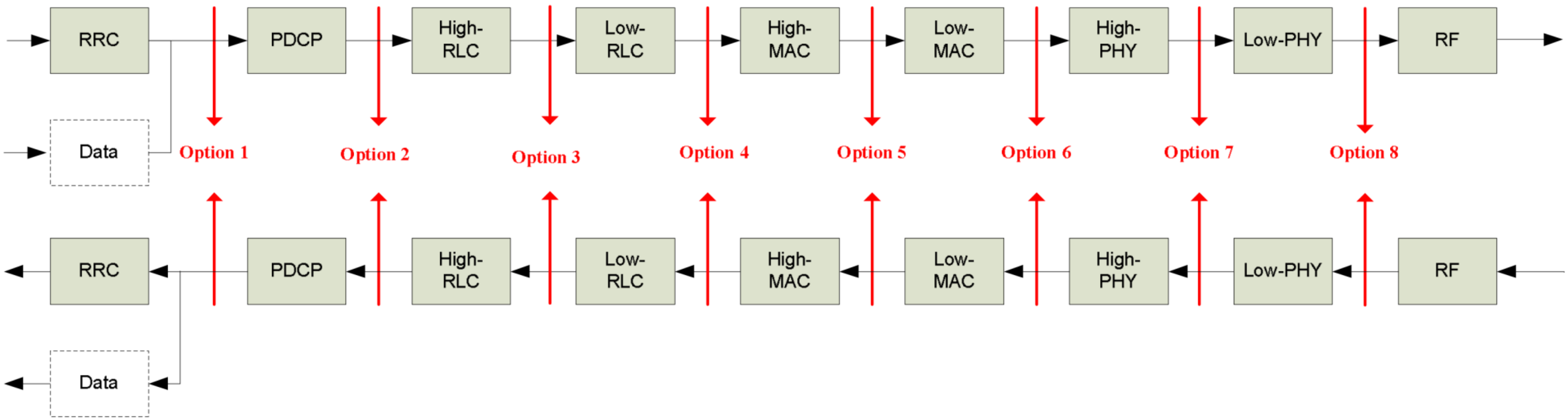
Outline

- Objective
- Proposed functional splits
- Simulation scenario
- Overhead computation
- Results
- Conclusions

Objective

- Evaluate the communication overhead between UE and BBU for different functional splits

Proposed functional splits – 3GPP



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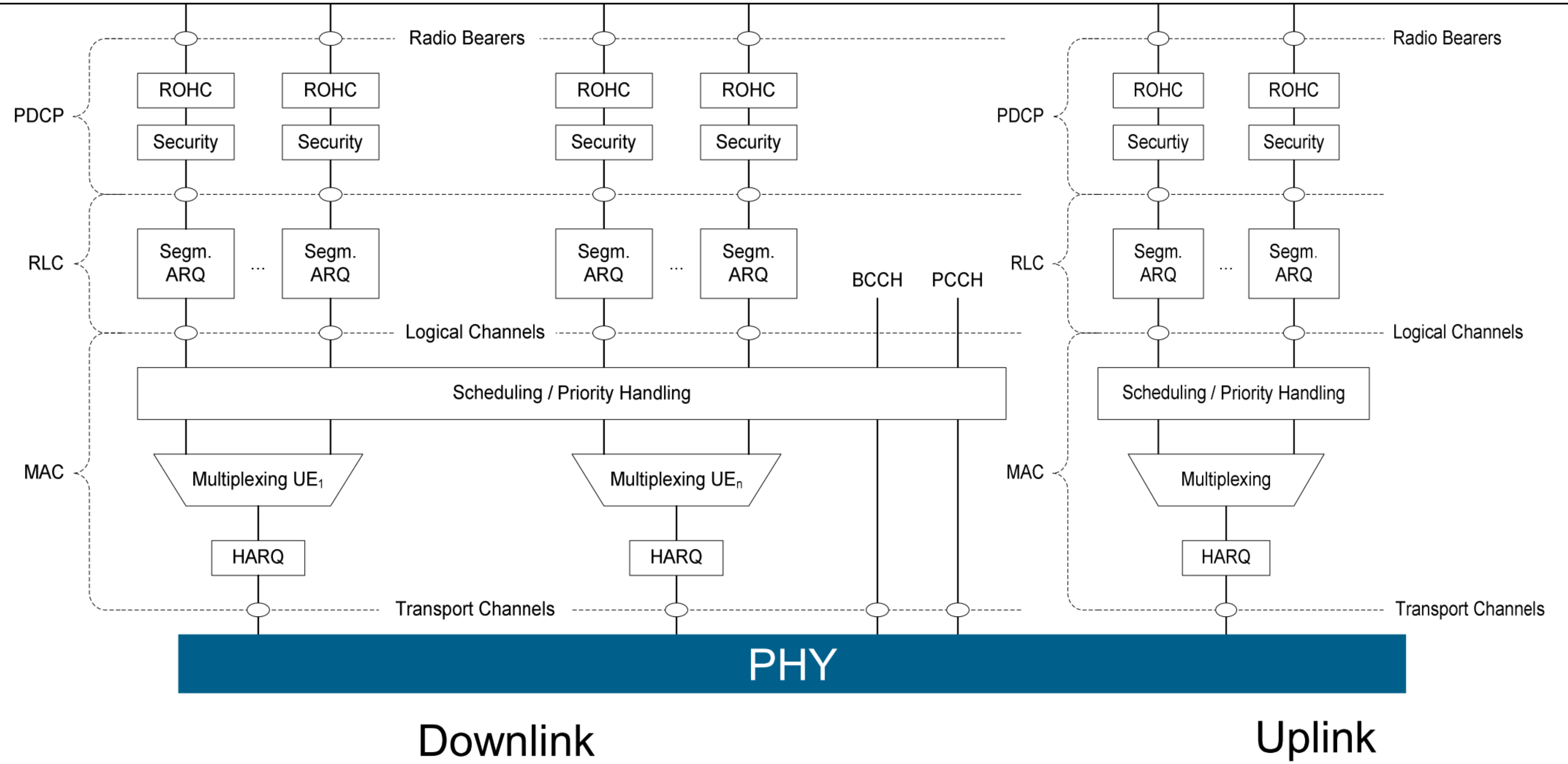
LTE-A Pro Protocol Stack

RRC: broadcast of System Information (i.e., System Information Blocks SIB); paging; mobility functions …



ROHC=robust header compression
ARQ=Automated Repreat reQuest
HARQ=Hybrid Automated Repeat reQuest

Fronthaul capacity requirements: previous work (1)

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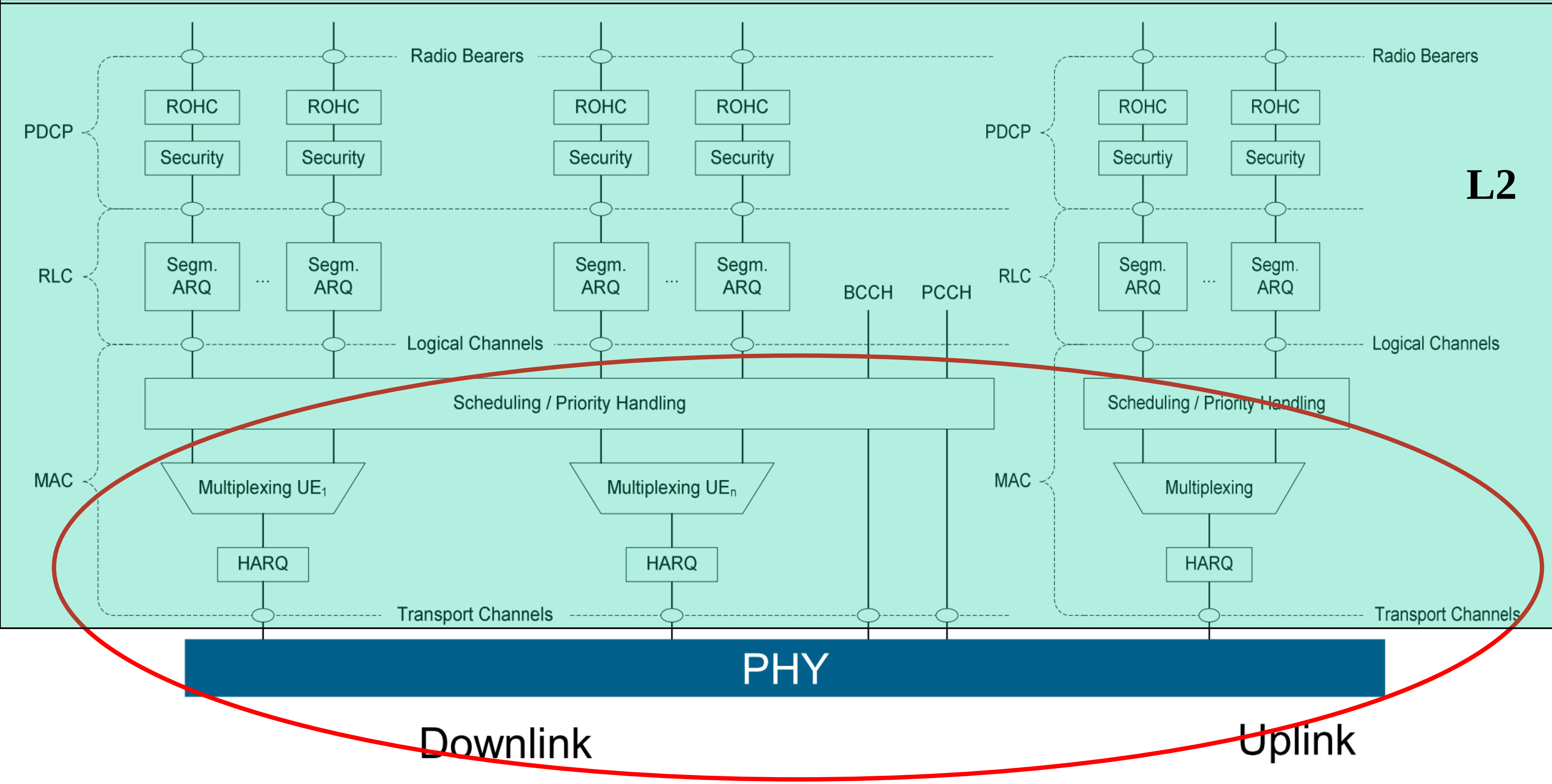

ROHC=robust header compression
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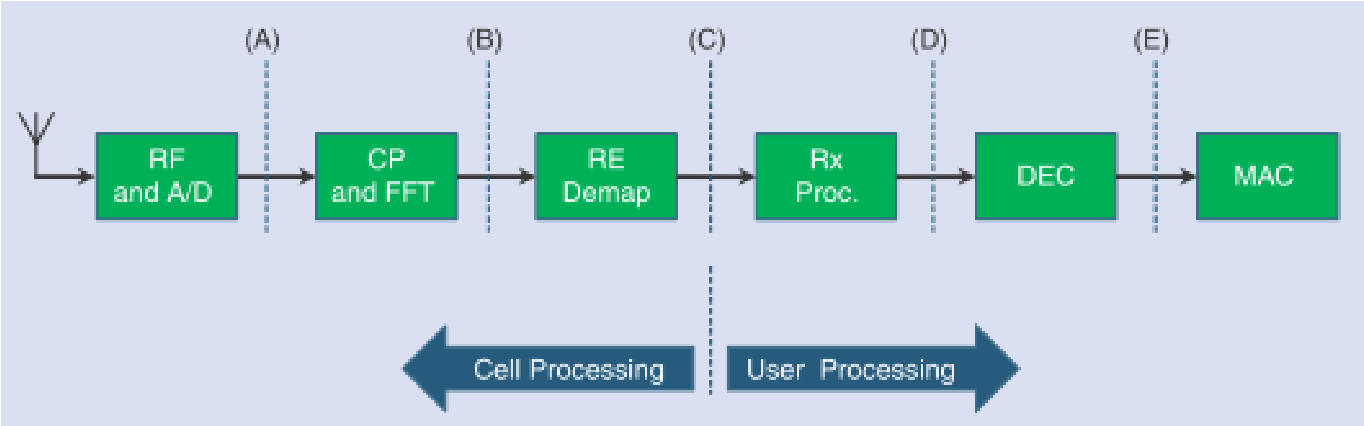
Fronthaul capacity requirements: previous work (2)

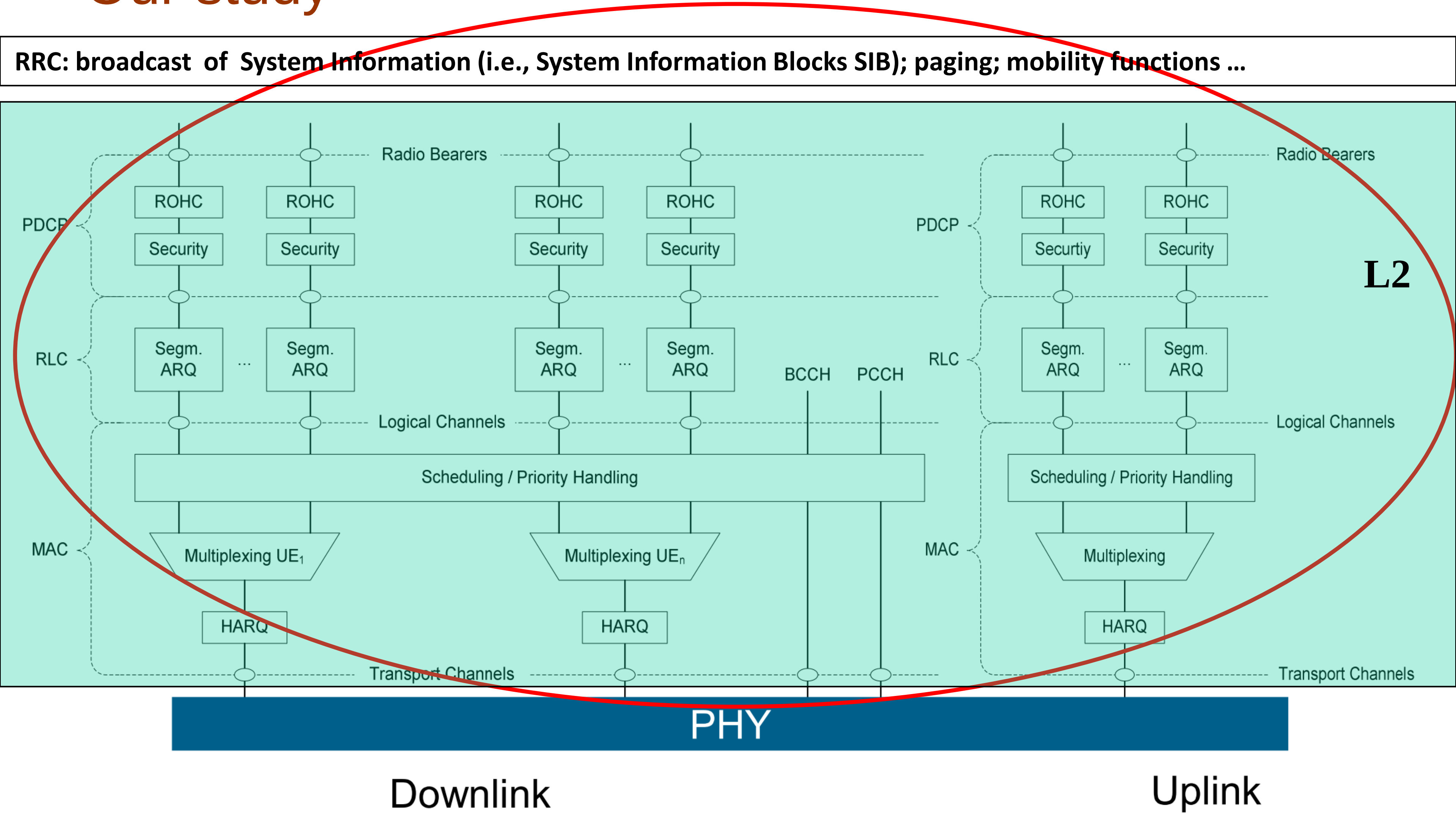


- Split A
  - Forwards the time-domain received signals that have been downconverted to the baseband and analog-to-digital (AD) converted (indicated by block RF/AD) (CPRI approach)
- Split B
  - Removes the Cyclic Prefix (CP) and transforms the Rx signal to frequency-domain using fast Fourier transformation (FFT), guard subcarriers can be removed (block CP/FFT).
- Split C
  - Only the resource elements (REs) remain after RE demapping (block RE Demap) and have to be forwarded to the cloud-platform (If only a part of the RE are actually utilized by the user equipment (UE) in a cell)
- Split D
  - The receive processing (block Rx Proc) per user consists of equalization in frequency domain, inverse discrete Fourier transformation (IDFT), MIMO receive processing, and demapping
- Split E
  - During forward error correction (FEC) decoding (block DEC), data bits are recovered from the received symbols and redundant bits are removed, resulting in the pure MAC payload at the decoder output.

Source: Dirk Wübben *et al.*, *" Benefits and Impact of Cloud Computing on 5G Signal Processing", IEEE SIGNAL PROCESSING MAGAZINE, Nov. 2014*

Our study

RRC: broadcast of System Information (i.e., System Information Blocks SIB); paging; mobility functions …



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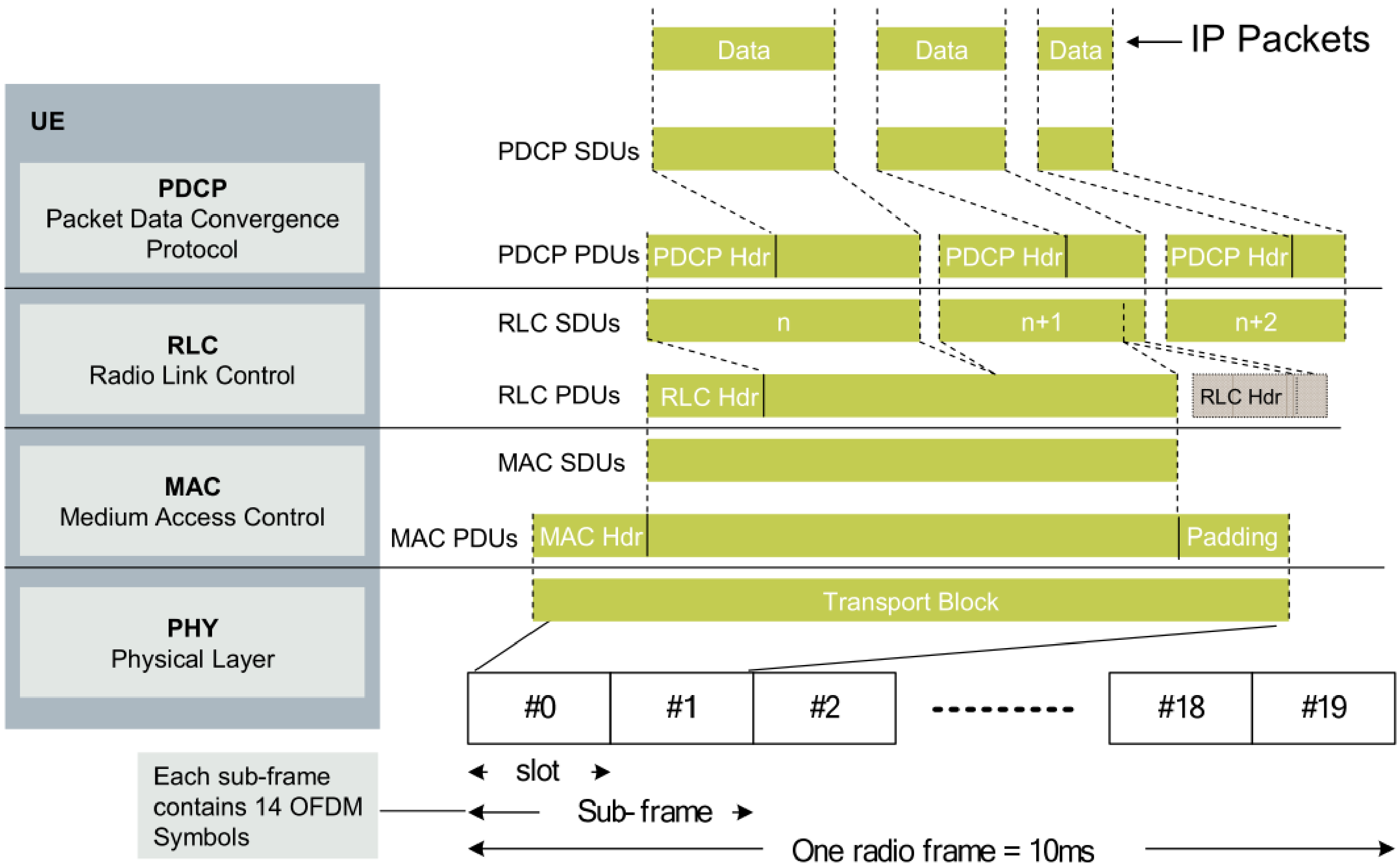
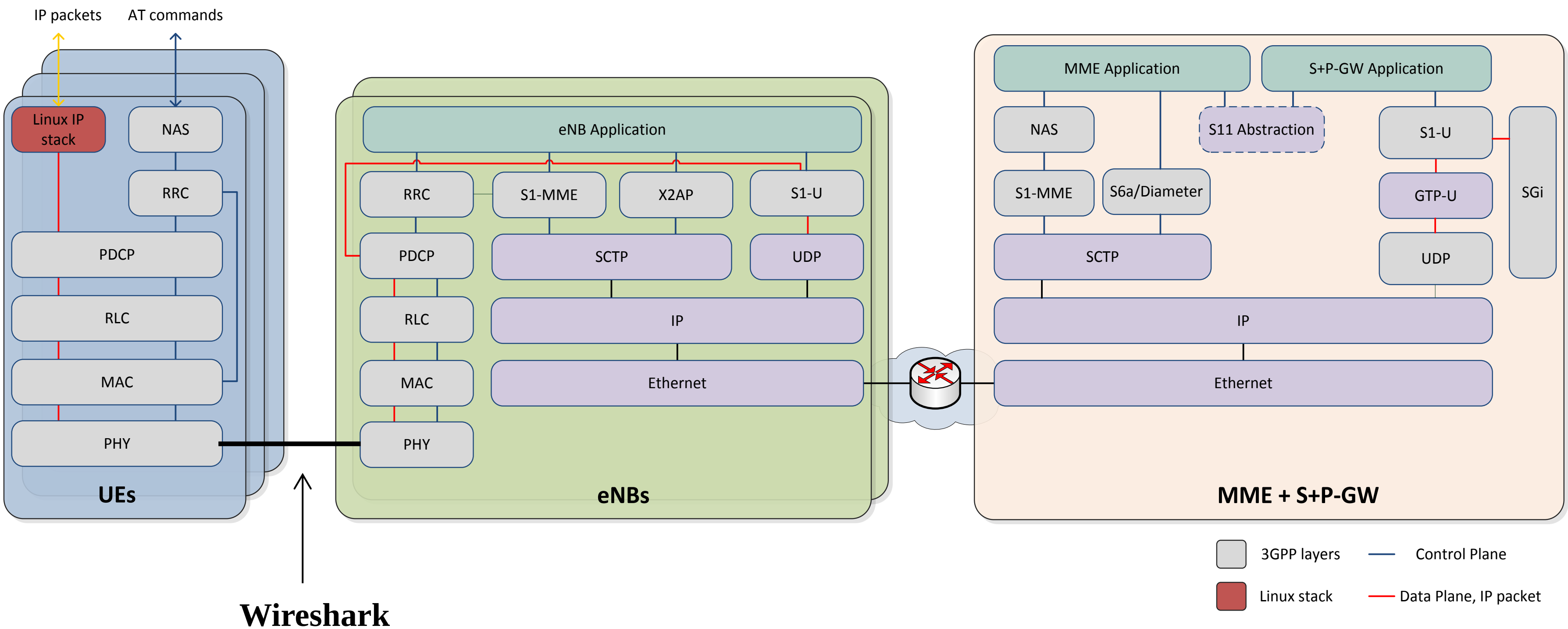
Downlink Packet Encapsulation



Adaptation from

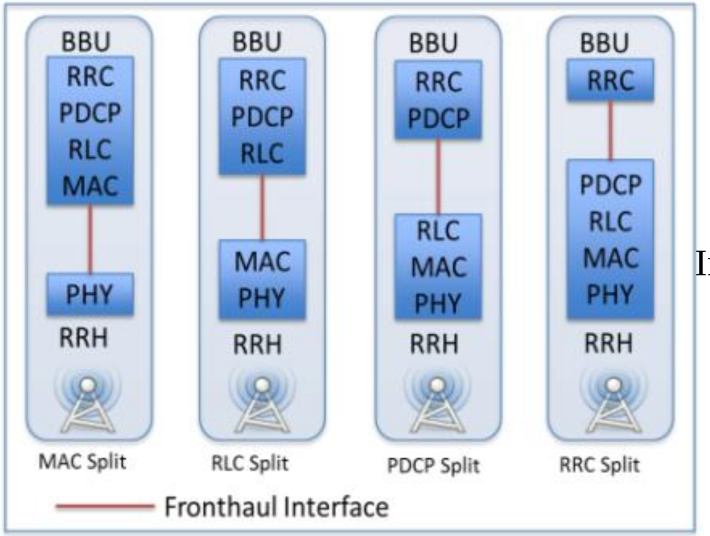
A. Larmo, M. Lindström, M. Meyer, G. Pelletier, J. Torsner and H. Wiemann, "The LTE link-layer design,"
A. in *IEEE Communications Magazine*, vol. 47, no. 4, pp. 52-59, April 2009.

Utilized tool OAI Software Stack



- Implements LTE Rel10 Access Stratum (eNB & UE) and EPC (MME, S+P-GW, HSS)
- All the stack (incl. PHY) runs entirely on a PC in real-time operating system (RTAI, Xenomai, low-latency kernel)
- Wireshark/tshark

Setup and Performance Evaluation Parameters



Parameter	Value
Simulation Duration	100000 TTIs
Duplexing Mode	FDD
PHY Layer Abstraction	NO
# eNBs	1
# UEs	1
Mobility	STATIC
Payload Size	200 bytes
IDT	1 ms
Offered load	1.6Mb/s
Traffic Type	SCBR
TX mode	1 (SISO)
Carrier Bandwidth	5 MHz
Multipath channel simulation	AWGN
Distance (D)	370m

100s

Inter departure time

Small packet CBR

Uplink traffic only

- *C-plane overhead* (at each layer)
  - the overall amount of control data and overhead exchanged in bytes including System Information Blocks (SIBs)
- *U-plane overhead* (at each layer)
  - number of overhead bytes used to transport the considered application data
- *C-plane functional split overhead (CFSO)*
  - the sum of C-plane overhead of each layer residing at the BBU based on the implemented functional split option
- *CFSO percentage*
  - the ratio between CFSO and the offered load.
- *Overhead capacity consumption*
  - the ratio between the overhead and the experiment duration for C-plane overhead, U-plane overhead, and CFSO

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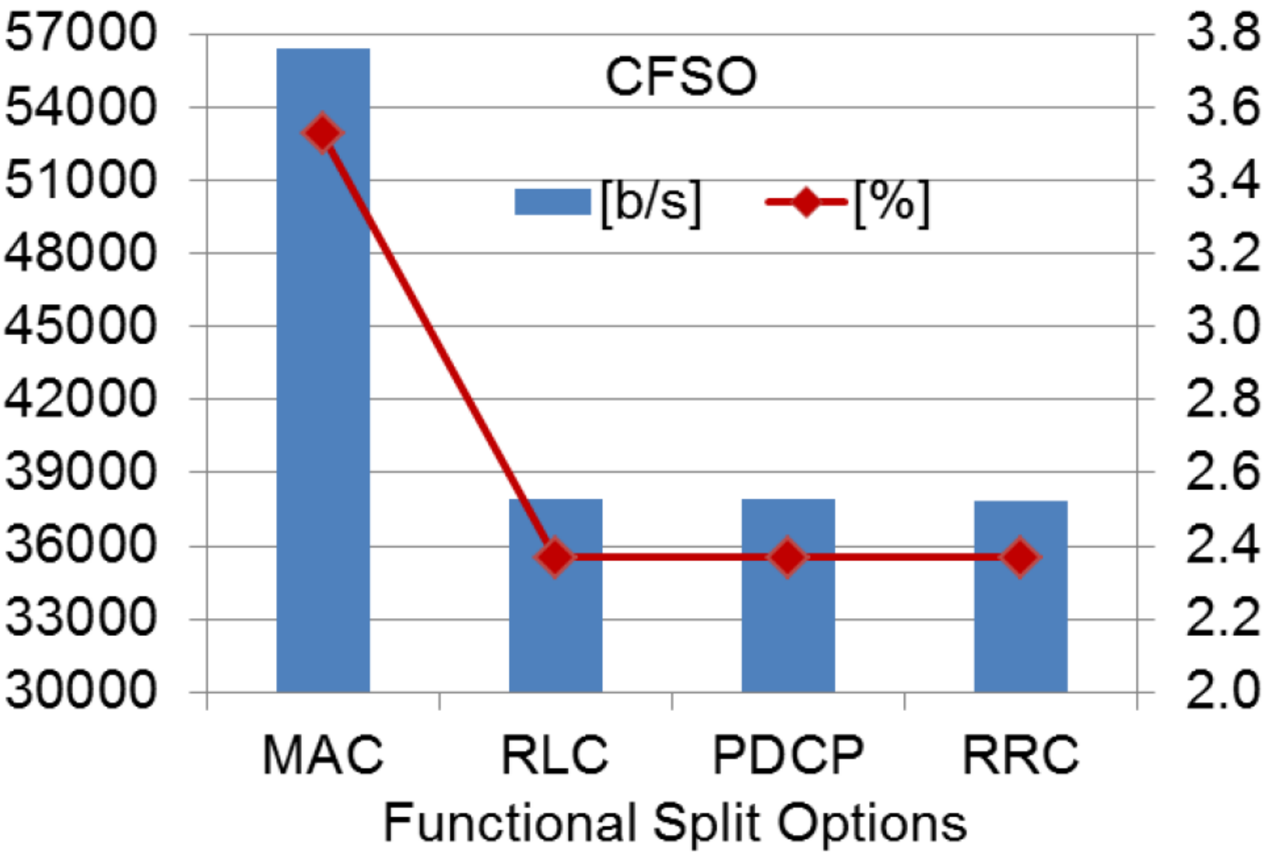
Results: overhead and overhead capacity

- RRC contribute more number of bytes to the C-plane overhead (periodic transmission of SIB information)
- PDCP and RLC have less contribution to C-plane overhead because these layers are involved only in transportation of DCCH for non-access stratum (NAS)-evolved packet core (EPC) access stratum (AS)-evolved packet core (EPC) connection
- RLC has other additional C-plane overhead to specify signalling radio bearers (SRB) for RRC and NAS signalling messages
- The C-plane MAC overhead includes MAC PDU header, buffer status report (BSR), and power headroom report (PHR) of MAC control elements
- Layer contributions are separate

LAYER	overhead [bytes]		overhead capacity consumption [b/s]		Logical/Transport Channels
	C- plane	U-plane	C-plane	U-plane	
RRC	473518	-	37881.44	-	BCCH, CCCH, DCCH
PDCP	115	45005	9.20	3600.40	DCCH
RLC	182	18002	14.56	1440.16	DCCH, SRB1
MAC	231358	4112279	18508.64	328982.45	BCH, SCH

Results: C-plane functional split overhead capacity and percentage

- Bottom layer sums the contribution by upper layers



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Conclusions

- Functional split overhead evaluation
- Functional split requirements
  - PDCP and RLC have a slight impact on the functional split requirements
  - From MAC above
    - Capacity required for transporting both user and control data are limited to slightly less than one Megabit per second.
  - The limiting requirement for the fronthaul is the latency which can vary from units of milliseconds (PHY split) to tens of seconds (RRC split)

thank you!

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Fronthaul capacity requirements

PARAMETER	SYMBOL	VALUE
BANDWIDTH	B	20 MHz
SAMPLING FREQUENCY	f_S	30.72 MHz
OVERSAMPLING FACTOR	N_O	2
NUMBER OF USED SUBCARRIERS	N_{SC}	1,200
SYMBOL DURATION	T_S	66.6 µs
QUANTIZATION/SOFT BITS PER I/Q	N_Q	10
RX ANTENNAS	N_R	2
SPECTRAL EFFICIENCY	S	3 bit/cu
ASSUMED RB UTILIZATION	η	50%

Split	Required bandwidth	In % of a)
a) I/Q Forwarding	2,457 Mbps	100.0 %
b) Subframe forwarding	720 Mbps	29.3 %
c) Rx Data forwarding	360 Mbps	14.7 %
d) Soft-Bit forwarding	180 Mbps	7.3 %
e) MAC Data	27 Mbps	1.1 %

Source: A. Maeder, M. Lalam, A. De Domenico, E. Pateromichelakis, D. Wubben, J. Bartelt, R. Fritzsche, P. Rost, "Towards a flexible functional split for cloud-RAN networks," in *Networks and Communications (EuCNC), 2014 European Conference on* , vol., no., pp.1-5, 23-26 June 2014

Fronthaul latency requirements

	Timer	Short description	Max Value
PHY	Subframe	Physical subframe length	1 ms (fix)
PHY	Frame	Physical frame length	10 ms (fix)
MAC	HARQ RTT Timer	When an HARQ process is available	8 ms (fix)
RLC	t-PollRetransmit	For AM RLC, poll for retransmission @tx side	500 ms
RLC	t-Reordering	For UM/AM RLC, RLC PDU loss detection @rx side	200 ms
RLC	t-StatusProhibit	Prohibit generation of a status report @rx side	500 ms
PDCP	discardTimer	Discard PDCP SDU / PDU if expiration or successful transmission	Infinity
RRC	TimeToTrigger	Time to trigger of a measurement report	5.12 s
RRC	T300	RRCConnectionRequest	2 s
RRC	T301	RRCConnectionReestablishmentRequest	2 s
RRC	T304	RRCConnectionReconfiguration	2 s or 8 s
RRC	T310	Detection of physical problem (successive out-of-sync from lower layers)	2 s
RRC	T311	RRC connection reestablishment (E-UTRA or another RAT).	30 s

Source: Common Public Radio Interface (CPRI) Specification V6.1. [Online] Available: http://www.cpri.info/spec.html, Tech. Rep., 2014