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Converged Networks and Mobility

5G Fronthaul Over DOCSIS: Transporting O-RAN's Split 7-2x with DOCSIS

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2021 Fall Technical Forum
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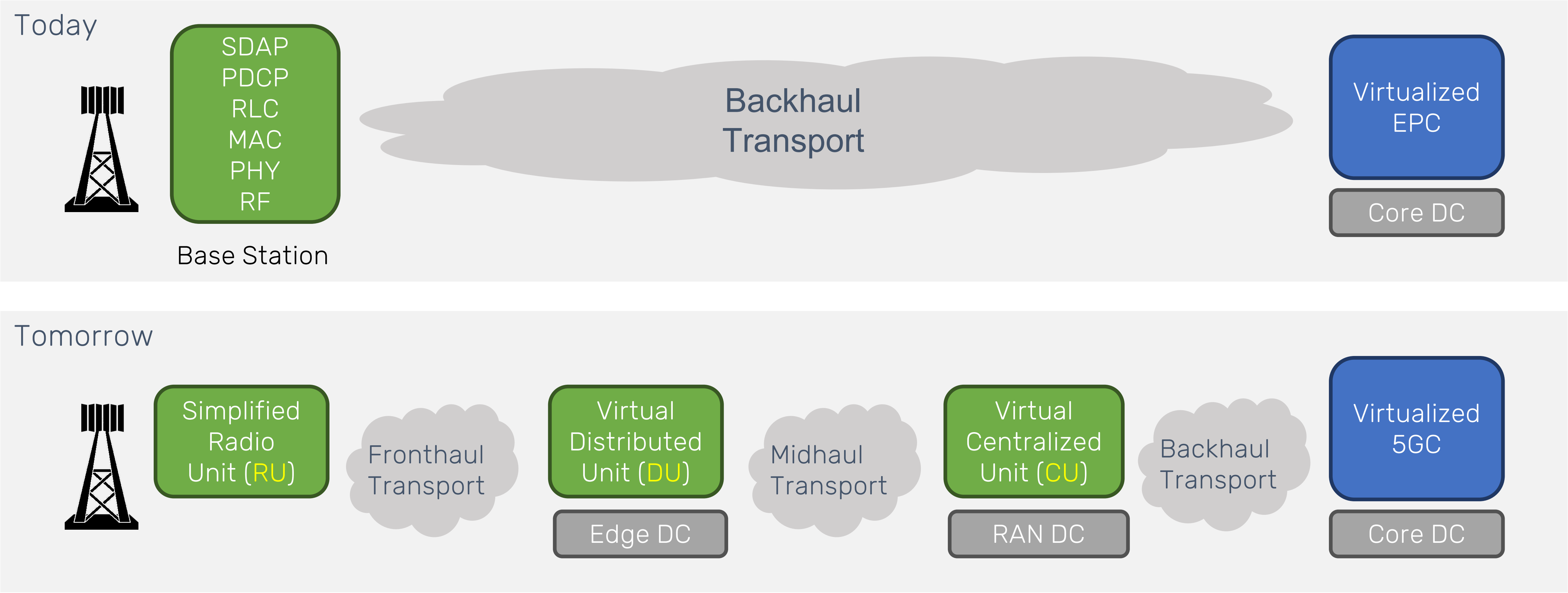
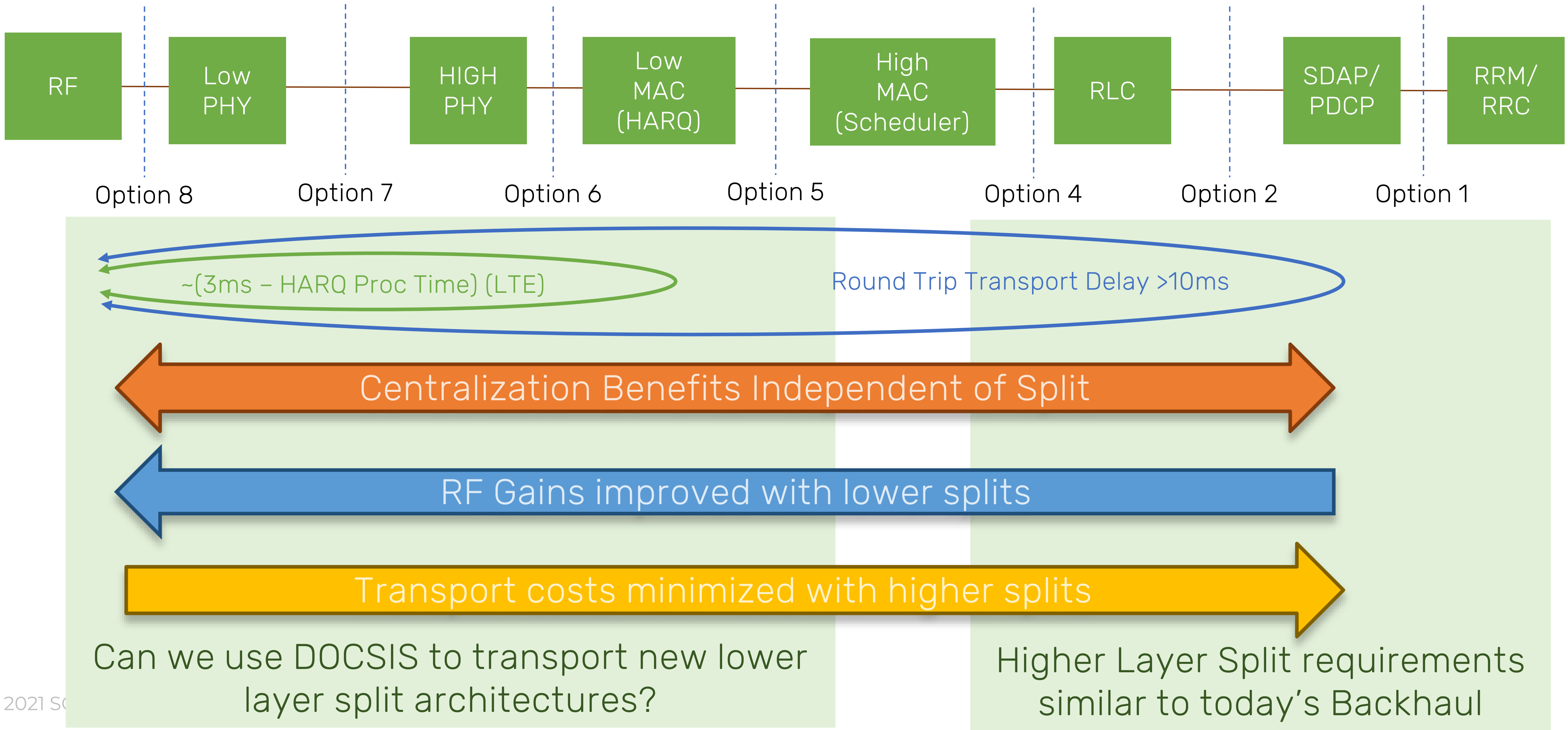
The Transition to a Decomposed Radio Access Network

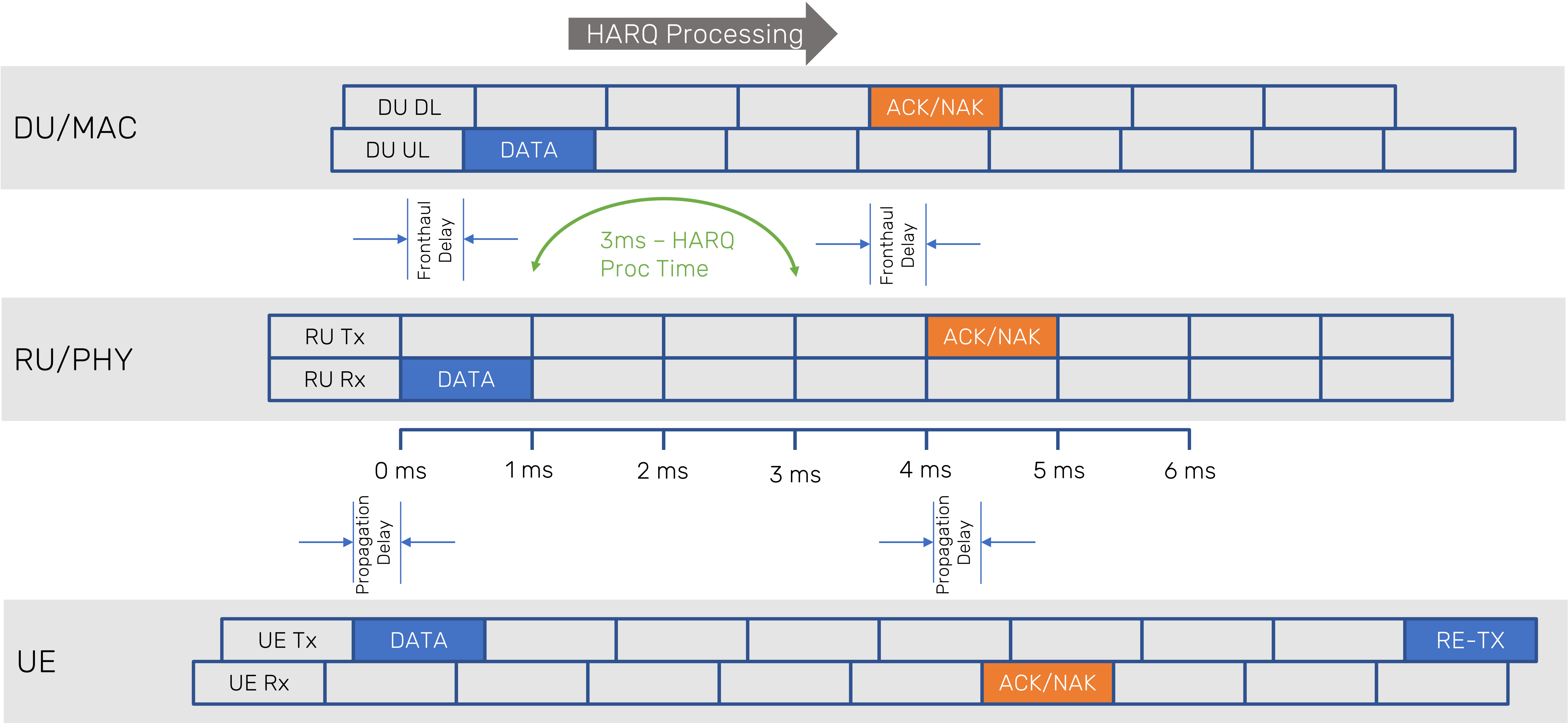


 | expo.scte.org

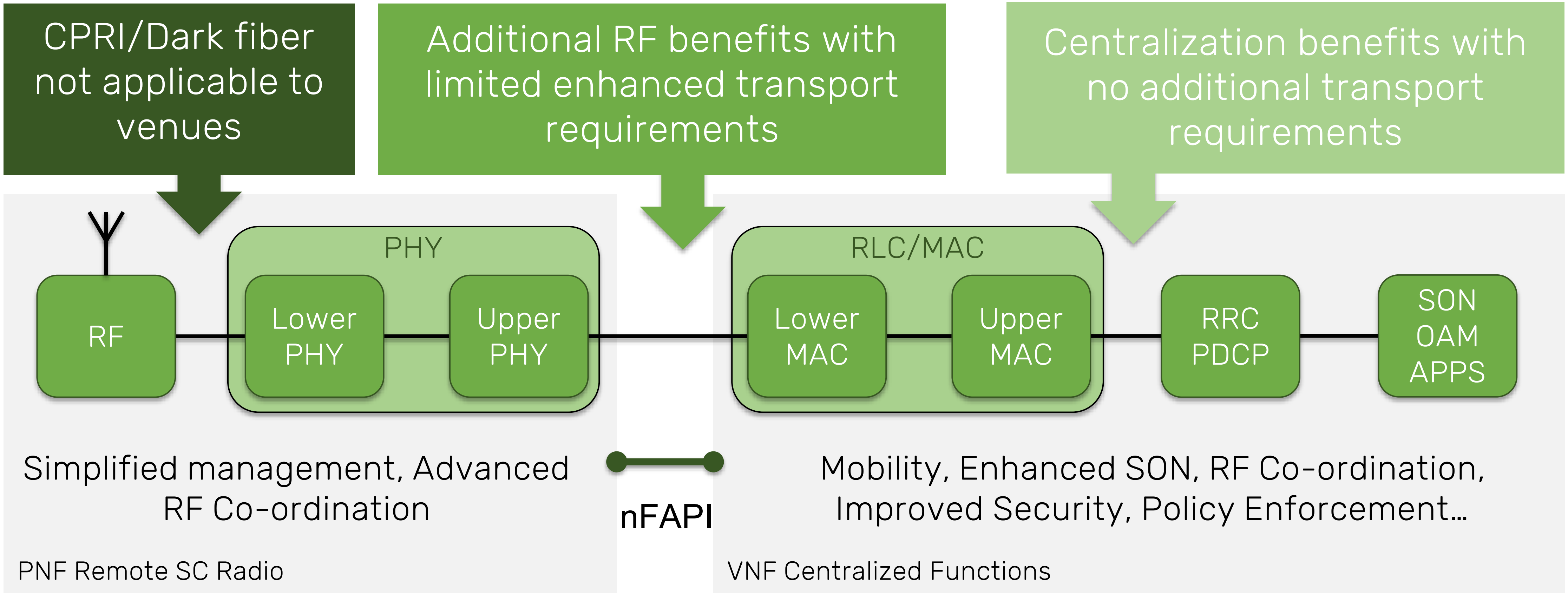
How Best to Split/Virtualize and Transport the RAN?



The LTE HARQ Hard Transport Delay Timing Constraint



Specification of Multi-Vendor MAC/PHY Split



RAN Splits: 3GPP Higher Layer and Lower Layer Splits

3GPP TR 38.801 V14.0.0 (2017-03)

Technical Report

3rd Generation Partnership Project;
Technical Specification Group Radio Access Network;
Study on new radio access technology:
Radio access architecture and interfaces
(Release 14)

The present document has been developed within the 3rd Generation Partnership Project (3GPP™) and may be further elaborated for the purposes of 3GPP.
The present document has not been subject to any approval process by the 3GPP Organizational Partners and shall not be implemented.
This Report is provided for future development work within 3GPP only. The Organizational Partners accept no liability for any use of this Specification.
Specifications and Reports for implementation of the 3GPP™ system should be obtained via the 3GPP Organizational Partners' Publications Offices.

11.1.5 Conclusions on functional split between central and distributed unit

Higher Layer Split

There shall be normative work for a single higher layer split option, i.e. Stage 2 and Stage3.

Lower Layer Split

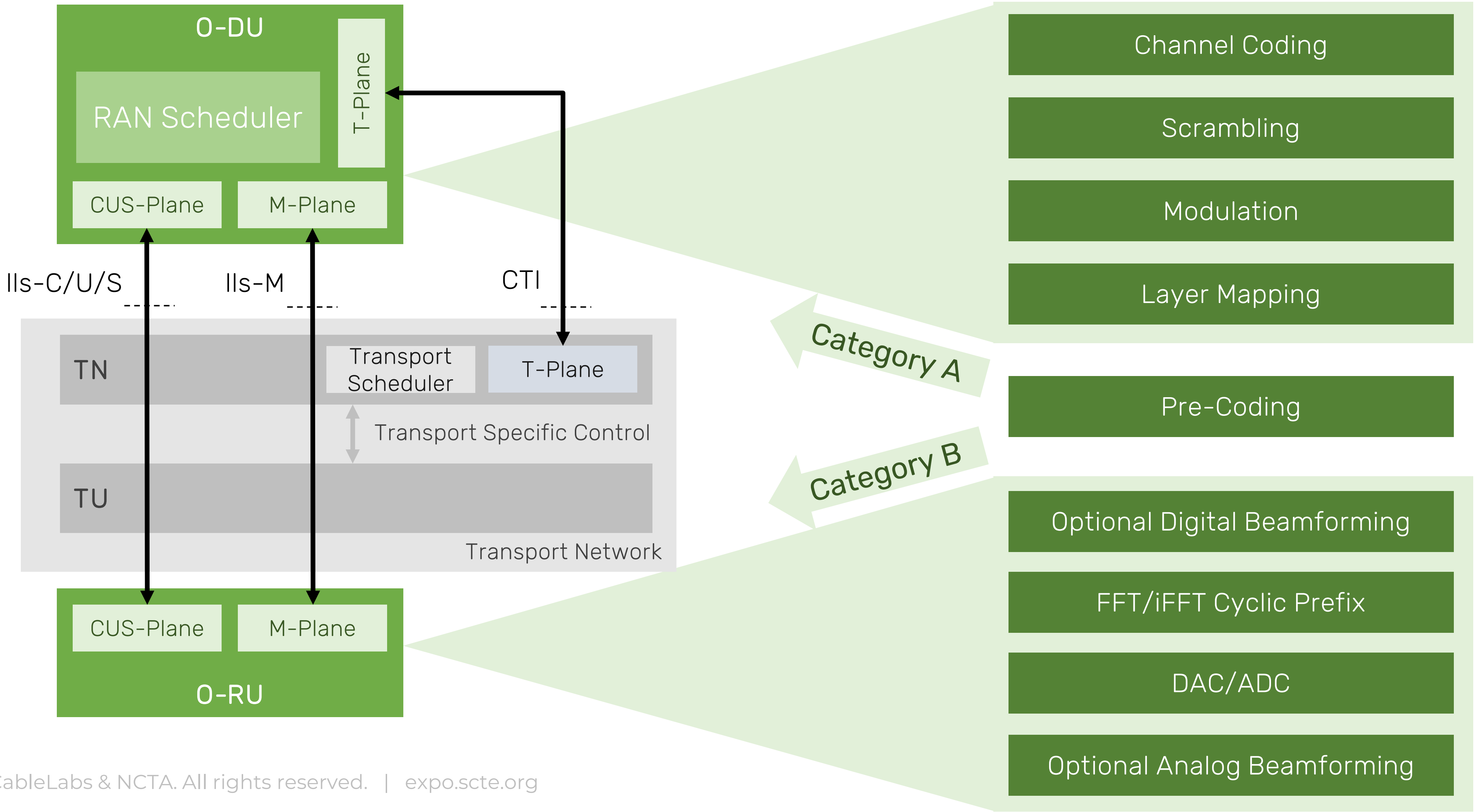
The study on lower layer split RAN architectures is not completed and postponed.

Further study is required to assess on low layer splits, their feasibility, the selection of options and assess the relative technical benefits, based on NR, before a decision to go to specification phase can be made. Discussions in the Study Item, favored option 6 and 7 for future study.

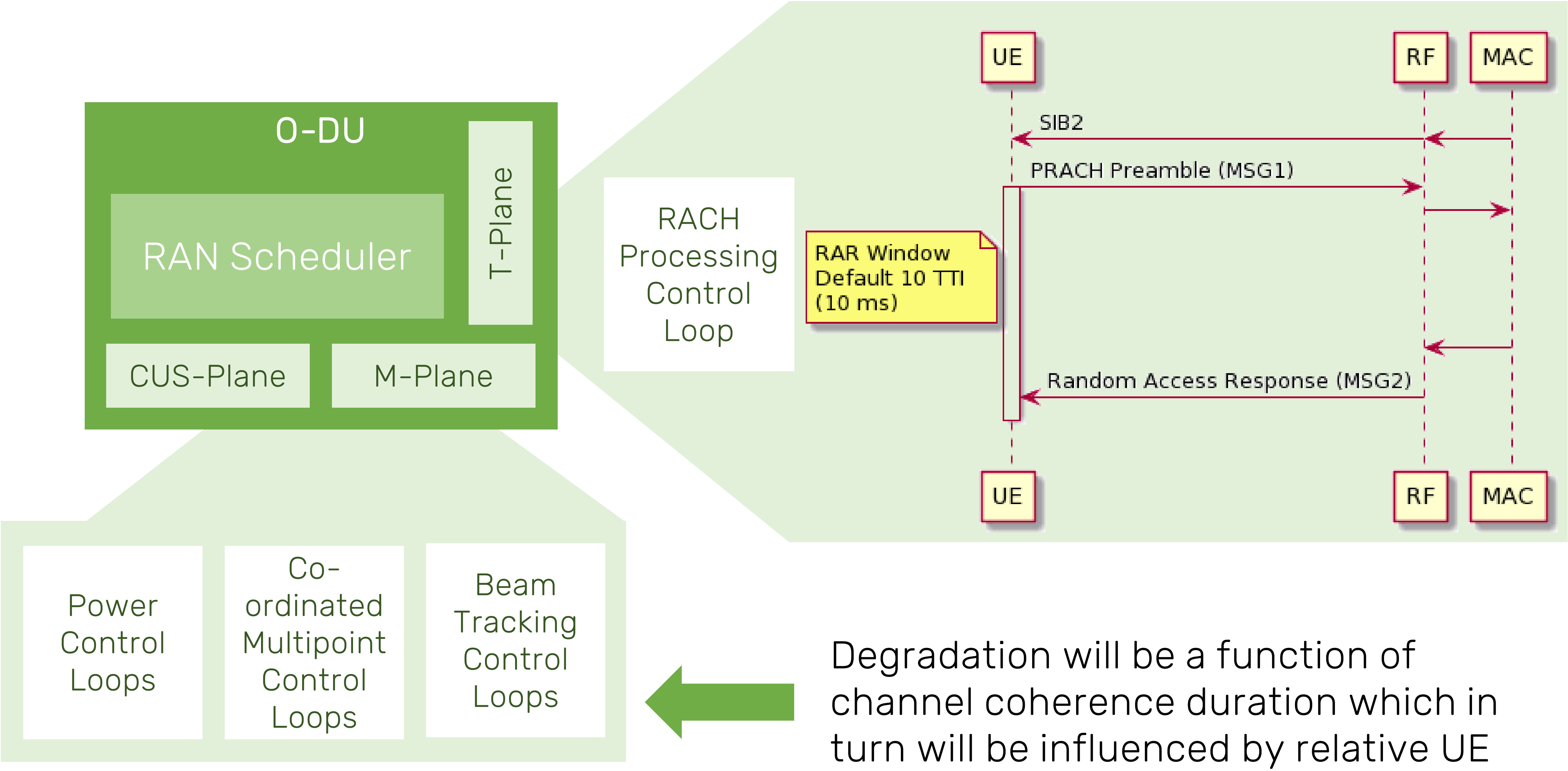
O-RAN ALLIANCE

- Formed in February 2019 through the merger of xRAN Forum and C-RAN Alliance
- >24 Operators & >130 Suppliers
- Open Architecture
- Open Software Community
- Open Hardware Reference Designs
- AI/ML – Defining the RAN Intelligent Controller
- Commercial License to use and modify O-RAN Specifications
- Testing and Integration – world wide plugfest and MV-interop
- Fully Specifying a Lower Layer Split, termed Split 7-2x

O-RAN Lower Layer Split 7-2x



The 5G NR Soft Transport Delay Timing Constraint



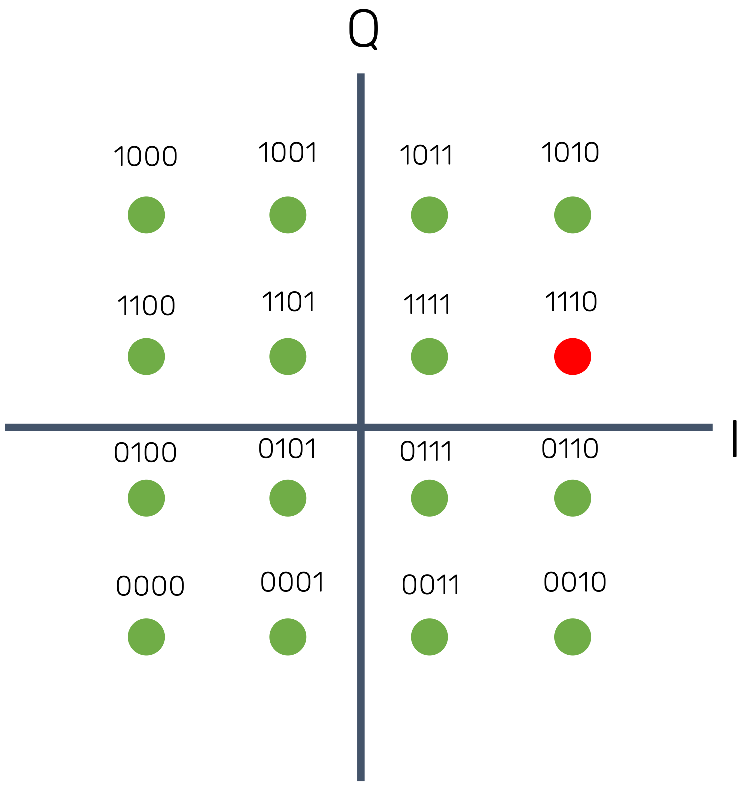
Degradation will be a function of channel coherence duration which in turn will be influenced by relative UE velocity

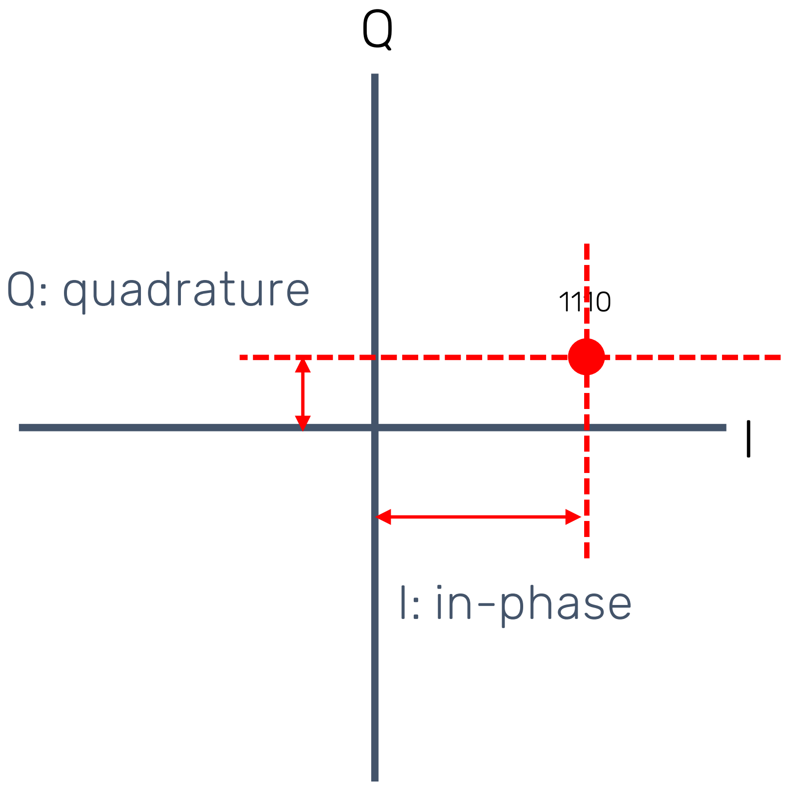
Split 7-2x Bandwidth Expansion

Bits to Transmit/
Modulate: 1110

Block Floating Point Compression
I: 9 bit mantissa
Q: 9 bit mantissa
E: 8 bit exponent every 12 IQ samples
(not shown in figure)

Block Floating Point
Bandwidth Expansion





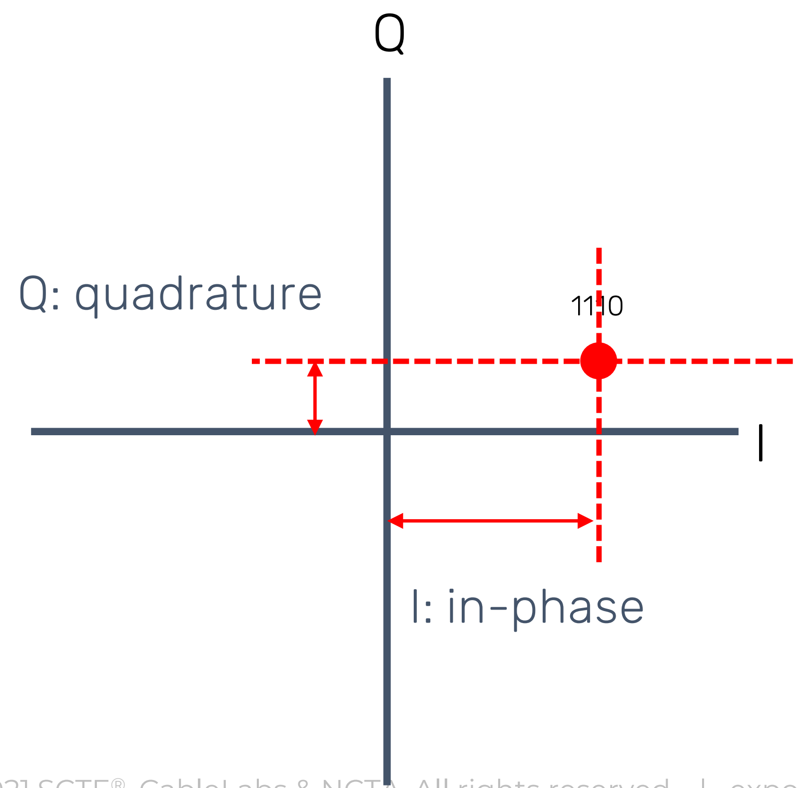
	16 QAM	256 QAM
Bits to Modulate	4	8
Block Floating Point bits	18 $^2/_3$	18 $^2/_3$
Bandwidth Expansion	4.67	2.33

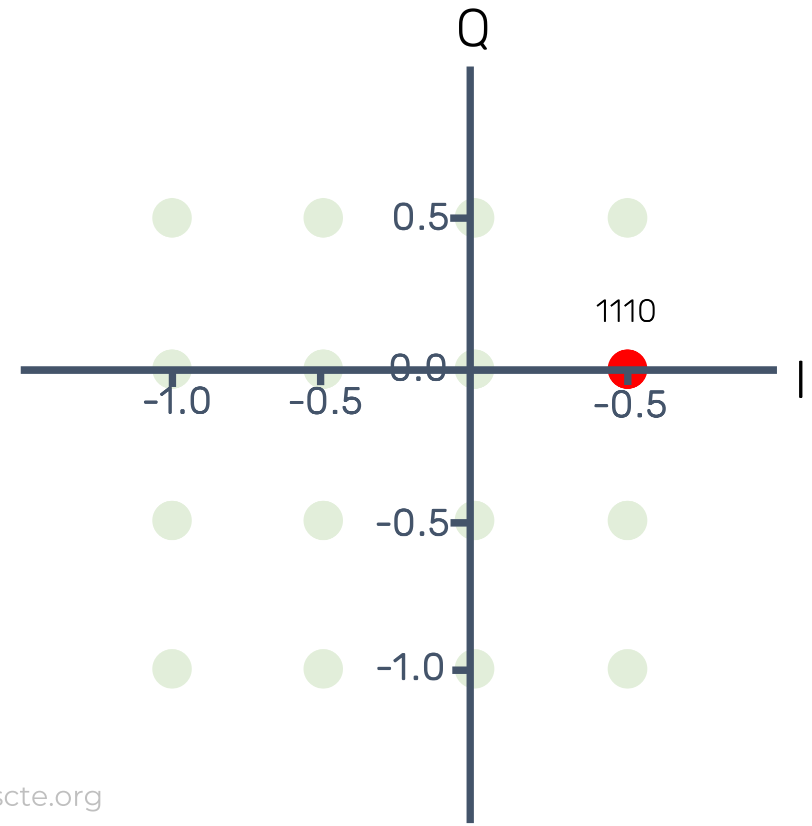
Modulation Compression to Limit BW Expansion

Block Floating Point Compression
I: 9 bit mantissa
Q: 9 bit mantissa
E: 8 bit exponent every 12 IQ samples (not shown in figure)

Modulation Compression
I: 2 bit
Q: 2 bit
S: 32 bit scalar every data section (not shown in figure)

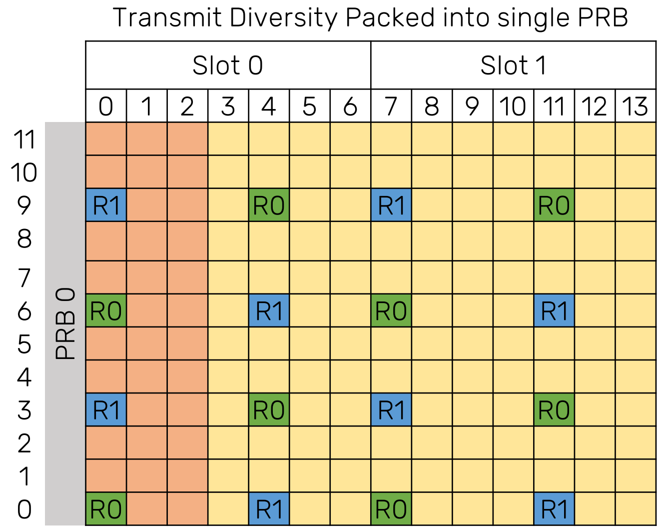
ModComp Bandwidth Expansion





	16 QAM	256 QAM
Bits to Modulate	4	8
Modulation Compression Bits	4.01 to 6.67	8.01 to 10.67
Bandwidth Expansion	1.00 to 1.67	1.00 to 1.33

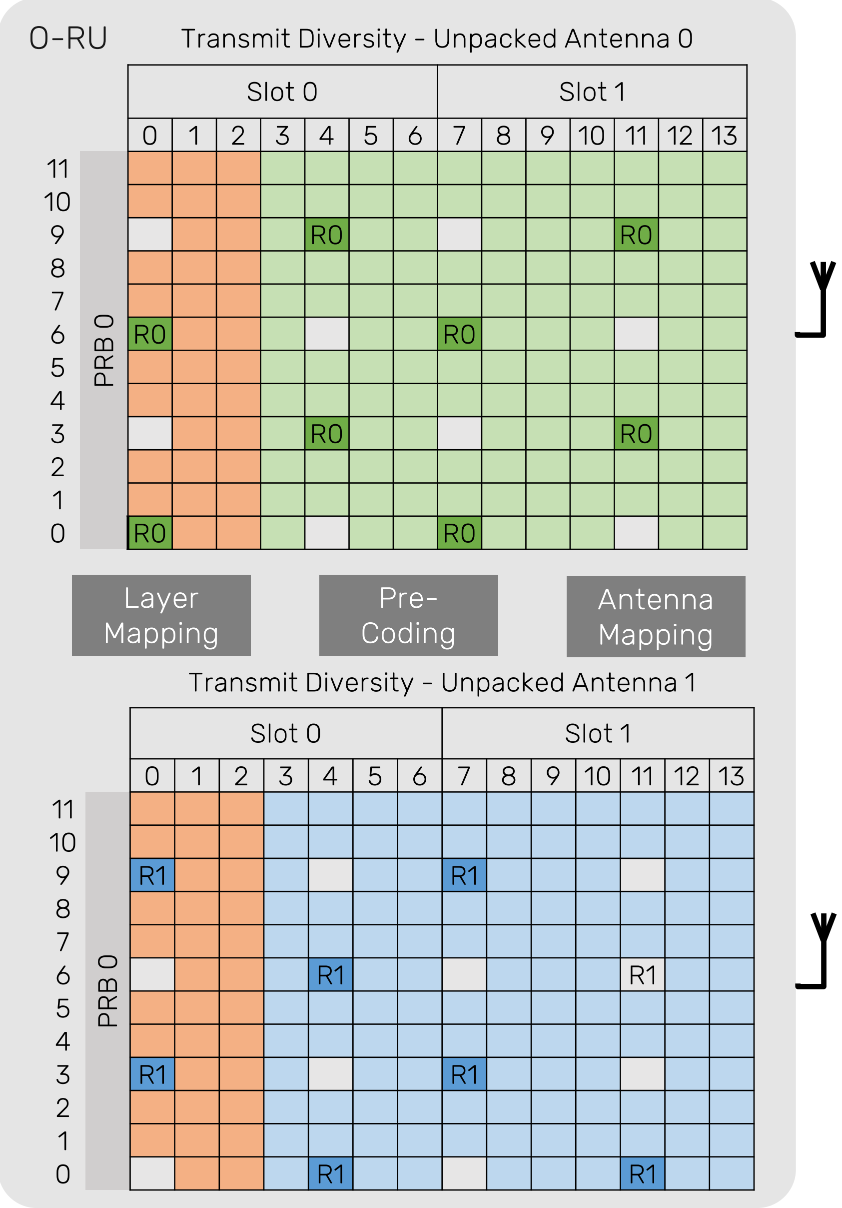
Split 7-2x MIMO Layer Optimization



Physical Downlink Control Channel
Physical Downlink Shared Channel – Antenna 0 & 1
Reference Symbols Antenna 0
Physical Downlink Shared Channel - Antenna 0
Reference Symbols Antenna 1
Physical Downlink Shared Channel - Antenna 1
Blank

Single PRB with time multiplexed reference symbols used to drive multiple antenna streams

fronthaul



Comparing nFAPI/Split 6 with O-RAN/Split 7-2x

Characteristic	nFAPI	Split 7-2x	Comment
Advanced RF Techniques	Supports 6 out of 8 RF techniques	Supports 8 out of 8 RF techniques	Split 7-2x supports higher order MIMO
Round-trip Transport Latency for LTE	Hard limit of 0.5 milliseconds	Hard limit of 0.5 milliseconds	Identical delay constraint as both splits are below HARQ
Round-trip Transport Latency for NR	Soft limit of 5 milliseconds	Soft limit of 5 milliseconds	Identical delay constraint
Bandwidth Expansion compared with HLS	Limited bandwidth expansion	~16-93% bandwidth expansion for 64 QAM	Split 7-2x has lower bandwidth expansion for higher modulation rates
MIMO Layer Bandwidth Expansion	None	Bandwidth scales with MIMO layers (Cat-B)	Key delta in bandwidth is due to expansion due to MIMO layers
Statistical Multiplexing in Transport	Yes	Yes	Both splits enable statistical multiplexing
RU Complexity	Similar to composed base station	Removes requirement for channel decoder in RU	Split 7-2x enables RU simplification

Example "off-tower" Fronthaul Deployment

LTE Fronthaul

2 x 20 MHz

2 x 2 MIMO

TDD Config: DSUUDDDDDD

DL: Modulation Compression

UL: Block Floating Point 9-bit Mantissa

Max Downstream Ethernet: 360 Mbps

Max Upstream Ethernet: 290 Mbps

Requires 85 MHz Return Path

5G Fronthaul

1 x 40 MHz

4 x 4 MIMO

TDD Config: DDDSU

DL: Modulation Compression

UL: Block Floating Point 9-bit Mantissa

Max Downstream Ethernet: 950 Mbps

Max Upstream Ethernet: 690 Mbps

Requires 204 MHz Return Path

Summary of Fronthaul Transport Requirements

- Compared SCF's nFAPI/Split 6 and O-RAN's Split 7-2x, including integrated CTI support
- Described changes to 5G NR HARQ that permits increased transport latency budgets
- Examined O-RAN Split 7-2x fronthaul compression techniques for DL and UL
- Analysis shows that even with a 4:1 UL/DL TDD ratio, the unequal compression ratios result in approximately symmetrical O-RAN fronthaul transport requirements
- Highlighted that Spatial Stream scaling drives key bandwidth expansion for Split 7-2x
- Analyzed spatial stream optimizations for the most commonly used Tx Diversity schemes
- Ended with analysis of two typical "off-tower" LTE and 5G NR Fronthaul scenarios
- LTE Fronthaul example drives requirement for 85 MHz DOCSIS return path, and 5G NR example drives requirement for 204 MHz return path

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Thank You!

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