Towards Bandwidth-Efficient Ethernet-Based 5G Mobile Fronthaul Networks

Group Meeting Presentation

Speaker: Yu Wu
03/09/2018

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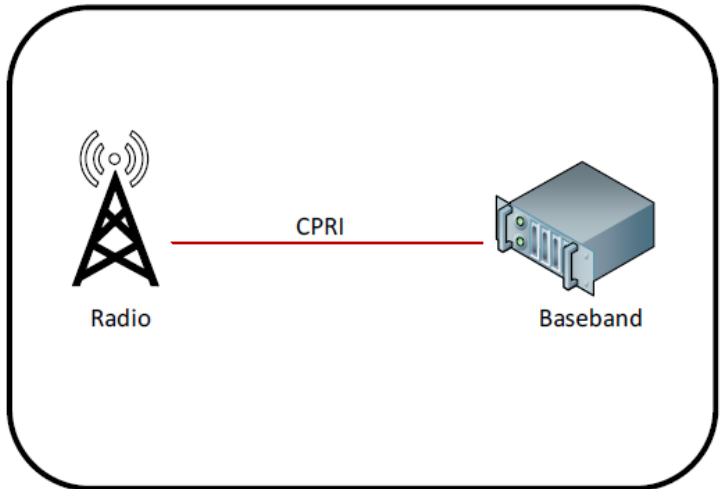
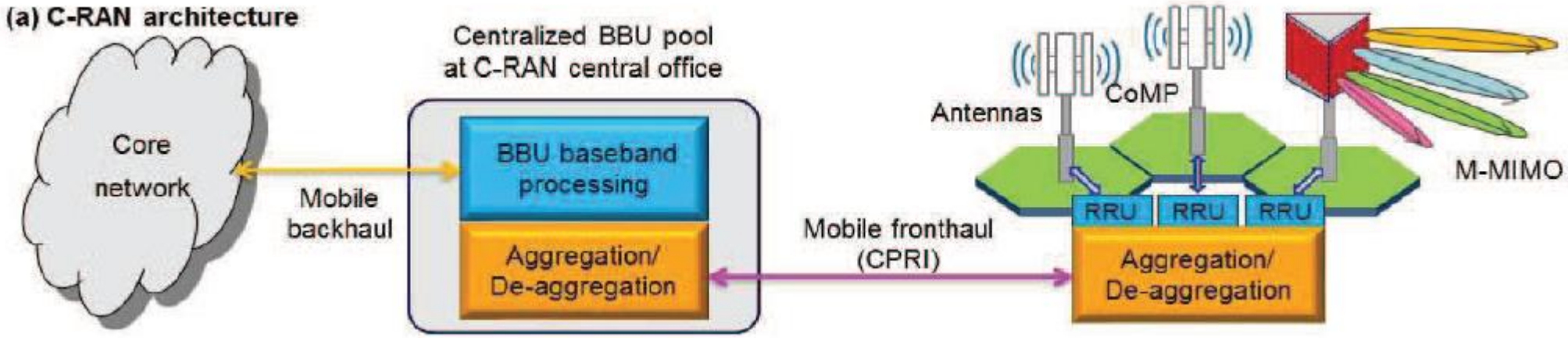
Mobile Fronthaul Recap

- Mobile fronthaul refers to the connection between BBU and RRU.

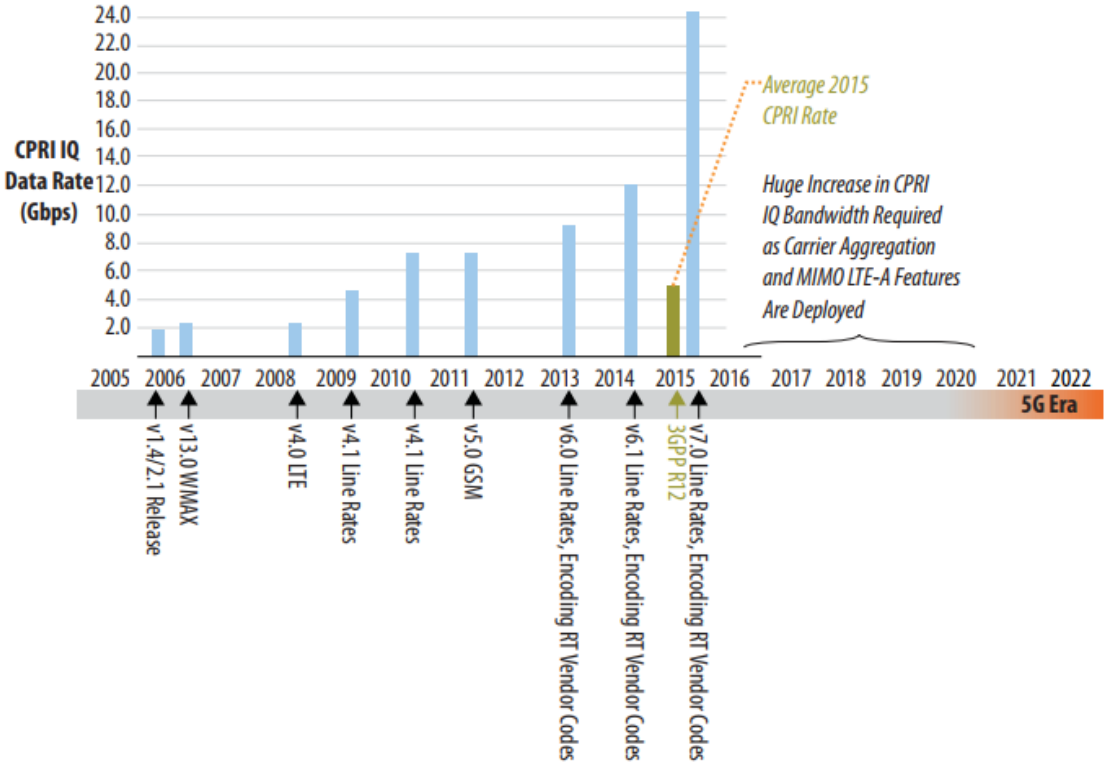


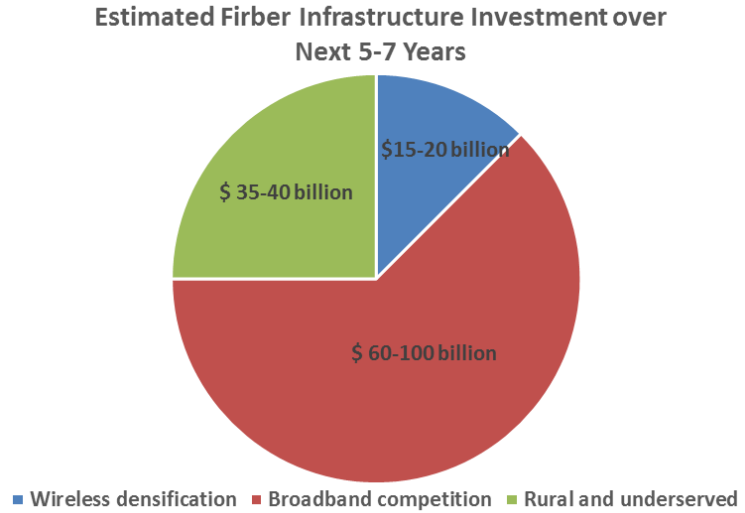


X. Liu, *et al.*, "Evolution of mobile fronthaul towards 5G wireless and its impact on time-sensitive optical networking." *Proc. OFC,* 2017.

Two Challenges

- Traditional C-RAN architecture relies on **CPRI/OBSAI** to carry sampled radio signal and synchronization data between BBU and RRU. This imposes very **high bandwidth requirements** on the mobile fronthaul network.
- Circuit-switched dedicated **fiber connections** for fronthaul are **expensive**.





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Altera White Paper, "The Emerging Need for Fronthaul Compression," June 2016.

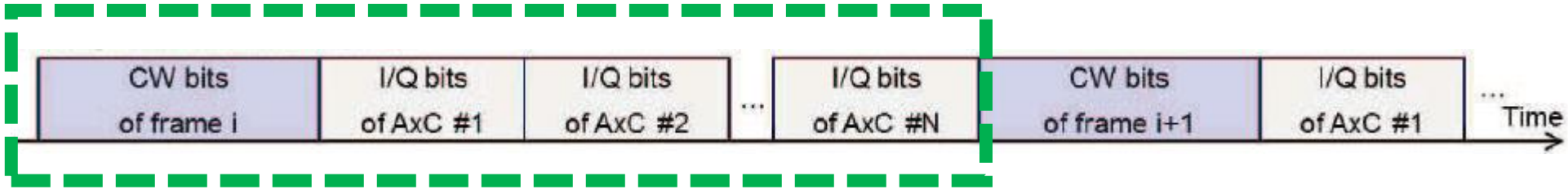
Deloitee, "Communications infrastructure upgrade – the need for deep fiber," July 2017.

Bandwidth Requirement Too High?

- Potential solutions:
  - **No functional split:**
    - CPRI data compression.
    - Useless traffic classification and sifting.
  - **Functional split:**
    - Next Generation Fronthaul Interface (NGFI).

CPRI Data Compression

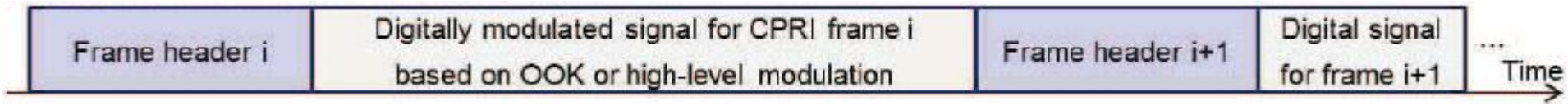
❑ CPRI basic frame



- ❖ Each frame has 16 words.
- ❖ First word is Control Word (CW).
- ❖ Next 15 words contains sampled I/Q data from receiving antennas.

❑ CPRI I/Q data compression

- ❖ Use high-level digital modulation to modulate I/Q data.



- ❖ Other possibilities – converting I/Q data series to frequency domain and encoding the frequency signal.

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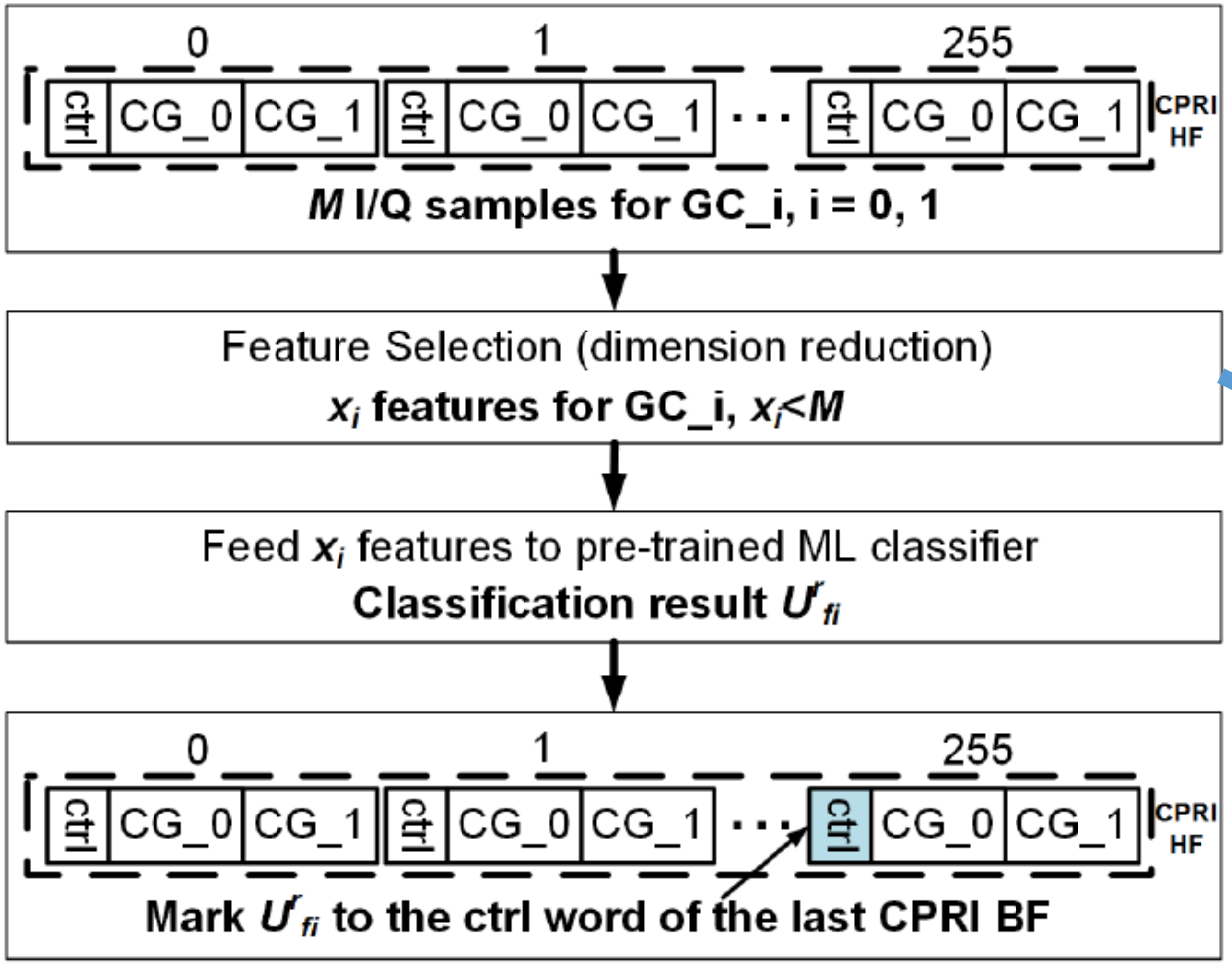
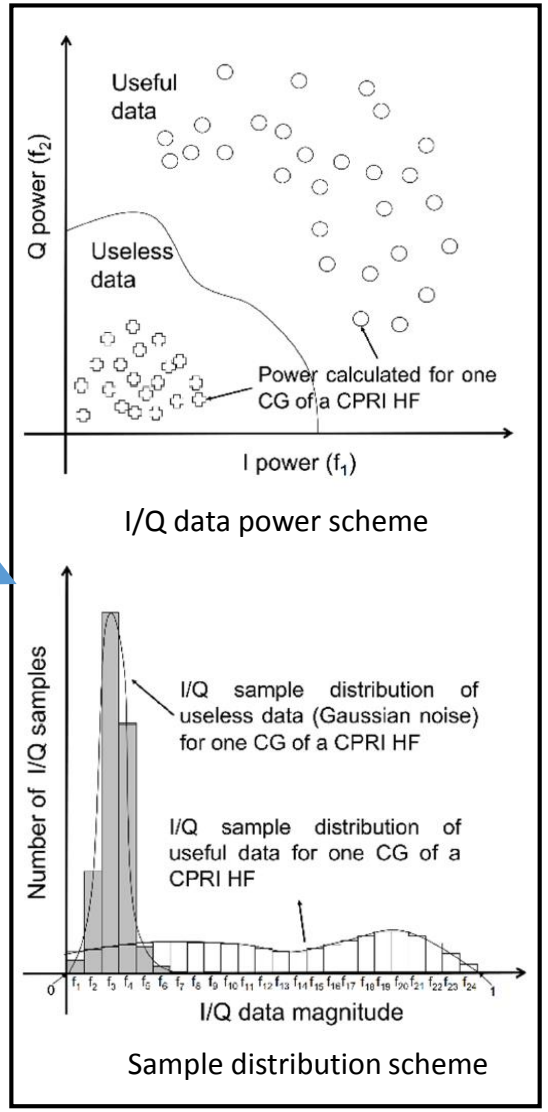
Useless Traffic Classification and Sifting





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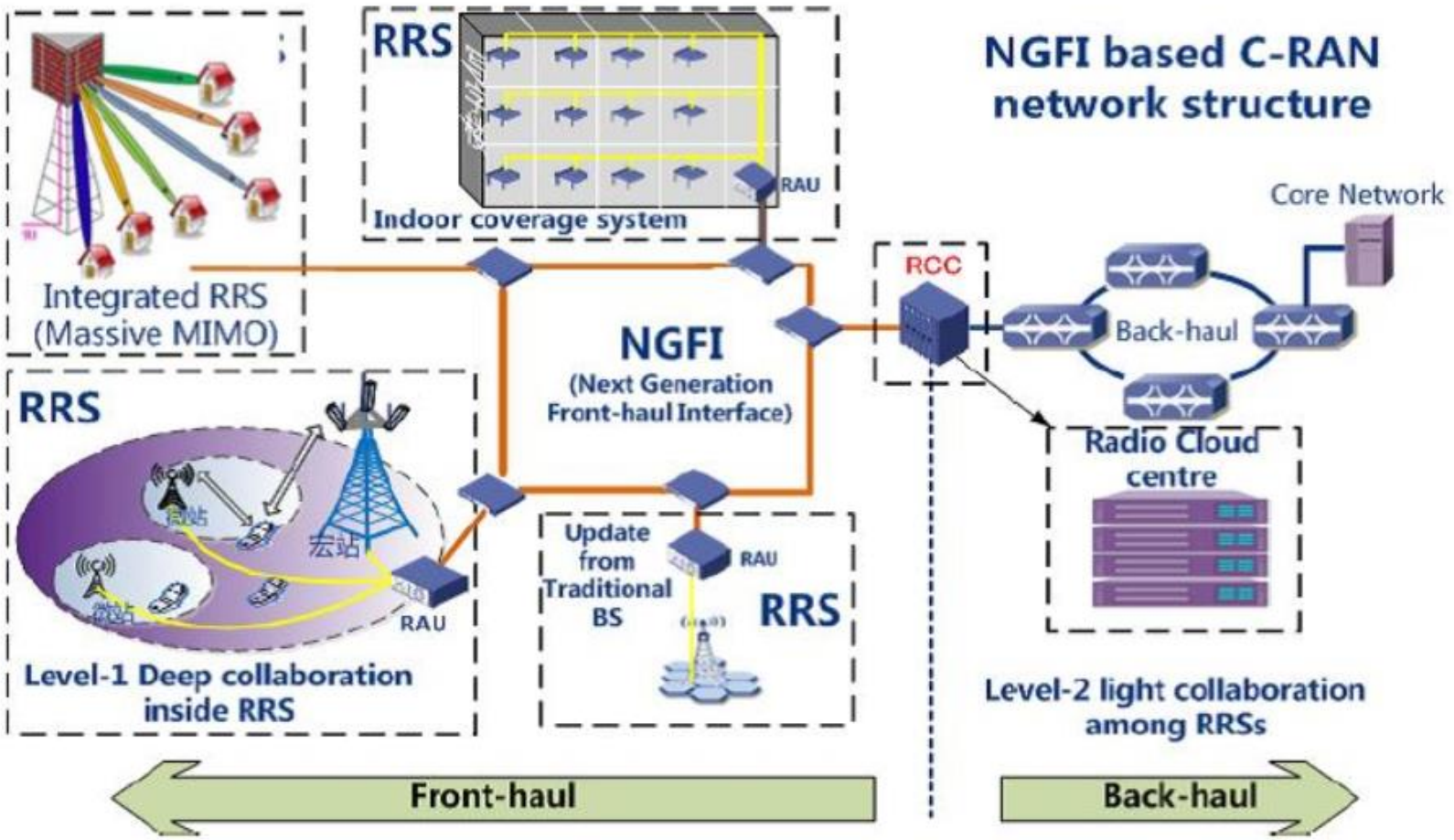
Next Generation Fronthaul Interface (NGFI)

- NGFI redefines the baseband processing split between BBU and RRU, hence redefining the positioning of eNB stack components between BBU/RRU.
- BBU is redefined as Radio Cloud Center (RCC) and RRU becomes Radio Remote System (RRS).
- NGFI architecture from China mobile envisions point-to-multipoint architecture from RCC-RRU, hence there is another element Radio Aggregation Unit (RAU) which interfaces with RCC and carries transport for several RRUs.
- In NGFI, various fronthaul functional splits are being defined to provide different tradeoffs among RRU complexity, system performance, and fronthaul bandwidth efficiency.

China Mobile NGFI white paper, available at http://labs.chinamobile.com/cran/2015/09/29/white-paper-of-ngfinext-generation-fronthaul-interface-version-1-0en/

Next Generation Fronthaul Interface (NGFI)

Architecture



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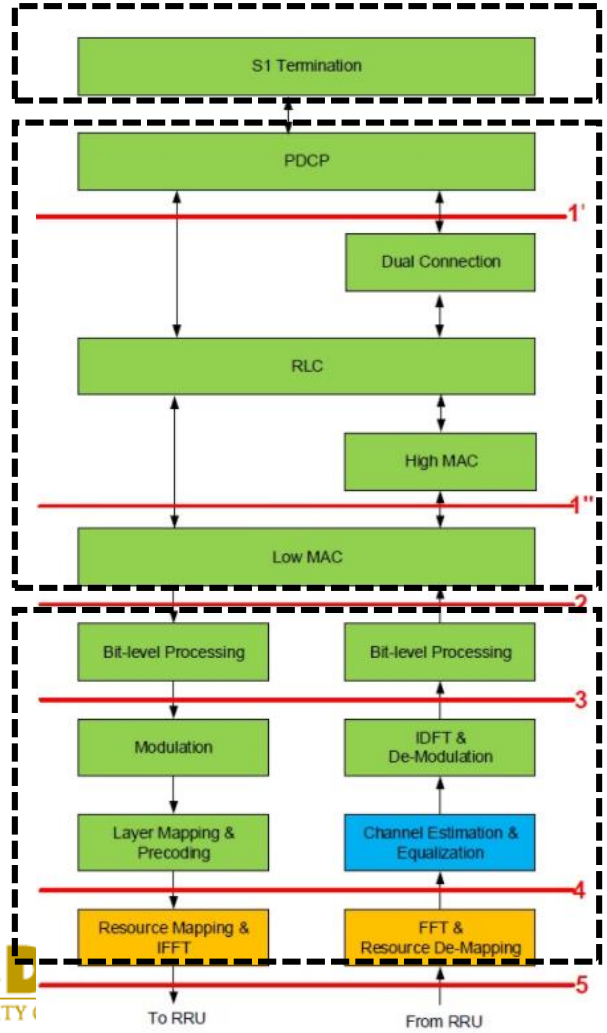
Next Generation Fronthaul Interface (NGFI)

Functional split



Layer 3 and above

Layer 2

Layer 1

Interface delay

Interface 1		Interface 2		Interface 3		Interface 4		Interface 5	
Delay	Ratio	Delay	Ratio	Delay	Ratio	Delay	Ratio	Delay	Ratio
Less than 100 ms	1	Less than 1 ms	100	Less than 1 ms	100	Less than 1 ms	100	Less than 1 ms	100

Maximum interface bandwidth

	Interface 1		Interface 2		Interface 3		Interface 4		Interface 5	
	Bandwidth	Ratio	Bandwidth	Ratio	Bandwidth	Ratio	Bandwidth	Ratio	Bandwidth	Ratio
Downlink	174 Mb/s	1	179.2 Mb/s	1	125.2 Mb/s	1	498 Mb/s	3	9,830.4 MB/s	66
Uplink	99 Mb/s	1	78.6 Mb/s	1	464.6 Mb/s	6	2,689.2 Mb/s	36	9,830.4 MB/s	131

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Next Generation Fronthaul Interface (NGFI)

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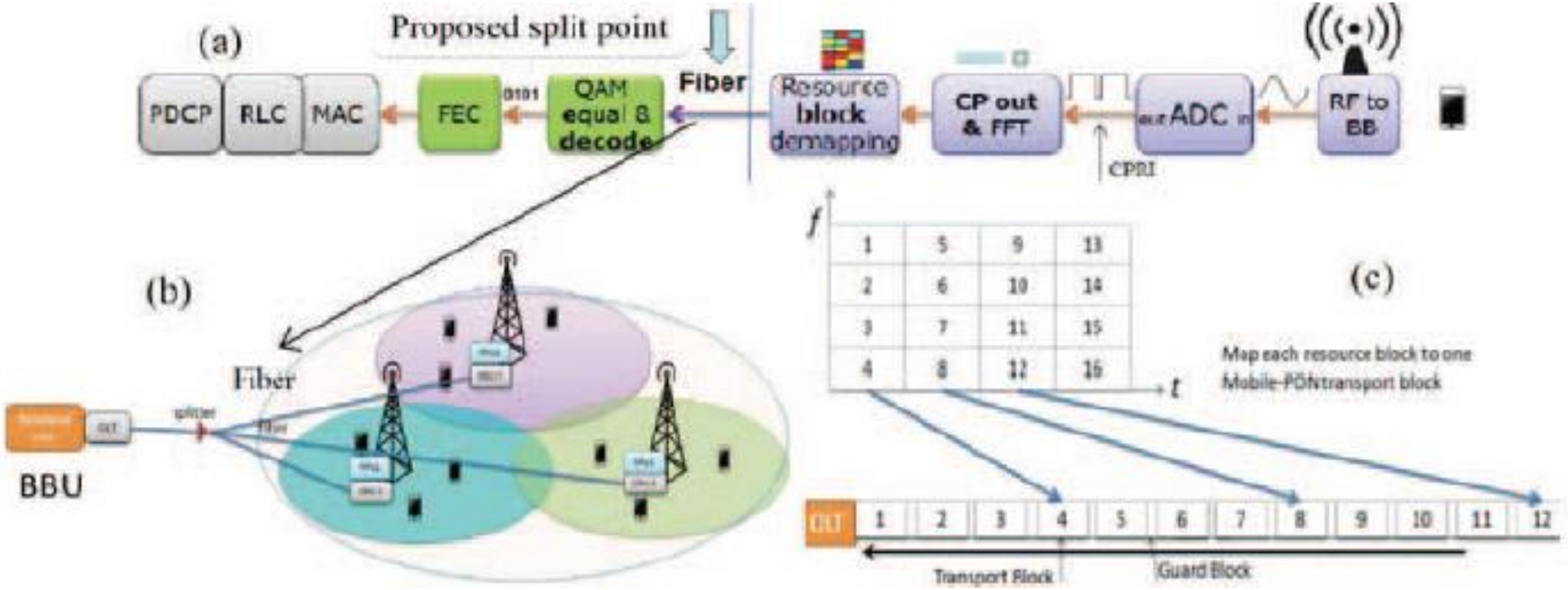

S. Zhou, *et al*., "Mobile-PON: a high-efficiency low-latency mobile fronthaul based on functional split and TDM-PON with a unified scheduler," *Proc. OFC*, 2017.

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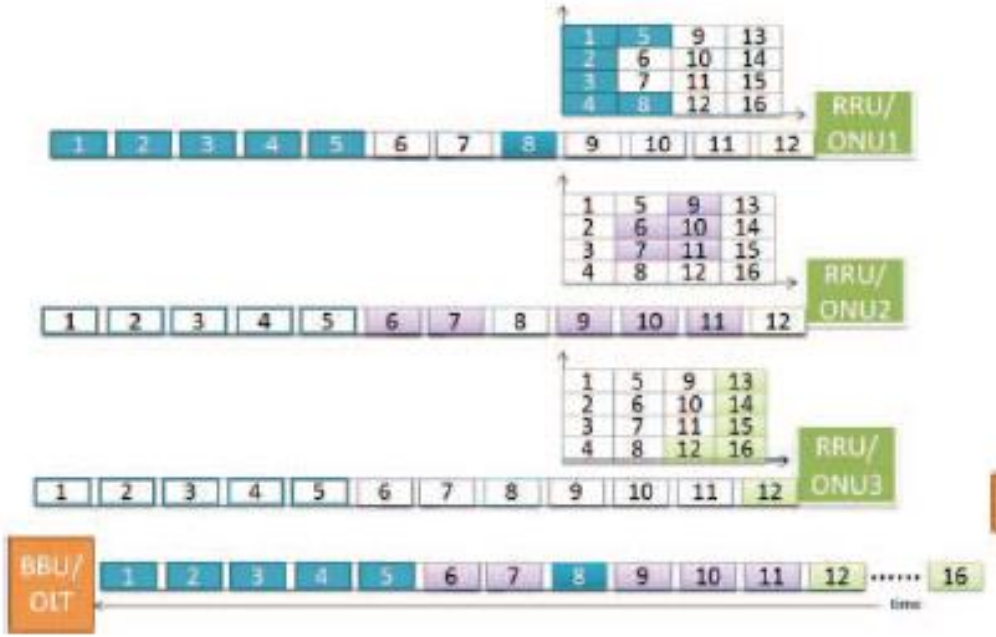
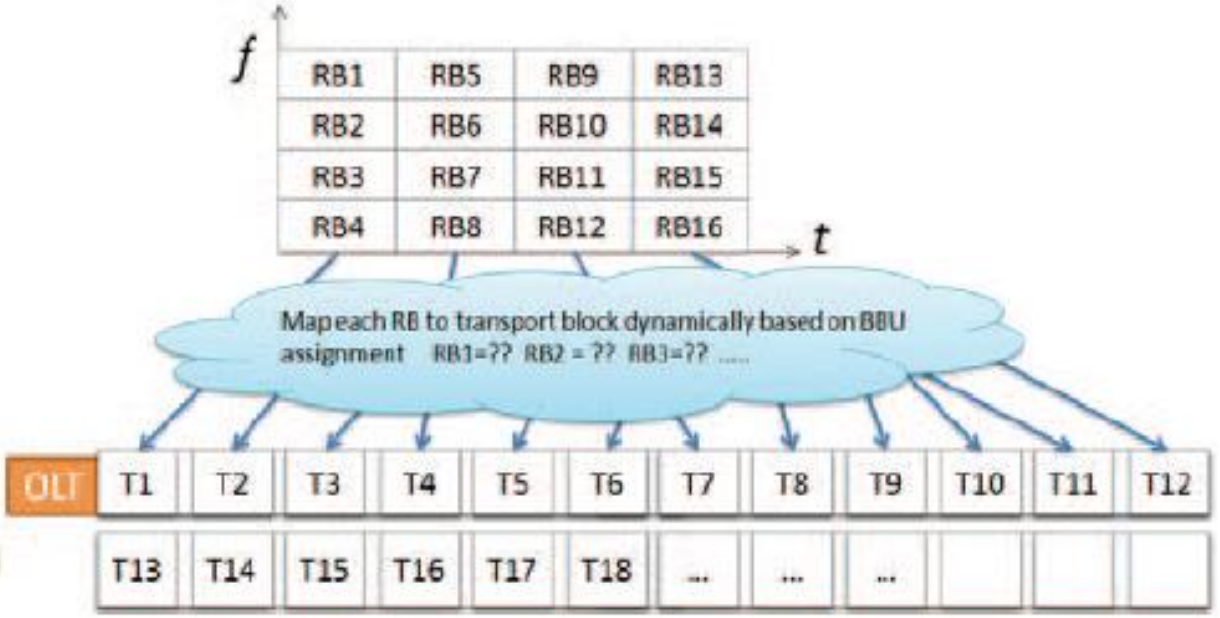


Static mapping



Dynamic mapping

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Next Generation Fronthaul Interface (NGFI)

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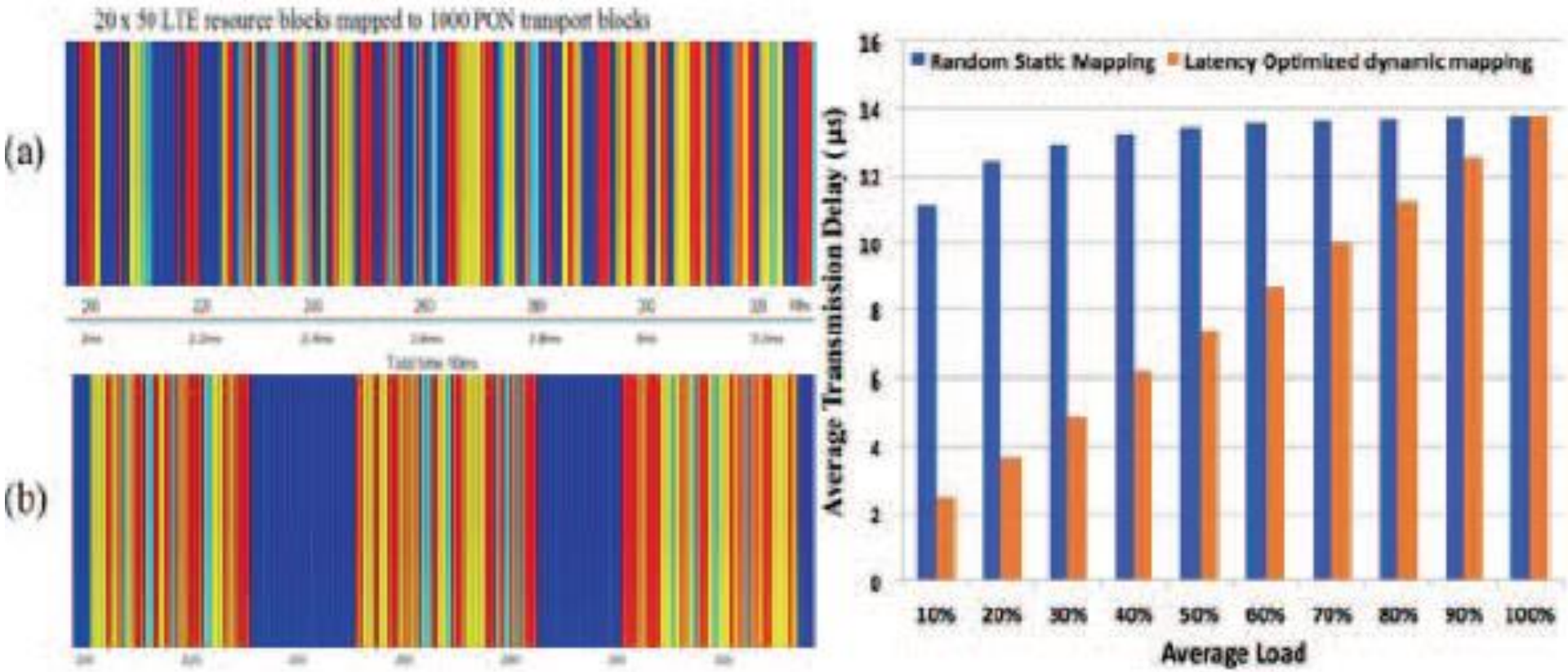

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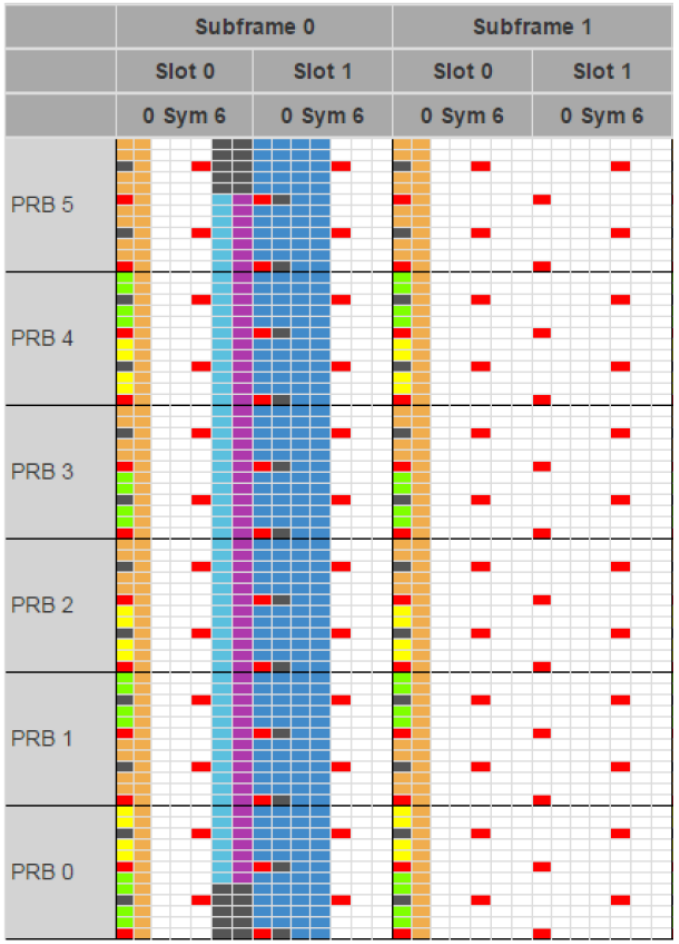
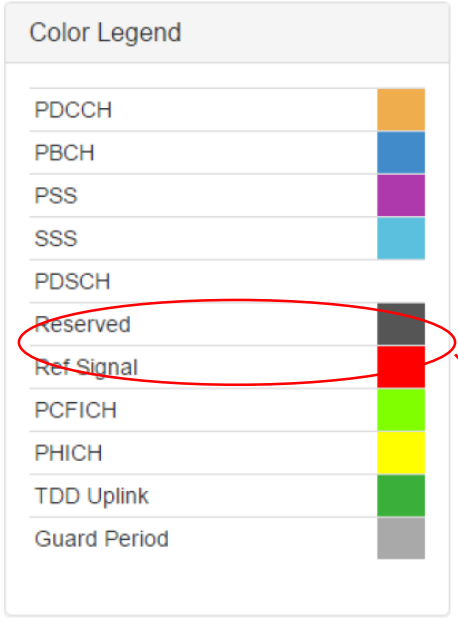
Next Generation Fronthaul Interface (NGFI)

Example 2:





Downlink shared-channel for user data

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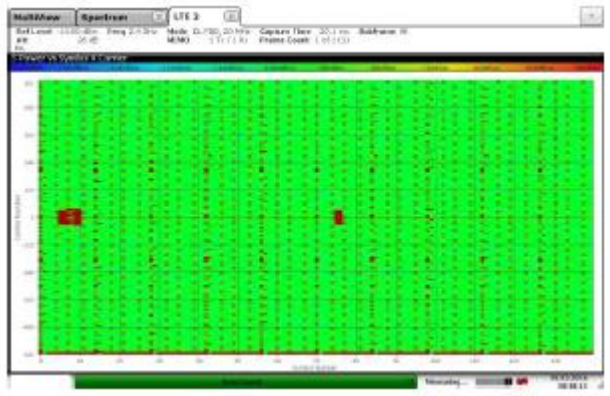
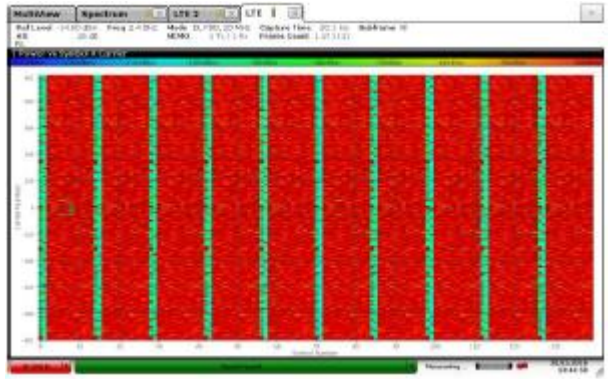
A. Lund , *et al*., "Radio over Ethernet Gateway for Future Fronthaul Networks," *FG IMT-2020 Workshop*.

Next Generation Fronthaul Interface (NGFI)

Example 2:



Low load in a 10 MHz cell



Peak load in a 10 MHz cell

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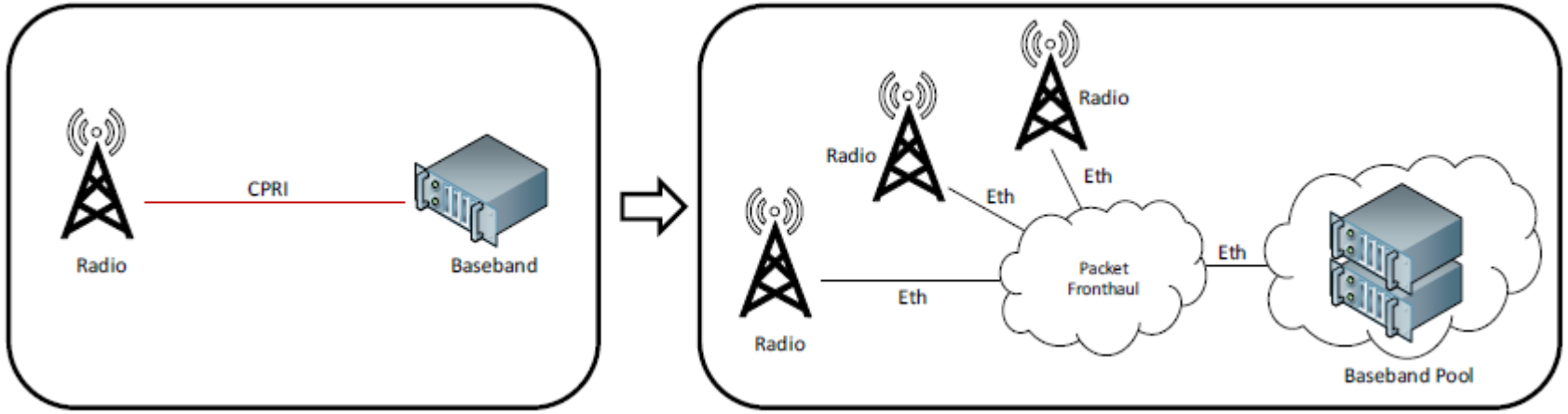
Dedicated Connections Too Expensive?

- Potential solutions:
  - **Reduce fronthaul line rate and take advantage of time-domain multiplexing**
    - TDM-PON
  - **From circuit switching to packet switching**
    - Ethernet -- IEEE 802.1CM Time-Sensitive Networking (TSN) in fronthaul

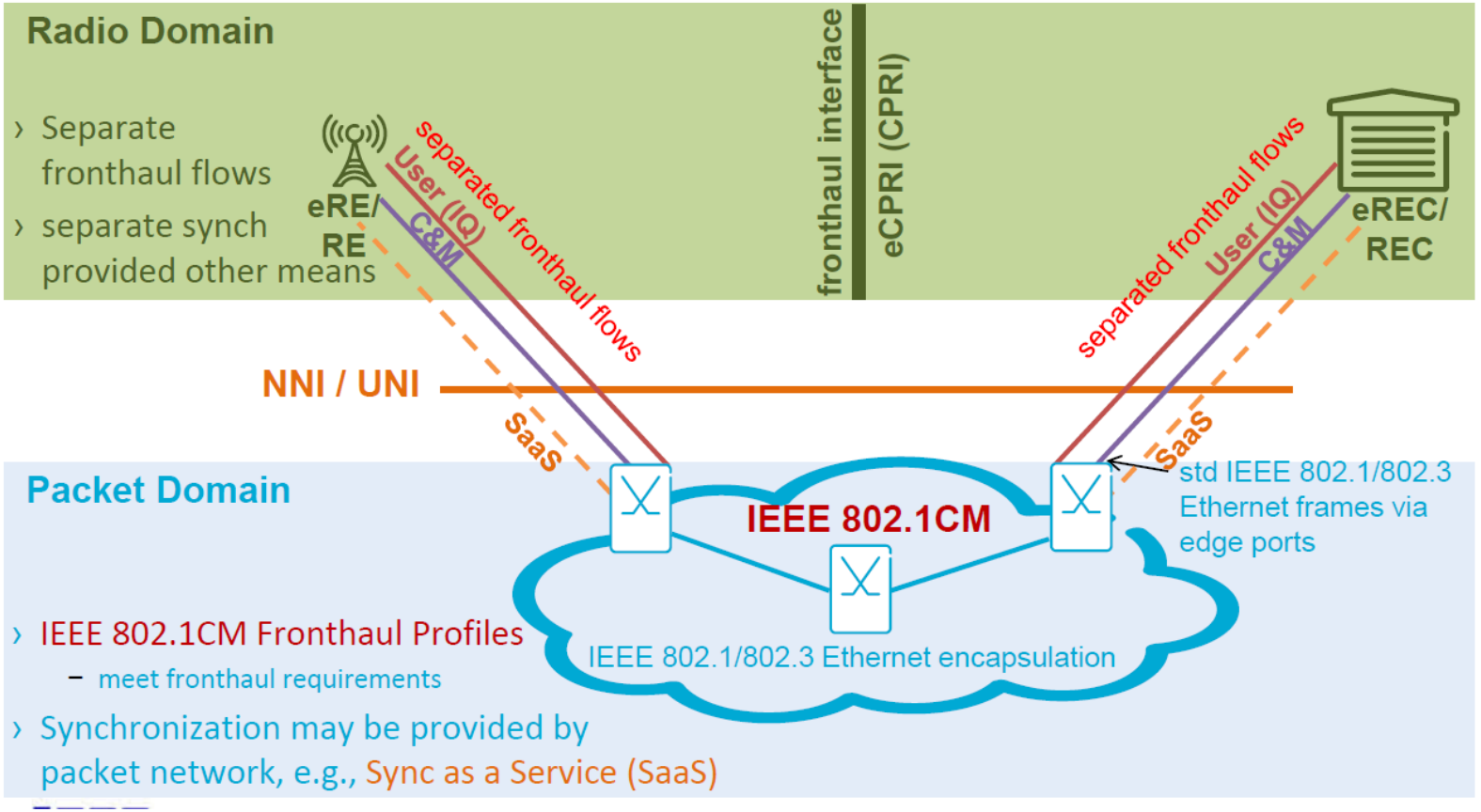
Ethernet

- **Motivation for Ethernet Based Fronthaul**
  - New fronthaul interface technologies are required to reduce fronthaul transmission costs.
  - Fronthaul architecture is migrating from traditional RAN where single BBU connects to single/few RRUs to architectures where multiple centralized BBUs connect to multiple RRUs making a packet switched technology ideal.
  - Ethernet is a widely adopted and nearly ubiquitous standard technology.



Ethernet

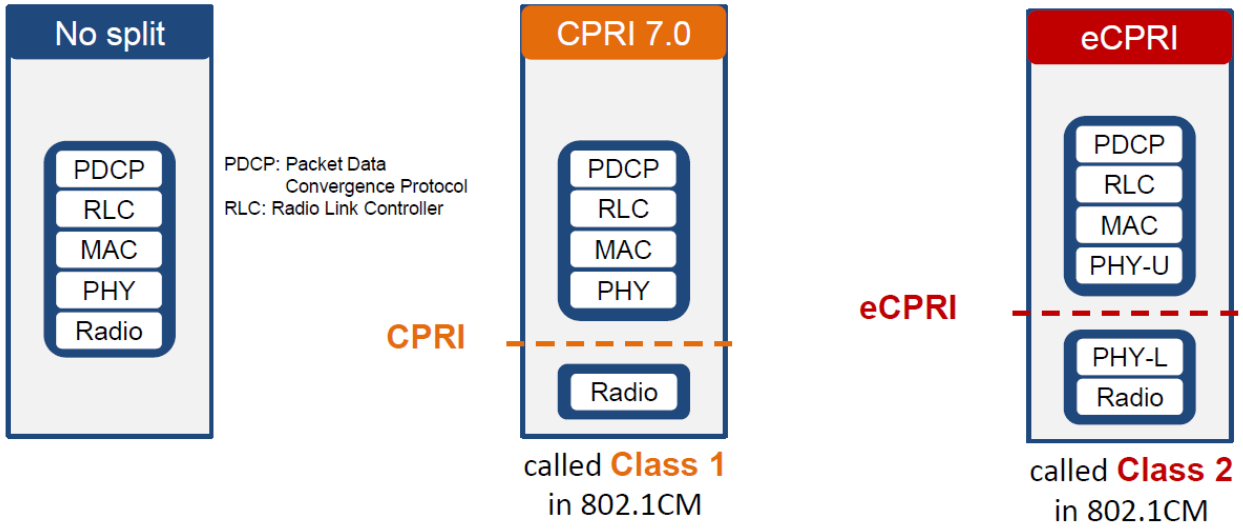
❑ IEEE 802.1CM Time-Sensitive Networking (TSN) in fronthaul



J. Farkas, *et al*., "IEEE 802.1CM Time-Sensitive Networking for Fronthaul," *proposal presentation slides*, 2018.

Ethernet

❑ IEEE 802.1CM Time-Sensitive Networking (TSN) in fronthaul



- ❑ **Two profiles for both Classes**
  - ❖ Profile A:
    - ➢ I/Q data: high-priority traffic class.
    - ➢ C&M data: lower-priority traffic class.
    - ➢ Max Ethernet frame size for all traffic: 2000 octets.
  - ❑ Profile B:
    - ➢ Fronthaul traffic: high-priority traffic class.
    - ➢ Non-fronthaul traffic: lower-priority traffic class with preemption.
    - ➢ Max Ethernet frame size for fronthaul traffic: 2000 octets.
    - ➢ Flexible frame size for non-fronthaul traffic.

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Thank you!