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# QoS and Performance in private Wireless Networks

Guillermo Jimenez

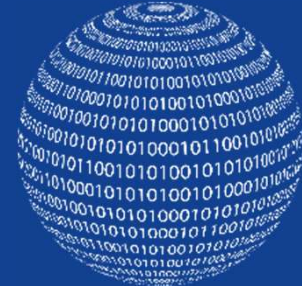
CTO Nokia Enterprise LAT

Sept 2021



# The journey to Industry 4.0

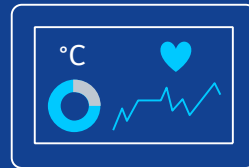
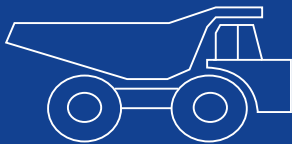
How digital technologies are transforming asset-intensive industries



Manual operation  
of physical assets

Real-time digital view  
of physical assets

Digitally controlled  
physical assets



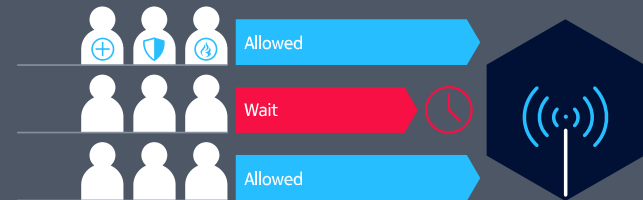
# Assured performance in the most demanding situations

## Implementing Prioritization mechanisms

1

### Access control

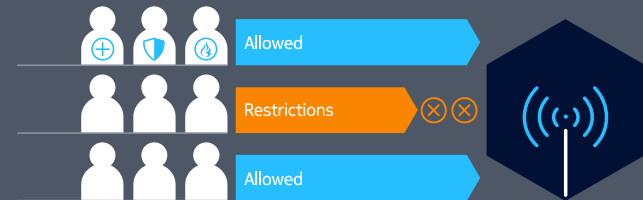
- Determines which users are allowed to access the cell and when they can try to access
- Access Classes (0-9, 11-15 on USIM)



2

### Admission control (and pre-emption)

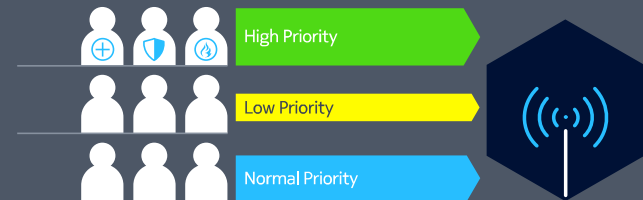
- Determines which users are served and the type of service offered
- ARP (Allocation and Retention Priority)



3

### Traffic Prioritization (Scheduling)

- Determines the quality of service (throughput and latency) for the offered services in use
- QCI (QoS Class Identifier)



# New QoS Class Identifiers (QCI) developed for Mission Critical in 3GPP (since Rel 12/13) Prioritized packet forwarding and scheduling

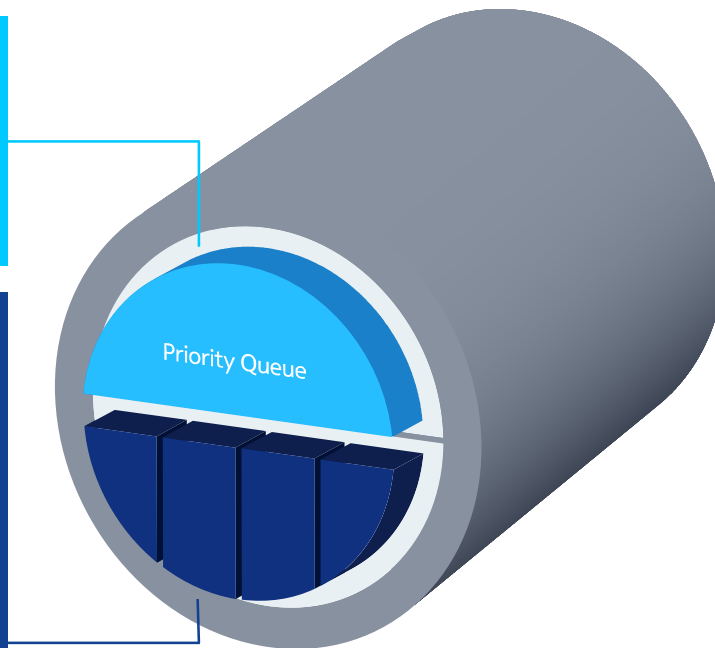
Guaranteed bit rate (GBR)

**QCI 65**  
Mission critical User Plane PTT voice  
Priority : 0.7  
Packet Delay : 75ms  
Packet loss :  $10^{-2}$

Non-Guaranteed bit rate (Non-GBR)

**QCI 69**  
Mission critical signaling  
Priority : 0.5  
Packet Delay : 60ms  
Packet loss :  $10^{-6}$

**QCI 70**  
Mission critical data  
Priority : 5.5  
Packet Delay : 200ms  
Packet loss :  $10^{-6}$



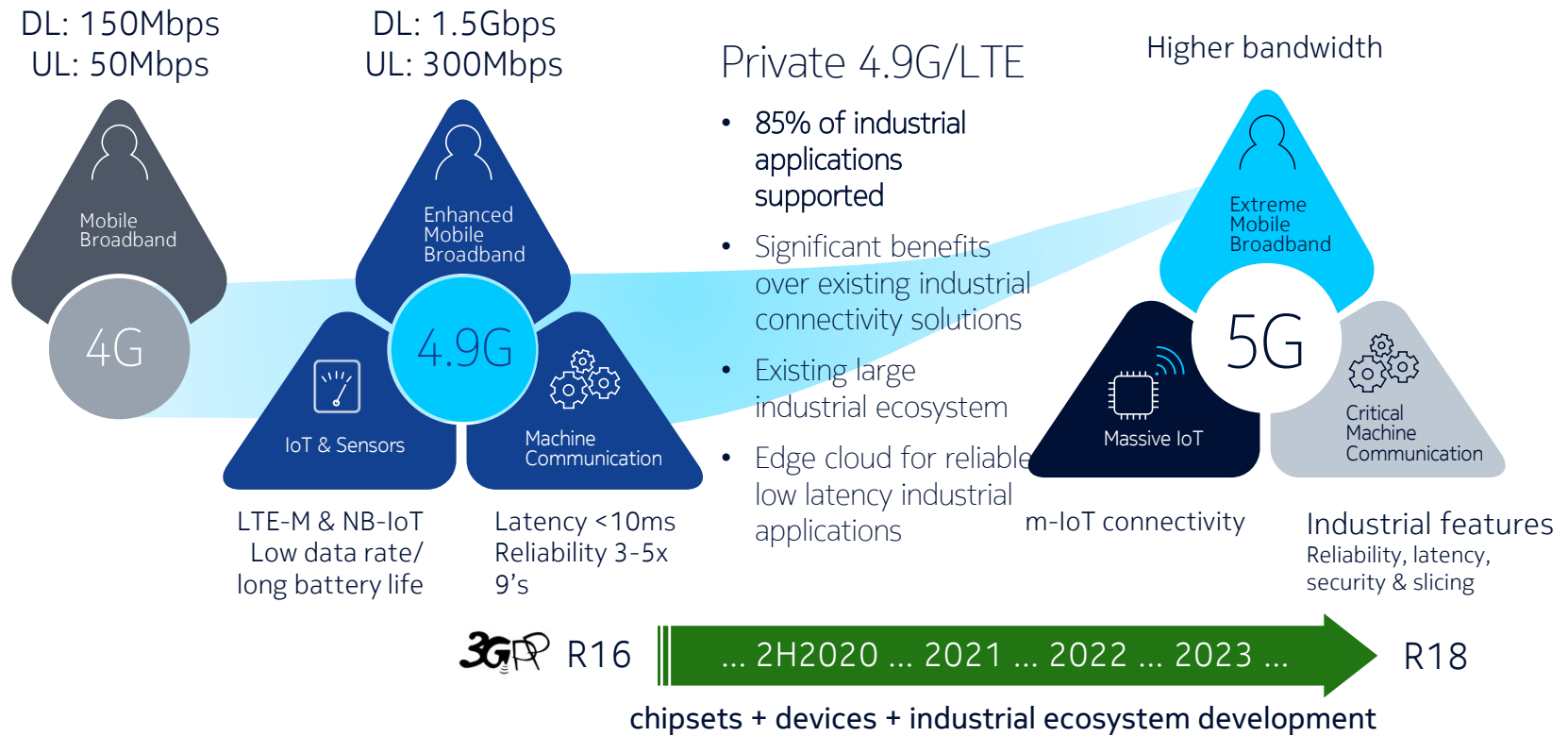
Mission critical communications prioritized versus commercial traffic

High Med Low

15x improved throughput for Mission critical customers

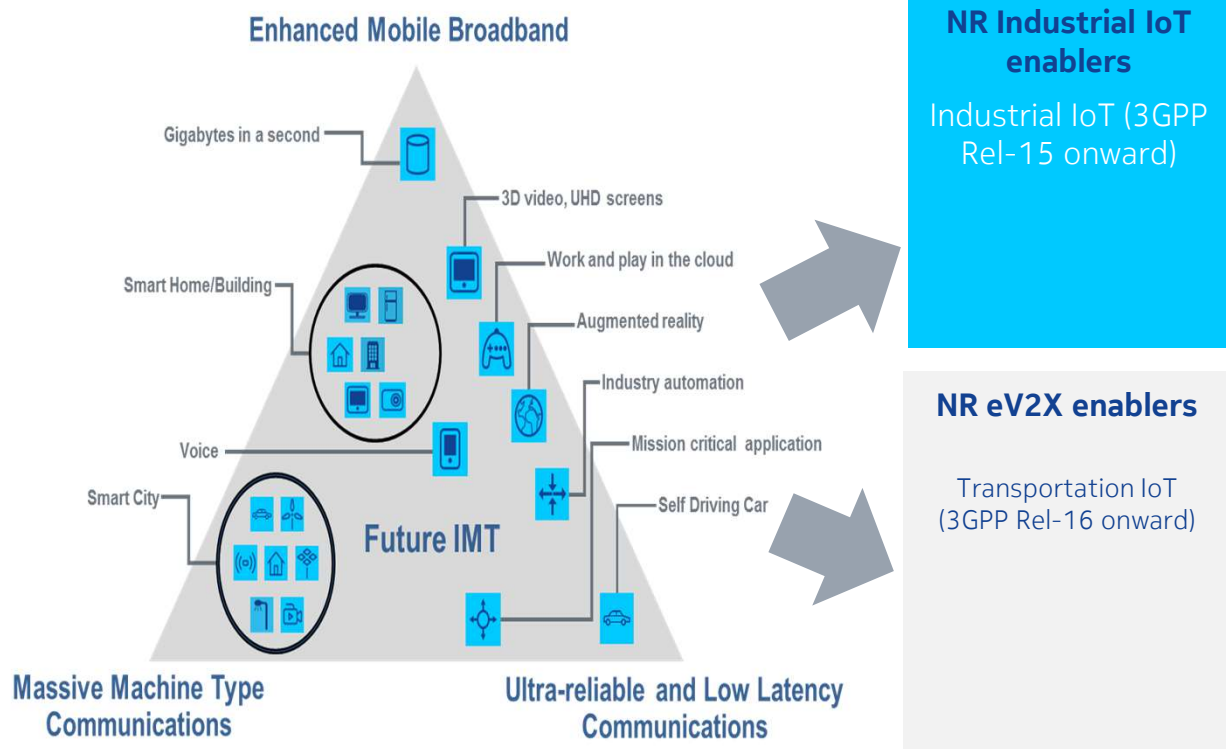
# Industrial-grade Private Wireless networks

4.9G today, 5G next for mission-critical and business-critical communications



# 5G URLLC concepts

## Mapping ITU-2020 URLLC



**3GPP Releases Targets**

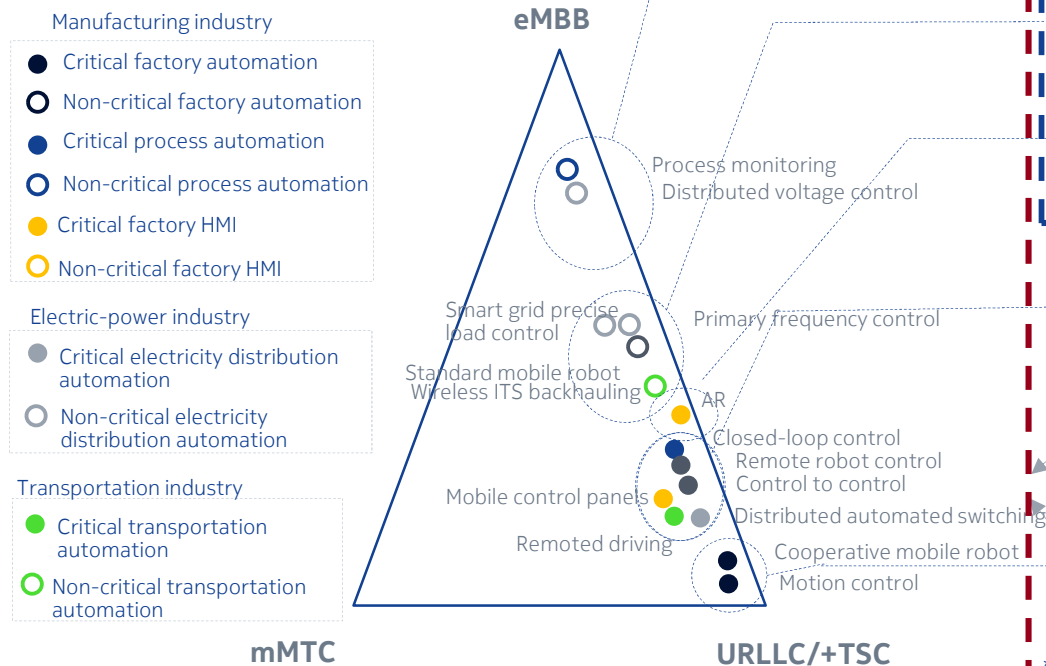
**Release 15**  
Provided basic URLLC functionality, targeting at 1ms latency and  $10^{-5}$  reliability (RAN)

**Release 16**  
Motivations to further enhance URLLC

- Latency in the range of 0.5 – 1 ms, reliability in the range of  $10^{-6}$  (RAN)
- Support new use cases, e.g. factory automation, transport industry
- Further enhance Release 15 use cases, e.g. AR/VR, gaming

# URLLC/TSC performance requirements

## Communication of performance mapping






Supported by 3GPP Rel15					URLLC
<b>Non-critical URC</b>					
E2E latency*	Availability	Reliability**	Jitter***	Synchronicity***	
<=100ms	>=99.999%	>=99.9%	-	-	
RAN U- latency	RAN C-latency	RAN U-reliability	HO latency		
<= 4ms	<= 50ms	>= 5 9s <= 40ms	<= 50ms		
<b>Non-critical URLLC</b>					
E2E latency*	Availability	Reliability**	Jitter***	Synchronicity***	
<=50ms	>=99.9999%	>=99.9%	-	-	
RAN U- latency	RAN C-latency	RAN U-reliability	HO latency		
<= 3ms	<= 20ms	>= 5 9s <= 20ms	<= 50ms		
<b>Moderate critical LLC</b>					
E2E latency*	Availability	Reliability**	Jitter***	Synchronicity***	
<=10ms	99.9%	90%	-	-	
RAN U- latency	RAN C-latency	RAN U-reliability	HO latency		
<= 2ms	<= 20ms	>= 5 9s <= 5ms	<= 20ms		
<b>Moderate critical URLL/TSC</b>					
E2E latency*	Availability	Reliability**	Jitter****	Synchronicity***	
<=10ms	>=99.999999%	>=99.99%	<=0.5~2.5m	<10us	
RAN U- latency	RAN C-latency	RAN U-reliability	HO latency		
<= 1ms	<= 10ms	>= 5 9s <= 2ms	<=10ms		
<b>Critical URLLC/TSC</b>					
E2E latency*	Availability	Reliability**	Jitter***	Synchronicity***	
<=5ms	>=99.999999%	>=99.99%	<=0.5ms	<1us	
RAN U- latency	RAN C-latency	RAN U-reliability	HO latency		
<= 0.5ms	<= 10ms	>= 5 9s <= 1ms	0ms		
<b>Highly critical URLLC/TSC</b>					
E2E latency *	Availability	Reliability **	Jitter	Synchronicity***	
<=0.5~2ms	>=99.999999%	>=99.99%	<=0.25ms	<1us	
RAN U- latency	RAN C-latency	RAN U-reliability	HO latency		
<= 0.5ms	<= 10ms	>= 5 9s <= 1ms	0ms		

\*: E2E network latency at communication interface  
 \*\*: Assumes survival time is one transfer cycle  
 \*\*\*: Optional for non-timing sensitive communication

**Supported by 3GPP Rel16**

# Latency → Precision in industrial / machine / control setting

	Speed	Distance Traveled		
		1 ms	10 ms	100 ms
	3 m/s	3 mm	3 cm	30 cm
	100 km/h	2.8 cm	28 cm	2.8 m
	150 km/h	4.2 cm	42 cm	4.2 m










# SMART GRID APPLICATIONS

## TYPICAL END-TO-END DELAY REQUIREMENTS

Application function	Delay Allowance (minimum)	Priority	Application type
	ms	0-max 100-min	
<b>Delay &lt;= 10 ms</b>			
(High speed) protection information	8, 10	2	Teleprotection (for 60 Hz, 50 Hz)
Load shedding for underfrequency	10	20	SCADA
<b>10 ms &lt; Delay &lt;= 20 ms</b>			
Breaker reclosers	16	15	Teleprotection
Lockout functions	16	12	Teleprotection
Many transformer protection and control applications	16	12	Teleprotection
PMU measurements + status (class A) if used for protection function	20	12	Synchrophasors
<b>20 ms &lt; Delay &lt;= 100 ms</b>			
PMU measurements + status (class A) if used for other than protection	60	10	Synchrophasors
SCADA periodic measurement + status, events, control	100	25	SCADA
DA periodic measurement+status, events, control	100	26	Distribution Automation
DG/DS measurement+ status, events, control	100	27	Distributed Generation / Distributed Storage
PTT signaling (critical)	100	30	MWF, Business voice
PMU clock synchronization	100	20	Synchrophasors
<b>100 ms &lt; Delay &lt;= 250 ms</b>			
VoIP bearer (including for PTT)	175	50	MWF, Business voice
VoIP signaling (person-to-person)	200	60	Business voice
Dynamic Line Rating (DLR) measurements, status, events, control	200	28	Dynamic Line Rating
Real-time video	200	55	MWF, CCTV
On demand CCTV video	200	55	CCTV
Critical grid operation data (e.g., DMS, TMS)	200	45	SCADA, DA, DG/DS, DLR, etc
Critical business data	250	70	Business data
DMS and TMS applications (other than included above)	250	65	SCADA
AMI – critical (e.g. VVVC)	250	40	AMI

# 4.9G/LTE use cases for mining

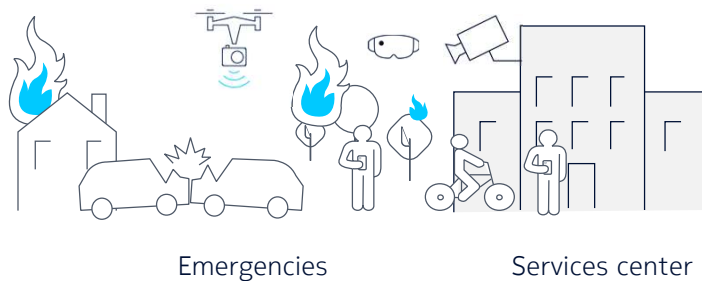
One single network for creating the connected digital mine

Real-time and near real-time broadband data			Mission-critical communications	Massive IoT & analytics	Worker health and safety	Optimized mine-to-port
						
On-demand adaptive bit rate video from vehicles and machines with potential for tele-operations.	Video monitoring and analytics on CCTV and drone camera streams for surveillance, inspections and repair.	Augmented reality (e.g. overlay of obstacle detection) on topographical maps, digital twin creation and synchronization.	Mission-critical Push-to-Talk (PTT) and Push-to-Video (PTV) services for worker safety and team communication applications (out-phasing TETRA/P25)	Communications from sensors for asset health and diagnostics, position reporting, environmental monitoring, process control and optimization.	Worker health and safety monitoring with digital Personal Protective Equipment (PPE) and wearables, geofencing for unauthorized or unsafe areas.	Leveraging extreme autonomy and near-real time equipment, load and people tracking for improved safety, productivity and efficiency.
High bit rate	High bit rate	Moderate bit rate	Low bit rate, low latency high priority	Low bit rate, moderate to high latency	Low to moderate bit rate and latency	Low to high bit rate, low to moderate latency
Low to moderate latency						

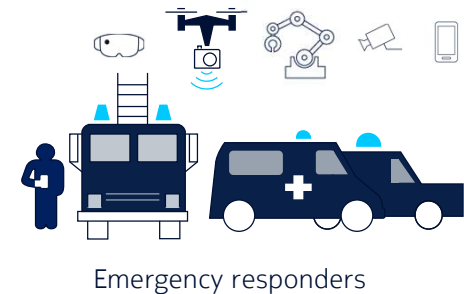
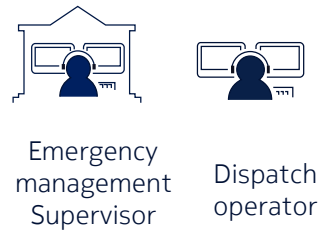
# Public Safety digital transformation

Addressing the gap

Commercial service provider networks  
Multimedia centric, 4G, 5G, IMS



Public safety digital transformed networks  
Multimedia centric, 4G, 5G, IMS  
Complementing or evolving from P25, TETRA



Access to:  
Voice, video, images, location, IoT

Access to:  
Voice, multimedia, location, IoT

Improved decision making:  
AI & ML

Access to:  
Voice, video, images, location, IoT

**New, multimedia based actionable information leading to saving more lives**

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