Low latency for DCI and mobile applications

Why and how?

Jörg-Peter Elbers

ECOC'19, WS04 "Low Latency Optical Communications"

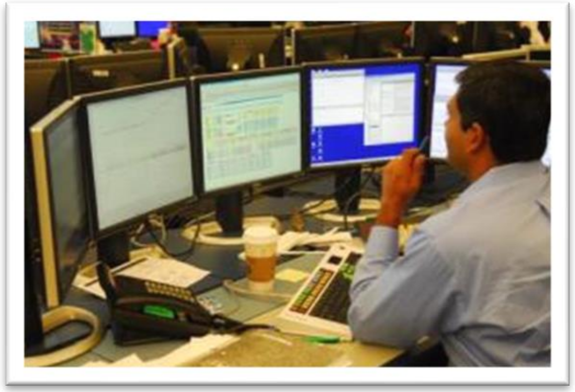
Is low latency just another …

?

Low latency - where do we need it

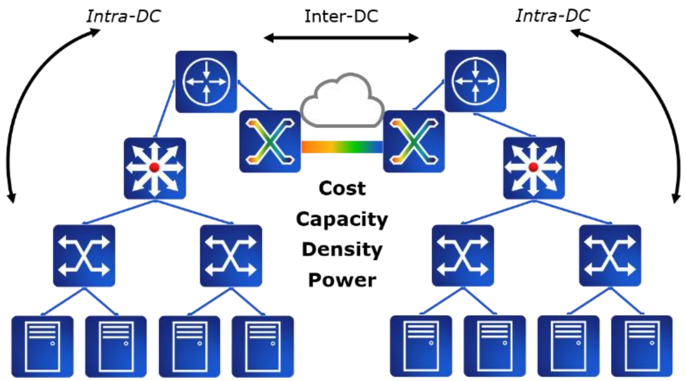
A few examples

High-frequency trading (HFT)



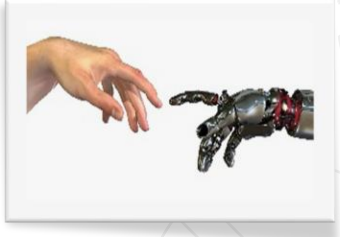
"A one-millisecond advantage in trading applications can be worth USD 100 million a year."

High-performance computing



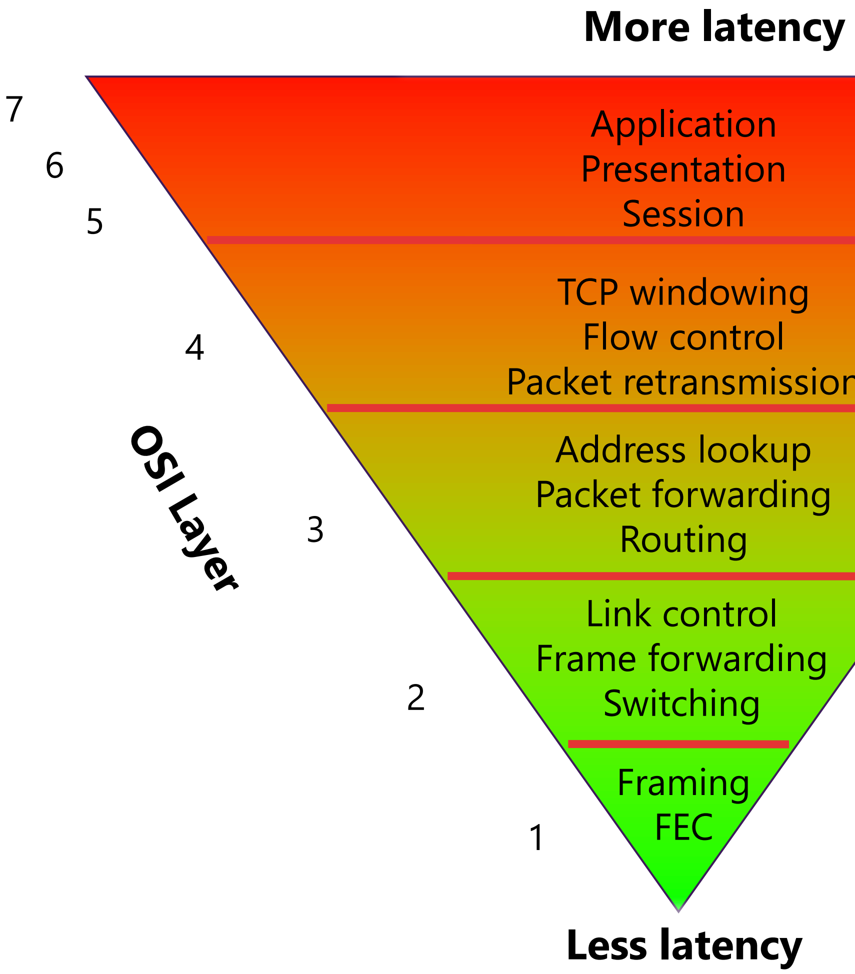
Mobile network infrastructure

Real-time (mobile) applications

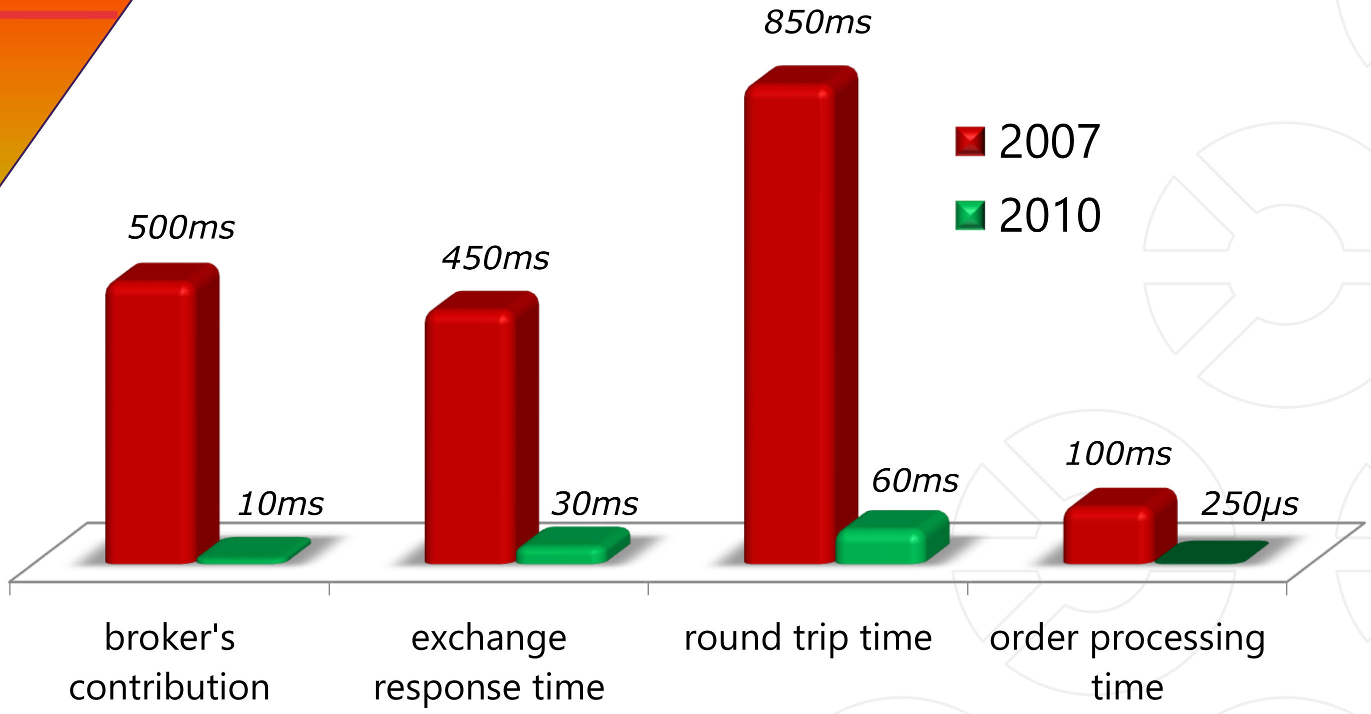


Low latency in DCI applications

Low latency is more than just fast transmission …



Speed-up in high-frequency trading



Applications require a maximum latency and controlled latency variation.

… but the transmission line can be critical

Latency close to fiber propagation delay (5µs/km)

Straight line connection

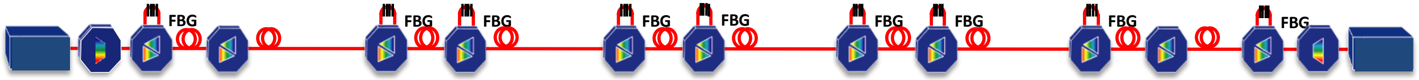
Minimization of equipment delay

1300km link for HFT, approx. 13ms round-trip time

Low latency design considerations

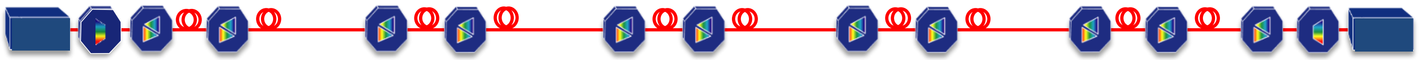
10G transparent regenerator-based design performs best

10G transparent 0.70µs



10G OTN 3.09µs

10G OTN + GFEC **9.39µs**



100G OTN + SD-FEC 15.24µs

100G OTN + SD-FEC * **11.44µs** (* reduced number of iterations)

System Component	Latency
Simple transparent 10G Regen	10 ns
Optical Mux/Demux	20 ns
Raman Amplification	30 ns
DCM (grating)	50 ns
10 Gb/s OTN line card	2.0 µs
100 Gb/s OTN line card w/ equalization	~ 9 µs
10 Gb/s 5.6dB NECG G.709 FEC	6.3 µs
100 Gb/s 11.1dB NECG SD-FEC	~5.6 µs

[B. Teipen et al., ECOC'12]

10 span system, 20dB loss per span

Configuration	Site 1				Site 2			Site 3			Site 4			Site 5			Site 6			Site 7			Site 8			Site 9			Site 10			Site 11				Equipment Latency
	x	m	r	d	x	r	d	x	r	d	x	r	d	x	r	d	x	r	d	x	r	d	x	r	d	x	r	d	x	r	d	x	m	r	d	
10G transparent																																				0.70 µs
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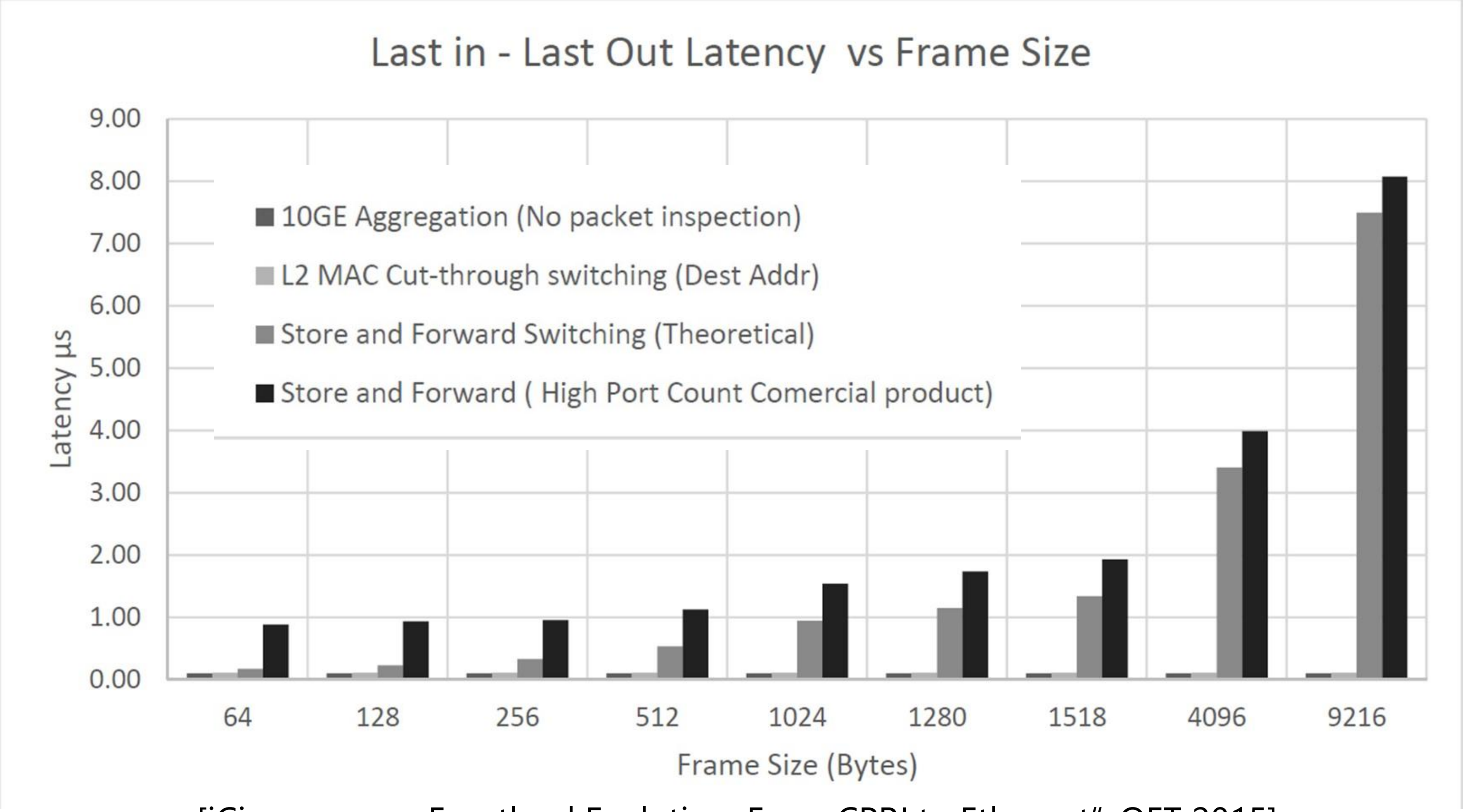
Recipe for low latency:

Limit excess fiber

and electronic processing

Directions to beat the fiber delay: µwave, free-space optics, low latency fibers

Ethernet aggregator latencies - Examples



[iCirrus paper „Fronthaul Evolution: From CPRI to Ethernet“, OFT 2015]

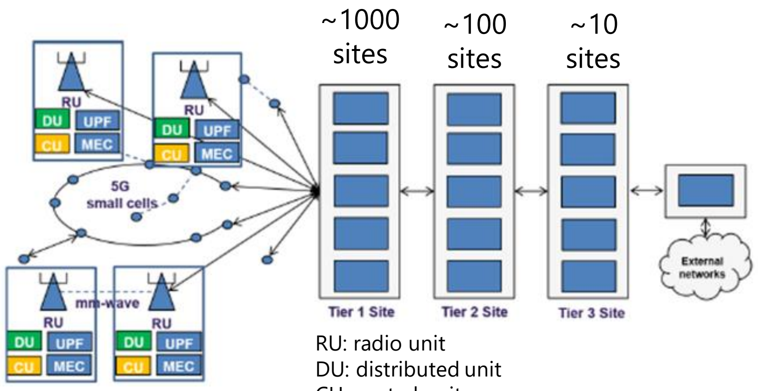
Rule of thumb: A few µs per network element.

Low latency in mobile applications

Latency determines location of RAN functions

Ultra low latency

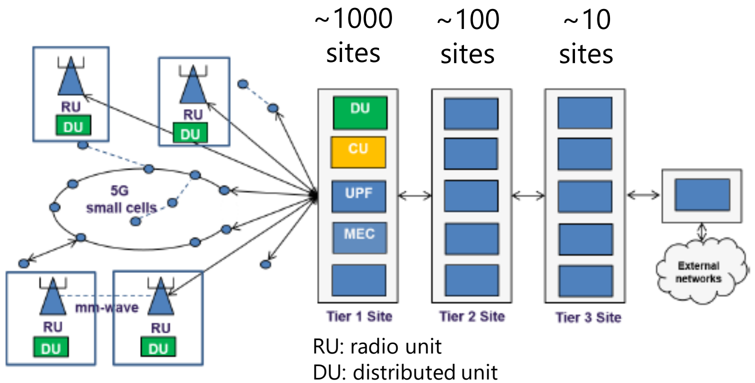
~1ms round-trip time



RU: radio unit
DU: distributed unit
CU: central unit
MEC: multi-access edge computing
UPF: user plane function

Very low latency

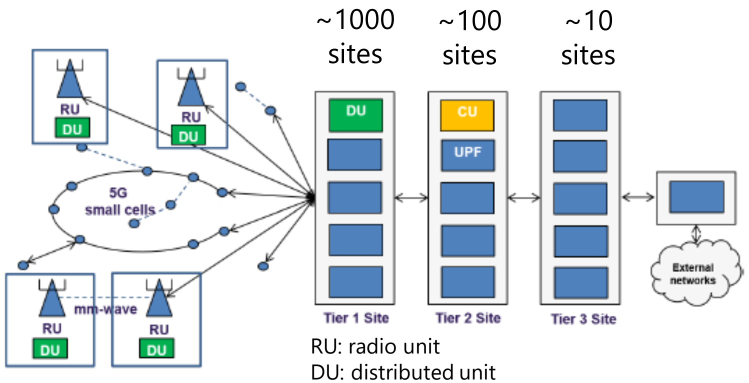
~5ms round-trip time



RU: radio unit
DU: distributed unit
CU: central unit
MEC: multi-access edge computing
UPF: user plane function

Low latency

~10ms round-trip time



RU: radio unit
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MEC: multi-access edge computing
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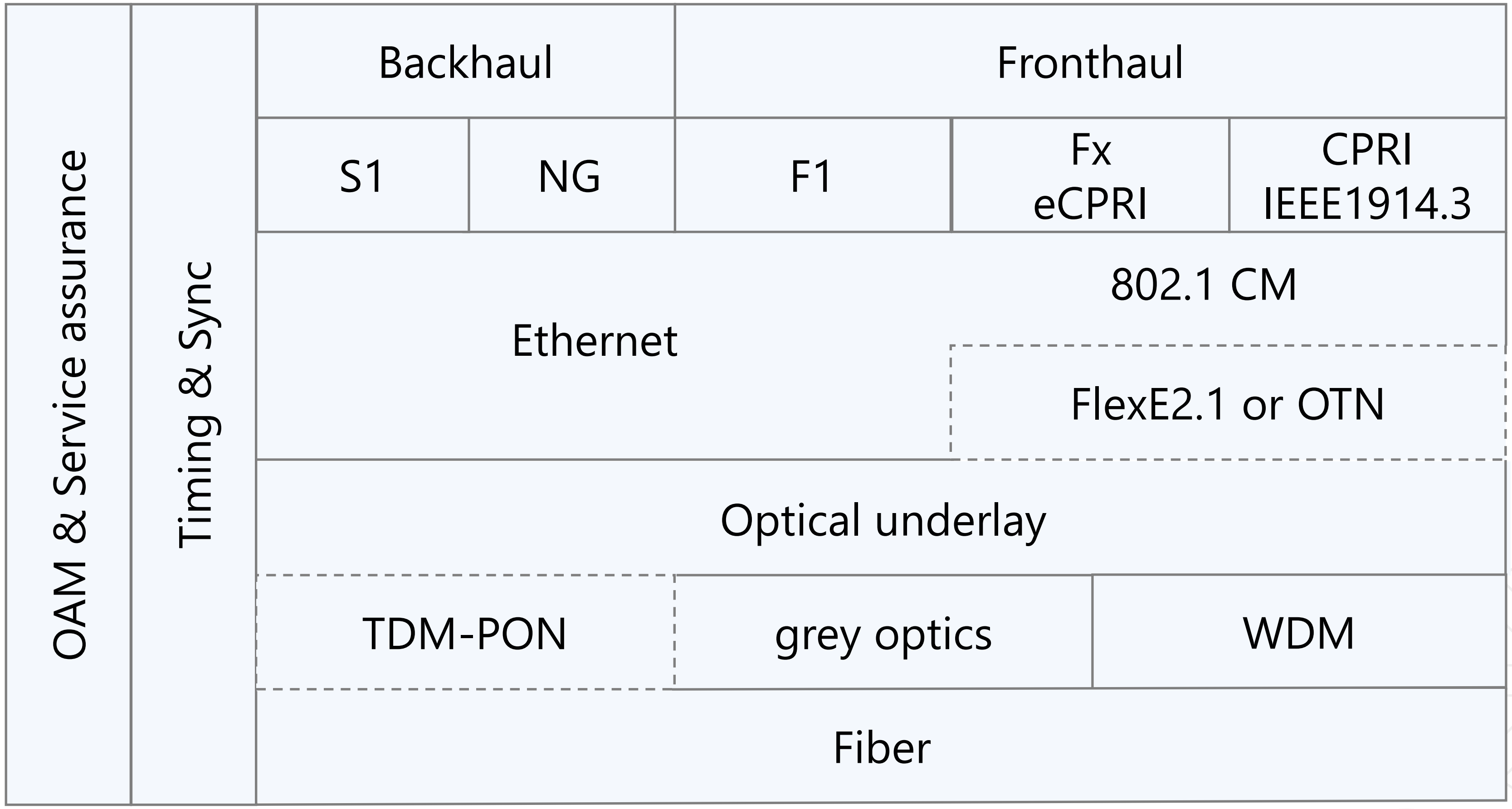
Source: NGMN Overview on 5G RAN Functional Decomposition

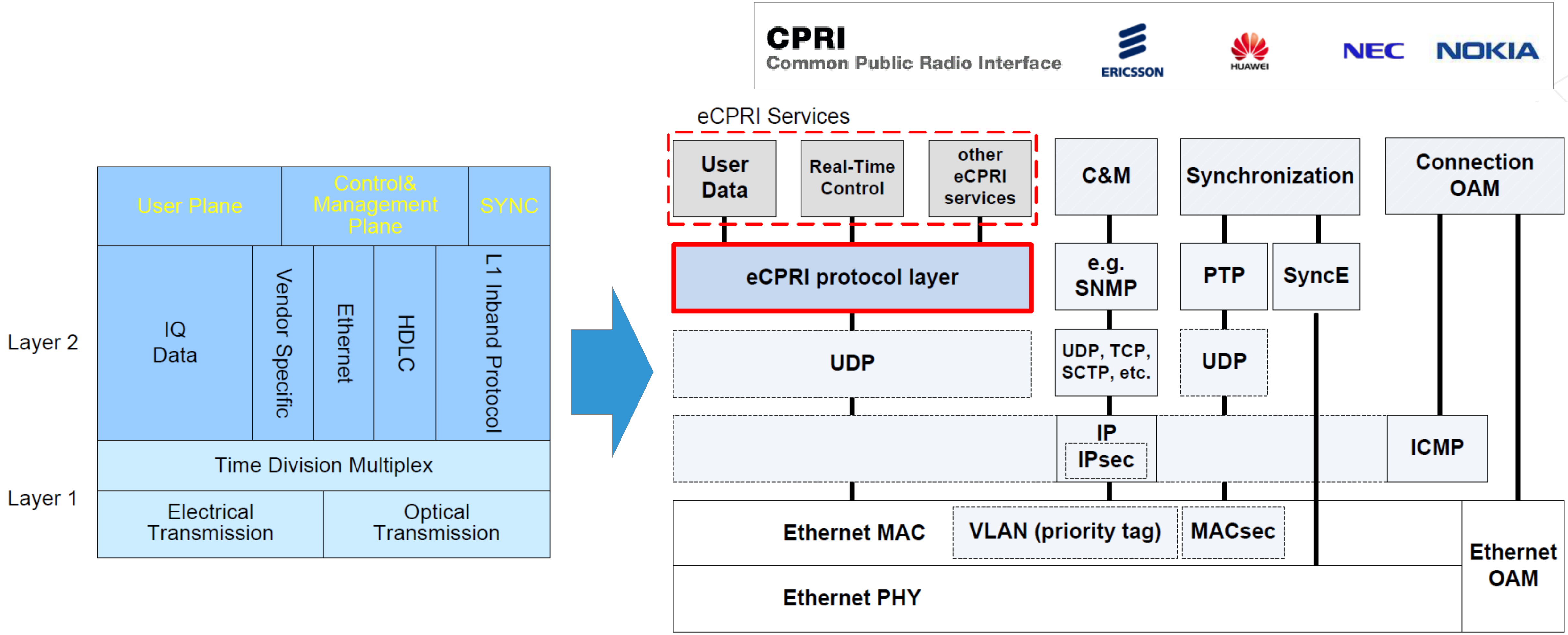
There will not be a one-fits-all configuration.

5G transport layer stack options



Ethernet is simplest. TDM-PON, FlexE and OTN add additional protocol layers.

With eCPRI, 5G goes Ethernet



eCPRI leverages Eth transport & OAM and offers ~10x reduction in bandwidth.

eCPRI latency and timing requirements

CoS	Traffic	Max. one-way frame delay	Use case	Max. one-way frame loss ratio
High25	User plane (fast)	25µs	Ultra-low latency applications	10^{-7}
High100		100µs	Full LTE or NR performance	
High200		200µs	Installations with long fiber links	
High500		500µs	Large latency installations	
Medium	User plane (slow), C&M plane (fast)	1ms	All	10^{-7}
Low	C&M plane	100ms	All	10^{-6}

Category	Maximum time error |TE| at UNI			Maximum time alignment error TAE between antenna ports
	T-TSC in radio equipment		T-TSC in transport network	
	T-TSC with |TEmax|=70ns (Class B)	T-TSC with |TEmax|=15ns		
A+ (relative)	n/a	n/a	20ns	65ns
A (relative)	n/a	60ns	70ns	130ns
B (relative)	100ns	190ns	200ns	260ns
C (absolute)	1100ns			3µs

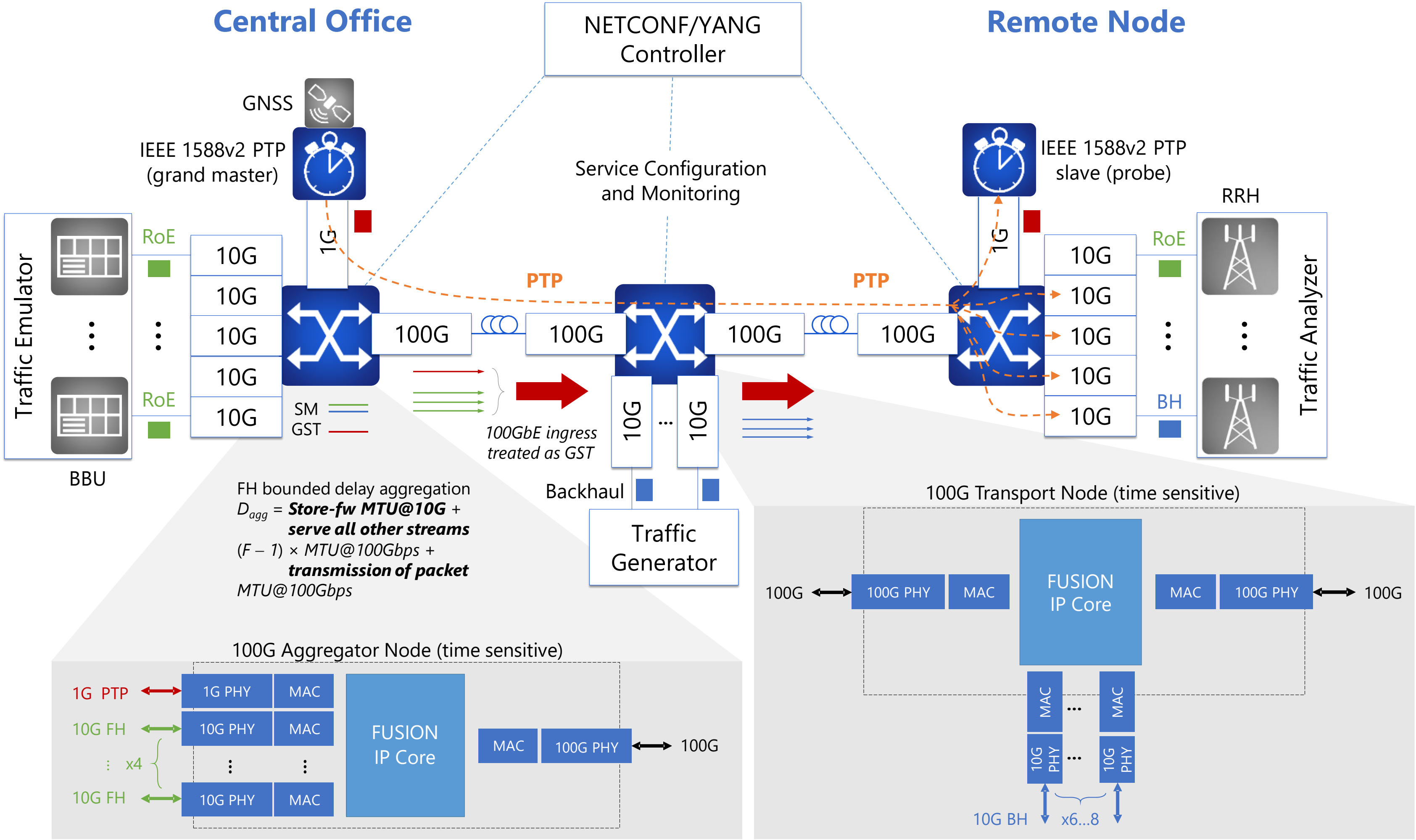
Maximum latency on the data path plus accurate timing delivery

ADVA

Limiting latency variation in x-haul network

5G-PICTURE

Low-latency timing-accurate mobile x-haul based on SDN-enabled 100G Ethernet aggregator



Best demo award

ECOC ROMA 2018

Paper Tu3B.3

Fronthaul traffic

(1522 Byte MTU):

- <3.1µs agg+deagg latency (1µs from MAC/PHY)
- <0.6µs transit node latency
- 5µs per fiber-km

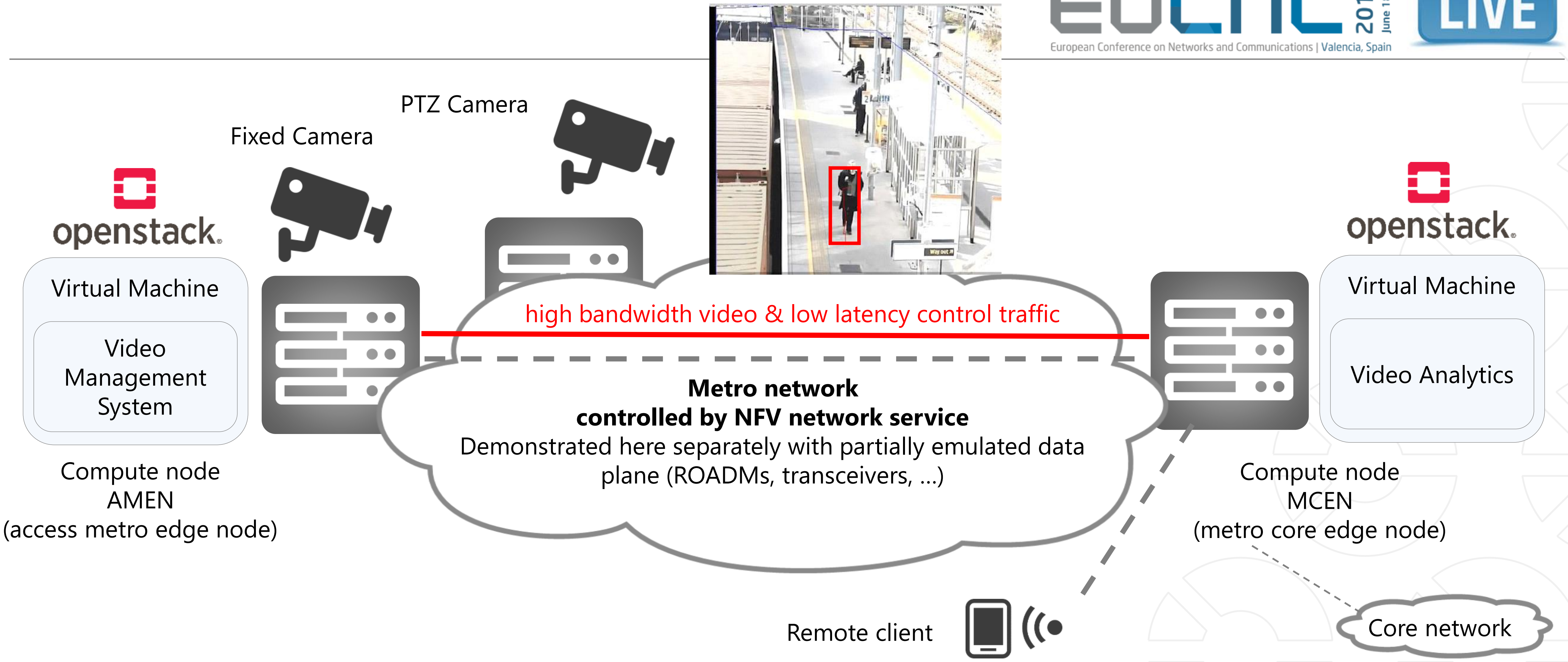
PTP traffic:

- <±75ns time error (w/o additional means)

TRANSPACKET ADVA

Low latency (mobile) application

Video surveillance demo at EUCNC 2019



Summary

Conclusions

Required latency and its value depends on the application

The network is only one contributor

Lower latency is often about simplification

Trade-off between dedicated solutions & economies of scale

More network layers may help short-term but can block future evolution

Latency becomes additional network dimensioning parameter

If you cannot measure it, you cannot monetize it

Thank you

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New standards for 5G fronthaul

3GPP

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)

Higher Layer Functional Split (HLS)

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.
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IEEE P802.1CM

IEEE STANDARDS ASSOCIATION — IEEE

IEEE Standard for
Local and metropolitan area networks—

Time-Sensitive Networking for Fronthaul

TSN for Fronthaul

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

IEEE Std 802.1CM™-2018

eCPRI

eCPRI Transport Network V1.2 (2018-06-25)

Requirements Specification

Common Public Radio Interface:
Requirements for the eCPRI Transport Network

Ethernet Transport Requirements

The eCPRI Transport Network Requirements Specification has been developed by Ericsson AB, Huawei Technologies Co. Ltd, NEC Corporation and Nokia (the "Parties") and may be updated from time to time. Further information about this requirements document and the latest version may be found at http://www.cpri.info.

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O-RAN

ORAN-WG4.CUS.0-v01.00

Technical Specification

O-RAN Fronthaul Working Group

Control, User and Synchronization Plane Specification

Lower Layer Functional Split (LLS): O-RAN 7.2x

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Ethernet becomes convergence layer for 5G transport

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