



# 5G-TSN Technology for Deterministic Communication Services

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### 5G-TSN Background and Motivation



5G-TSN Architecture and Techniques



5G-TSN Prototype for Industrial Scenario

### **TSN for Industrial Automation**







- Industrial 4.0
- More intelligent devices
- **Traditional Fieldbus** techniques can not satisfy high-bandwidth and deterministic services at one network. Low latency Low jitter **Bounded delay Multi-service bearer**

### **TSN to Wireless TSN**







Wired network is not suitable for flexible production in smart factory

### **5G-TSN: Unified network for smart factory**



### Deterministic Network Integrated with wireless and wired networks



**High bandwidth** 

High data rate

**Wireless Networking** 

**Multi-Service Bearing** 

**Time Synchronization** 

**Deterministic transmission** 

**Compatible for Ethernet** 

**Multi-Service Bearing** 





### 5G-TSN Architecture and Techniques



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5G-TSN Prototype for Industrial Scenario

# 5G TSN Bridge defined by 3GPP



- In 2020.7, 3GPP R16 introduced TSN techniques into 5G system to improve deterministic transmission capability.
- Serval new entities are implemented and enhanced in 5Gs to support TSN features, such as IEEE 802.1AS, 802.1 Qbv, 802.1 Qci, et al.



• DS-TT(Device-Side TSN Translator)

• TSN-AF

NW-TT(Network-side TSN Translator)

### **5G TSN Bridge defined by 3GPP**



#### **The whole 5G system is regard as a TSN Bridge**



5G system as a logic TSN Bridge

## **Time Synchronization across 5G and TSN**



#### Time synchronization is the basis for deterministic communication service of 5G-TSN.



#### **Boundary Time Synchronization**

#### **Time synchronization in NW-TT.**



#### **Time synchronization in 5G NR**



### **5G-TSN QoS Interworking**



5G and TSN are totally different in terms of QoS management, scheduling mechanisms and MAC protocols, it's a big challenge for deterministic communication across 5G and TSN.



LI Wei, SUN Lei\*, et.al., Key technologies to enable 5G and TSN coordination for industrial automation. Chinese Journal of Engineering, 2022, 44(6).

### Low latency Guarantee in 5G

time-sensitive services

- THE REF. 1952 MU
- □ Low latency capability is the <u>basic guarantee for deterministic communication</u>.
- Radio channel brings the most uncertainty for low latency data transmission across 5G and TSN.
- Mini-Slot Scheduling 7 or 14 OFDM symbols >2, 4, 7 symbols
  Fast Scheduling Re-scheduling before ACK/NACK response
  Semi-Persistent Scheduling Reserve resources for

Low latency and high reliability always are contradictory

Frequency

**OFDM Symbol** 

Time

# **5G-TSN Joint Scheduling Scheme**



- End to End latency requirement is seprated into <u>latency budget in TSN</u> <u>domain and latency budget in 5G system</u>, which is used to set Gate <u>Control List for time-critical services</u>
- □ With Time-Aware Shaping (TAS) scheme in TSN, <u>5G system can provide</u> <u>deterministic data transmission for time-critical automation traffics</u>.



SUN Lei, et.al., Research on 5G-TSN joint scheduling mechanism based on radio channel information, Journal on Communications, 2021, 42(12).

## **5G-TSN Joint Scheduling Scheme**



- □ In order to improve the multi-services bearing capability as well as to provide solid guarantee for time-ciritical services, 5G-TSN joint scheduling takes both <u>GCL state in TSN</u> domain and <u>dynamic radio</u> <u>resource allocation in 5G</u> into consideration
- Deep reinforcement learning model is used to optimize the 5G resource allocation based on GCL information from TSN domain.



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Yuan ZHU, Lei SUN\*, et.al., Deep Reinforcement Learning based Joint Scheduling of 5G and TSN in Industrial Networks, Electronics, 2023, 12, 2686.



- Gorden Science Scie
- □ <u>The radio channel is a big challenge</u> not only for precise time synchronization, but also for low latency and high reliable guarantee across 5G and TSN .
- □ The 5G system is more complex than TSN, in order to <u>make full</u> <u>use of radio resouces and improve the service bearing ability of</u> <u>5G-TSN collobarative network</u>, it should be better to take GCL state of TSN into consideration when gNB makes resource allocation decisions.





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### **5G-TSN prototype for industrial scenario**





# **5G-TSN prototype for industrial scenario**



#### **G-TSN** Testbed in the lab

- □ Evaluate the performance of 5G-TSN techniques
- □ Test the cloud control mechanisms based on 5G-TSN collaborative network







# **Thanks for Your Attention**

建于1952年,海淀区学院路上的八大学院之一的北京科技大学