5G SBP Use Cases related 5G Service Requirements

Ike Alisson The below added information on 3GPP standard specified for 5G Service Requirements (predomininantly for 3GPP Rel. 17 and Rel. 18) for various Use Cases (UCs) aim to assist the 5G Super Blueprint members and enable them to pursue the following two (2) purposes:

1. To be able to map/identify each LFN 5G Super Blueprint member Project UC and respective specified Service Requirements that they work to implement/deploy and commission as a Service on the Market;
2. To be able to support 5G Super Blueprint member Projects Service(s) Roadmap aligned with the respective 5G System enhancements for the respective UCs and their Service Requirements as specified by 3GPP.

One should distinguish between System and Network configuration-specification and implementation of 3GPP standard specified Features and Functionalities into Network Capabilities to enable fulfillment and commissioning of Service Requirements for 5G Services. At the very end of this information-input, there is a snapshot presentation on the Business Model difference between Telco and DevOps use of SW to shed some light on the above statement.

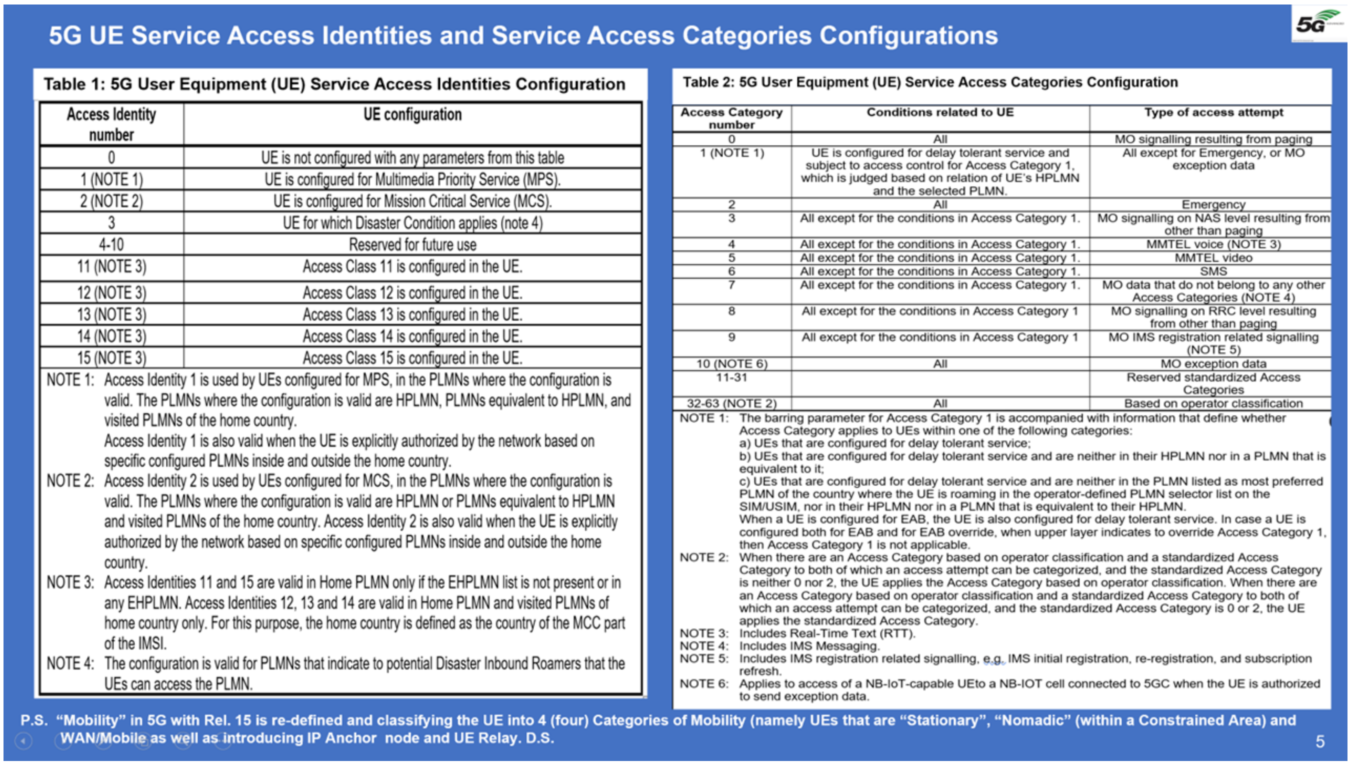


Table 1: 5G User Equipment (UE) Service Access Identities Configuration

Access Identity number	UE configuration
0	UE is not configured with any parameters from this table
1 (NOTE 1)	UE is configured for Multimedia Priority Service (MPS).
2 (NOTE 2)	UE is configured for Mission Critical Service (MCS).
3	UE for which Disaster Condition applies (note 4)
4-10	Reserved for future use
11 (NOTE 3)	Access Class 11 is configured in the UE.
12 (NOTE 3)	Access Class 12 is configured in the UE.
13 (NOTE 3)	Access Class 13 is configured in the UE.
14 (NOTE 3)	Access Class 14 is configured in the UE.
15 (NOTE 3)	Access Class 15 is configured in the UE.

NOTE 1: Access Identity 1 is used by UEs configured for MPS, in the PLMNs where the configuration is valid. The PLMNs where the configuration is valid are HPLMN, PLMNs equivalent to HPLMN, and visited PLMNs of the home country.
Access Identity 1 is also valid when the UE is explicitly authorized by the network based on specific configured PLMNs inside and outside the home country.
NOTE 2: Access Identity 2 is used by UEs configured for MCS, in the PLMNs where the configuration is valid. The PLMNs where the configuration is valid are HPLMN or PLMNs equivalent to HPLMN and visited PLMNs of the home country. Access Identity 2 is also valid when the UE is explicitly authorized by the network based on specific configured PLMNs inside and outside the home country.
NOTE 3: Access Identities 11 and 15 are valid in Home PLMN only if the EHPLMN list is not present or in any EHPLMN. Access Identities 12, 13 and 14 are valid in Home PLMN and visited PLMNs of home country only. For this purpose, the home country is defined as the country of the MCC part of the IMSI.
NOTE 4: The configuration is valid for PLMNs that indicate to potential Disaster Inbound Roamers that the UEs can access the PLMN.

Table 2: 5G User Equipment (UE) Service Access Categories Configuration

Access Category number	Conditions related to UE	Type of access attempt
0	All	MO signalling resulting from paging
1 (NOTE 1)	UE is configured for delay tolerant service and subject to access control for Access Category 1, which is judged based on relation of UE's HPLMN and the selected PLMN.	All except for Emergency, or MO exception data
2	All	Emergency
3	All except for the conditions in Access Category 1.	MO signalling on NAS level resulting from other than paging
4	All except for the conditions in Access Category 1.	MMTEL voice (NOTE 3)
5	All except for the conditions in Access Category 1.	MMTEL video
6	All except for the conditions in Access Category 1.	SMS
7	All except for the conditions in Access Category 1.	MO data that do not belong to any other Access Categories (NOTE 4)
8	All except for the conditions in Access Category 1	MO signalling on RRC level resulting from other than paging
9	All except for the conditions in Access Category 1	MO IMS registration related signalling (NOTE 5)
10 (NOTE 6)	All	MO exception data
11-31		Reserved standardized Access Categories
32-63 (NOTE 2)	All	Based on operator classification

NOTE 1: The barring parameter for Access Category 1 is accompanied with information that define whether Access Category applies to UEs within one of the following categories:
a) UEs that are configured for delay tolerant service;
b) UEs that are configured for delay tolerant service and are neither in their HPLMN nor in a PLMN that is equivalent to it;
c) UEs that are configured for delay tolerant service and are neither in the PLMN listed as most preferred PLMN of the country where the UE is roaming in the operator-defined PLMN selector list on the SIM/USIM, nor in their HPLMN nor in a PLMN that is equivalent to their HPLMN.
When a UE is configured for EAB, the UE is also configured for delay tolerant service. In case a UE is configured both for EAB and for EAB override, when upper layer indicates to override Access Category 1, then Access Category 1 is not applicable.
NOTE 2: When there are an Access Category based on operator classification and a standardized Access Category to both of which an access attempt can be categorized, and the standardized Access Category is neither 0 nor 2, the UE applies the Access Category based on operator classification. When there are an Access Category based on operator classification and a standardized Access Category to both of which an access attempt can be categorized, and the standardized Access Category is 0 or 2, the UE applies the standardized Access Category.
NOTE 3: Includes Real-Time Text (RTT).
NOTE 4: Includes IMS Messaging.
NOTE 5: Includes IMS registration related signalling, e.g. IMS initial registration, re-registration, and subscription refresh.
NOTE 6: Applies to access of a NB-IoT-capable UEto a NB-IOT cell connected to 5GC when the UE is authorized to send exception data.

5G UEs Ranging can be supported with or without 5G coverage, Fig. below is an illustration of ranging between UEs that are in Coverage, Out of Coverage, or with Partial Coverage.

Both Licensed and Unlicensed Spectrum can be used for Ranging. If Licensed Spectrum is used, it shall be fully under Operator Control. Ranging-based services are the applications utilizing the distance between two UEs and/or the direction of one UE from the other one.

In 3D Case, direction includes horizontal direction and elevation direction. Ranging-based Services can apply to a variety of **Verticals, such as Consumer, Smart Home, Smart City, Smart Transportation, Smart Retail, and Industry 4.0. Some ranging-based services** can only require the distance measurement, some can only require direction measurement, others can require both distance and direction measurement.

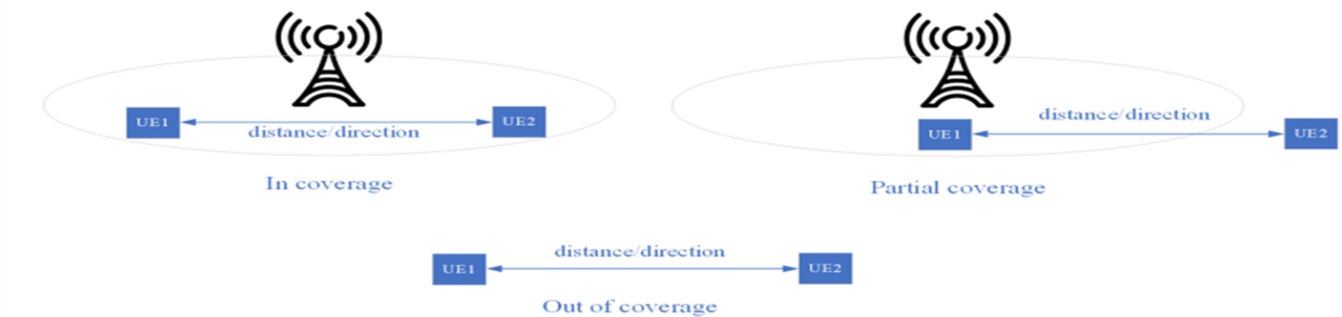


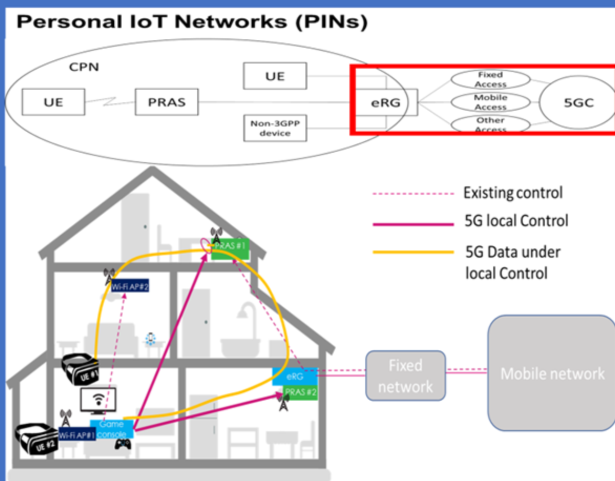
Fig. Illustration of Ranging between UEs with or without 5G Coverage

5G Ranging based Services Performance Requirements

Table Performance requirements for ranging based services

Ranging scenario	Ranging Accuracy (95 % confidence level): Distance Accuracy	Ranging Accuracy (95 % confidence level): Direction Accuracy	Availability	Latency	Effective ranging distance	Coverage	NLOS/LOS	Relative UE velocity	Ranging interval	Number of concurrent ranging operation for a UE	Number of concurrent ranging operation in an area
Smart TV Remoter	10cm up to 3 meter separation	±2° horizontal direction accuracy at 0.1 to 3 meter separation and AoA coverage of (-60°) to (+60°); ±2° Elevation direction accuracy at 0.1 to 3 meter separation and AoA coverage of (-45°) to (+45°)	99 %	50ms	10m	IC/PC/OOC	LOS	Static/ Moving (<1m/s)	50ms	-	-
Picture and video sharing based on Ranging results	10cm	2°	99 %	50ms	10m	IC/PC/OOC	LOS	Static/ Moving (<1m/s)	50ms	-	-
Distance based smart device control	10cm	-	99 %	100ms	20m	IC/PC/OOC	LOS	Static/ Moving (<1m/s)	50ms	20	-
Smart Vehicle Key	10 cm	-	99 %	50ms	30m	IC/PC/OOC	LOS	Static/ Moving (<2m/s)	25ms	-	50UEs/ (10^4m^2)
Touchless Self-checkout Machine Control	10cm	-	99 %	150ms	1m	IC/PC/OOC	LOS	Static/ Moving (<1m/s)	100ms	-	-
Hands Free Access	10cm	-	99 %	500ms	10 m	IC/PC/OOC	LOS	Static/ Moving (1 m/s)	50ms	-	20 UEs/3.14*100 m^2
Smart Transportation Metro/Bus Validation	10cm	-	99 %	-	2m	IC/PC/OOC	LOS	Static/ Moving (3km/h)	50ms	20	100 in the area of 8 m^2
Ranging of UEs in front of vending machine	20cm	10°	-	1s	5m	IC/PC/OOC	LOS	Static/ Moving (<1m/s)	50ms	-	10
Finding Items in a supermarket	50 cm	5 degree	95 %	-	100m	IC/PC/OOC	LOS	Static/ Moving (<1m/s)	250ms	-	100 UEs/ ($3.14*10^4m^2$)
distance based intelligent perception for public safety	50cm	-	99 %	-	20m	IC/PC/OOC	LOS	Static/ Moving (<20km/h)	-	100	-
Long Distance Search	20m	5°	99 %	-	100m-1km	IC/PC/OOC	LOS	Static/ Moving (up to 10m/s)	5s	-	-
Long range approximate location	[10m]	±[12.5°]	99 %	-	500m	IC/PC/OOC	LOS	Static/ Moving (<10m/s)	-	1	[50]UEs/ (10^6m^2)

Personal IoT Networks **(PINs) &** Customer Premises Networks **(CPNs)** provide local connectivity between UEs and/or non-3GPP devices. The CPN via an eRG, or PIN Elements via a PIN Element with Gateway Capability can provide access to 5G Network Services for the UEs &/or non-3GPP devices on the CPN or PIN. CPNs & PINs have in common that in general they are owned, installed &/or (at least partially) Configured by a Customer of a Public Network Operator. A CPN is a Network located within a premises **(e.g. a Residence, Office or Shop)….** the CPN provides connectivity to the 5G Network (5G CN) via Wireline, Wireless, or Hybrid Access. A Premises Radio Access Station (PRAS) is a Base Station installed in a CPN. Through the PRAS, UEs can get access to the CPN &/or 5G Network Services. The PRAS can be configured to use licensed, unlicensed, or both frequency bands. Connectivity can use any suitable non-3GPP Technology (e.g. Ethernet, optical, WLAN). **Examples of PINs include Networks of Wearables & Smart Home/Smart Office Equipment**. Via a PIN Element with Gateway Capability, PIN Elements have access to the 5G Network Services and can communicate with PIN Elements that are not within range to use PIN Direct Connection.



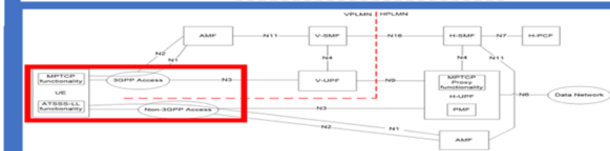


Figure : Roaming with Home-routed architecture for ATSSS support (UE registered to different PLMNs)

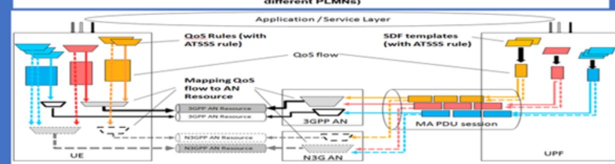


Figure : The traffic splitting based on the QoS rule (with ATSSS rule)

Providing Access to Localized Services Consolidated Potential Requirements (CPR) -

NOTE 1: **Both the Home and the Hosting Network can be a PLMN or**

NOTE 2: Only Subscribers of a Public Network can roam into a PLMN.

Hosting Network Localized Services and Home Operator Services

Table - Hosting Network Localized Services and Home Operator Services Consolidated Requirements

CPR #	Consolidated Potential Requirement	Original PR #	Comment
CPR 6.5-001	The 5G network shall enable the home network operator to indicate to the UE what services are preferred to be used from the home network when the UE connects to a hosting network and the requested services are available from both the hosting and the home network.	PR.5.3.6-4	
CPR 6.5-002	Based on localized service agreements, the hosting network shall be able to provide required connectivity and QoS for a UE simultaneously connected to the hosting network for localized services and its home network for home network services.	PR.5.4.6-3	
CPR 6.5-003	A UE shall be able to connect to its home network via the hosting network, if supported by the hosting network and the home network based on localized service agreements.	PR.5.4.6-4	

Returning to Home Network

Table - Returning to Home Network Consolidated Requirements

CPR #	Consolidated Potential Requirement	Original PR #	Comment
CPR 6.6-001	The 5G system shall provide mechanisms to mitigate user plane and control plane overload caused by a high number of UEs returning from a temporary local access of a hosting network to their home network in a very short period of time.	PR.5.14.6-1	
CPR 6.6-002	The 5G system shall provide mechanisms to minimize the impact on the UEs communication e.g., to prevent user plane and control plane outages when returning to a home network together with other high number of UEs in a very short period of time, after terminating their temporary local access to a hosting network.	PR.5.14.6-2	

5G Tactile and Multi-modal VR Communication Service

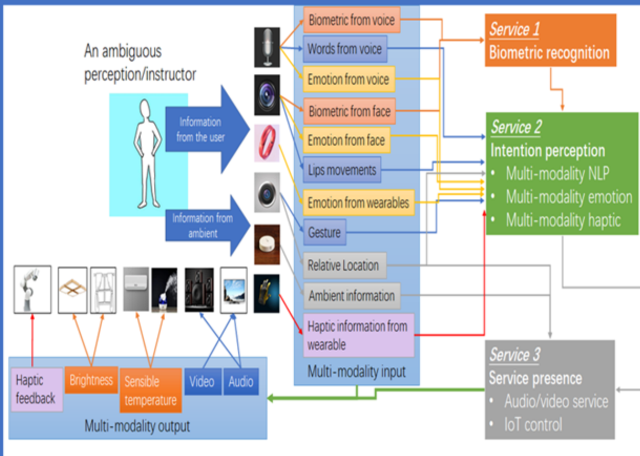


Figure Multi-modal interactive system

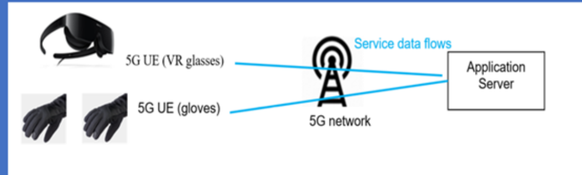


Figure . Immersive multi-modal VR application with multiple 5G UEs directly connected to 5G network

Table : Typical synchronization thresholds for immersive multi-modality VR applications

Media components	synchronization threshold (note 1)	
audio-tactile	audio delay: 50 ms	tactile delay: 25 ms
visual-tactile	visual delay: 15 ms	tactile delay: 50 ms
NOTE 1: for each media component, "delay" refers to the case where that media component is delayed compared to the other.		

Use case - 5G Immersive Multi-modal Virtual Reality (VR) Application Key Performance Requirements

Table Potential key performance requirements for immersive multi-modal VR applications

Use Cases	Characteristic parameter (KPI)			Influence quantity				Remarks
	Max allowed end-to-end latency	Service bit rate: user-experienced data rate	Reliability	Message size (byte)	# of UEs	UE Speed	Service Area	
Immersive multi-modal VR (UL: device → application sever)	5 ms (note 2)	16 kbit/s -2 Mbit/s (without haptic compression encoding); 0.8 - 200 kbit/s (with haptic compression encoding)	[99.9%] (without haptic compression encoding) [99.999%] (with haptic compression encoding)	1 DoF: 2-8 3 DoFs: 6-24 6 DoFs: 12-48 More DoFs can be supported by the haptic device	-	Stationary or Pedestrian	typically < 100 km² (note 3)	Haptic feedback
	5 ms	< 1Mbit/s	[99.99%]	MTU	-	Stationary or Pedestrian	typically < 100 km² (note 3)	Sensor information e.g. position and view information generated by the VR glasses
Immersive multi-modal VR (DL: application sever → device)	10 ms (note1)	1-100 Mbit/s	[99.9%]	1500	-	Stationary or Pedestrian	typically < 100 km² (note 3)	Video
	10 ms	5-512 kbit/s	[99.9%]	50	-	Stationary or Pedestrian	typically < 100 km² (note 3)	Audio
	5 ms (note 2)	16 kbit/s -2 Mbit/s (without haptic compression encoding); 0.8 - 200 kbit/s (with haptic compression encoding)	[99.9%] (without haptic compression encoding) [99.999%] (with haptic compression encoding)	1 DoF: 2-8 3 DoFs: 6-24 6 DoFs: 12-48	-	Stationary or Pedestrian	typically < 100 km² (note 3)	Haptic feedback

NOTE 1: Motion-to-photon delay (the time difference between the user's motion and corresponding change of the video image on display) is less than 20 ms, the communication latency for transferring the packets of one audio-visual media is less than 10 ms, e.g. the packets corresponding to one video/audio frame are transferred to the devices within 10 ms.

NOTE 2: According to IEEE 1918.1 [3] as for haptic feedback, the latency is less than 25 ms for accurately completing haptic operations. As rendering and hardware introduce some delay, the communication delay for haptic modality can be reasonably less than 5 ms, i.e. the packets related to one haptic feedback are transferred to the devices within 10 ms.

NOTE 3: In practice, the service area depends on the actual deployment. In some cases a local approach (e.g. the application servers are hosted at the network edge) is preferred in order to satisfy the requirements of low latency and high reliability.

Use case - 5G Immersive Multi-modal Remote Control Robot Key Performance Requirements

Table : Potential Key performance requirements for remote control robot [3]

Use Cases	Characteristic parameter (KPI)			Influence quantity				Remarks
	Max allowed end-to-end latency	Service bit rate: user-experienced data rate	Reliability	Message size (byte)	# of UEs	UE Speed	Service Area[21]	
Remote control robot	1-20ms	16 kbit/s -2 Mbit/s (without haptic compression encoding); 0.8 - 200 kbit/s (with haptic compression encoding)	99.99%	2-8/DoF	-	high-dynamic (≤ 50 km/h)	≤ 1 km²	Haptic feedback
	20-100ms	16 kbit/s -2 Mbit/s (without haptic compression encoding); 0.8 - 200 kbit/s (with haptic compression encoding)	99.99%	2-8/DoF	-	Stationary or Pedestrian	≤ 1 km²	Haptic feedback
	5 ms	1-100 Mbit/s	99.9%	1500	-	Stationary or Pedestrian	≤ 1 km²	Video
	5 ms	5-512 kbit/s	99.9%	50-100	-	Stationary or Pedestrian	≤ 1 km²	Audio
	5 ms	< 1Mbit/s	99.999%	-	-	Stationary or Pedestrian	≤ 1 km²	Sensor information

5G Multi-modal Remote Communication Service Performance Requirements

Table : Multi-modal communication service performance requirements.

Use Cases	Characteristic parameter (KPI)			Influence quantity				Remarks (NOTE 1)
	Max allowed end-to-end latency (NOTE 2)	Service bit rate: user-experienced data rate	Reliability	Message size (byte)	# of UEs	UE Speed	Service Area	
Skillset sharing low-dynamic robotics (including teleoperation) Controller to controlee	5-10ms	0.8 - 200 kbit/s (with compression)	[99,999%]	n DoFs: (2n)-(8n) (n=1,3,6)	-	Stationary or Pedestrian	100 km²	Haptic (position, velocity)
Skillset sharing low-dynamic robotics (including teleoperation) Controlee to controller	5-10ms	0.8 - 200 kbit/s (with compression)	[99,999%]	n DoFs: (2n)-(8n) (n=1,10,100)	-	Stationary or Pedestrian	100 km²	Haptic feedback
	10ms	1-100 Mbit/s	[99,999%]	1500	-	Stationary or Pedestrian	100 km²	Video
	10ms	5-512 kbit/s	[99,9%]	50	-	Stationary or Pedestrian	100 km²	Audio
Highly dynamic/ mobile robotics Controller to controlee	1-5ms	16 kbit/s -2 Mbit/s (without haptic compression encoding); 0.8 - 200 kbit/s (with haptic compression encoding)	[99,999%] (with compression) [99,9%] (w/o compression)	n DoFs: (2n)-(8n) (n=1,3,6)	-	high-dynamic	4 km²	Haptic (position, velocity)
Highly dynamic/ mobile robotics Controlee to controller	1-5ms	0.8 - 200 kbit/s	[99,999%] (with compression) [99,9%] (w/o compression)	n DoFs: (2n)-(8n) (n=1,10,100)	-	high-dynamic	4 km²	Haptic feedback
	1-10ms	1-10 Mbit/s	[99,999%]	2000-4000	-	high-dynamic	4 km²	Video
	1-10ms	100-500 kbit/s	[99,9%]	100	-	high-dynamic	4 km²	Audio

NOTE 1: Haptic feedback is typically haptic signal, such as force level, torque level, vibration and texture.
NOTE 2: The latency requirements are expected to be satisfied even when multi-modal communication for skillset sharing is via indirect network connection (i.e., relayed by one UE to network relay).

5G Multi-modal Remote Communication Service Haptic Feedback for a Personal Exclusion Zone in Dangerous Remote Environments

With the assistance of 5G Networks, many Industries including Mining, Operate Unmanned and Automated. In Mining Scenarios, Drilling Safety and Precise Control for Automated Rigs and sending Effective Alarms when needed to the onsite crew is vital for their safety. When crew move heavy lifting equipment wearing personal protection equipment (PPE) for their safety or work in a noisy/poor visibility environment, audio/light alarm systems coverage may not be detected for immediate reaction therefore use of wearables (belts, shoe sole, arm/shoulder tactile equipment) can improve the reliability of alarm system. The nature of Human Brain Response Time to Light and Audio makes the use of Haptic Feedback to alert faster and more reliable. Human brain response to the sense of touch in range of 1 ms where the response to Audio and Video is in 100s of milliseconds. Therefore, the Alarm System can be enriched with additional Haptic Information and Multi-Modal Session can be relayed to the On-Site Crew over to accelerate human response time and improve the System Reliability.

As an example, in a large mining environment, a hazard scenario is detected by the remote control unit to notify and navigate on-site workers by a multi-modal alarm system to avoid exclusion zones. Ambient Sensory Information (Smoke, Temperature, Audio/Video) can be relayed to a remote central monitoring and control unit to predict/detect hazard scenarios. The Personal Exclusion Zone needs to be defined to prohibit the entry of the on-site workers which can change over time. The detected exclusion zone information from remote control unit will actuate devices (e.g., Siren and Light) fixed in the local site or in drones as well PPE haptic belt actuator to navigate the workers.

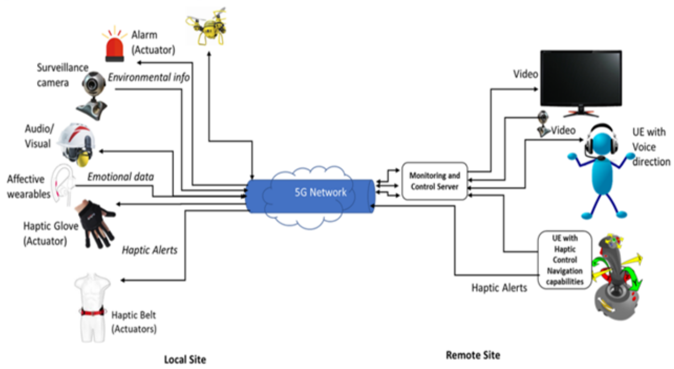


Figure Example of a personal exclusion zone

Table : Potential Key performance requirements for synchronization thresholds for a personal exclusion zone in dangerous remote environments.

synchronisation threshold		
audio-tactile	audio delay: [50 ms]	tactile delay: [25 ms]
visual-tactile	visual delay: [15 ms]	tactile delay: [50 ms]

Table Typical QoS requirements for multi-modal streams

	Haptics	Video	Audio
Jitter (ms)	≤ 2	≤ 30	≤ 30
Delay (ms)	≤ 50	≤ 400	≤ 150
Packet loss (%)	≤ 10	≤ 1	≤ 1
Update rate (Hz)	≥ 1000	≥ 30	≥ 50
Packet size (bytes)	64-128	≤ MTU	160-320
Throughput (kbit/s)	512-1024	2500 - 40000	64-128

5G Multi-modal Remote Communication Potential Key Performance Requirements for a Personal Exclusion Zone in Dangerous Remote Environments

Table : Potential Key performance requirements for a personal exclusion zone in dangerous remote environments.

Use Cases	Characteristic parameter (KPI)			Influence quantity				Remarks
	Max allowed end-to-end latency	Service bit rate: user-experienced data rate	Reliability	Message size (byte)	# of UEs	UE Speed	Service Area	
Immersive multi-modal navigation applications Remote Site → Local Site (DL)	50 ms [11]	16 kbit/s - 2 Mbit/s (without haptic compression encoding) 0.8 - 200 kbit/s (with haptic compression encoding)	[99.999 %]	1 DoF: 2 to 8 10 DoF: 20 to 80 100 DoF: 200 to 800	-	Stationary or Pedestrian	≤ 100 km² NOTE 2	Haptic feedback
	< 400 ms [11]	1-100 Mbit/s	[99.999 %]	1500	-	Workers: Stationary/ or Pedestrian,	≤ 100 km² NOTE 2	Video
	< 150 ms [11]	5-512 kbit/s	[99.9 %]	50	-	Stationary or Pedestrian	≤ 100 km² NOTE 2	Audio
	< 300 ms	600 Mbit/s	[99.9 %]	MTU	-	Stationary or Pedestrian	≤ 100 km² NOTE 2	VR
Local Site → Remote Site (UL)	< 300 ms	12 kbit/s [26]	[99.999 %]	1 500	-	Stationary or Pedestrian	≤ 100 km² NOTE 2	Biometric / Affective
	< 400 ms [11]	1-100 Mbit/s	[99.999 %]	1 500	-	Workers: Stationary/ or Pedestrian, UAV: [30-300mph]	≤ 100 km² NOTE 2	Video
	< 150 ms [11]	5-512 kbit/s	[99.9 %]	50	-	Stationary or Pedestrian	≤ 100 km² NOTE 2	Audio
	< 300 ms	600 Mbit/s	[99.9 %]	MTU	-	Stationary or Pedestrian	≤ 100 km² NOTE 2	VR

NOTE 1: The number of UEs is not indicated in the table, but the number depends on the application, the actual deployment, the service area and the distributed UEs chosen to improve / address required user experience.

NOTE 2: The service area depends on the deployment but is the same for uplink and downlink traffic. A local approach can be used in order to satisfy requirements of low latency and high reliability (i.e. the application server will be hosted at the network edge).

5G Performance Requirements for High Data Rate and Traffic Density Scenarios

Table Performance requirements for high data rate and traffic density scenarios.

	Scenario	Experienced data rate (DL)	Experienced data rate (UL)	Area traffic capacity (DL)	Area traffic capacity (UL)	Overall user density	Activity factor	UE speed	Coverage
1	Urban macro	50 Mbit/s	25 Mbit/s	100 Gbit/s/km² (note 4)	50 Gbit/s/km² (note 4)	10 000/km²	20 %	Pedestrians and users in vehicles (up to 120 km/h	Full network (note 1)
2	Rural macro	50 Mbit/s	25 Mbit/s	1 Gbit/s/km² (note 4)	500 Mbit/s/km² (note 4)	100/km²	20 %	Pedestrians and users in vehicles (up to 120 km/h	Full network (note 1)
3	Indoor hotspot	1 Gbit/s	500 Mbit/s	15 Tbit/s/km²	2 Tbit/s/km²	250 000/km²	note 2	Pedestrians	Office and residential (note 2) (note 3)
4	Broadband access in a crowd	25 Mbit/s	50 Mbit/s	[3,75] Tbit/s/km²	[7,5] Tbit/s/km²	[500 000]/km²	30 %	Pedestrians	Confined area
5	Dense urban	300 Mbit/s	50 Mbit/s	750 Gbit/s/km² (note 4)	125 Gbit/s/km² (note 4)	25 000/km²	10 %	Pedestrians and users in vehicles (up to 60 km/h)	Downtown (note 1)
6	Broadcast-like services	Maximum 200 Mbit/s (per TV channel)	N/A or modest (e.g. 500 kbit/s per user)	N/A	N/A	[15] TV channels of [20 Mbit/s] on one carrier	N/A	Stationary users, pedestrians and users in vehicles (up to 500 km/h)	Full network (note 1)
7	High-speed train	50 Mbit/s	25 Mbit/s	15 Gbit/s/train	7,5 Gbit/s/train	1 000/train	30 %	Users in trains (up to 500 km/h)	Along railways (note 1)
8	High-speed vehicle	50 Mbit/s	25 Mbit/s	[100] Gbit/s/km²	[50] Gbit/s/km²	4 000/km²	50 %	Users in vehicles (up to 250 km/h)	Along roads (note 1)
9	Airplanes connectivity	15 Mbit/s	7,5 Mbit/s	1,2 Gbit/s/plane	600 Mbit/s/plane	400/plane	20 %	Users in airplanes (up to 1 000 km/h)	(note 1)

5G KPI for High Data Rate and Low Latency Service

Dependent on the Use Case (UC), the **EEL** (*Edge Enabling Layer*) may apply different additional criteria to determine this **common EAS.**

E.g., it could be desirable to determine the **EAS** so that the **Latency** for all the **ACs** in the session is approximately the same or that the **Latency** for a specific **AC** is minimized.

There is further utilization of Capabilities related to **EEL** (*Edge Enabling Layer*) and **AEF** (*API Exposing Function*) and **5G NDL** (*Network Data Layer)* specified and stored **NF's Application Context** (***ACR/ACT,*** *Application Context Relocation/Application Context Transfer*) for assuring Service Continuity between **S-EAS** and **T-EAS**) as well as *Data Traffic split rendering* between **EASs** and **CAS** (*Cloud Application Server*).

Table: KPI Table for Additional High Data Rate and Low Latency Service

Use Cases	Characteristic parameter (KPI)			Influence quantity		
	Max allowed end-to-end latency	Service bit rate: user-experienced data rate	Reliability	# of UEs	UE Speed	Service Area (note 2)
Cloud/Edge/Split Rendering (note 1)	5 ms (i.e. UL+DL between UE and the interface to data network) (note 4)	0,1 to [1] Gbit/s supporting visual content (e.g. VR based or high definition video) with 4K, 8K resolution and up to120 frames per second content.	99,99 % in uplink and 99,9 % in downlink (note 4)	-	Stationary or Pedestrian	Countrywide
Gaming or Interactive Data Exchanging (note 3)	10ms (note 4)	0,1 to [1] Gbit/s supporting visual content (e.g. VR based or high definition video) with 4K, 8K resolution and up to120 frames per second content.	99,99 % (note 4)	≤ [10]	Stationary or Pedestrian	20 m x 10 m; in one vehicle (up to 120 km/h) and in one train (up to 500 km/h)
Consumption of VR content via tethered VR headset (note 6)	[5 to 10] ms (note 5)	0,1 to [10] Gbit/s (note 5)	[99,99 %]	-	Stationary or Pedestrian	-

NOTE 1: Unless otherwise specified, all communication via wireless link is between UEs and network node (UE to network node and/or network node to UE) rather than direct wireless links (UE to UE).
NOTE 2: Length x width (x height).
NOTE 3: Communication includes direct wireless links (UE to UE).
NOTE 4: Latency and reliability KPIs can vary based on specific use case/architecture, e.g. for cloud/edge/split rendering, and may be represented by a range of values.
NOTE 5: The decoding capability in the VR headset and the encoding/decoding complexity/time of the stream will set the required bit rate and latency over the direct wireless link between the tethered VR headset and its connected UE, bit rate from 100 Mbit/s to [10] Gbit/s and latency from 5 ms to 10 ms.
NOTE 6: The performance requirement is valid for the direct wireless link between the tethered VR headset and its connected UE.

5G Architecture enhancement enabling Service Continuity interaction between Edge (EAS) & Cloud (CAS) using Application Context Relocation (ACR)

This enhancement s to support (among many) Service Continuity for **ACs** (*Application Clients*) in the **UE** to minimize *Service Interruption* while switching the *Application Server* (**AS**) between **Edge & Cloud**. To support *Service Continuity*, the *Application Context* is transferred between **EAS & CAS.** The Fig. below shows the Architecture enhancement enabling interactions between EAS & CAS. Compared to the previous Release, in this Architecture enhancement, new entity, *Cloud Application Server* (**CAS**) is proposed along with the new *Reference Points* **EDGE-14** (between **EES** & **CAS**), **EDGE-15** (between **ECS** & **CAS**) & **EDGE-16** (between *3GPP Core Network* (**CN**) & **CAS**). When a UE moves to a new location, *different EASs or Cloud Application Server (CAS)* can be more suitable for serving the ACs in the UE. *Such transitions can result from a non-mobility event also*, requiring support to maintain the Continuity of the Service. Enhancement of the Service Continuity Planning Capability is expected to support update of ACR (Application Context Relocation). As it is seen at the Fig. below, this Solution proposes the ACR Update Capabilities as Enhancements after the ACR launch to deal with UE behavior changes & includes: **a Detection Entity** (e. g. **S-EAS, S-EES, EEC), a Decision Update Entity,** & an **ACR Update Execution Entity.** These Entities can be different based on the scenarios identified. Generally, *one (1) AC on the UE has one (1) associated Application Context at the S-EAS.* To support **Service Continuity, this Application Context is transferred from the S-EAS to a T-EAS**. The Capabilities for supporting Service Continuity provided at the *Edge Enabler Layer* (**EEL**) may consider various Application Layer Scenarios in which there may be involvement of AC & one (1) or more EAS(s). Following intra-EDN, inter-EDN & LADN (overlapping LADN Service Areas) related Scenarios are supported for Service Continuity: - UE Mobility, including Predictive or Expected UE Mobility; - Overload situations in S-EAS or EDN; & - Maintenance Aspects such as graceful shutdown of an EAS. ACR is invoked as a result of the UE moving to, or the UE expecting to move to, a new location which is outside the Service Area of the Serving EAS (S-EAS). It further relies on the EEC being triggered as a result of the UE's movement & implemented Service Provisioning & DNS procedures to discover the CAS that shall serve the AC as a result of the UE's new location, & that shall receive the Application Context from the serving EASs. The procedure should be repeated for each active AC in the UE for which EAS or EDN is not available on that UE location. After the ACT is completed, the AC remains connected to the CAS & disconnects from the S-EAS; the EEC is informed of the completion of the ACT. The S-EAS or CAS can further decide to terminate the ACR, & the CAS can discard the Application Context (e.g. based on monitoring the UE location.

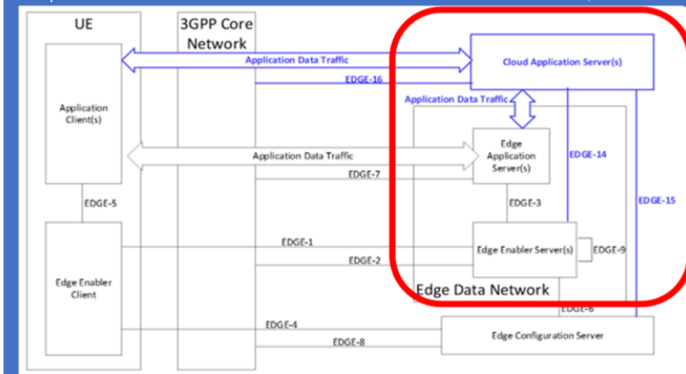


Fig.: Architecture for enabling interaction between Edge Application Server (EAS) and Cloud Application Server (CAS) using Application Context Relocation (ACR) to maintain Service Continuity

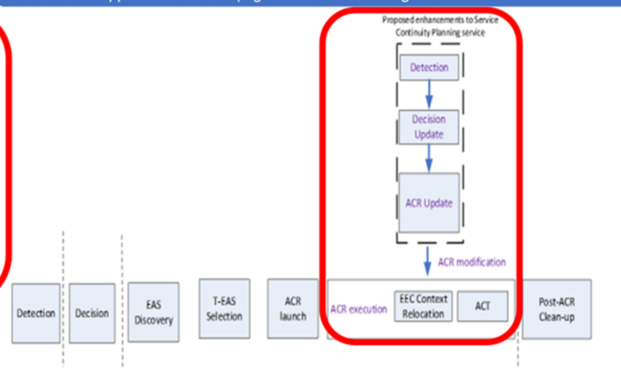


Fig.: High level Illustration of proposed Service Continuity through ACR (Application Context Relocation) Update Planning Enhancements

5G ACT & ACR (Application Context Transfer & Application Context Relocation for Service Continutiy T-EAS & S-EAS

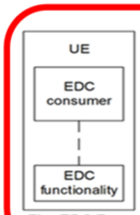


Fig. EDC Funct. in the UE

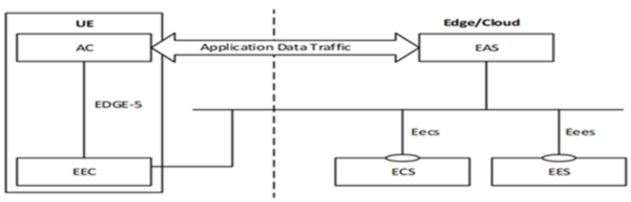


Fig. Archit. For Enabling Edge Applic. - Service-based Represent

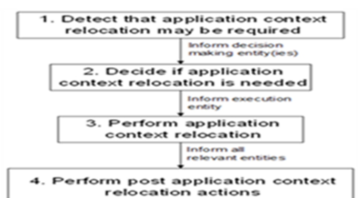


Fig. High level overview of ACR (Application Context Relocation)

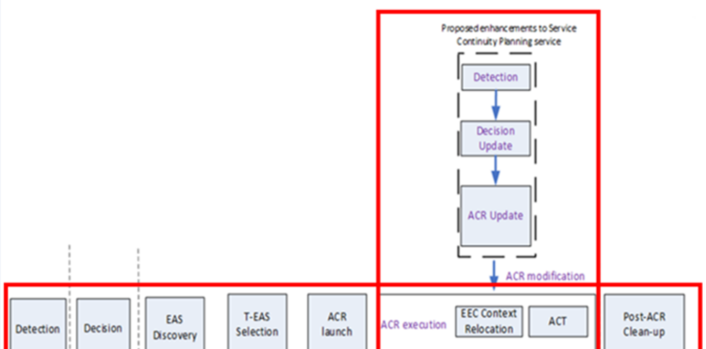


Fig. High-level of proposed ACR update in Service Continuity Planning Enhancement

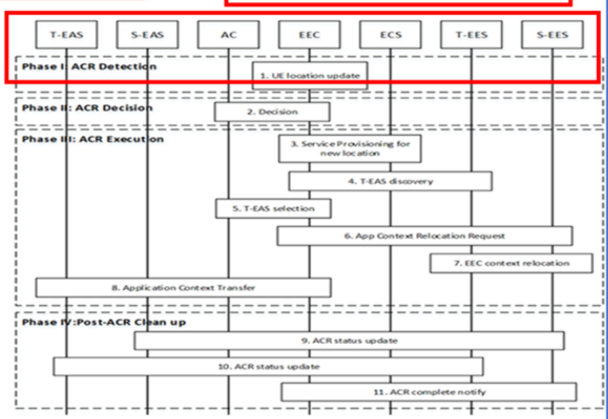


Fig. ACR initiated by the EEC & AC

3GPP RAN Rel-16 progress and Rel-17 potential work areas

July 18, 2019

https://www.3gpp.org/news-events/2058-ran-rel-16-progress-and-rel-17-potential-work-areas

Slide 7

Release 16 progressing towards completion

- 5G V2X
  - Targeting advanced use cases beyond LTE V2X
- Industrial IoT and URLLC enhancements
  - Adding 5G NR capabilities for full wired Ethernet replacement in factories: Time Sensitive networking, etc... with high reliability
- 5G NR operation in unlicensed bands
  - Includes both Licensed Assisted Access (LAA), as well as Standalone Unlicensed operation
- System improvements and enhancements
  - Positioning
  - MIMO enhancements
  - Power Consumption improvements

5G Wired to Wireless Link replacement - Factory of the Future

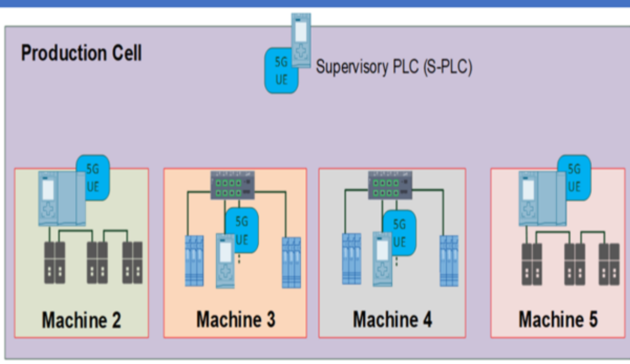


Figure : Example of four cooperating machines with wireless connections

Table : Service performance requirements for wired to wireless link replacement

Use case #	Characteristic parameter			Influence quantity					
	Communication service availability: target value [%]	Communication service reliability: mean time between failures	End-to-end latency: maximum	Data rate [Mbit/s]	Transfer interval	Survival time	UE speed	# of UEs	Service area (note 1)
1 (periodic traffic)	99.999 9 to 99.999 999	~ 10 years	< transfer interval value	50	≤ 1 ms	3 x transfer interval	stationary	2 to 5	100 m x 30 m x 10 m
1 (aperiodic traffic)	99.999 9 to 99.999 999	~ 10 years	< transfer interval value	25	≤ 1 ms (note 2)		stationary	2 to 5	100 m x 30 m x 10 m
2 (periodic traffic)	99.999 9 to 99.999 999	~ 10 years	< transfer interval value	250	≤ 1 ms	3 x transfer interval	stationary	2 to 5	100 m x 30 m x 10 m
2 (aperiodic traffic)	99.999 9 to 99.999 999	~ 10 years	< transfer interval value	500	≤ 1 ms (note 2)		stationary	2 to 5	100 m x 30 m x 10 m

NOTE 1: Length x width x height.
NOTE 2: Transfer interval also applies for scheduled aperiodic traffic

3GPP 5G Relation of Reliability and Communication Service Availability

"Reliability" covers the Communication-related aspects between two (2) nodes (here: End Nodes), while

Communication Service "Availability" addresses the Communication-related aspects between two (2) Communication Service Interfaces.

This might seem to be a "small difference", but this "difference" can lead to situations, where "Reliability" and Communication ´Service "Availability" have different values.

Example: Traffic gets "stuck" The related Scenario is depicted in Fig. below.

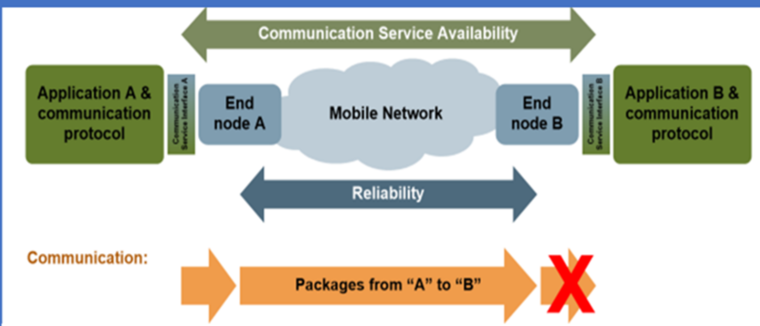


Fig.: Example in which Reliability and Communication Availability have different vaues. Packets are reliably transmitted from the Communication Service Interface A to the End Node B, but they are not exposed at the Communication Service Interface B.

Table: Example of Relationship between Reliability and Communication Service Availability when the Survival Time is equal to the Transfer Interval

Communication service availability	Reliability 1 - p
99.999 9 %	99.9 %
99.999 999 %	99.99 %
99.999 999 99 %	99.999 %
99.999 999 999 9 %	99.999 9 %
99.999 999 999 999 %	99.999 99 %

3GPP 5G Relation of Reliability and Communication Service Availability

Relation of Communication Service: Availability and Reliability

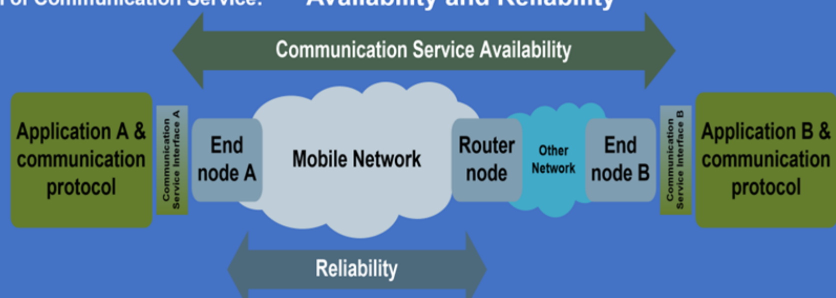


Table: Example of Relationship between Reliability and Communication Service Availability when the Survival Time is equal to the Transfer Interval

Communication service availability	Reliability 1 - p
99.999 9 %	99.9 %
99.999 999 %	99.99 %
99.999 999 99 %	99.999 %
99.999 999 999 9 %	99.999 9 %
99.999 999 999 999 %	99.999 99 %

Figure C-4: Example in which communication Service Availability & Reliability have different values.

Packets are delivered over a daisy chain of a Mobile Network and another Network (e.g. IEEE 802.11n based).

Reliability is evaluated for the Mobile Network only,
Availability depends on the performance of both Networks.

Communication Service **Availability** - measured between the two (2) Communication Service Interfaces,
Reliability - measured between End Node A and the Router Node.

This has implications for, e.g. the maximum communication latency allowed for each network. In case the agreed end-to-end latency between the service interfaces is, for instance, 100 ms, and the 802.11n network has a latency of 30 ms, the maximum allowable latency for packages in the mobile network is 70 ms NOTE). So, if the latency in the mobile network exceeds 70 ms, the communication service availability is 0%, despite the agreed QoS stipulating a larger end-to-end latency, i.e. 100ms.

NOTE: The transit time through the router node is not considered here. It is assumed to be very small and much less than 100 ms.

5G Service Performance Requirements for Vertical Domains - Factory of the Future (FoF)

Table : Mapping of the considered use cases (columns) to application areas (rows)

	Motion control	Control-to-control	Mobile control panels with safety	Mobile robots	Remote access and maintenance	Augmented reality	Closed-loop process control	Process monitoring	Plant asset management
Factory automation	X	X		X					
Process automation				X			X	X	X
HMIs and Production IT			X			X			
Logistics and warehousing		X		X					X
Monitoring and maintenance					X				

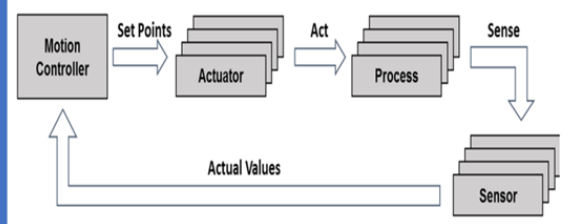


Figure : Schematic representation of a motion control system

5G Service Performance Requirements for Vertical Domains - Factory of the Future (FoF) - Motion Control

Table : Service performance requirements for motion control

Use case #	Characteristic parameter				Influence quantity						
	Communication service availability: target value [%]	Communication service reliability: mean time between failures	End-to-end latency: maximum	Service bitrate: user experienced data rate	Message size [byte]	Transfer interval: lower bound	Transfer interval: upper bound	Survival time	UE speed	# of UEs	Service area (note)
1	99.999 to 99.999 99	~ 10 years	< transfer interval value	–	50	500 µs – 500 ns	500 µs + 500 ns	500 µs	≤ 72 km/h	≤ 20	50 m x 10 m x 10 m
2	99.999 9 to 99.999 999	~ 10 years	< transfer interval value	–	40	1 ms – 500 ns	1 ms + 500 ns	1 ms	≤ 72 km/h	≤ 50	50 m x 10 m x 10 m
3	99.999 9 to 99.999 999	~ 10 years	< transfer interval value	–	20	2 ms – 500 ns	2 ms + 500 ns	2 ms	≤ 72 km/h	≤ 100	50 m x 10 m x 10 m
NOTE: Length x width x height.											

Table : Service performance requirements for control-to control communication in motion control

Use case #	Characteristic parameter			Influence quantity					
	Communication service availability: target value [%]	Communication service reliability: mean time between failures	End-to-end latency: maximum	Message size [byte]	Transfer interval	Survival time	UE speed	# of UEs	Service area (note 1)
1 (note 2)	99.999 9 to 99.999 999	~ 10 years	< transfer interval value	1 k	≤ 10 ms	10 ms	stationary	5 to 10	100 m x 30 m x 10 m
2 (note 2)	99.999 9 to 99.999 999	~ 10 years	< transfer interval value	1 k	≤ 50 ms	50 ms	stationary	5 to 10	1,000 m x 30 m x 10 m
NOTE 1: Length x width x height. NOTE 2: Communication may include two wireless links (UE to UE)									

Use case one

Control-to-control communication between different motion (control) subsystems, as addressed in Subclause A.2.2.1. An exemplary application for this is large printing machines, where it is not possible or desired to control all actuators and sensors by one motion controller only.

Use case two

Control-to-control communication between different motion (control) subsystems. Exemplary application for this are extra-large machines or individual machines used for fulfilling a common task (e.g., machines in an assembly line).

5G Service Performance Requirements for Vertical Domains - Factory of the Future (FoF) - Mobile Robots

Use Case (UC) 1 : *Periodic communication for the support of Precise Cooperative Robotic Motion Control (transfer interval: 1 ms), Machine Control (Transfer Interval: 1 ms to 10 ms), Co-operative driving (10 ms to 50 ms).*

Use Case (UC) 2: *Periodic Communication for Video-operated Remote Control.*

Use Case (UC) 3: Periodic Communication for Standard Mobile Robot Operation and Traffic Management.

Use Case (UC) 4: *Real-time Streaming Data Transmission (Video Data) from a Mobile Robot to the Guidance Control System.*

Table : Service performance requirements for mobile robots

Use case #	Characteristic parameter				Influence quantity							
	Communication service availability: target value [%]	Communication service reliability: mean time between failures	End-to-end latency: maximum	Service bitrate: user experienced data rate	Message size [byte]	Transfer interval: lower bound	Transfer interval: target value (note)	Transfer interval: upper bound	Survival time	UE speed	# of UEs	Service area
1	> 99.999 9	~ 10 years	< target transfer interval value	–	40 to 250	– < 25 % of target transfer interval value	1 ms to 50 ms	+ < 25 % of target transfer interval value	target transfer interval value	≤ 50 km/h	≤ 2,000	≤ 1 km²
2	> 99.999 9	~ 1 year	< target transfer interval value	–	15 k to 250 k	– < 25 % of target transfer interval value	10 ms to 100 ms	+ < 25 % of target transfer interval value	target transfer interval value	≤ 50 km/h	≤ 2,000	≤ 1 km²
3	> 99.999 9	~ 1 year	< target transfer interval value	–	40 to 250	– < 25 % of target transfer interval value	40 ms to 500 ms	+ < 25 % of target transfer interval value	target transfer interval value	≤ 50 km/h	≤ 2,000	≤ 1 km²
4	> 99.999 9	~ 1 week	10 ms	> 10 Mbit/s	–	–		–	–	≤ 50 km/h	≤ 2,000	≤ 1 km²
NOTE:	The transfer interval is not so strictly periodic in these use cases. The transfer interval deviates around its target value within bounds. The mean of the transfer interval is close to the target value.											

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5G Enhanced Architecture for enabling Edge Constrained Devices with limited capabilities

This Architecture option adds support for certain ¨Constrained Devices which either don't have enough Capabilities to execute its own EEC (e.g., the Constrained Device may not have a Mobile Termination entity) or do not execute its own EEC to save essential Resources such as Processing Power and Battery.

Such Constrained Devices (e.g., Terminal Equipment will benefit by being able to utilize services of an EEC running on a different UE, using EDGE-5.

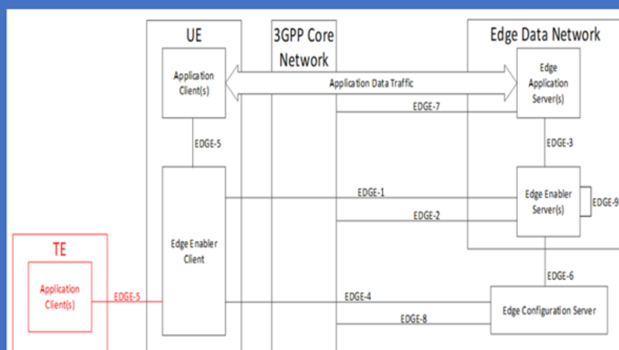

Figure : Architecture supporting constrained devices

5G Service Performance Requirements for Low Power High Accuracy Positioning Use Cases (UCs)

Use case 1 - Process automation: Dolly tracking (outdoor).

Use case 2 - Process automation: Asset tracking.

Use case 3 - Flexible modulare assembly area: Tool tracking in flexible, modular assembly areas in smart factories.

Use case 4 - Process automation: Sequence container (ntralogistics).

Use case 5 - Process automation: Palette tracking (e.g. in turbine construction).

Use case 6 - Flexible modulare assembly area: Tracking of workpiece (in- and outdoor) in assembly area and warehouse.

Use case 7 - Flexible modulare assembly area: Tool assignment (assign tool to vehicles in a production line, left/right) in flexible, modular assembly area in smart factories.

Use case 8 - Flexible modulare assembly area: Positioning of autonomous vehicles for monitoring purposes (vehicles in line, distance 1.5 meter).

Use case 9 - (Intra-)logistics: Asset tracking

Table : Low power high accuracy positioning use cases

Use Case #	Horizontal accuracy	Corresponding service level (22.261)	Positioning interval/ duty cycle	battery life time/ minimum operation time
1	10 m	Service Level 1	on request	24 months
2	2 m to 3 m	Service Level 2	< 4 seconds	> 6 months
3	< 1 m	Service Level 3	no indication	1 work shift - 8 hours (up to 3 days, 1 month for inventory purposes)
4	< 1 m	Service Level 3	1 second	6 - 8 years
5	< 1 m	Service Level 3	5 seconds - 15 minutes	18 months
6	< 1 m	Service Level 3	15 s to 30 s	6 - 12 months
7	30 cm	Service Level 5	250 ms	18 months
8	30 cm	Service Level 5	1 second	6 - 8 years (no strong limitation in battery size)
9	10 m	Service Level 1	20 minutes	12 years (@20mJ/position fix)

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5G Architecture for Hybrid and Multi-Cloud Environment and related Business Models for Telco and DevOps Open Source use of SW (Ref. Ericsson, March, 2022).

5G Architecture for Hybrid and Multi-Cloud Environments and related Business Models for Telco and DevOps Open Source SW use

A Unified Approach to Developing, Deploying & Operating 5G Services - including 5G RAN, Core, OSS & BSS Applications – in Public & Private Cloud Environments is a Key Enabler for Communication Service Providers (CSPs) to successfully adopt a Hybrid & Multi-Cloud Strategy. The "main benefits" are "Faster Time to Market" (TTM) & "Lower Total Cost of Ownership" (TCO). As *Figure 2* illustrates, this approach could *lead to a lot of Diversity & Heterogeneity in the Deployment Targets for Network SW* Vendors. Designing & Operating an Application that is capable of utilizing such a Diverse Set of HCP Managed Services also creates *Several Challenges for Network SW* Vendors & CSPs alike. **The Main Challenges to overcome in a Hybrid & Multi-Cloud Strategy** are: *1. Maintaining Portability; 2. Controlling the Total Cost of Ownership (TCO); 3. Optimizing Productivity & Time to Market (TTM).* **DevOps** – *a Set of Practices* that brings together *SW Development & IT operations* with the **Goal of Shortening the Development & Delivery Cycle & increasing SW Quality - is often thought of and discussed in the Context of a Single Company or Organization.** The Company usually Develops the SW, Operates it & Provides it as a Service to Customers, according to the SW-as-a-Service (SaaS) Model. **Within this context**, it is easier to have **Full Control over the Entire Flow**, including **Full Knowledge of the Target Deployment Environment.** In the **Telecom Space**, by contrast, we typically follow the **"as-a-Product (aaP) Business model**, in which **SW is developed by Network SW Vendors** such as Ericsson (Nokia, Huawei, ZTE) & provided to Communication Service Providers (CSPs) that Deploy & Operate it within their Network. This **Business Model requires the consideration of additional aspects**. As shown in *Figure 1*, **the most important contrasts between the Standard DevOps SaaS Model & the Telecom aaP Model** are the **Multiplicity of Deployment Environments & the fact the Network SW Vendor Development Teams cannot know upfront exactly what the Target Environment looks like**. Although a SaaS Company is likely to Deploy & Manage its SW on two (2) or more different Cloud Environments, this is inevitable within Telco, as each CSP creates &/or selects its own Cloud infrastructure.

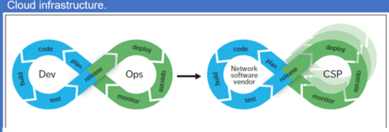

Figure 1: The DevOps and (Telecom) aaP Business Models

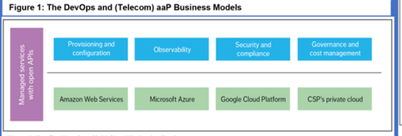

Figure 3: Key Enablers for a Multi-Cloud Native Application

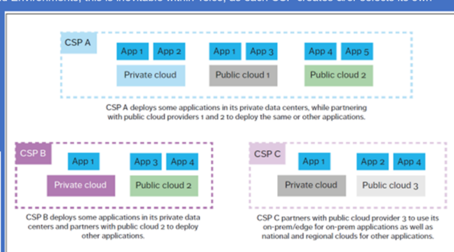

Figure 2: Examples of Hybrid and Multi-Cloud Deployment Scenarios that Applications must be able to support

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