

5G – Ultra-Reliable Wireless Technology with Low Latency

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Outline



- 5G URLLC use cases & overview
- 5G NR low-latency features
- 5G NR reliability features
- 5G multi-connectivity features
- Integration of 5G and TSN
- 5G and DetNet combinations
- Summary



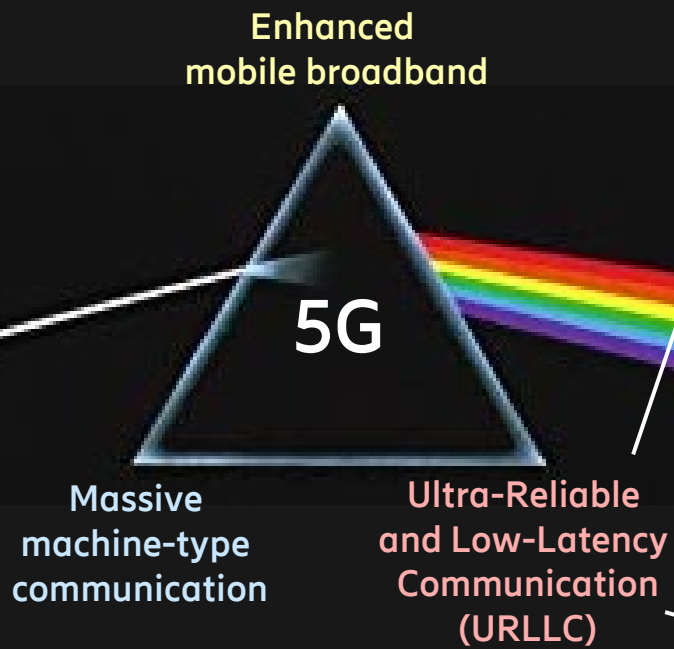
Industrial Use Cases and Requirements



Use case (high level)		Availability	Cycle time	Typical payload size	# of devices	Typical service area
Motion control	Printing machine	>99.9999%	< 2 ms	20 bytes	>100	100 m x 100 m x 30 m
	Machine tool	>99.9999%	< 0.5 ms	50 bytes	~20	15 m x 15 m x 3 m
	Packaging machine	>99.9999%	< 1 ms	40 bytes	~50	10 m x 5 m x 3 m
Mobile robots	Cooperative motion control	>99.9999%	1 ms	40-250 bytes	100	< 1 km ²
	Video-operated remote control	>99.9999%	10 – 100 ms	15 – 150 kbytes	100	< 1 km ²
Mobile control panels with safety functions	Assembly robots or milling machines	>99.9999%	4-8 ms	40-250 bytes	4	10 m x 10 m
	Mobile cranes	>99.9999%	12 ms	40-250 bytes	2	40 m x 60 m
Process automation (process monitoring)		>99.99%	> 50 ms	Varies	10000 devices per km ²	

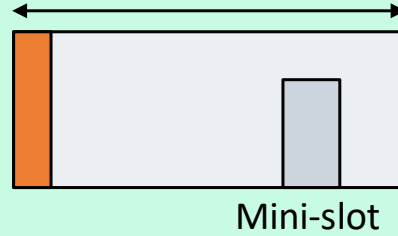
Source: [5G-ACIA: White Paper, "5G for Connected Industries and Automation," Feb. 2019](#)

5G URLLC Overview

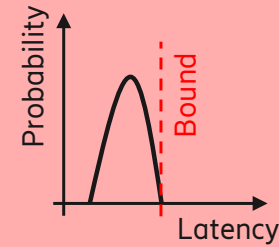


Low latency

NR slot = 14 OFDM symbols

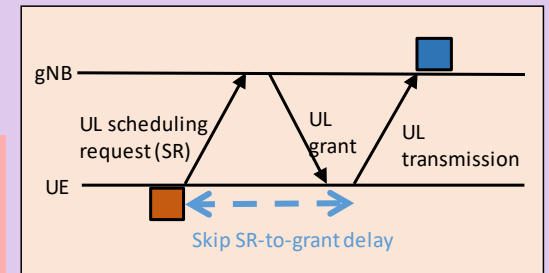


5G URLLC

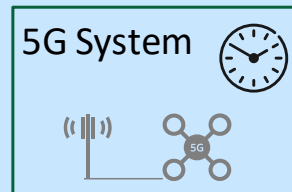


5G ultra-reliable and low-latency communication

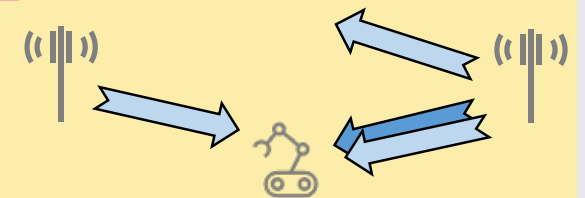
Resource management



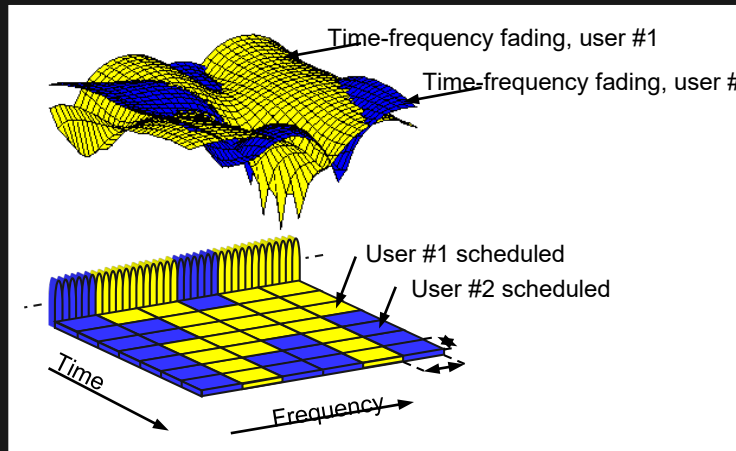
Time synchronization



Reliability

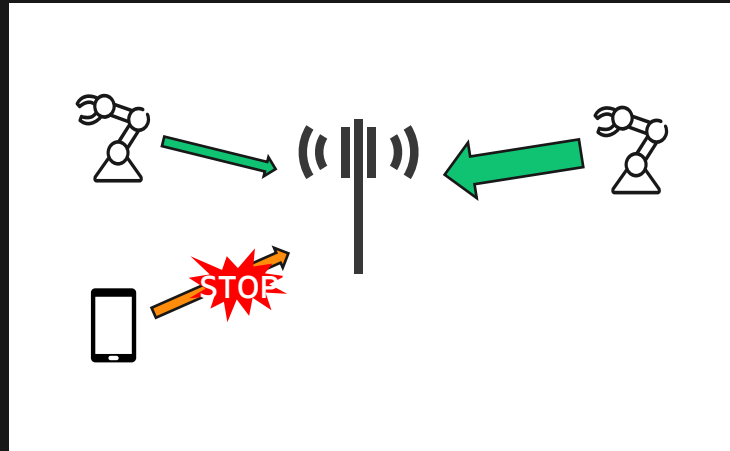


5G NR – Scheduled Wireless Access



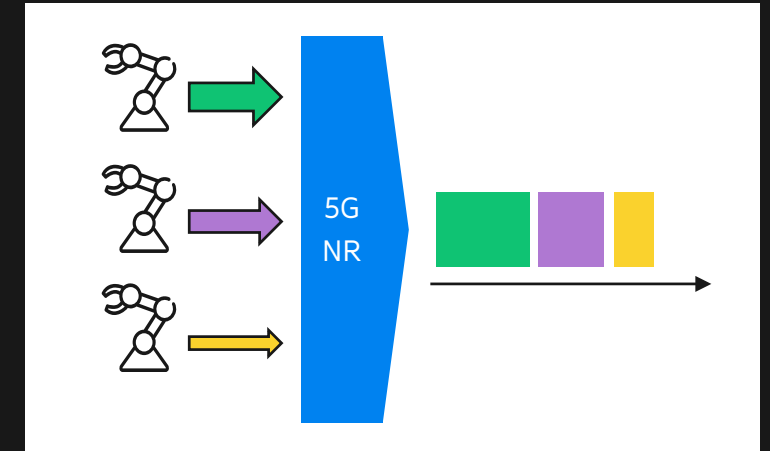
Dynamic DL & UL resource assignments

- gNB schedules radio resources according to availability and QoS
- primarily licensed spectrum



Admission control

- QoS of existing users ensured by admission control of further users



Quality of Service (QoS)

- QoS flows established through core and radio network
- Packet delay budget, priority, packet error rate

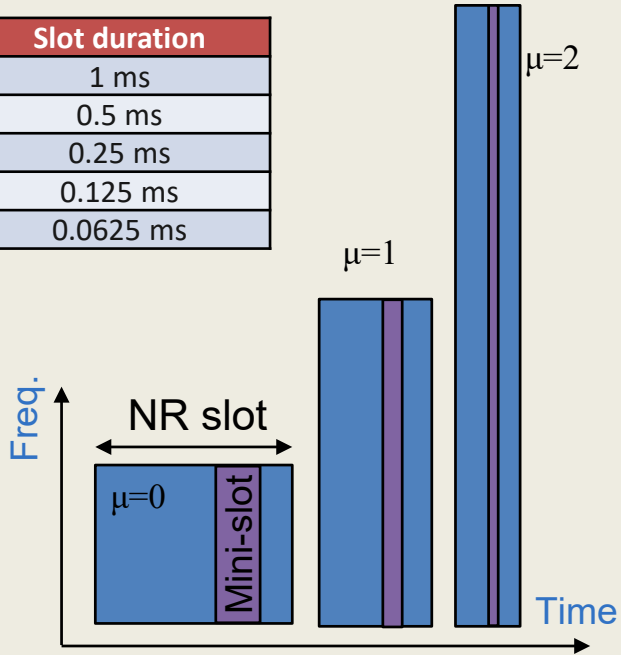
5G NR – Low-latency Features



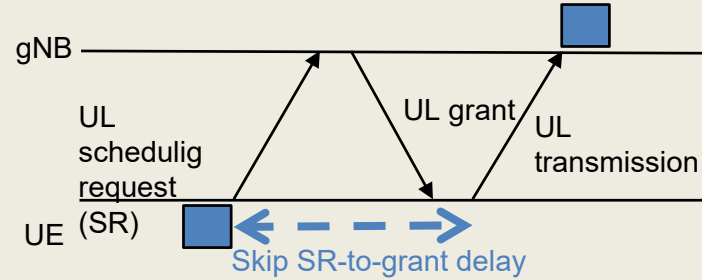
Applicable to both IP and Ethernet PDU sessions

Numerology & mini-slot

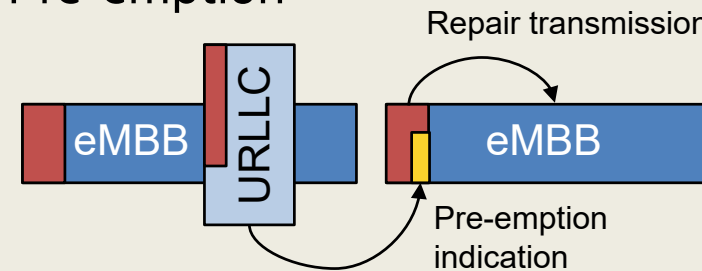
μ	SCS [kHz]	Slot duration
0	15	1 ms
1	30	0.5 ms
2	60	0.25 ms
3	120	0.125 ms
4	240	0.0625 ms



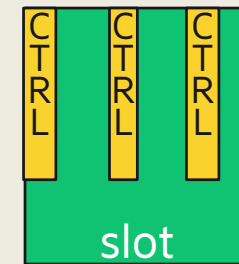
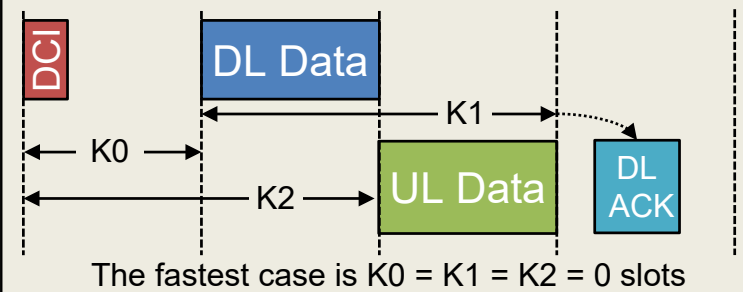
Pre-scheduling



Pre-emption



Fast processing & re-tx (HARQ)

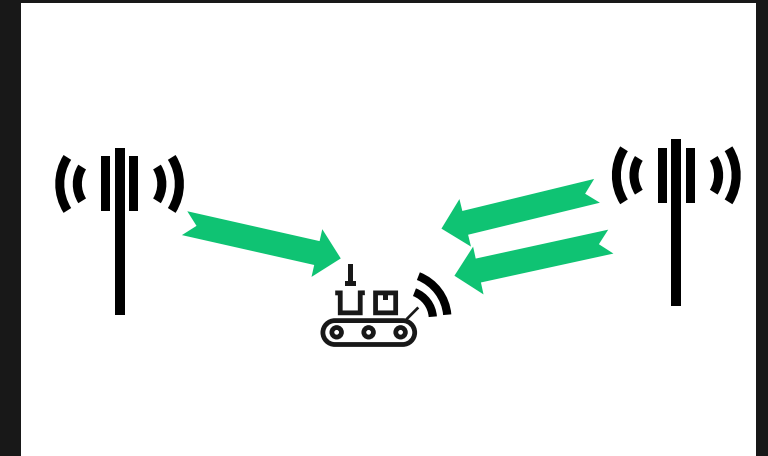
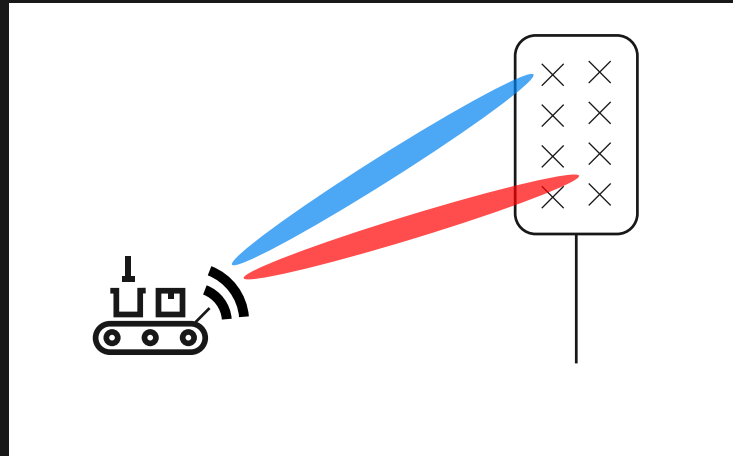
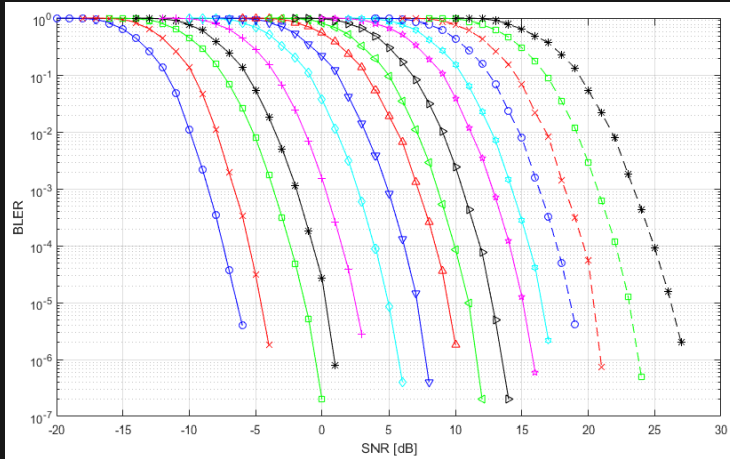


Multiple Control channel monitoring occasions within one slot is supported

5G NR – Reliability Features



Applicable to both IP and Ethernet PDU sessions



Robust control and data channels

- Extra-robust modulation and coding schemes
- Robust control channel design
- Channel state reporting and centralized link adaptation

Multi-antenna techniques

- Exploit diversity and increased channel quality of multiple antennas at transmitter and receiver

Multi-connectivity

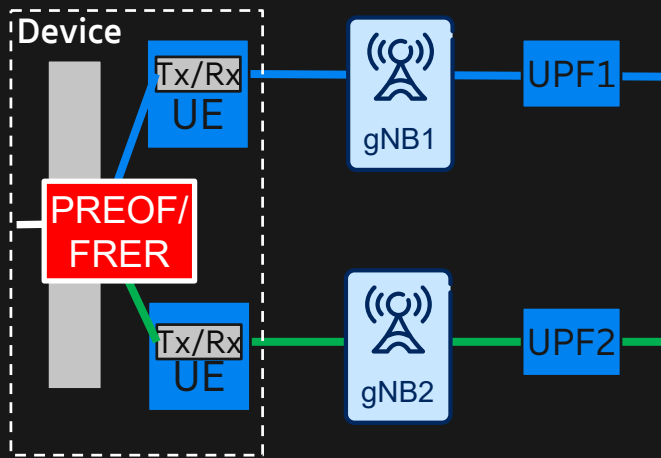
- Multiple duplicate transmissions on different carriers
- More on next slide ...

5G – Multi-connectivity Features



Applicable to both IP and Ethernet PDU sessions

Dual UEs in the Device



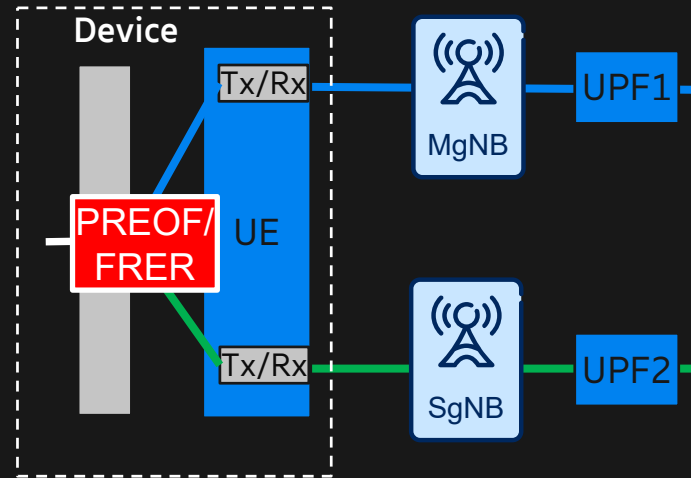
— Full redundancy of UE and network

— 5G is ready for DetNet service protection:

— PREOF: Packet Replication, Elimination, and Ordering Functions, see RFC 8655 DetNet Architecture

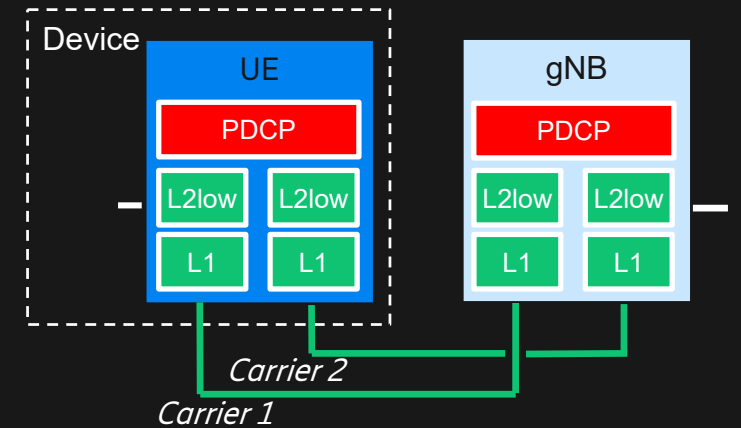
— FRER: Frame Replication and Elimination for Reliability, see IEEE Std 802.1CB

Dual Connectivity



— Network user plane redundancy

RAN internal: PDCP duplication



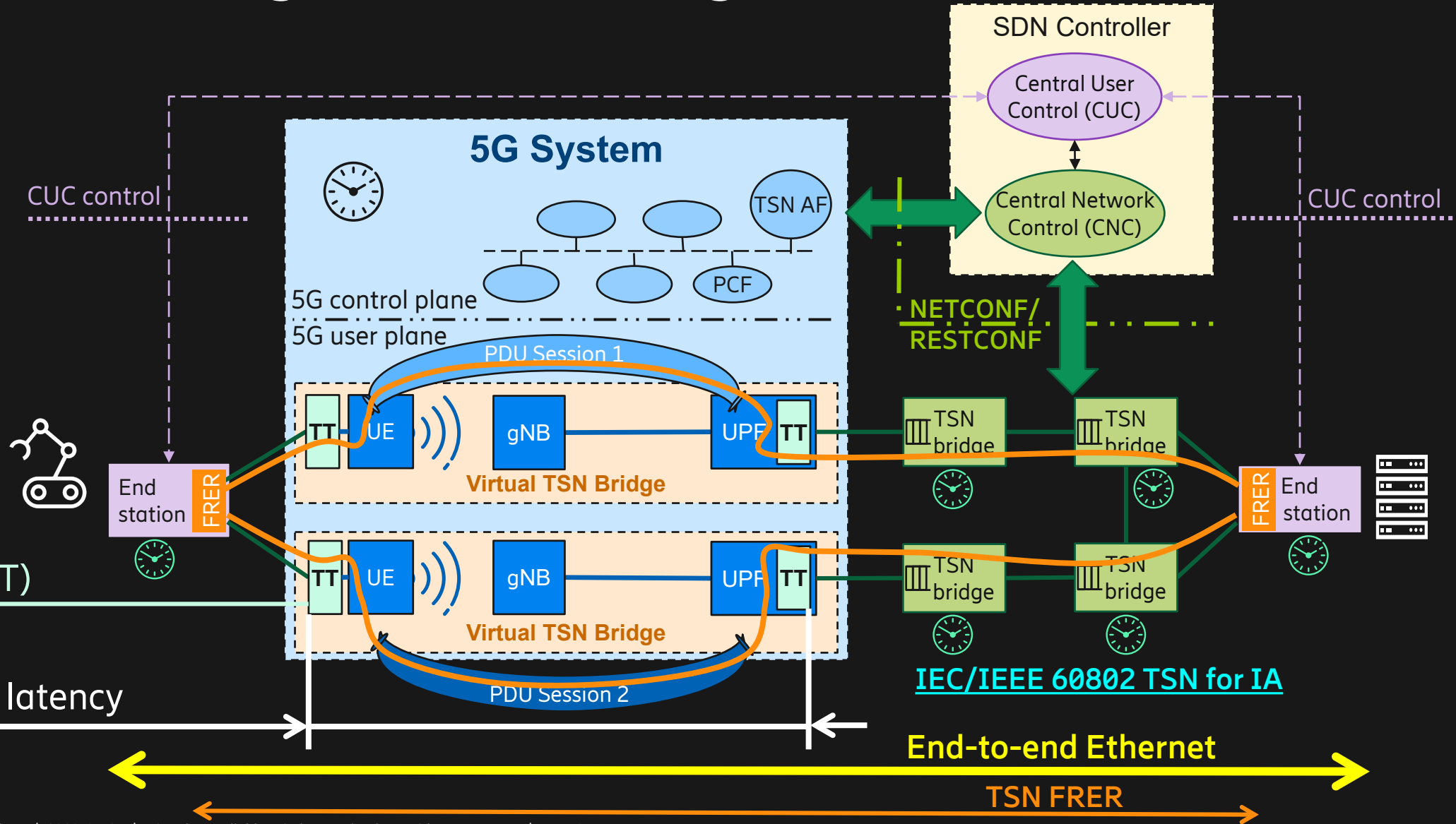
— Redundant over-the-air transmissions

5G as Virtual Bridge for TSN Integration

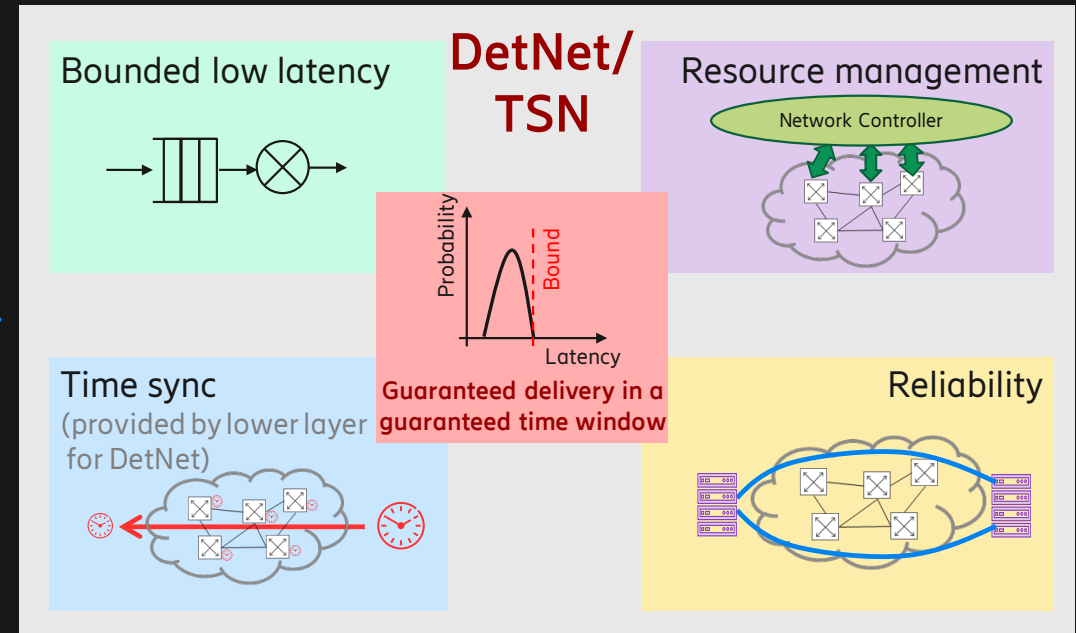
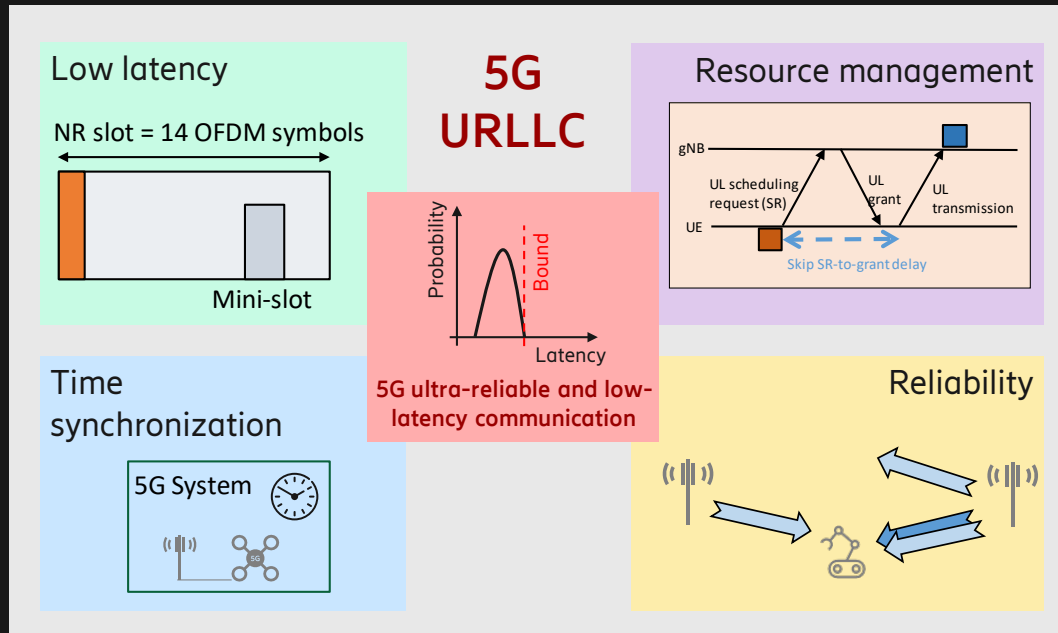


TSN Translator (TT)
for Interworking

deterministic latency



5G Matches Deterministic Wireline Networking



5G and DetNet Combination Examples

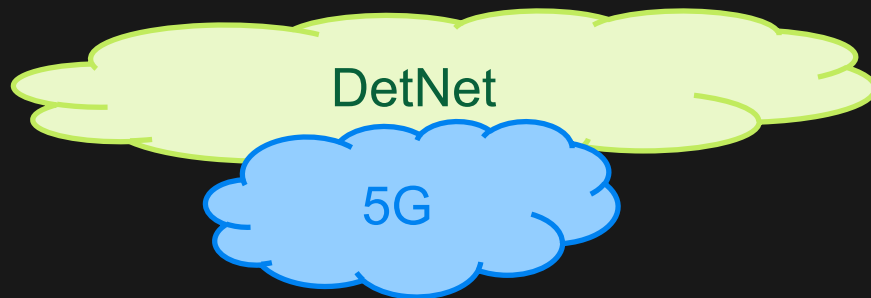


a) TSN was considered as first sub-network technology candidate for DetNet, but more to come ...

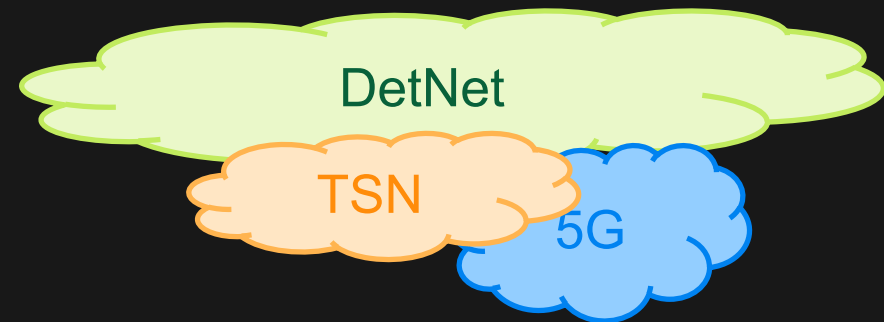


[I-D.ietf-detnet-ip-over-tsn](#)
[I-D.ietf-detnet-mpls-over-tsn](#)

b) 5G acting as a sub-network for DetNet



c) 5G & TSN sub-networks for DetNet



Summary



- 5G provides centrally controlled scheduled wireless segments with high reliability and availability
 - Dynamic and pre-scheduled DL & UL resource assignment
 - Admission control to ensure QoS
- 5G provides QoS guarantees for latency and reliability
 - latency below 1ms with reliability up to 99.999%
- 5G contains several features to achieve ultra-reliable and low latency performance, e.g.,:
 - support for different OFDM numerologies and slot-durations
 - fast processing capabilities
 - redundancy techniques
- 5G includes features to support Industrial IoT
- 5G supports integration with TSN
 - Reliability equally applicable to DetNet
- 5G is DetNet ready



Thank you!

Q&A