Comparing the adoption of TSN between automotive and non-automotive networks

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KEYSIGHT TECHNOLOGIES

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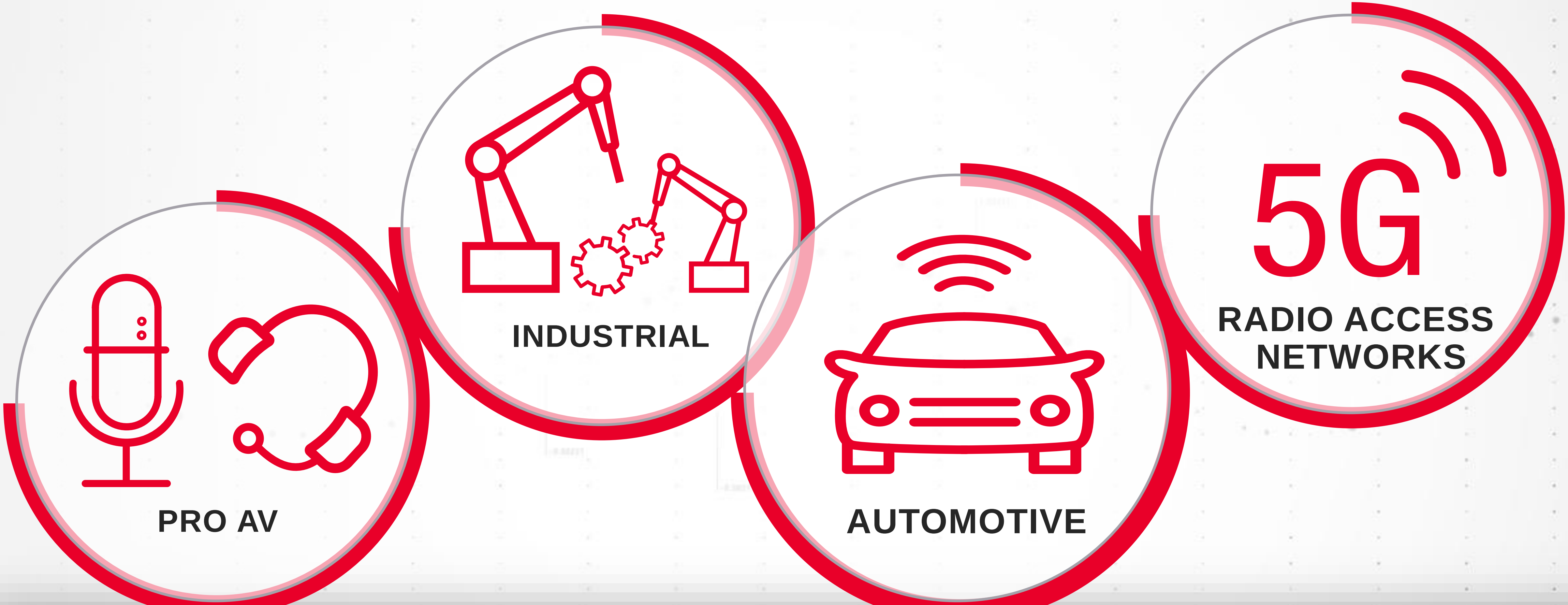
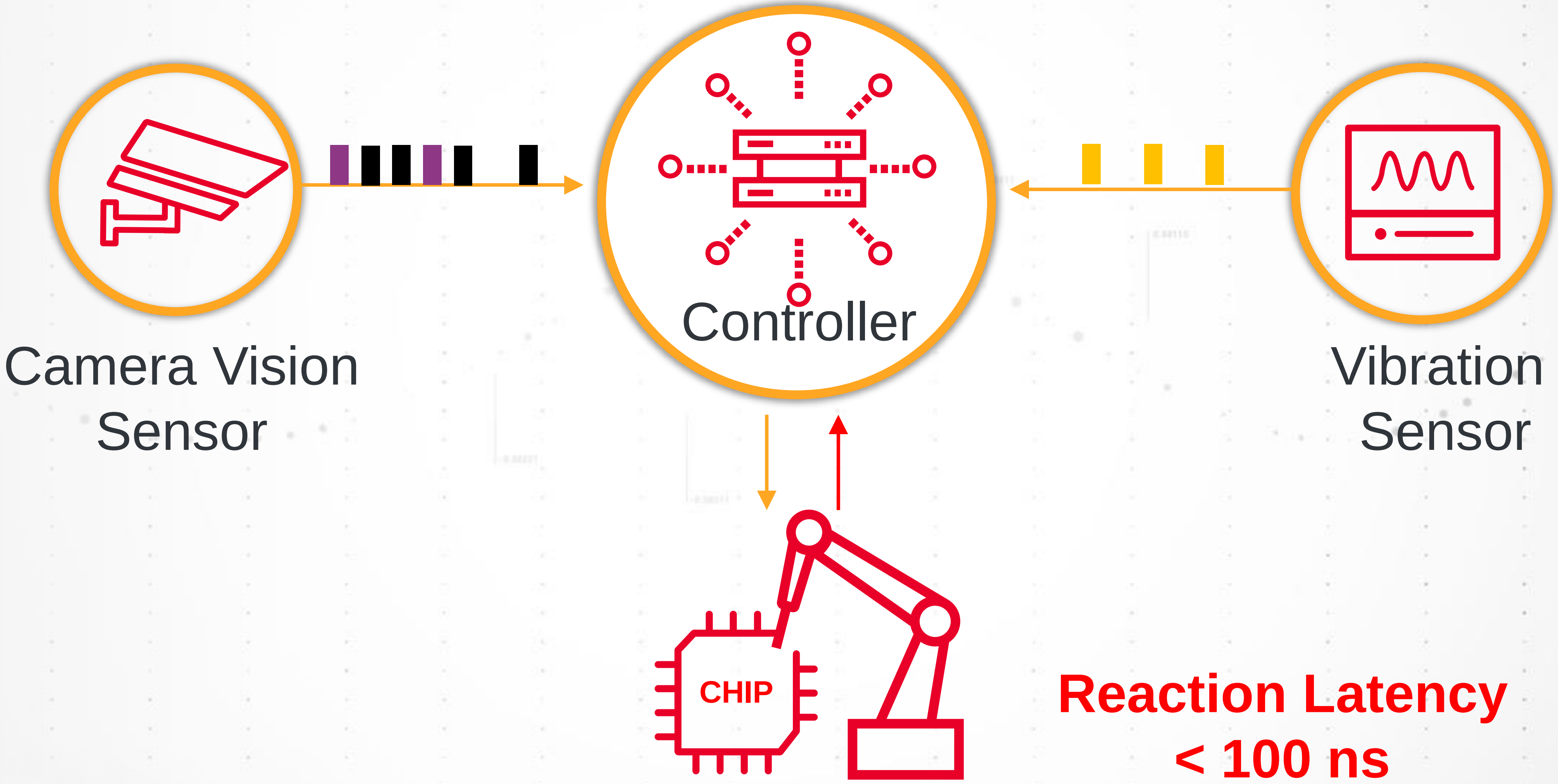
What is common in these industries?



LOW & DETERMINISTIC LATENCY

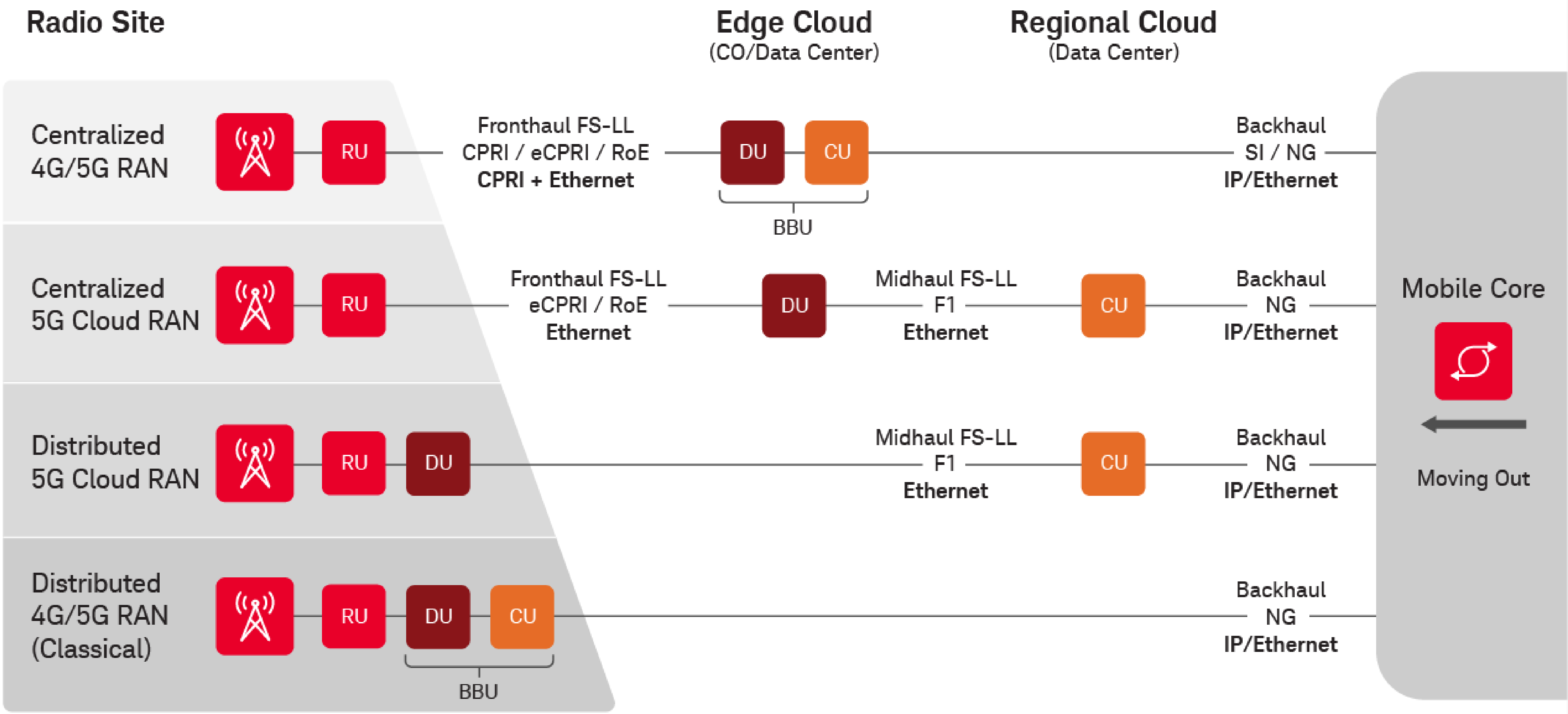
GUARANTEED DELIVERY

Scenario 1: A semiconductor fabrication plant

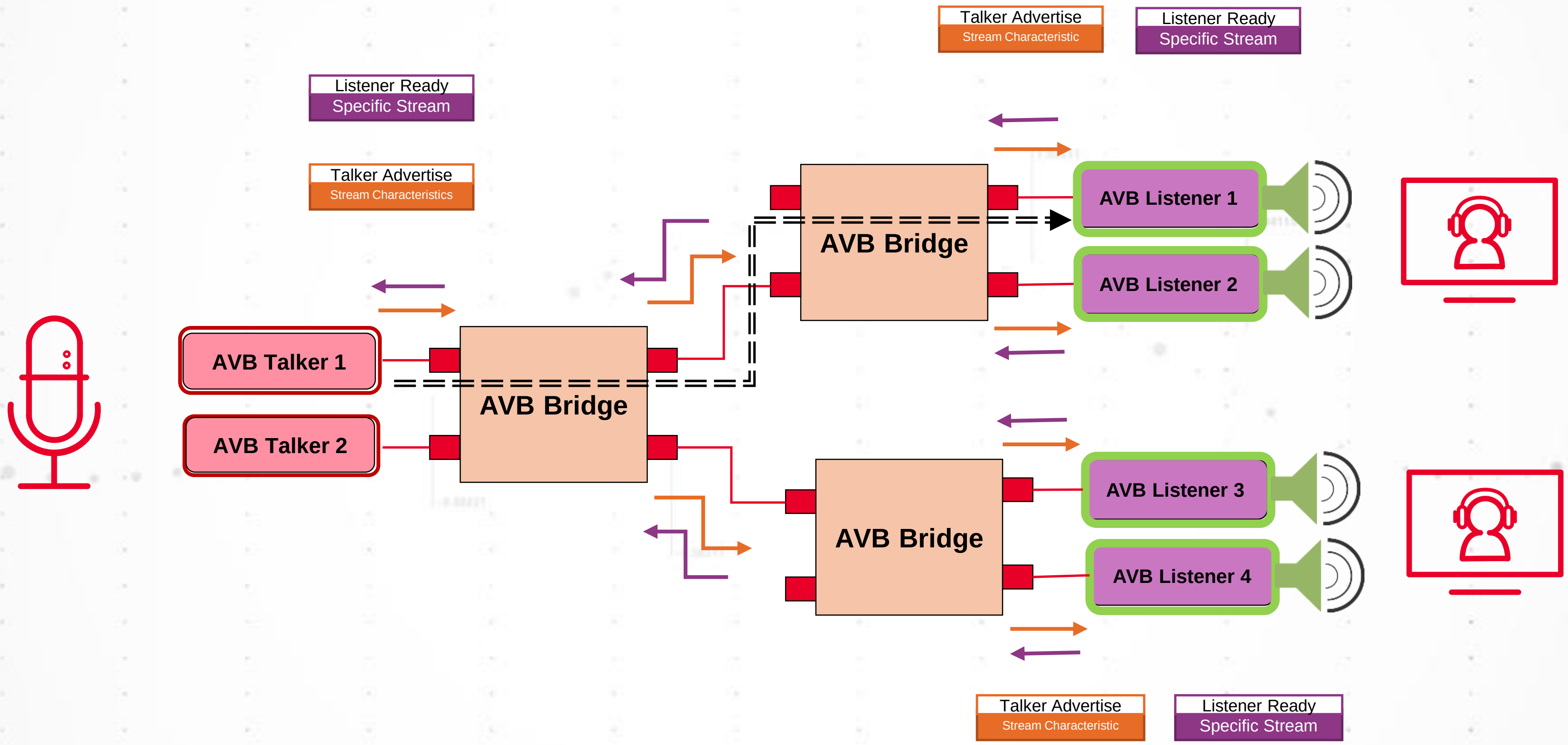


Reaction Latency
< 100 ns

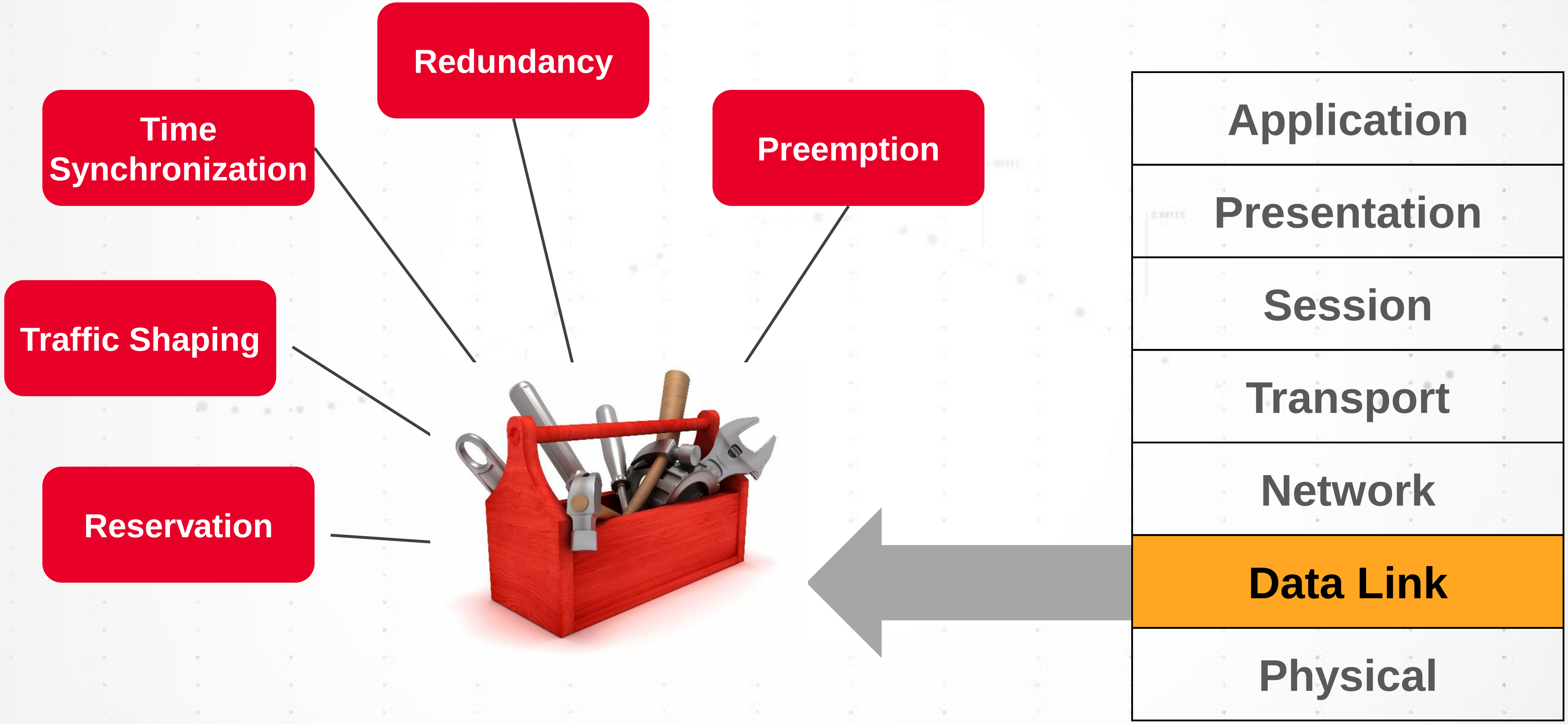
Scenario 2: A 5G fronthaul network carrying radio data



Scenario 3: Audio Video broadcasting network



The TSN “ToolBox” approach



The Network requirements are very different from each other

Characteristics	Automotive	Industrial	Pro AV	5G RAN
Network Size	Small	Medium	Medium / Large	Large
Network Type	Static	Mixed	Mixed	Dynamic
Interface speeds	Mostly <= 1G Occasionally 2.5/5/10GE	< 10GE	Mostly 10/40 GE Occassionally 100GE	10/25/50/100GE
Traffic Types	Engineered	Engineered	Engineered	Non-Engineered

Implementing Redundancy is expensive for large networks

Eliminates complexities from change in configuration over network lifetime

Gain of preemption diminishes with higher link speed

Time based traffic shaping is more effective in engineered networks

The Latency requirements vary based on application needs

TABLE I

END-TO-END LATENCY AND JITTER REQUIREMENTS FOR TYPICAL ULL APPLICATIONS

Area	Application	QoS Requirements Latencies	Jitter
Medical [47]–[49]	Tele-Surgery, Haptic Feedback	3–10 ms	< 2 ms
Industry [50]	Indust. Automation, Control Syst.	0.2 μs–0.5 ms for netw. with 1 Gbit/s link speeds	meet lat. req.
		25 μs–2 ms for netw. with 100 Mbit/s link speeds	meet lat. req.
	Power Grid Sys.	approx. 8ms	few μs
Banking [51]	High-Freq. Trading	< 1 ms	few μs
Avionics [52]	AFDX Variants	1–128ms	few μs
Automotive [53]–[56]	Adv. Driver. Assist. Sys. (ADAS)	100–250 μs	few μs
	Power Train, Chassis Control	$< 10\mu$s	few μs
	Traffic Efficiency & Safety	< 5 ms	few μs
Infotainment [57]	Augmented Reality	7–20 ms	few μs
	Prof. Audio/Video	2–50 ms	< 100 μs

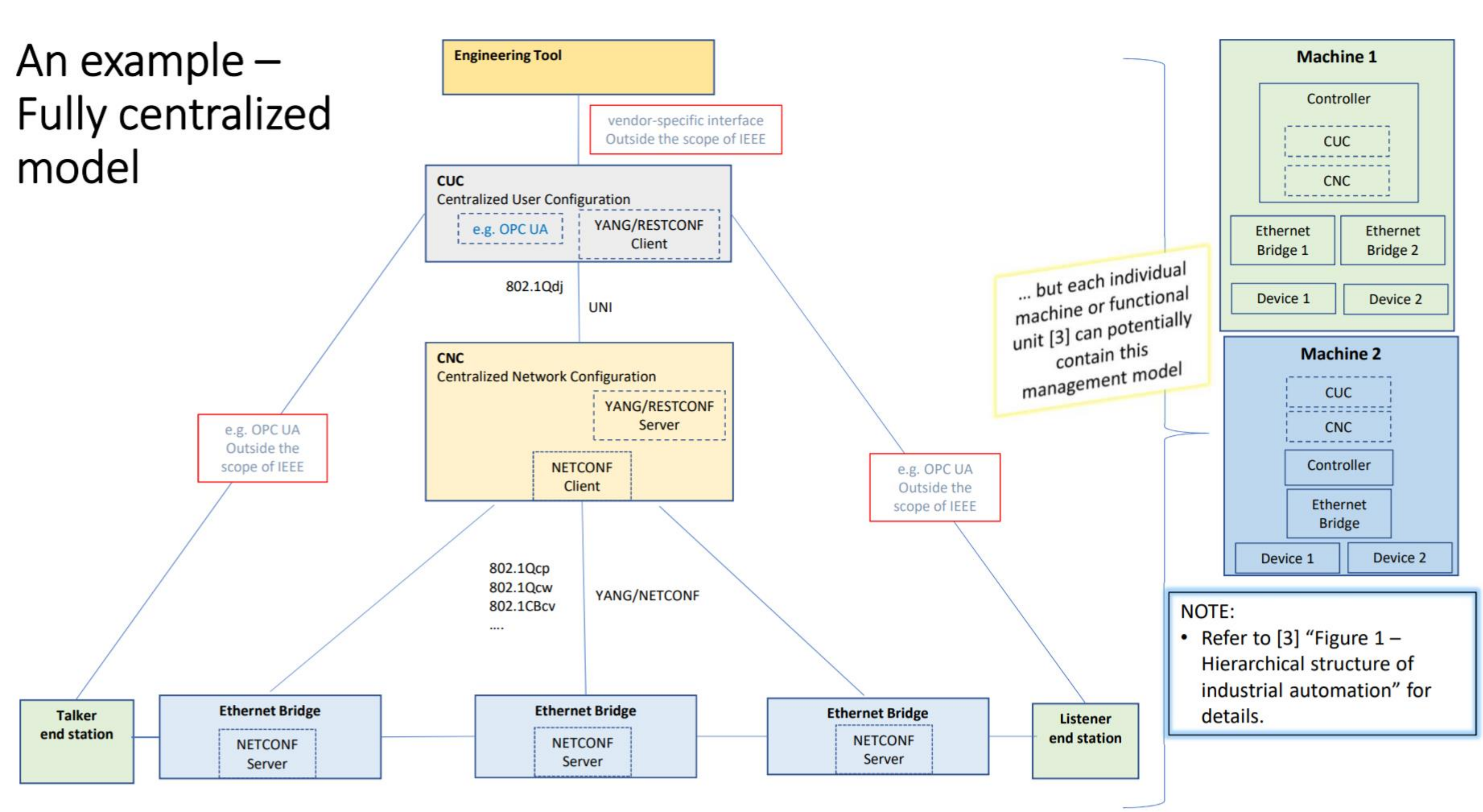
Source: Ultra-Low Latency (ULL) Networks: The IEEE TSN and IETF DetNet Standards and Related 5G ULL Research

How are Keysight's customers using TSN?

AVB/TSN Standards		Automotive	Industrial	Pro AV	5G
Time Synchronization	802.1AS	Adopting	Adopting	Adopting	Using
	802.1AS-Rev	Adopting	Adopting	Exploring	
Traffic Shaping	802.1Qav	Adopting	Adopting	Adopting	
	802.1Qbv	Adopting	Adopting		
Frame Preemption	802.1Qbu	Exploring	Adopting		Using
Redundancy	802.1CB	Adopting	Exploring	Exploring	
Filtering Policing	802.1Qci	Adopting	Exploring	Exploring	
Configuration Management	802.1Qcc		Exploring	Exploring	

COMPARING TSN METHODS USED ACROSS INDUSTRIES & VALIDATION METHODS

Industrial vs Automotive : Dynamic network configuration



INDUSTRIAL

Dynamic Network
Variety of Devices

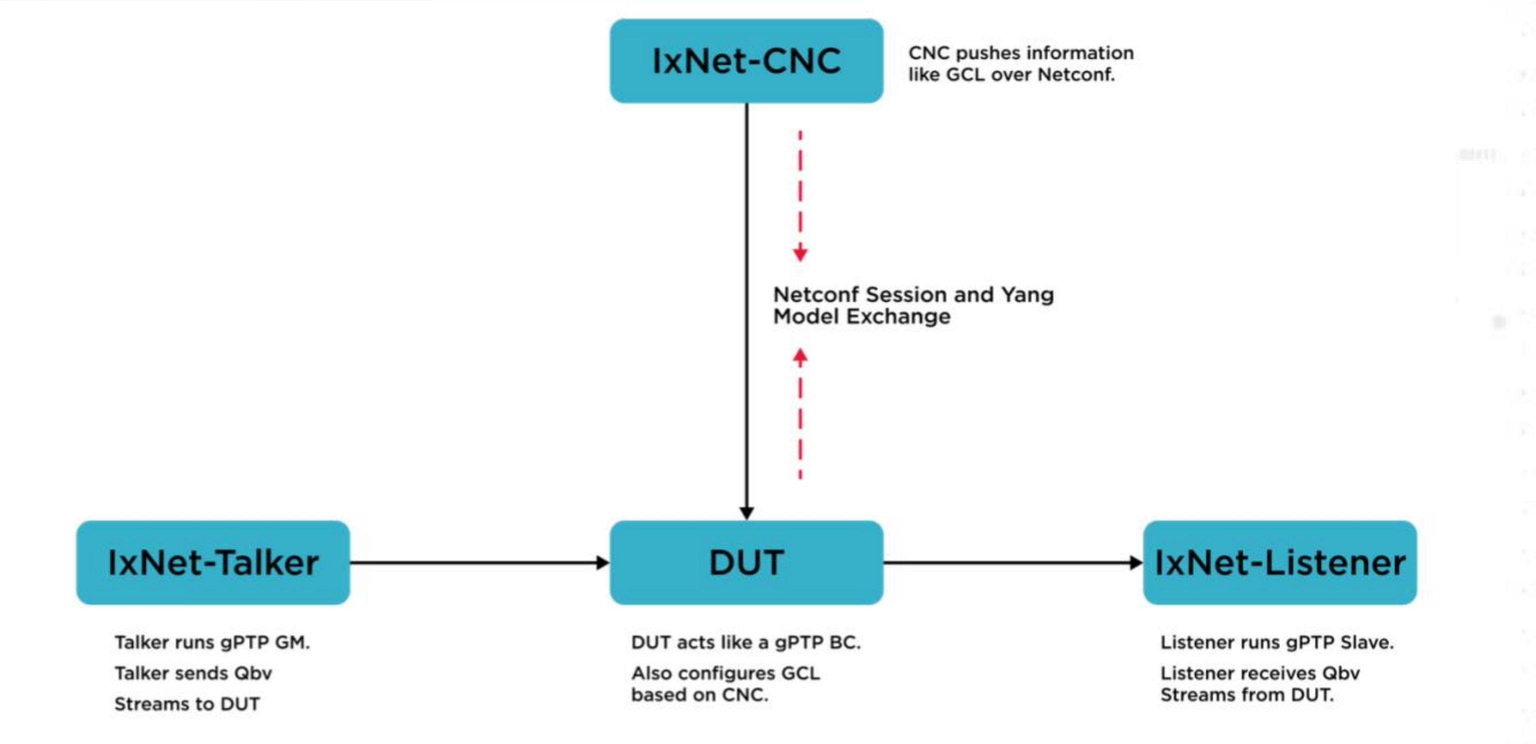
AUTOMOTIVE

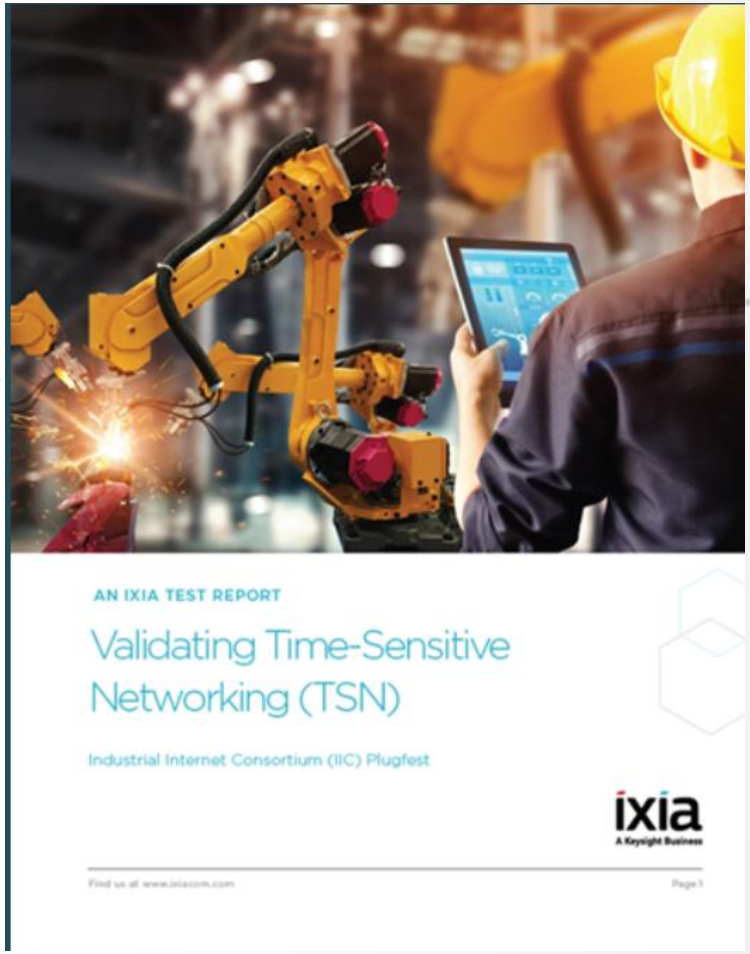
Network mostly static over lifetime

Source: http://www.ieee802.org/1/files/public/docs2020/60802-abdul-hierarchical-CUC-CNC-management-model-0520-v02.pdf

Industrial vs Automotive : Dynamic network configuration

Tests performed at the IIC Plugfest with a Qbv switch





https://www.ixiacom.com/resources/validating-time-sensitive-networking-tsn-iic-plugfest-report

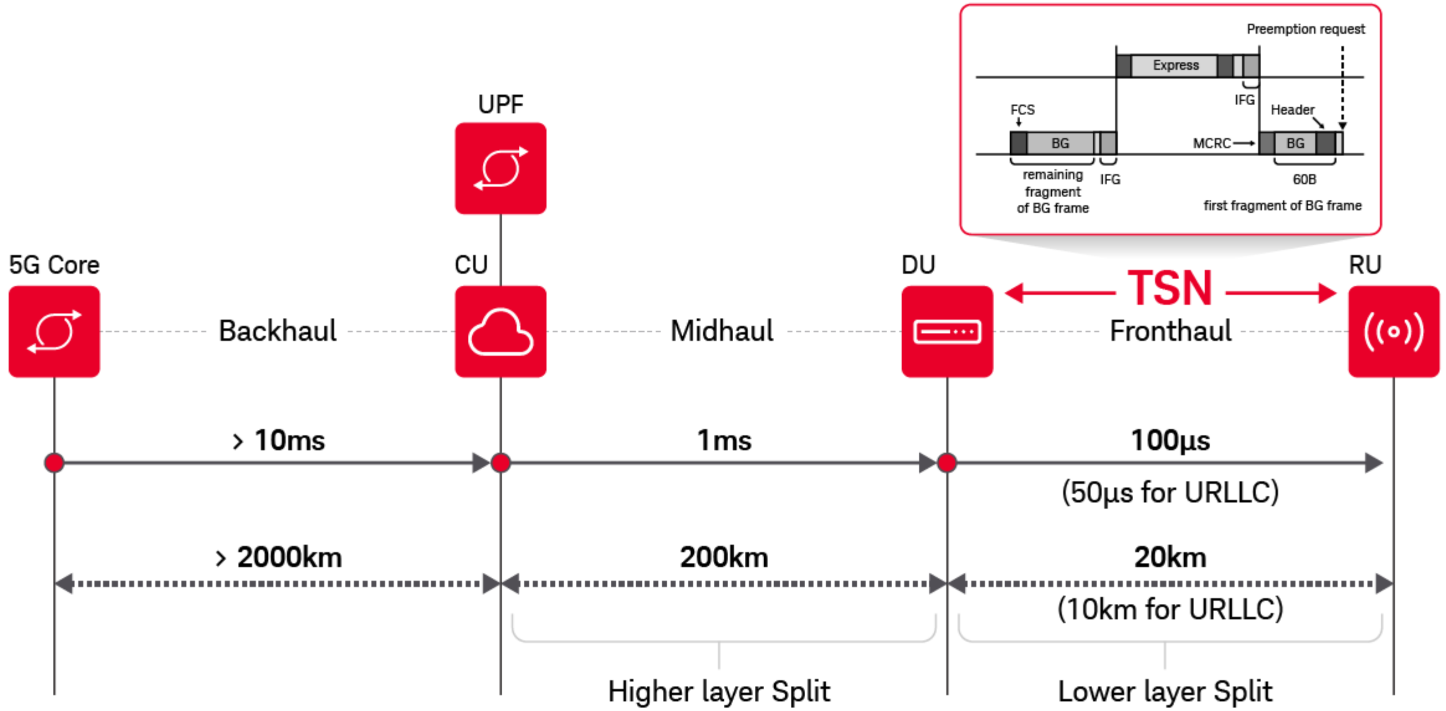
5G RAN vs Automotive : More Stringent Latency

5G RAN FRONTHAUL

- More stringent Latency
- End-to-end 100us over 20km
- Other Traffic not predictabl

AUTOMOTIVE

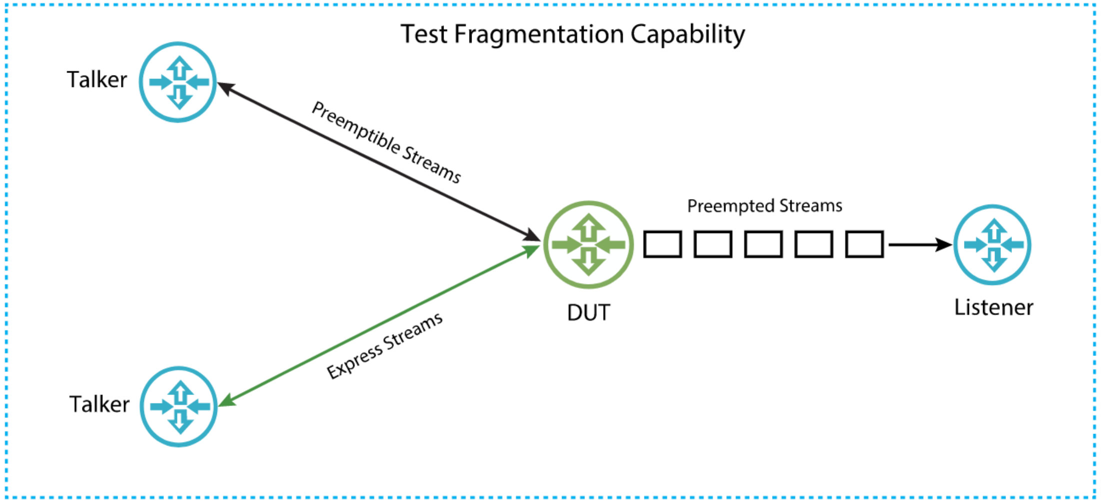
- Relatively Lenient
- Traffic Engineering Possible
- Frame preemption not required



5G RAN vs Automotive : More Stringent Latency

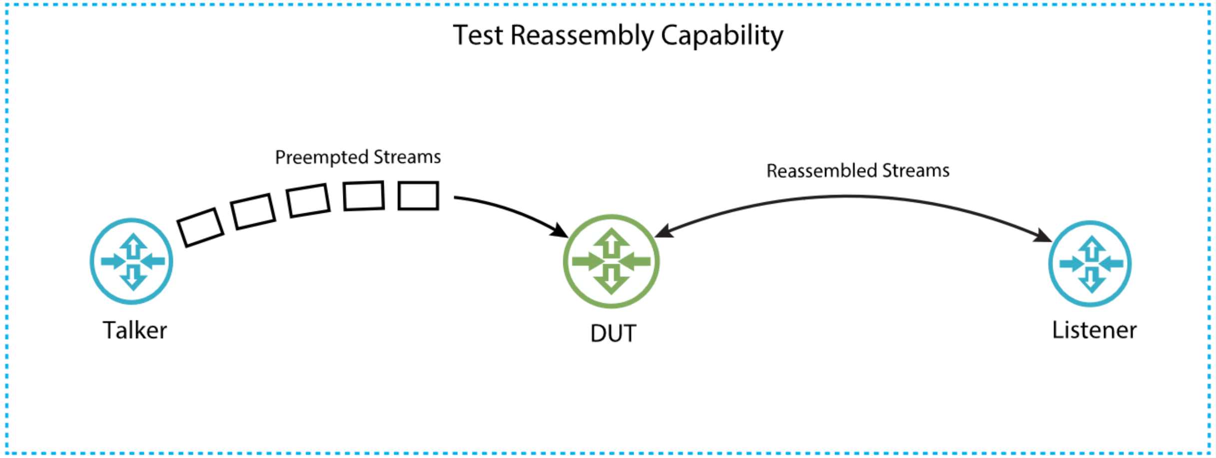
IxNetwork tests performed by the 5G fronthaul vendors

Validate Fragmentation capability of the switch



1. Emulate a mix of Express radio traffic and low priority preemptable traffic
2. Validate the fragmentation done at the fronthaul switch at line rate
3. Ensure latency guarantee of the express radio traffic.

Validate Reassembly capability of the switch



1. Emulate a mix of fragmented traffic and Express radio traffic.
2. Ensure these is no loss for the fragmented traffic.
3. Validate reassembly of fragments by the receiving fronthaul switch.

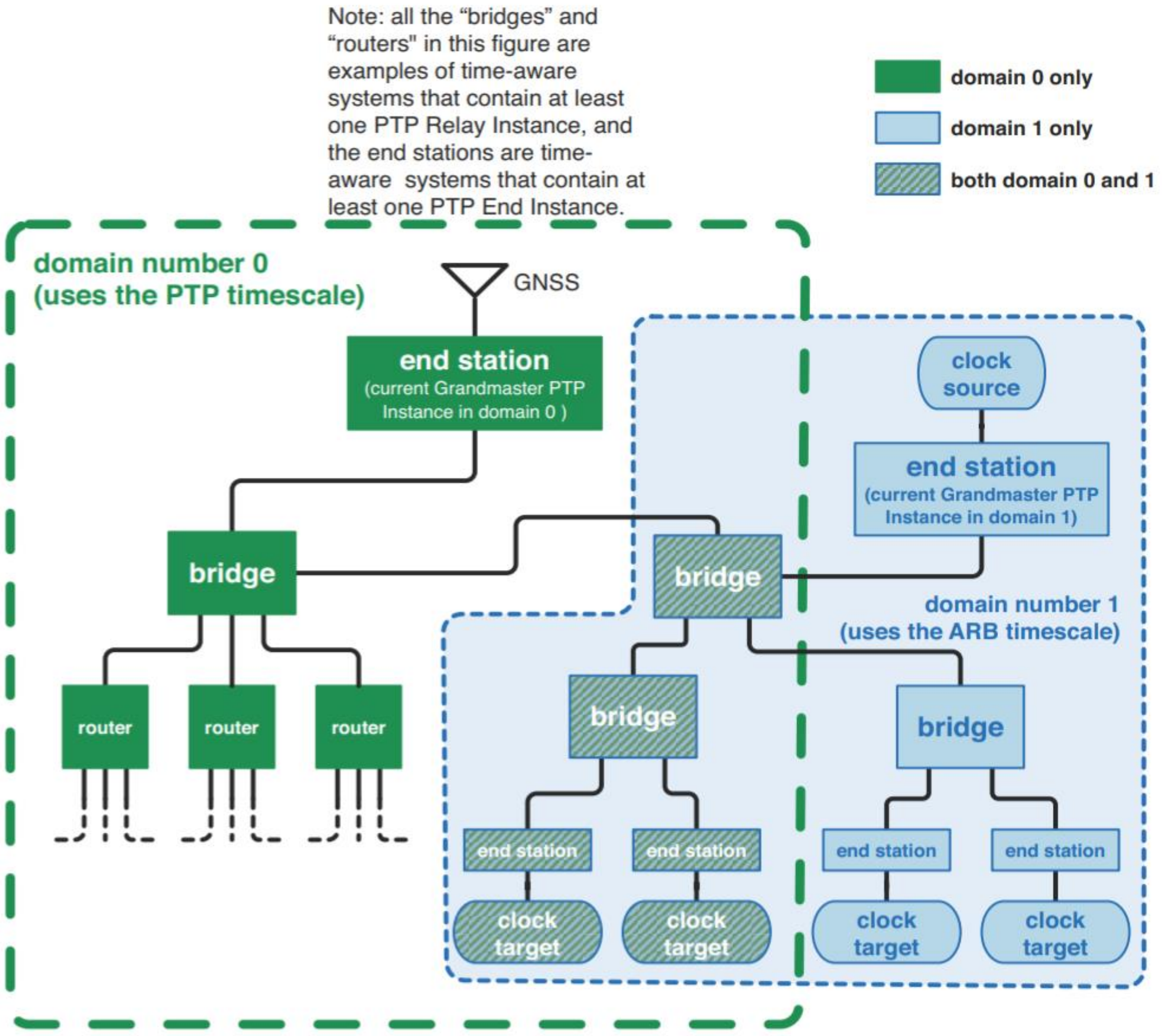
Open Networks vs Automotive : 1588 Time Domains

AUTOMOTIVE

- Domain based Architecture
- Internal Domain can be isolated from the outside world
- Usage of ABR Time scale
- Multiple domain over ARB and PTP Time scale

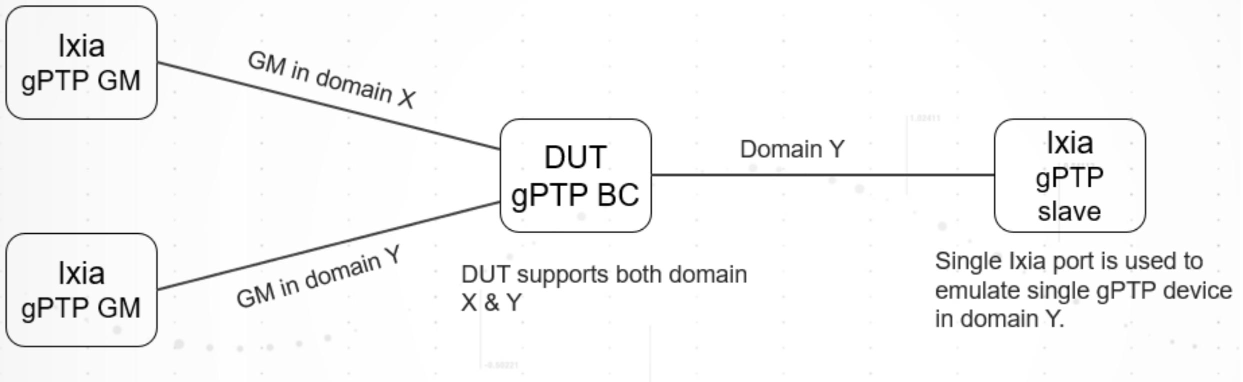
INDUSTRIAL / TELECOM

- Shared Network Architecture
- Need to be in sync with Global components
- Usage of PTP Time scale



Open Networks vs Automotive : 1588 Time Domains

Validation method of 802.1AS2020 by Automotive engineers



- Validating Domain gateways which are part of two different time domains
- Validating PTP enabled nodes are able to maintain time sync based on ARB time scale

Time Synchronisation Redundancy Used in Automotive vs Non-Automotive

Automotive

- GM roles are preconfigured into ECU's and doesn't change too often.
- Need for running BMCA is less as new node addition to IVN is not a dynamic process.
- In absence of BMCA, Standby GM is best option for maintaining synchronization in case of a Node Failure.

Non-Automotive

- GM roles are not preconfigured in nodes that part of an Industrial Network.
- Whenever there is need for re-electing GM, BMCA runs across to elect the best clock as GM.
- Multiple domains can be still used in industrial networks, but Standby GM can be avoided.

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