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Experimenting Deterministic Communication Services on the Operator Side

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Agenda

- Context and motivation
- Experiments and work in progress
  - Interconnection of TSN islands
  - TSN FRER in a 5G Mobile Packet Core Environment
  - DetNet PREOF
  - Basic characterization of FlexE performance
  - Path Computation based on Precision Metrics
- Conclusions

Context and Motivation

Context and motivation

- The main driver for the evolution of telecommunication networks has been the continuous increment of the offered **throughput** as main key performance indicator.
  - Network planning and operation has been traditionally focused on capacity upgrades and bandwidth reservation.
- However, a new breed of services has emerged (e.g. VR, AR, industrial, etc) demanding more careful consideration of **latency and jitter**, as relevant parameters to ensure correct service delivery, which requires **to define, measure and enforce relevant network KPIs** for those.
  - Guaranteed delivery is also necessary for some of those use cases where reliability is essential
- Bottlenecks in networks will never disappear
  - However we can mitigate and minimize their effects, or at least keep them under control
- So, how to integrate deterministic services in the network of an operator?
- The following slides present some of the initiatives explored by Telefónica CTIO in this direction

Time-critical communications

Figure 16: Time-critical use cases common across various sectors

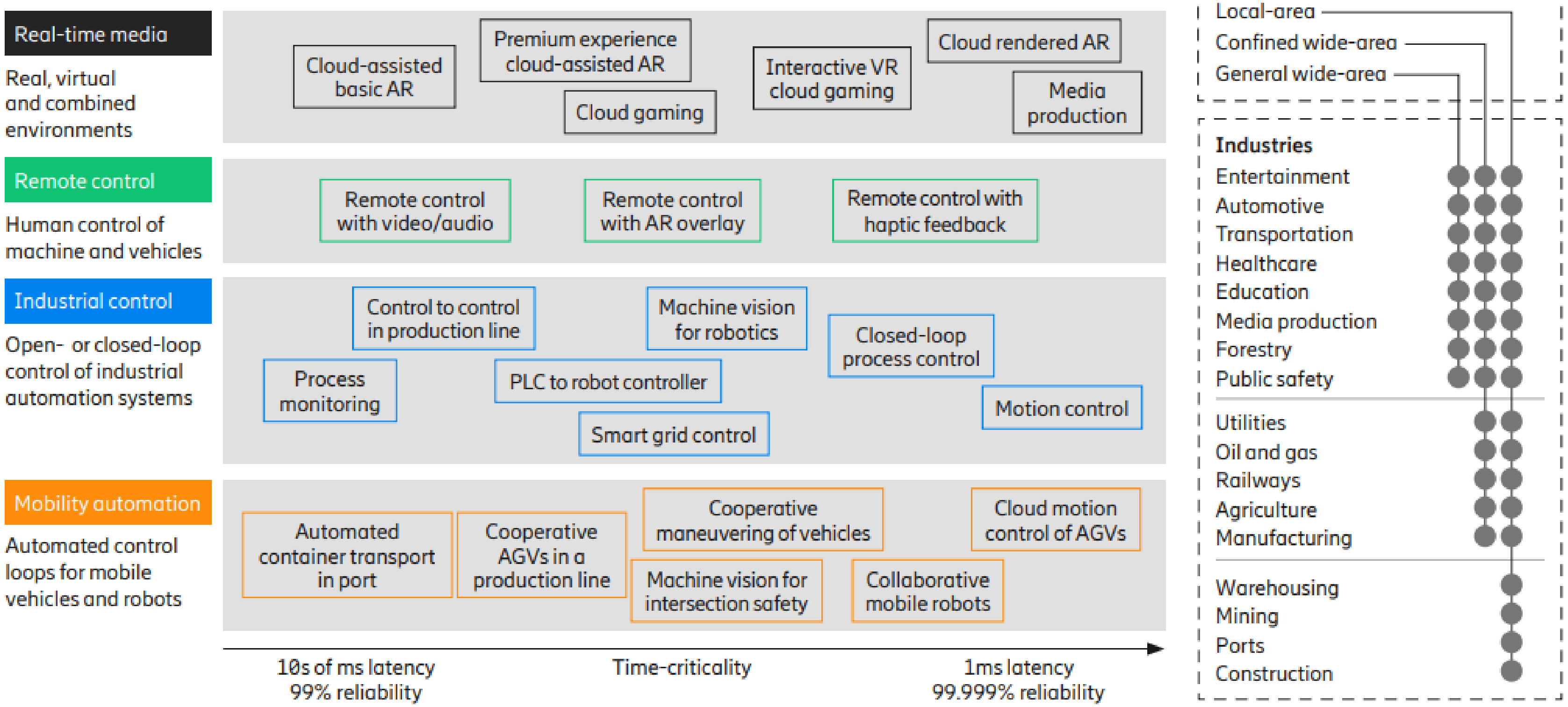


Figure 25: Gamers' reaction to gaming lag (network latency)

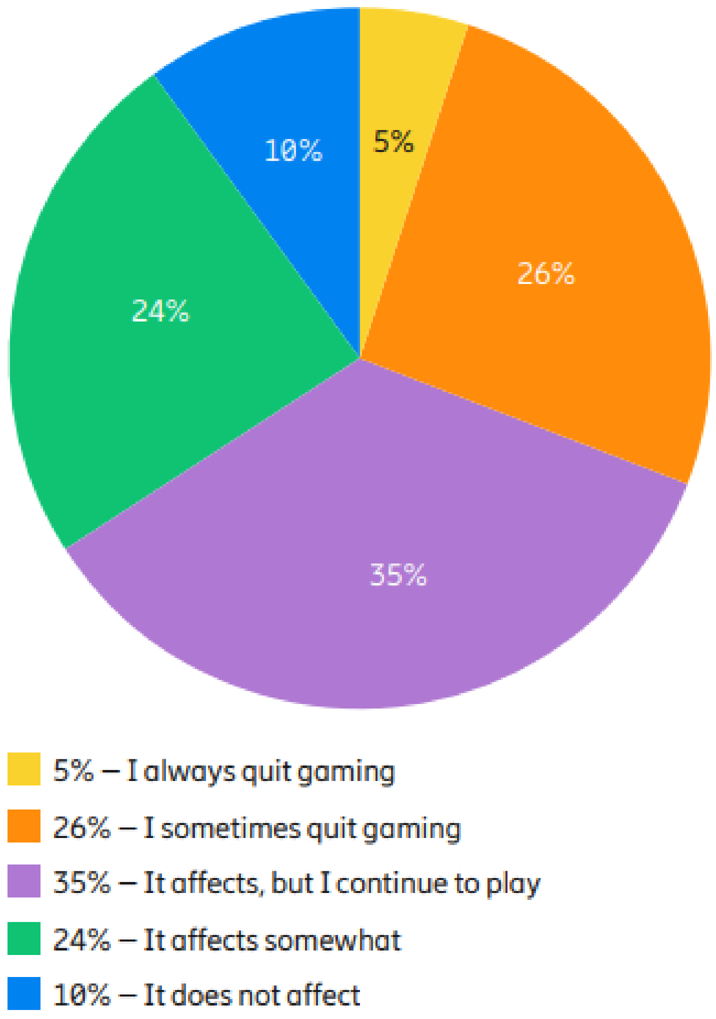
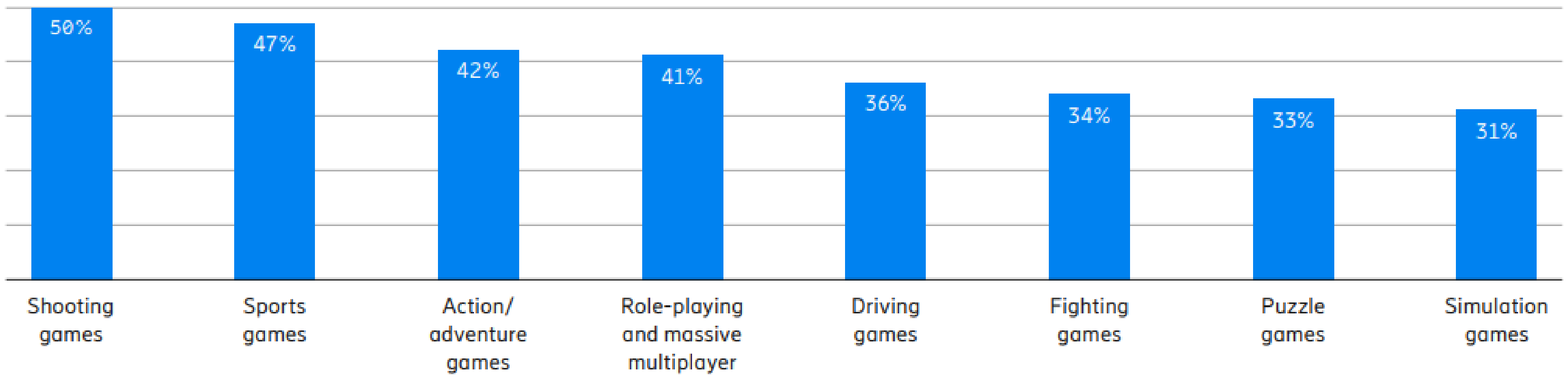


Figure 26: Share of gamers experiencing gaming lag (network latency) by game genre



Source: Ericsson Mobility Report, Nov 2020.

Reference of low latency demanding use cases

Use case	Latency [ms]		Jitter [ms]		Throughput DL [Mbps]		Throughput UL [Mbps]	
	Max**	Recomm.	Max**	Recomm.	Min***	Recomm.	Min***	Recomm.
Holoverse	20	< 10			120	380	160	480
Holoverse	20	< 10			160	480	10	30
Holoverse	100	< 50			3	3	0,05	0,1
Karaoke	45	15	10	3	0,5	0,15	0,128	0,512
Immersive streaming for live events	600	200			15	20	15	20
Augmented Reality	33	5	10	0	10	40	3	10
Drones	80	40	30	10	17	50	60	80
Face recognition: Surveillance	100	50			10	40	10	30
Automated Guided Vehicles (AGVs)	30	< 15			15	20	15	20
Metaverse		15		20				
High density Vehicle platooning	10							
Vehicle platooning	25							
Automotive:	10				25		25	
eV2X	5				1		20	
Automated driving	25							
Automated driving	100				0,5		0,5	
Video data sharing for assisted and improved automated driving - human visual system	50				10		10	
Video data sharing for assisted and improved automated driving - machine-centric video data analysis (e.g. ultra-accurate position estimation)	10				100	700	100	700

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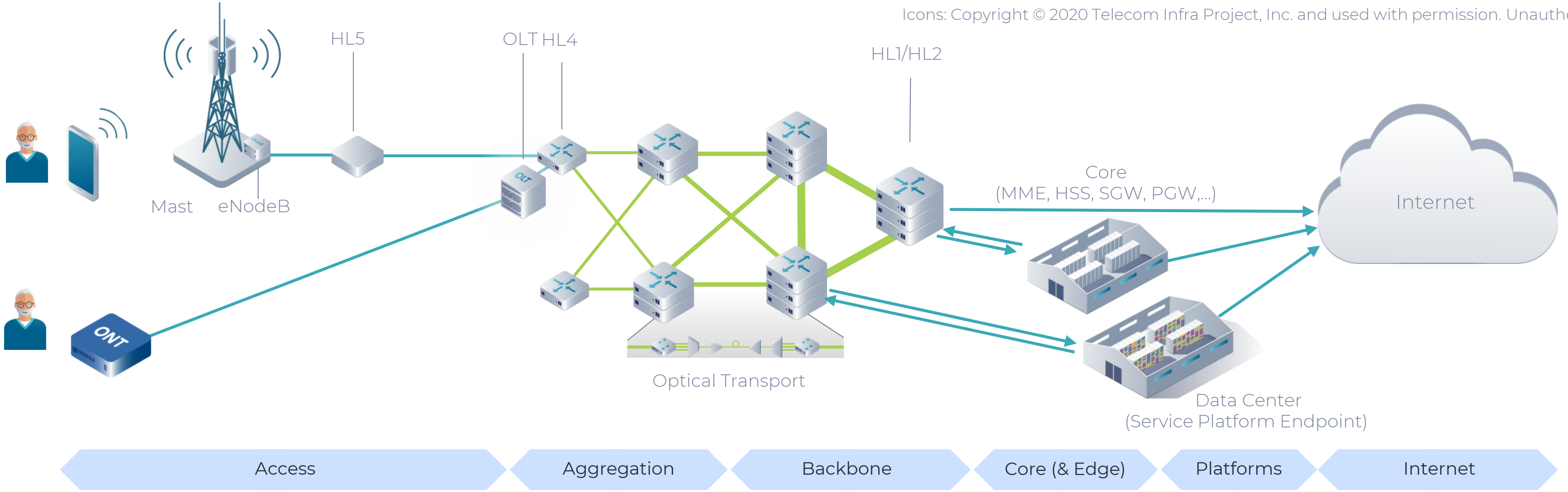
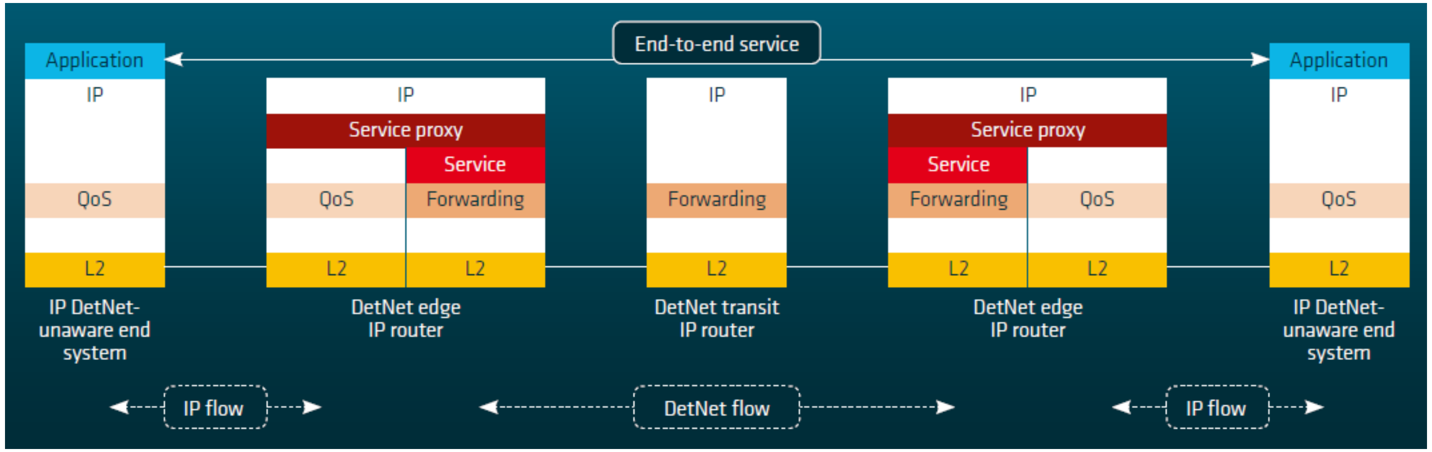
Source: work of MEC initiative at Telefonica CTIO and V2N latency references at 3GPP (TS 22.886).

Scope

Service latency and jitter requirements apply to **all elements included in e2e service delivery** i.e. application, service platforms, network access, transport or mobile core. A **holistic** approach will be important for an optimal service and network dimensioning in terms of efficiency and performance.





Source: 5G-ACIA, "DetNet-Based Deterministic IP Communication Over a 5G Network for Industrial Applications"

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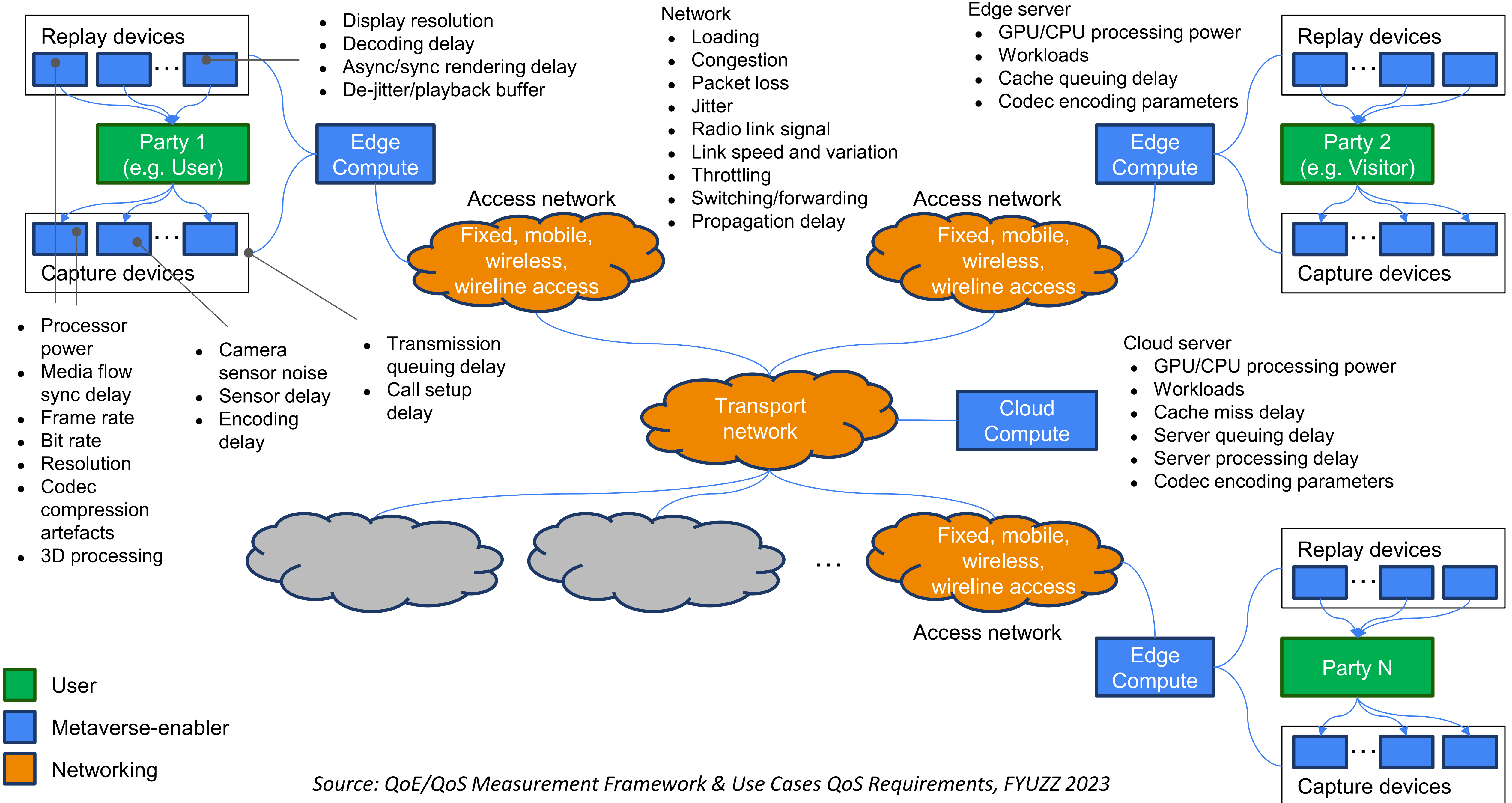
Impacts

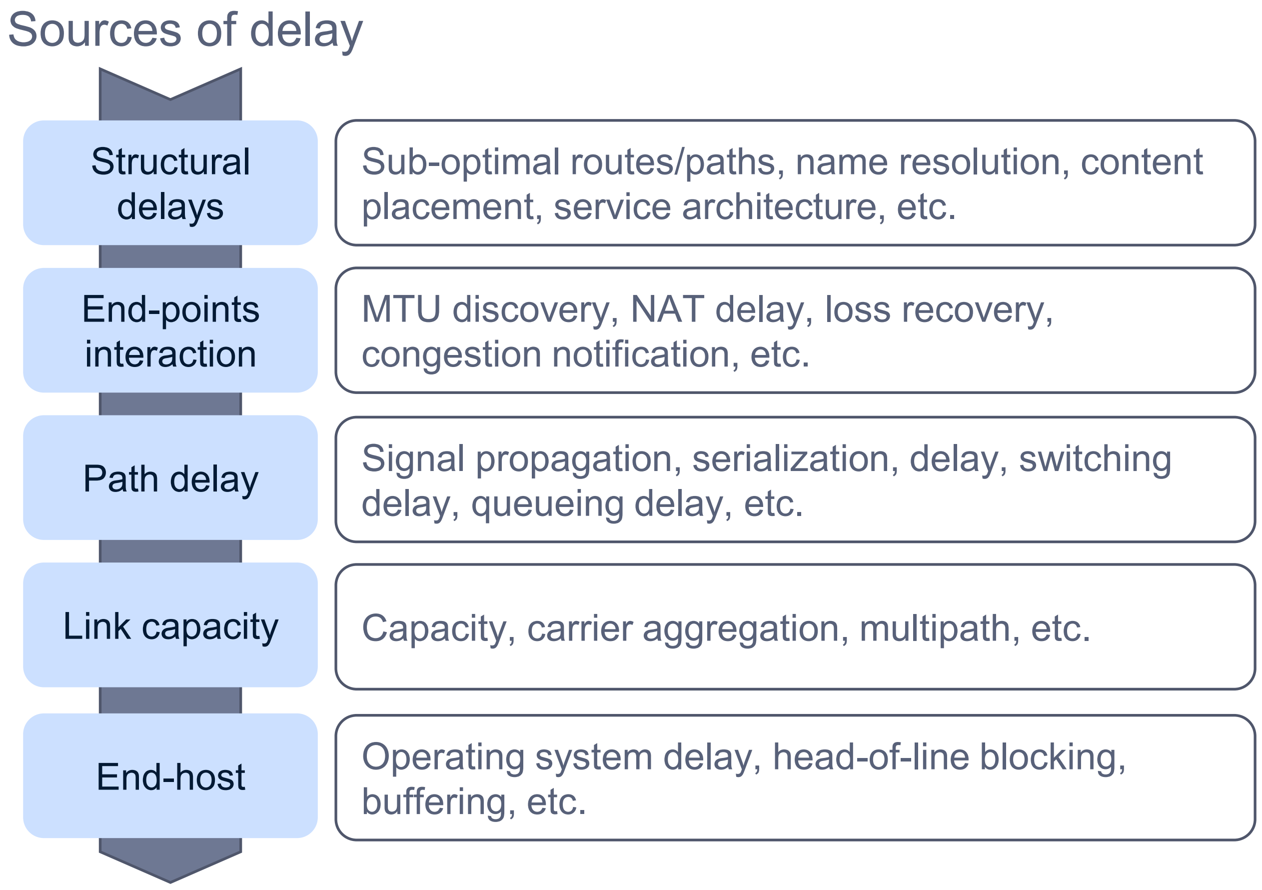


Source: QoE/QoS Measurement Framework & Use Cases QoS Requirements, FYUZZ 2023

Source: B. Briscoe et al., "Reducing Internet Latency: A Survey of Techniques and Their Merits" IEEE Comm. Surveys & Tutorials, vol. 18, no. 3, pp. 2149-2196, Third Quarter 2016

Sources of delay (and jitter)

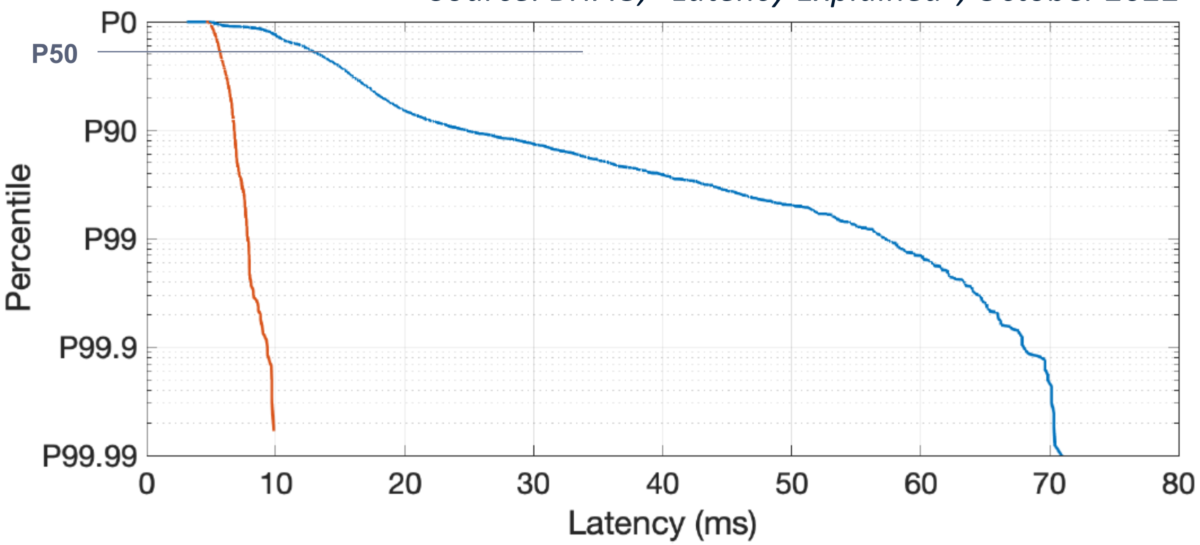
- Latency for a path in a live network is variable, following a statistical distribution
- Multiple sources of delay influence the overall measured latency (and jitter)
- Average latency is usually taken as reference value, but it is not sufficient for proper assessment of observable latency as experienced by customers
- Another approach is to characterize a set of packet latency samples using order statistics, e.g., minimum (P0), 25th percentile (P25), median (P50), P90, P99, maximum



Multiple directions to take: from planning to engineering, including introduction of novel data planes and more efficient architecture

Quality metrics

Source: BITAG, "Latency Explained", October 2022



Example: The graph above shows the behavior of two technologies both with a minimum latency of 5 ms. However, the "red" one gives consistently low latency below 10 ms for more than 99.9% of its packets, whereas with the "blue" one 10% of packets suffer delays of above 25 ms, and fully 1% of packets suffer delays above 55 ms. Using order statistics, e.g., P99, can be useful for applications employing a "jitter buffer", since latency variation can be converted into fixed latency and residual packet loss

Metric	Capture probability of general applications working well	Easy to articulate Application requirements	Composable
Average latency	Yes for some applications	Yes	Yes
Variance of latency	No	No	Yes
IPDV	Yes for some applications	No	No
PDV	Yes for some applications	No	No
Average Peak Throughput	Yes for some applications	Yes	No
99th Percentile of Latency	No	No	No
Trimmed mean of latency	Yes for some applications	Yes	No
Round Trips Per Minute	Yes for some applications	Yes	No
Quality Attenuation	Yes	No	Yes

Source: B.I. Teigen, M. Olden, "Requirements for a Network Quality Framework Useful for Applications, Users, and Operators", draft-teigen-ippm-app-quality-metric-reqs-02 (work in progress), October 2023

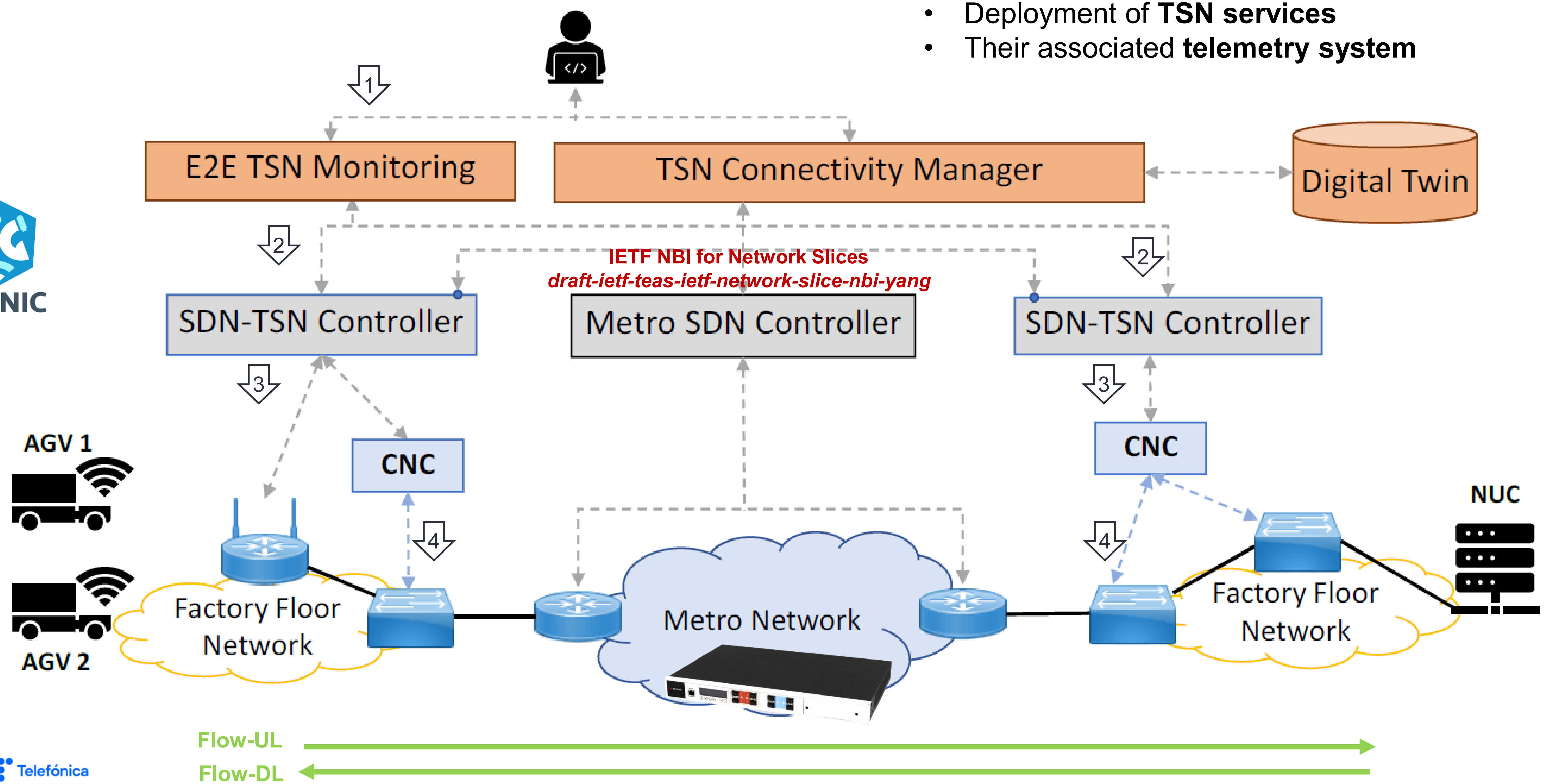
Experiments

Interconnection of TSN islands

Interconnection of TSN islands

Two main operational flows:

- Deployment of **TSN services**
- Their associated **telemetry system**



Demo without TSN

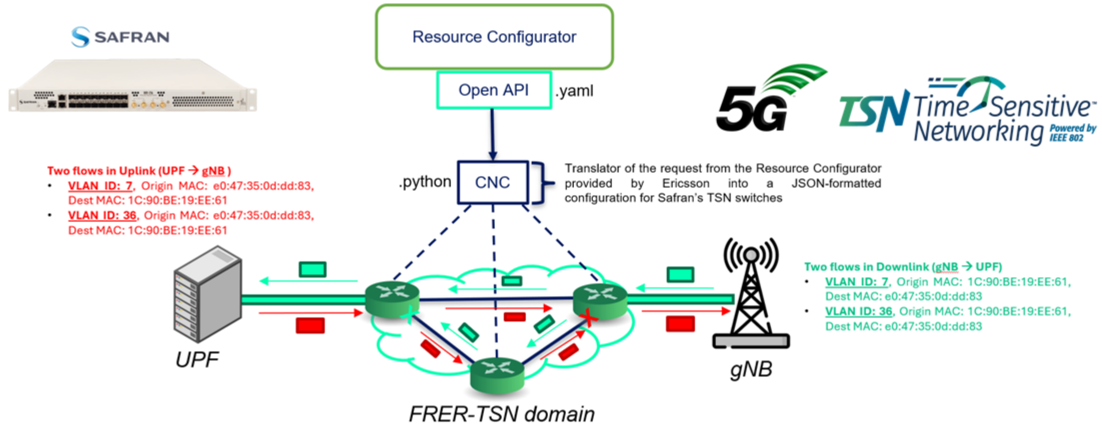
Demo with TSN

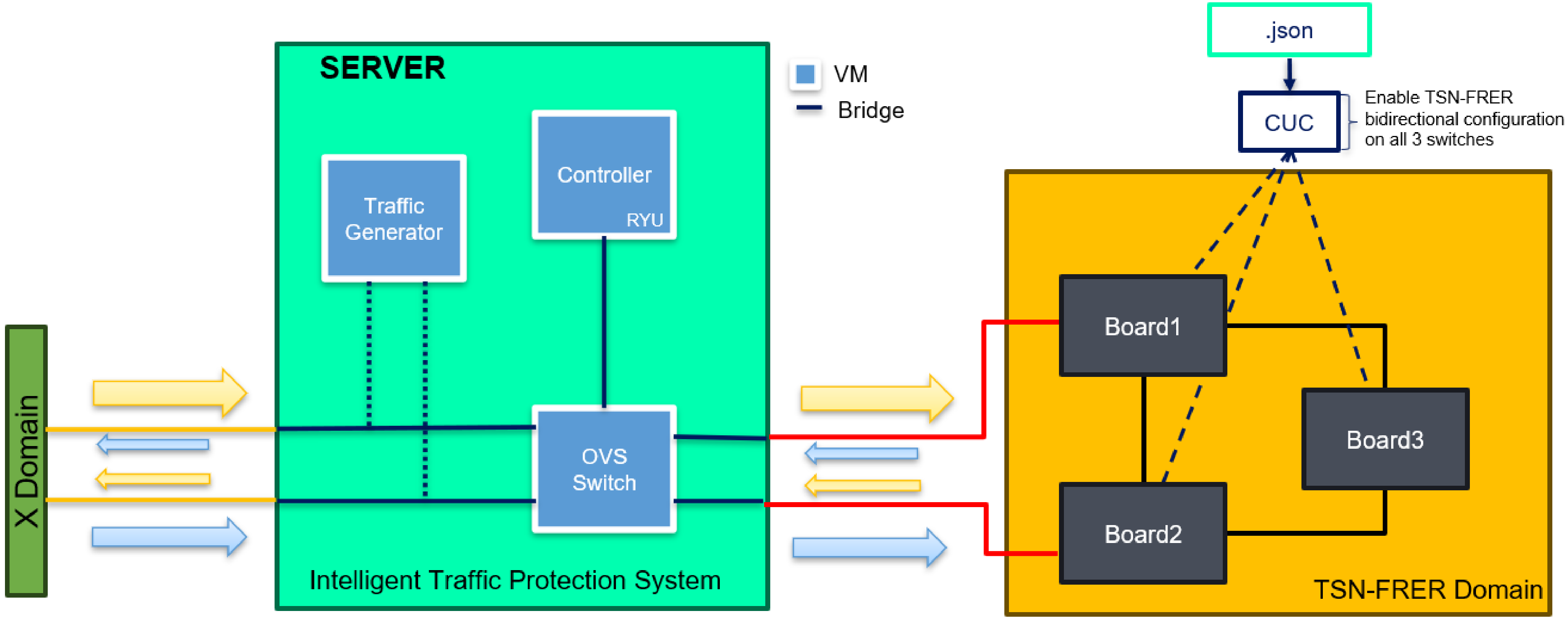
Experiments

TSN FRER in a 5G Mobile Packet Core Environment

Smart Traffic Protection in TSN Networks Based on Application Needs

- Selective Traffic Protection Activation in TSN Networks (using FRER) Based on IP and Application Type (IPsec)





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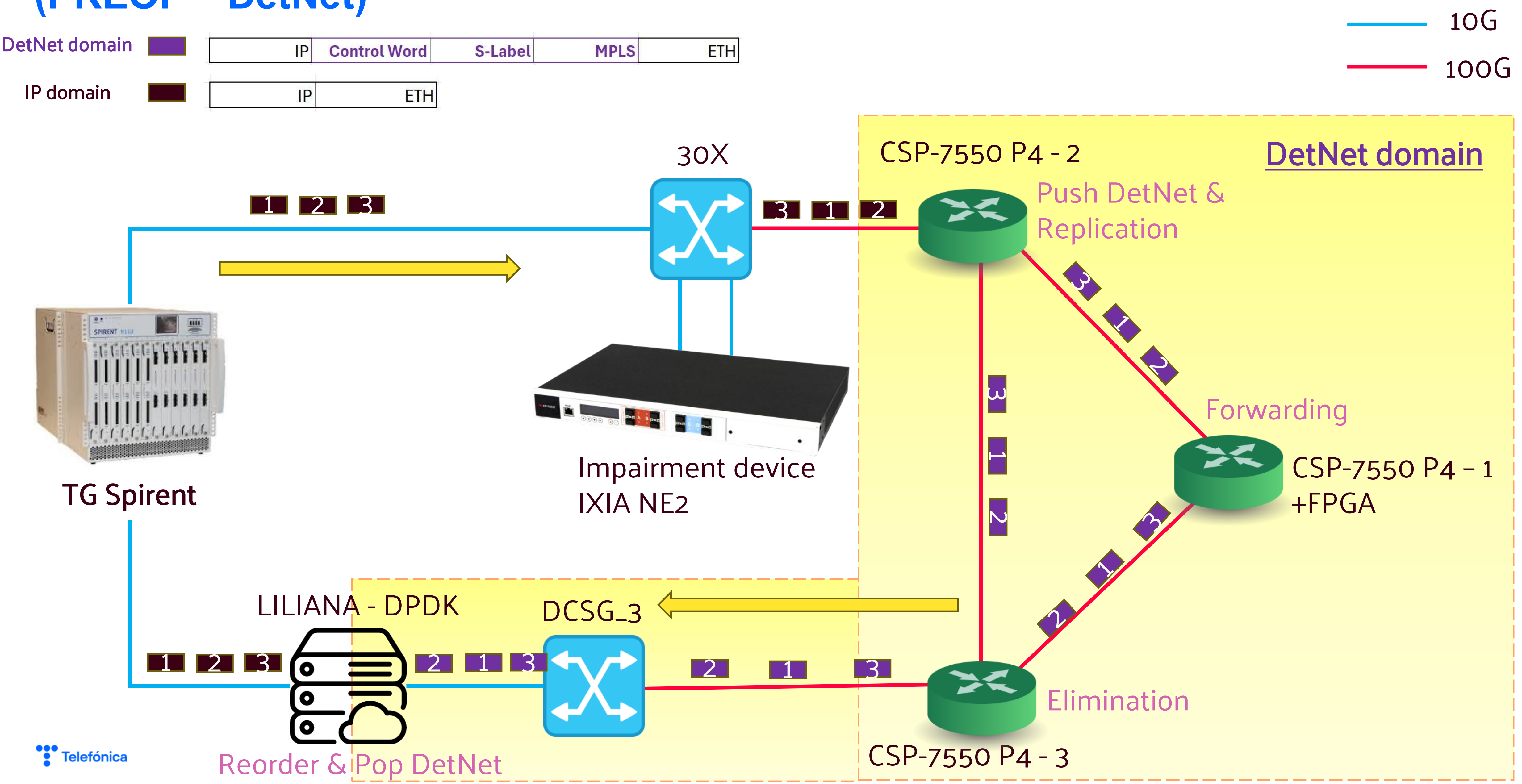
Experiments

DetNet PREOF

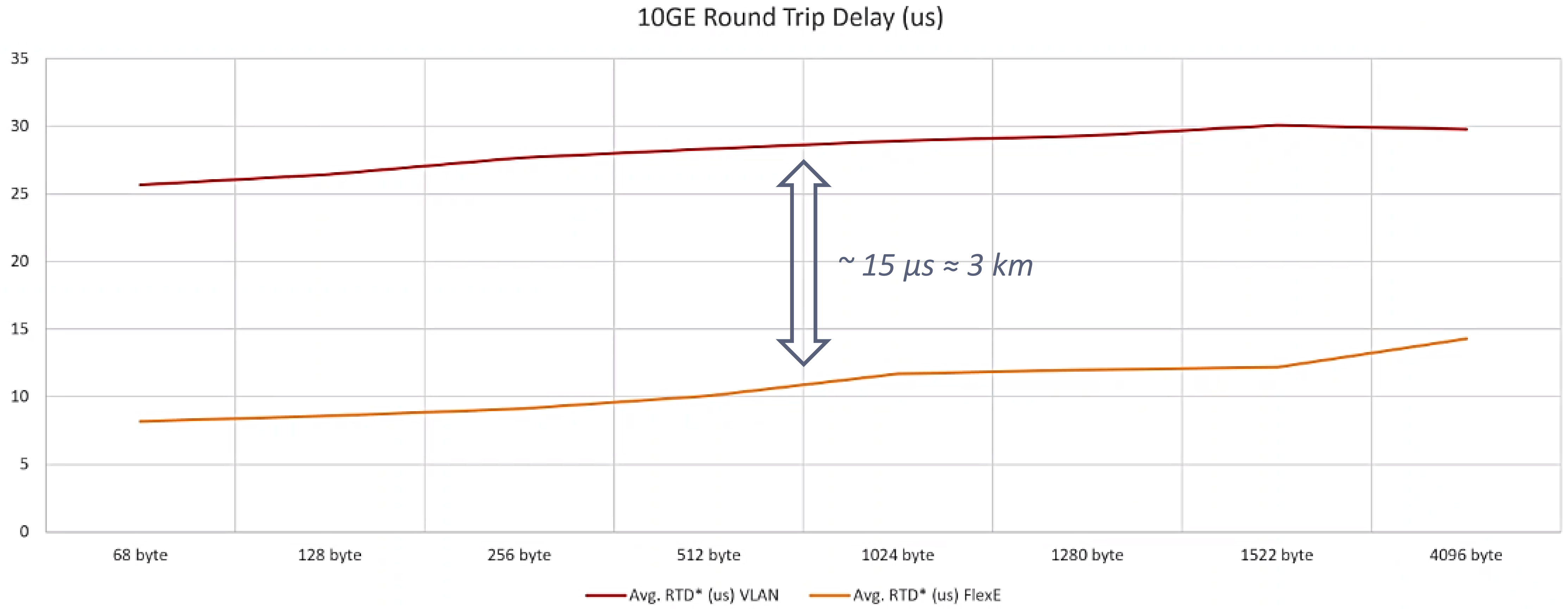
Packet Replication, Elimination and Ordering Functions (PREOF – DetNet)

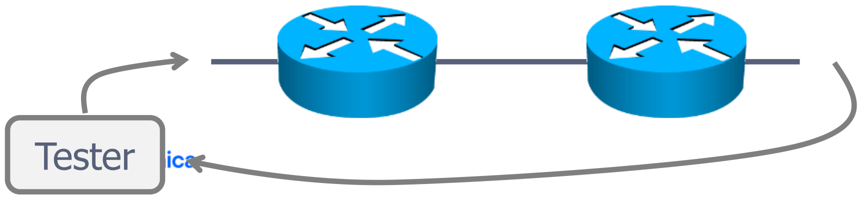


Experiments

Basic characterization of FlexE performance

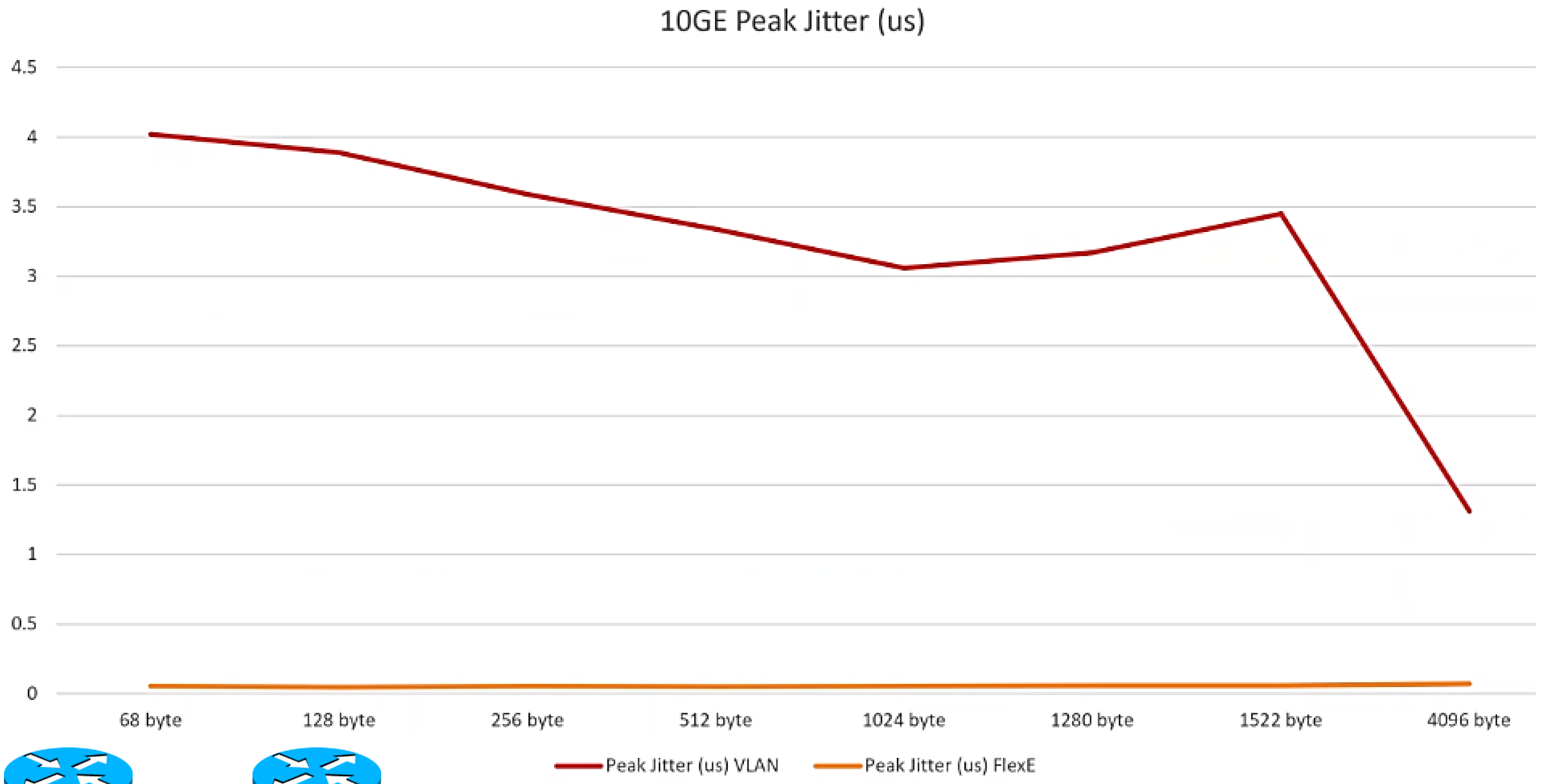
10 GE round trip delay - vlan switching vs FlexE

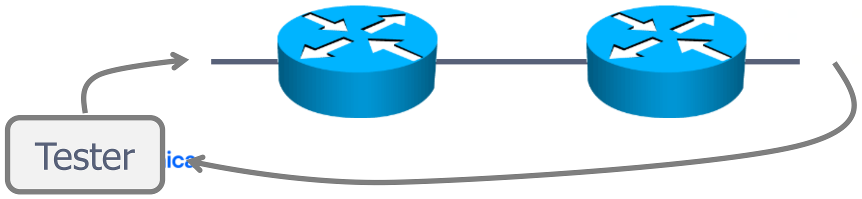




Round trip delay is 4x the value of one way delay in a single device

10 GE jitter - vlan switching vs FlexE





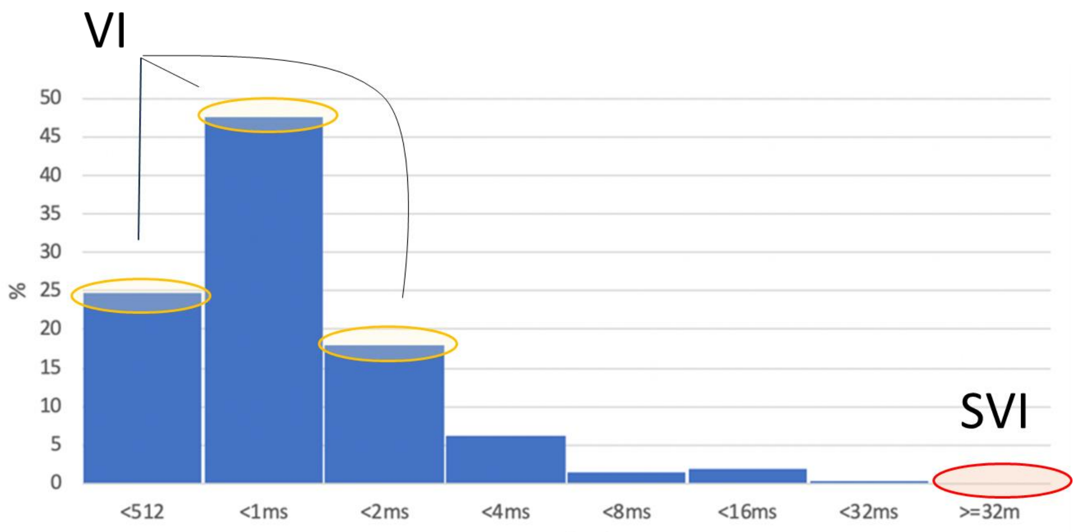
Cumulative jitter (4 hops)

Work in Progress

Path Computation based on Precision Metrics

Path Computation Based on Precision Availability Metrics for ensuring SLOs

- Some communication services present performance requirements expressed as Service Level Objectives (SLO), as it is the case of network slices (e.g., [RFC9543])
- Performance Availability Metrics (PAM) have been defined for for describing and monitoring SLOs [RFC9544]
- The Path Computation Element (PCE) nowadays can compute or select paths based on metrics that can represent a bound or maximum, but not in the form of PAM
- For services with SLOs is convenient to create / select a path knowing its behavior along the time



VI: Violated Interval; SVI: Severe Violated Interval

Proposed new PRECISION METRIC Object

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Flags   |C|S|       Type      | Stat Function |     Tiers   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     AvPeriod    |     TI_Units    |            TI_Value         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Violated Interval Ratio                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                Severely Violated Interval Ratio                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                                 |
~                           Thresholds                            ~
|                                                                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

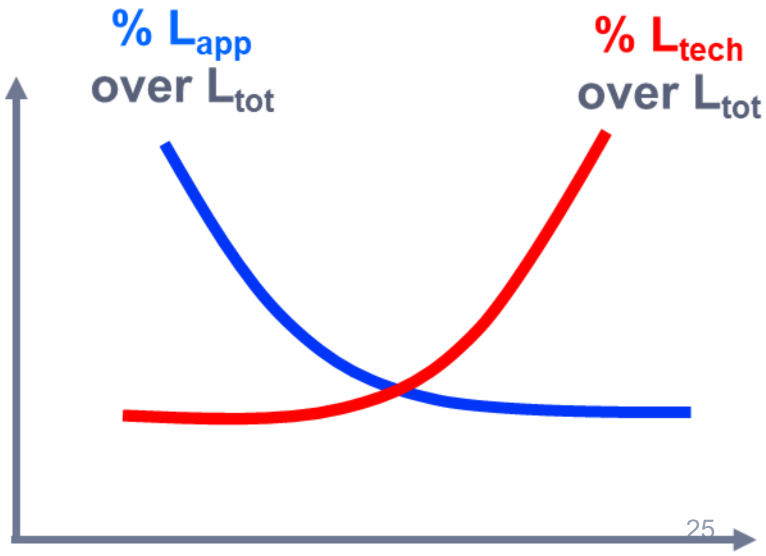

L.M. Contreras, F. Agraz, S. Spadaro, Q. Xiong, "Path Computation Based on Precision Availability Metrics", draft-contreras-pce-pam-05 (work in progress), July 2025

Conclusion

Conclusions

- Latency, jitter and reliability are emerging as new dimensions relevant for the process of network planning
- There are multiple parameters and variables across different network segments impacting both latency and jitter
  - Not all the segments are under control of the operator, e.g. devices
- It is necessary to understand (= get visibility) of how each piece on the chain affects the overall picture in order to cure as much as possible the implications (= define actions)
  - Multiple fronts: technology, network / service engineering, methodology, etc
- Assuming no additional latency due to service definition (i.e. non optimal service paths), two main components define the total latency: *Latency of the application* (L_{app}) and *Latency of the network technology* (L_{tech})
- Determine the ratio % L_{app} vs % L_{tech} in each case, and act when % L_{tech} ≥ % L_{app}
- Leverage on standard approaches as common reference, when possible (e.g. TWAMP)
- Refer to P9X rather than average values to better understand expectation form end users

$$L_{tot} = L_{app} + L_{tech}$$



Results based on the following projects

PREDICT-6G

https://predict-6g.eu/

DESIRE6G

https://desire6g.eu/

TIMING

https://timing.upc.edu/

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Acknowledgement

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