Towards Seamless Connectivity: Exploring the Future of Real-Time Networks through TSN and 5G Integration

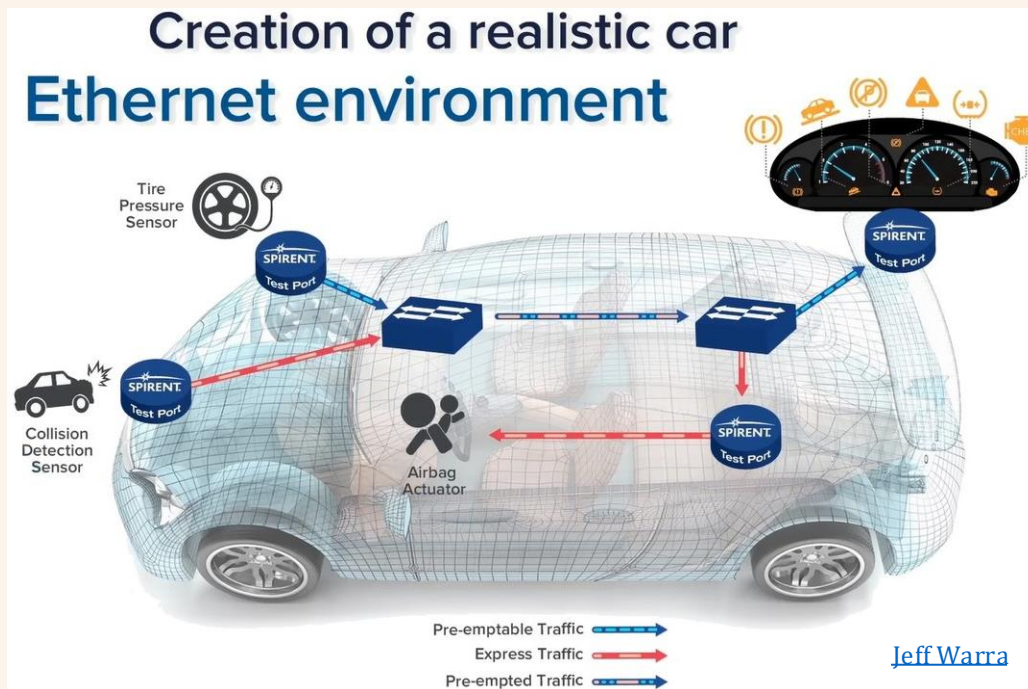Zenepe Satka, School of Innovation, Design and Engineering

DIVERSE Workshop, ETFA 2024

Mälardalen University

Towards Seamless Connectivity

Time-Sensitive Network (TSN)

- Real-time Application

- Critical Data

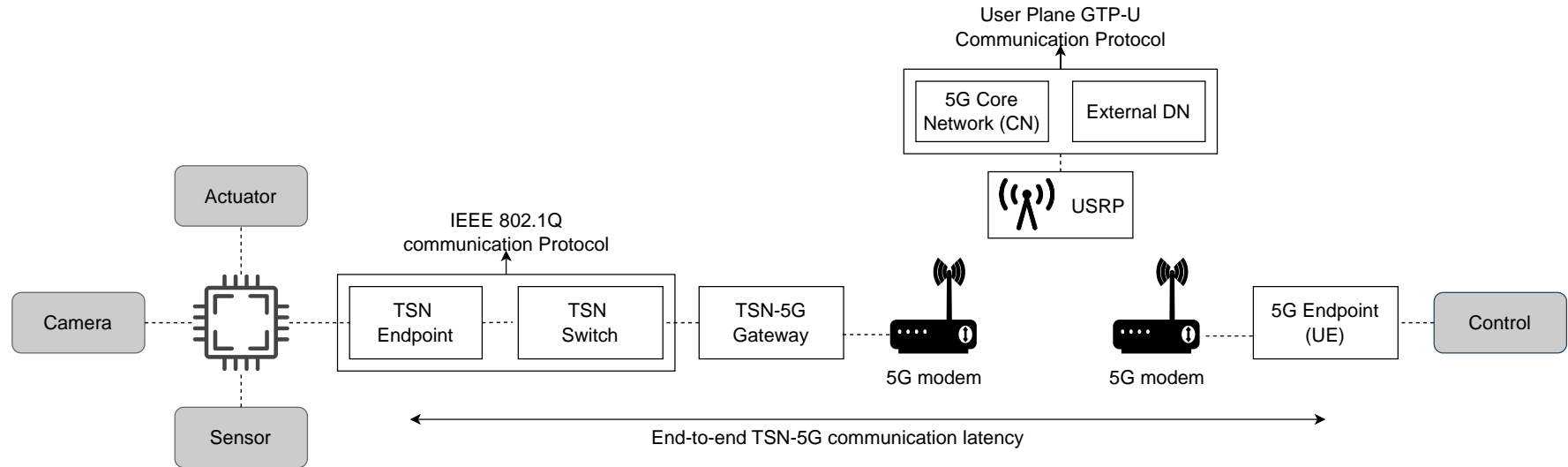- Bounded Low-Latency

Jeff Warra

Mobile Connection

5G cellular network:

- Speed: 100Mbps-10Gbps
- Latency down to 1ms
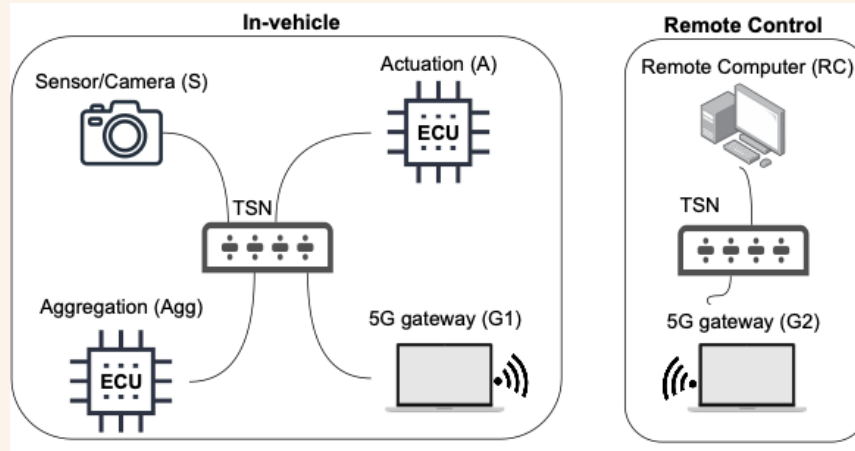- Ultra-reliability
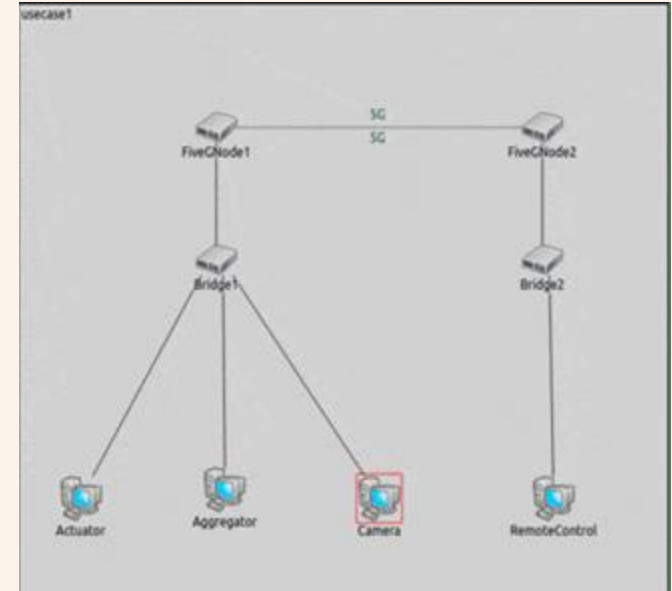- Higher bandwidth

MDU TSN-5G Testbed

A translation technique for TSN-5G

"A technique to translate the traffic between TSN and 5G communication technologies"

Automotive industrial use case utilizing TSN & 5G

Z. Satka *et al.*, "Developing a Translation Technique for Converged TSN-5G Communication," *2022 IEEE 18th International Conference on Factory Communication Systems (WFCS)*, Pavia, Italy, 2022, pp. 1-8, doi: 10.1109/WFCS53837.2022.9779191.12

A QoS mapping mechanism for TSN-5G

"A novel and efficient mapping algorithm to map different TSN traffic flows to 5G QoS flows"
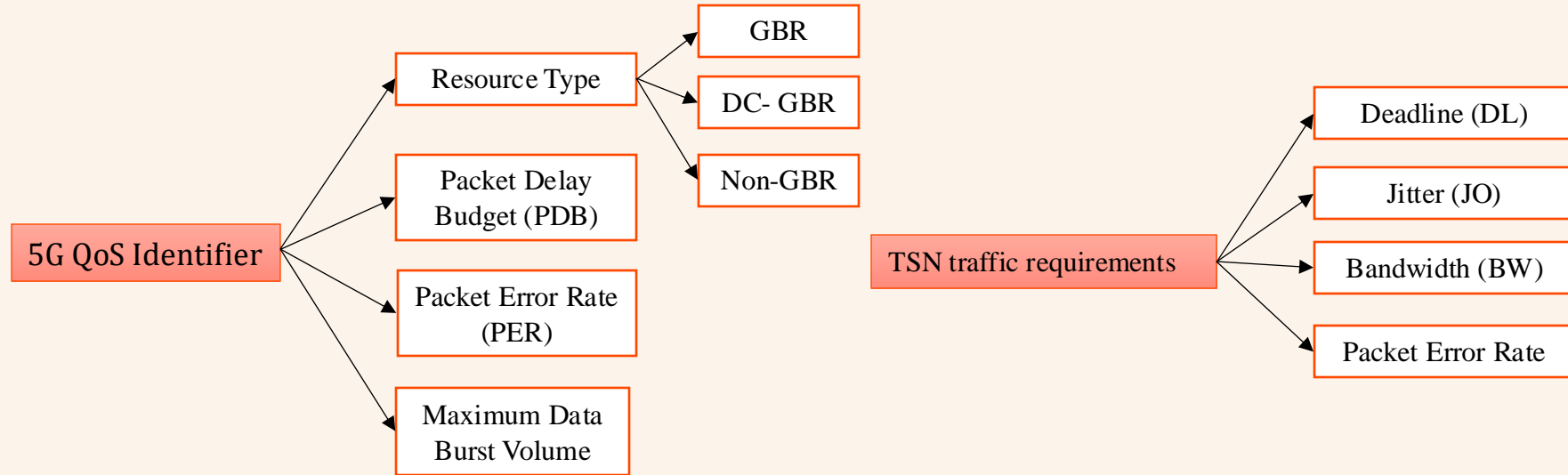
Z. Satka, M. Ashjaei, H. Fotouhi, M. Daneshtalab, M. Sjödin and S. Mubeen, "QoS-MAN: A Novel QoS Mapping Algorithm for TSN-5G Flows," *2022 IEEE 28th International Conference on Embedded and Real-Time Computing Systems and Applications (RTCSA)*, Taipei, Taiwan, 2022, pp. 220-227, doi: 10.1109/RTCSA55878.2022.00030.

PRIVATE 5G MADE SIMPLE
- Firecell 4G/5G Labkit 40

A **ready-to-run network** in a box
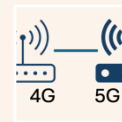
Built from **OpenAirInterface (OAI)**

Open source 4G & 5G (SA) network

Essential **3GPP Release 16** components

Sub-6 **GHz frequency bands** in TDD and FDD

5G Non-Standalone (NSA) support

Firecell 4G/5G Labkit 40

1 Compact Server running 4G and 5G

The **Core Network** in charge of
- Network Management
- Data Traffic Routing
- User Management
- Authentication and Encryption

Firecell 4G/5G Labkit 40

The **Radio Access Network (RAN)** in charge of the air interface management

- Schedules the transmission of IP packets from the Core Network to the radios
- Receives IP packets from devices via the radios, forwarding them to the Core Network.

Software Defined Radio (SDR) which supports 4G, and 5G in all sub-6 GHz bands, TDD and FDD.

Current Labkit Performance

Performance over 4G	
Max Bandwidth	20MHz
Max DL Throughput	70Mbps
Max UL throughput	7 Mbps
Max simultaneous UEs	16
Subcarrier spacing	15 kHz
Latency (RT)	< 50ms
Bands	All < 6 GHz

Performance over 5G	
Max Bandwidth	40MHz
Max DL Throughput	100 Mbps
Max UL throughput	20 Mbps
Max simultaneous UEs	10
Subcarrier spacing	30 kHz
Latency (RT)	< 20ms
Bands	All FR1 (< 6 GHz)

Comparing the 5G Standalone and 5G Non-Standalone Setup with LTE and Wi-Fi
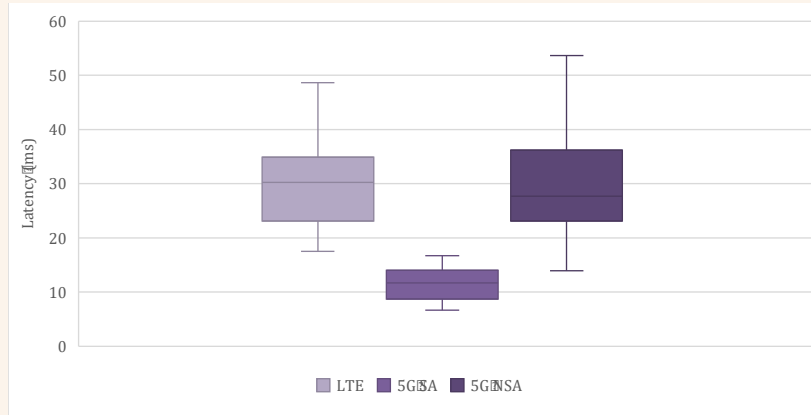
End-to-end Latency Components in TSN-5G
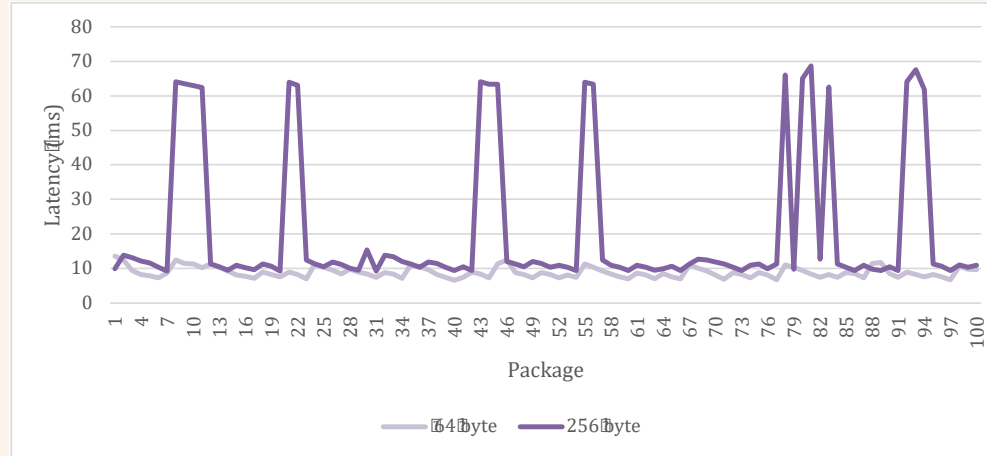
Packet Size	TSN Transmission Time (ms)	Gateway Processing Time (ms)	5G Radio Transmission Time (ms)	5G Core Network Processing Time (ms)	E2E TSN-5G Latency (Avg) (ms)	Min E2E Latency (ms)	Max E2E Latency (ms)
64 bytes	1.07006	0.0342	8.8689	0.1	9.97316	6.57	13.6
128 bytes	1.09143	0.0342	8.7787	0.1	9.90433	6.46	12.8
256 bytes	1.07841	0.0342	20.4585	0.1	21.67111	9.24	68.6

Thank you for your attention!