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GROUP REPORT

Multi-access Edge Computing (MEC); Abstracted Network Information Exposure for Vertical Industries

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Foreword

This Group Report (GR) has been produced by ETSI Industry Specification Group (ISG) Multi-access Edge Computing (MEC).

Modal verbs terminology

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1 Scope

The present document studies use cases, analyses their information needs and provides recommendations related to exposing network information for vertical industries in an abstracted manner. The assumption here is that the radio part of the network between the edge cloud and the UE is typically the weakest link, impacting to a large part the quality of the connection; yet, other properties of the cellular network will be considered too. The aim for the abstraction is to provide a developer-friendly API that hides the complexity and does not require the developers to have deep understanding of the underlying 3GPP network and that is supporting the use cases and related requirements from vertical industries. Different industry segments have different needs for the abstracted information and a few different industry areas are used to study the use cases and the related information needs. The outcome of the study is to generate recommendations for the future standard work on exposing abstracted cellular network information. Such abstracted network information is intended to be usable by vertical industries application developers without deep understanding of the underlying network, and is supporting multiple different vertical industry use case deployments and their particular requirements, respectively.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long-term validity.

The following referenced documents may be useful in implementing an ETSI deliverable or add to the reader's understanding, but are not required for conformance to the present document.

[i.1] ETSI GR MEC 001: "Multi-access Edge Computing (MEC); Terminology".

[i.2] GSMA and GUTMA Aerial Connectivity Joint Activity.

[i.3] 5G-ACIA: "Key 5G Use Cases and Requirements, White Paper".

[i.4] ETSI TS 123 288: "5G; Architecture enhancements for 5G System (5GS) to support network data analytics services (3GPP TS 23.288 Release 18)".

[i.5] ETSI TS 123 501: "5G; System architecture for the 5G System (5GS) (3GPP TS 23.501 Release 18)".

[i.6] 5GAA white paper: "Making 5G proactive and predictive for automotive industry".

[i.7] 5GAA A-200055 eNESQO Technical Report: "5GS Enhancements for Providing Predictive QoS in C-V2X".

[i.8] 5GAA Automotive Association Technical Report: "C-V2X Use Cases and Service Level Requirements Volume II".

[i.9] 5GAA A-200146 MEC4AUTO Technical Report: "Use Cases and initial test specifications review".

[i.10] 5GAA A-200150 MEC4AUTO Task2 Technical Report: "MEC for Automotive-in-Multi-Operator-Scenarios".

[i.11] 5GAA: "C-V2X Use Cases and Service Level Requirements Volume I".

[i.12] 5GAA: "C-V2X Use Cases and Service Level Requirements Volume II".

[i.13] 5GAA: "C-V2X Use Cases and Service Level Requirements Volume III".

[i.14] ETSI TS 122 125: "5G; Unmanned Aerial System (UAS) support in 3GPP (3GPP TS 22.125 Release 18)".

[i.15] Federal Aviation Administration of the U.S.: "UPP 2 Final Report".

[i.16] Hans Similon: "Using 5G for Drone Operations makes S E N S E !", Presentation at "MEC meets Uncrewed Aerial Systems", Live panel hosted by ETSI ISG MEC, 26 June 2023, Sophia Antipolis, France.

[i.17] ETSI EN 302 637-2 (V1.4.1): "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 2: Specification of Cooperative Awareness Basic Service".

[i.18] 5GAA: "Tele-Operated Driving (ToD): System Requirements Analysis and Architecture", 15 September 2021.

[i.19] Metaverse Standards Forum: "D1: Network Requirements for Metaverse Services", 2024.

[i.20] Josh Arensberg: "Next Gen Gaming@The-Edge", Presentation at "ETSI MEC meets vertical markets: Spatial Computing and Gaming", Live panel hosted by ETSI ISG MEC, 09 April 2024, online.

[i.21] Mathieu Duperre: "Edge computing applied to today's gaming market: a case study", Presentation at "ETSI MEC meets vertical markets: Spatial Computing and Gaming", Live panel hosted by ETSI ISG MEC, 09 April 2024, online.

[i.22] Winnie Nakimuli, Jaime Garcia-Reinoso, J.E. Sierra-Garcia, Pablo Serrano: "Exploiting radio access information to improve performance of remote-controlled mobile robots in MEC-based 5G networks", Computer Networks, Vol 212 (2022).

[i.23] ETSI TR 102 638 (V2.1.1): "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Release 2".

[i.24] 5G-ACIA Whitepaper: "Industrial 5G Edge Computing - Use Cases, Architecture and Deployment".

[i.25] ETSI TS 122 104: "5G; Service requirements for cyber-physical control applications in vertical domains (3GPP TS 22.104 Release 18)".

[i.26] 5G-MAG: "Network Capability Exposure and APIs for Content Production and Contribution Scenarios" (snapshot of work in progress).

[i.27] 3GPP TR 22.827: "Study on Audio-Visual Service Production (Release 17)".

[i.28] ETSI TS 123 222: "LTE; 5G; Common API Framework for 3GPP Northbound APIs (3GPP TS 23.222 Release 18)".

[i.29] TM Forum TMF657: "Service Quality Management API User Guide", Version 4.0.1.

[i.30] 5G-EMERGE: "Satellite-enhanced media delivery at the edge", Second White Paper, September 2024, Revised December 2024.

[i.31] ETSI GS MEC 012: "Multi-access Edge Computing (MEC); Radio Network Information API".

[i.32] ETSI GS MEC 030: "Multi-access Edge Computing (MEC); V2X Information Services API".

[i.33] ETSI GS MEC 013: "Multi-access Edge Computing (MEC); Location API".

[i.34] ETSI TS 126 501: "5G; 5G Media Streaming (5GMS); General description and architecture (3GPP TS 26.501 Release 18)".

[i.35] ETSI TS 123 247: "5G; Architectural enhancements for 5G multicast-broadcast services (3GPP TS 23.247 Release 18)".

[i.36] ETSI TS 103 720 (V1.2.1): "5G Broadcast System for linear TV and radio services; LTE-based 5G terrestrial broadcast system".

[i.37] ETSI TS 122 261: "5G; Service requirements for the 5G system (3GPP TS 22.261 Release 18)".

[i.38] ETSI TS 129 122: "Universal Mobile Telecommunications System (UMTS); LTE; 5G; T8 reference point for Northbound APIs (3GPP TS 29.122 Release 18)".

[i.39] 5G-MAG: "Towards a comprehensive 5G-based toolbox for live media production", 5G-MAG Report.

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the terms given in ETSI GR MEC 001 [i.1] apply.

3.2 Symbols

Void.

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in ETSI GR MEC 001 [i.1] and the following apply:

5G-ACIA	5G Alliance for Connected Industries and Automation
5GAA	5G Automobile Association
5G NR	5G New Radio
5QI	5G QoS identifier
ACJA	Aerial Connectivity Joint Activity
AGV	Automated Guided Vehicle
AV	Autonomous Vehicle
BVLOS	Beyond-Visual-Line-Of-Sight
CAM	Cooperative Awareness Messages
CDN	Content Delivery Network
C-V2X	Cellular V2X
DTE	Direct-To-Edge
DTH	Direct-To-Home
DTV	Direct-To-Vehicle
GFBR	Guaranteed Flow Bit Rate
GUTMA	Global UTM Association
HD	High Definition
HV	Host Vehicle
ICT	Information and Communication Technology
IoT	Internet of Things
MABR	Multicast Adaptive Bit Rate
NEF	Network Exposure Function
NIE	Network Information Exposure
NWDAF	NetWork Data Analytics Function
PDB	Packet Delay Budget
QCI	QoS Class Identifier
QEF	Quasi Error Free
RAM	Random Access Memory
RV	Remote Vehicle
SLA	Service Level Agreement
TOD	Tele-Operated Driving
TV	TeleVision
UAV	Uncrewed Aerial Vehicle

UAS	Uncrewed Aircraft System
UC	Use Case
UHD	Ultra High Definition
UTM	Uncrewed Traffic Management
V2I2X	Vehicle-to-Infrastructure-to-everything
V2N2X	Vehicle-to-Network-to-everything
V2N2I	Vehicle-to-Network-to-Infrastructure
V2N2P	Vehicle-to-Network-to-Pedestrian
V2N2V	Vehicle-to-Network-to-Vehicle
V2V	Vehicle to Vehicle
Wi-Fi®	Wireless Fidelity

4 Overview

MEC provides a platform for innovation that can create new business opportunities. This is enabled by offering cloud-computing capabilities and an IT service environment at the edge of the network. The edge environment is characterized by proximity, ultra-low latency and high bandwidth. Furthermore, the MEC platform can provide insight of real-time network and context information that can be used to optimize network and service operation and proactively maintain customer experience. For example, being aware of the near real-time capacity available at the radio downlink interface, a video server can improve the utilization of radio resources and accelerate the video delivery improving the video quality. Several industry segments are already defining use cases that can be enhanced by MEC offering contextual information from the radio and core networks. The availability of both accurate and localized access network information provided by MEC services can create new types of services to support vertical applications.

ETSI MEC has already defined its Radio Network Information API (ETSI GS MEC 012 [i.31]) that exposes detailed information from the 4G and 5G networks. Currently, the network information exposed to service consumers is raw data and it requires technical skills or knowledge to be able to leverage them. If simple and contextualized information was provided, focusing on the desired operation of the vertical applications, this could be leveraged by developers to innovate and to co-create value towards enterprise industries, optimizing their applications and processes.

Based on the feedback from the developer community, there is the need for exposure of abstracted network information. Various organizations representing different industry segments are working on use cases that can benefit from such information. 5GAA is working on V2X services with a list of use cases [i.11] where many of those can be either realized or further enhanced with assistive information from the network. The same applies to drones where the joint activity of GUTMA and GSMA, GUTMA ACJA [i.2], is working on new use cases for Uncrewed Aerial Vehicles (UAV), or to industrial automation use cases created by 5G-ACIA [i.3].

Surveys and analysis from different industries suggest that there is the need for abstracted network information exposure, but that the information and its use would have to be made easier for developers to understand. The present document considers the feedback from different industry segments asking them what kind of information and in which form they would like to use it. The analysis focuses on selected use cases of different industries and supports those by information that is tailored and abstracted to a level that is easy to understand without deep knowledge of mobile networks.

As the result, recommendations are given which information items to expose via a general, cross-verticals abstracted network information exposure service API. Such network information exposure service will provide abstracted information related to an actual communication service that is provided by the network, for instance by exposing current or predicted service quality parameters related to said communication service. This information will allow applications to become network-aware and to adapt to different network conditions.

5 Industry segments and related use cases

5.1 Industry Segment: V2X

5.1.1 Description

The 5G Automotive Association (5GAA) is an important global, cross-industry organization of companies from the automotive, technology and telecommunications industries (ICT), working together to develop end-to-end solutions for future mobility and transportation services. In 2019, 5GAA started the work item MEC4AUTO that discusses the V2X use cases that can benefit from multi-access edge computing, proposes deployment architecture of these V2X use cases in multiple operator networks and considers multiple car provider (OEM) clouds. The MEC4AUTO V2X use cases are described in the published deliverables [i.9] and [i.10]. An exhaustive list of up-to-date Use Cases (UCs) for Cellular Vehicle-to-Everything (C-V2X) is presented and elaborated in [i.11], [i.12] and [i.13].

Exemplary V2X use cases that can benefit from MEC deployment can be classified as follows:

- Cooperative vehicle to network/infrastructure to everything (V2N2X/V2I2X) use cases, where the vehicles are communicating with other network elements such as vehicles, infrastructure, pedestrian/cyclists, etc. by means of networks from multiple operators.
- In-vehicle entertainment use cases, where the MEC system is offloading/caching video flow towards the vehicle.
- High-definition map update use cases where the MEC system is performing data fusion from sensors deployed in a region in order to update a local dynamic map and timely transmit the updated map to the vehicles.

The Use Cases (UCs) defined in [i.11], [i.12] and [i.13] are characterized by SLRs (e.g. in terms of latency or reliability), service flows (depending on the specific scenario) and contextual information (e.g. vehicles location and dynamics, traffic stop signs, road conditions). This context information in [i.11], [i.12] and [i.13] are rather application-specific, so no abstracted radio network information is needed.

5.1.2 Use case 1.1: Vehicle to network to everything (V2N2X)

5.1.2.1 Description

When looking at the use cases defined by the 5GAA in [i.8], it is seen that a good proportion of the vehicular use cases can be considered as part of a more general Vehicle to Network to everything (V2N2X) use cases category.

Figure 5.1.2.1-1 shows the general view of the V2N2X use cases for MEC deployments in multiple operator networks and for multiple cloud OEMs.

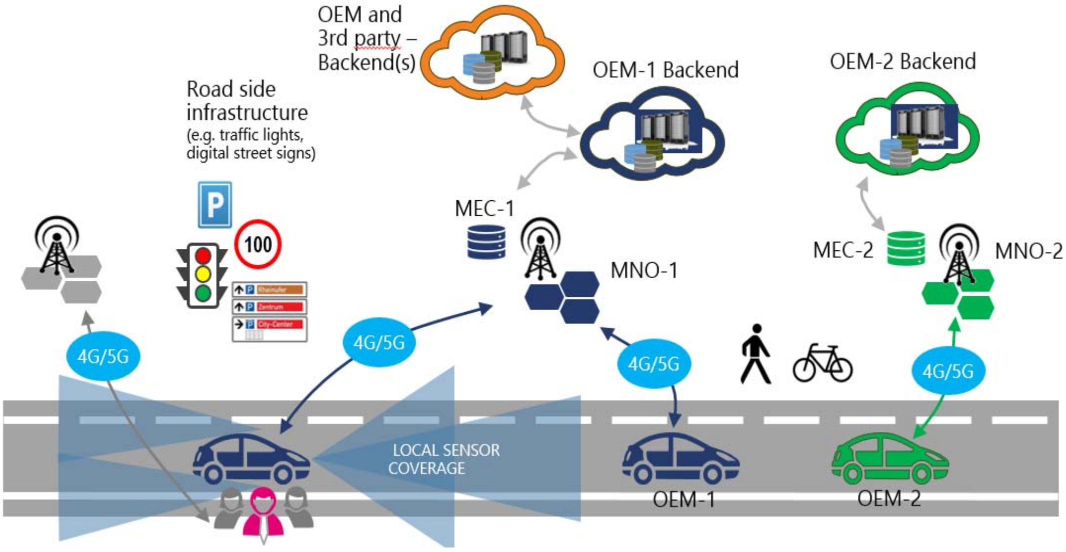

Figure 5.1.2.1-1: Edge Computing support for automotive scenarios [i.10] (Courtesy of 5GAA)

The V2N2X use cases family can be described as multiple use cases where MEC services are deployed over multiple networks from multiple Mobile Network Operators (MNOs) in order to enable communication between multiple vehicles from multiple manufacturers (OEMs), i.e. V2N2V communications; communications between vehicles and the infrastructure, i.e. V2N2I communications; and communications between the vehicle and vulnerable road users such as pedestrians, i.e. V2N2P communications. Typical V2N2P use case could be for example the vulnerable road user use case where a warning is transmitted to the vehicle in near real-time in order to prevent collision with a crossing pedestrian on the road as described in [i.9] and [i.10]. Other important use cases from the V2N2X use cases family are the cooperative V2N2V use cases involving cooperative manoeuvres between multiple vehicles in a region such as cooperative lane merge and group start use cases in [i.9] and [i.10].

5.1.2.2 Analysis

5GAA listed in section 6.4 of [i.6] a number of measurements that can be returned as QoS prediction/analytics. These are essentially expressed in terms of application layer Key Performance Indicators (KPIs) of V2N2X use cases. The reference [i.7], section 4 analyses a number of use cases, including V2N2X use cases, in terms of potential application reaction and related predicted QoS KPIs. This application reaction is used by the V2X application in order to find measures that allow compensating for communication service level drop in the area and thus ensuring the service level requirements of V2N2X use cases.

5GAA suggested to use, for the QoS predictions, high level QoS KPIs that can be representative of the application requirements. These high level QoS KPIs could be the ones listed in clause 5.6.3 of ETSI TS 123 501 [i.5] and are provided by Network Data Analytics Function (NWDAF) of the 3GPP 5G networks as well as additional Service Level Requirements (SLRs).

Table 5.1.2.2-1 provides examples of information items to support the use case.

Table 5.1.2.2-1: Needed information to enable the use case

Information item	Description
Service throughput	The data rate provided by the communication service. In case of interaction with 3GPP networks according to clause 6.9 of ETSI TS 123 288 [i.4], this can be mapped to a specific value of the guaranteed flow bit rate GFBR, maximum flow bit rate or to radio access UE throughput.
Service latency	The delay characteristics of the communication service. In case of interaction with a 3GPP network, according to clause 6.9 of ETSI TS 123 288 [i.4], this can be mapped to a specific value of the Packet Delay Budget (PDB).
Service reliability	The ability of the communication service to achieve the service level requirements expressed as guaranteed service bit rate and service latency for a given time interval, under given conditions. This information could range from 99,9 % for the vulnerable road user protection use case towards 99,999 % for the group start use-case.
Service coverage	The region where the communication service is available, achieving some specific combination of service bitrate, latency and reliability. The service coverage information may be expressed as service range information in the specific region.
Service capability	The possible quality of service in the service coverage area. A level of service is being defined as a combination of service bitrate, latency and reliability.
Location	The location of a UE (such as a car) in the service coverage area. This information could be used by the application layer as a trigger to assess V2N2X use cases deployment in the area.

The high level QoS information described above is essentially the so-called "abstracted network related information" that is needed for the optimization of the V2N2X use cases, as applications primarily consider what kind of communication QoS they can obtain from network. Such abstracted information has much higher value for the application, since it encompasses the whole user plane link between the two application instances and - differently from lower layer measurements - can correctly be used to trigger application specific reactions. Additional information is also considered by 5GAA to be provisioned to the vehicles. This information is described as:

- Support of notice period/time horizon, which is defined as the minimum time interval that is needed for the vehicles to receive the notification before the event happens (time of the QoS prediction).
- Support for confidence - the confidence of a specific QoS information and/or prediction. The semantic and use of confidence can be left to implementation.

5.1.3 Use Case 1.2: Cross-traffic Left-Turn Assist (LTA)

5.1.3.1 Description

This use case is within the Safety category and is proposed to assist a Host Vehicle (HV) attempting to turn left across traffic approaching from the opposite, left, or right direction [i.11] or in the presence of an overtaking vehicle or vehicle in a blind spot [i.23]. Considering the diverse data sources, i.e. vehicles, that are involved in this use case, and the low delay needed for promptly warning the HV, this use case will benefit from the deployment of MEC.

Based on the type of scenario (either adjacent traffic from the left, or adjacent traffic from the right, or oncoming traffic [i.11] or overtaking vehicle or vehicle in a blind spot [i.23]), the right of way conditions, the estimation of vehicles' trajectories, and the estimated stopping distance, an LTA application might warn a HV about the risk of collision [i.11].

As inputs for the above estimations, an LTA application requires contextual information about HV and Remote Vehicles (RVs), especially location and dynamics, turn signal state, estimated acceleration from stopped, lane designations and geometry, intersection geometry, traffic stop signs, traffic light signal phase and timing, traffic rules and laws for three-way stops, four-way stops and unsigned intersections, current road conditions, etc. However, some network information to enable the use case is also needed.

5.1.3.2 Analysis

According to [i.11], the LTA use case is based on Cooperative Awareness Messages (CAMs) exchanged between the vehicles involved in the use case. Based on ETSI EN 302 637-2 [i.17], the frequency of generation of CAMs depends on the time elapsed since the last CAM generation, and can be adjusted if the absolute difference between the current heading direction and the one in the previous CAM exceeds 4°, or the difference between the current location and the one in the previous CAM exceeds 4 m, or if the absolute difference between the current speed and the one in the previous CAM exceeds 0,5 m/s.

The provisions in [i.17] define the CAM generation interval not to be inferior to 100 ms and not to be superior to 1 000 ms. In [i.11], two user stories for LTA use case are presented considering different message sizes and Service Level Requirements (SLRs). US1 corresponds to the situation in which no information about future trajectories is exchanged among the cars. In US2 autonomous cars exchange planned, future trajectories directly with each other via the sidelink (V2V cooperation), to support turning scenarios in which overtaking vehicles or vehicles in a blind spot are involved, e.g. as indicated in clauses 5.7.5 and 5.7.6 in [i.23]. However, only US1 shown in table 5.1.3.2-1 (which reproduces the quantities in [i.11] for the sake of readability) is relevant in the context of the present document. User story US2 is not relevant in the present document, because the network monitoring or prediction of sidelink performance is out of scope.

Table 5.1.3.2-1: LTA use case: SLR

User Story	Message Size [Bytes]	Latency [ms]	Reliability [%]
US1	300	100	90
US2	1 000	10	99,9

To enable making optimal decisions by the LTA application backend, Abstracted NIE should provide meaningful and sufficient information to the application about the E2E communication service performance.

QoS parameters to support the use case are provided in table 5.1.3.2-2.

Table 5.1.3.2-2: Needed information to enable the use case

Information item	Description
Service throughput	Service throughput includes the bitrate in the downlink and in the uplink.
Service latency	Service latency includes the delay in the downlink towards the UE, and in the uplink from the UE.
Service reliability	Service reliability describes the robustness of packet transmission, such as packet loss.
NOTE: The information items are under the assumption the communication service is delivered over the 5G system between the UE and the 5G network interface towards the Data Network.	

Traditionally in the mobile network, some fixed QoS classes (5QI in 5G, QCI in 4G) were used internally in order to satisfy communication needs of applications, however, the E2E communication service experience was not measured. The actual mobile network QoS classes (5QI, QCI) are too low-level, and the information needs to be abstracted. The concept of QoS classes is probably still applicable but should be technology-agnostic.

5.1.4 Use case 1.3 Tele-Operated Driving (TOD)

5.1.4.1 Description

The TOD use cases defined by the 5GAA in clauses 5.4.10 to 5.4.12 of [i.9] imply that vehicles are directly controlled remotely, either by a human or by an automated system. For a human as remote driver, the main upstream data from the HV (i.e. host vehicle) are video streams, which are optionally enriched with additional data e.g. from sensors. For an automated system as remote driver, the upstream data typically are pre-processed environment data (e.g. from sensors) that allows the remote driver to acquire the correct (current) view of the surroundings (e.g. by building a model of the vehicle's surroundings).

The TOD scenarios can benefit significantly from Multi-access Edge Computing (MEC) to achieve low latency and high reliability communication. TOD becomes essential under conditions where human oversight is crucial (e.g. in case autonomous systems face unexpected failures) for ensuring both safety & efficiency. Also, accuracy of determining the vehicle's location is needed to navigate around objects blocking parts of the driving lane and to navigate through small gaps between two or more objects.

Below is a list of TOD use cases from [i.9]:

- **Tele-Operated Driving:** When an autonomous vehicle encounters a situation where it cannot make the appropriate decisions for a safe and efficient manoeuvre, a remote driver can take control of the vehicle to resolve the difficult situation, after which the vehicle switches back to autonomous operation.
- **Tele-Operated Driving support:** An AV or driver can encounter conditions such as complex urban environments or sudden obstacles, where it is impossible to make safe and efficient decisions. In these cases, the AV or driver can request support by human intervention (e.g. from a remote driver tele-operator) to take control of the vehicle (e.g. remote steering in case of road blockage) to navigate the vehicle to a safe location.
- **Tele-Operated Driving for parking, also known as Automated Valet Parking:** When an AV arrives at a parking location, it can be controlled by a remote driver in the scenarios of tight or complex parking conditions where human judgment and precision are needed.

A further use case is rental car delivery by a remote driver; in cases when the delivered car does not support (fully) autonomous driving.

5.1.4.2 Analysis

Considering the use cases, service level requirements and network information in [i.9] and [i.21], the related network information items for TOD use cases are described in table 5.1.4.2-1.

Table 5.1.4.2-1: Information items to support the use case

Information item	Description
Service throughput	The data rate provided by the communication service which is important for the persistence and quality of vehicle and TOD operator communication. 5GAA has defined these values as follows (see clause 6.6 in [i.18]): In the uplink, 32 Mbps are needed for video-only (assuming four streams), or 36 Mbps for video plus data. In the downlink, 400 Kbps are needed to transmit the steering commands.
Service latency	Details the delay characteristics of the communication service which are important for real-time responses in TOD operations. 5GAA has defined these values as follows (see clause 6.5.2.1 in [i.18]): The service-level latency needs to be less than 100 ms in the uplink and less than 20ms in the downlink.
Service reliability	Indicates the ability of the communication service to meet the defined service level requirements in a given time period. 5GAA has defined these values as follows (see clause 6.6 in [i.18]): In the uplink, 99 % are needed, whereas in the downlink (e.g. remote steering from remote driver to HV), the requirement is much higher at 99,999 %.
Service coverage	The communication service has to cover the whole trajectory of a planned tele-operated drive, meeting the specified quality parameters.
Location	Determining the precise location of a vehicle is essential for the use case, but the precision requirements depend on the actual mode (e.g. whether the vehicle is driven based on sensor data or based on video streams). If the network determines the location, information about achieved precision can be part of the exposed network information.

MEC can significantly enhance the TOD operations by decreasing the latency, as well as enhancing the throughput and the reliability of the communication, which is vital for the dynamic functional requirements of TOD operations. Exposed high-level QoS information can guide the application behaviour and methods which can improve the operational efficiency and safety of TOD vehicles. QoS KPIs and predictions can help in proactive adaptations within the TOD operations to react upon expected changes in network conditions. Secure communication and authentication (refer to clause 5.4.10 in [i.9]) are essential for TOD so that the crucial information can be transmitted without spoofing which can provide defence against potential cyber threats.

5.2 Industry Segment: Drones

5.2.1 Description

The drone industry, also known as the Uncrewed Aerial Vehicle (UAV) or Uncrewed Aircraft System (UAS) industry, is undergoing significant growth and innovation. It provides services to a wide range of industries and applications, as UAS are continuously exercising new, beneficial applications for their operations, including activities such as goods delivery, infrastructure inspection, search and rescue, public safety, and agricultural monitoring. The variety of applications for drones is expected to expand.

The drone industry is leveraging continued advances in technology, including improved battery life, better obstacle avoidance systems, enhanced camera capabilities, specialized sensors, communications and the integration of artificial intelligence for autonomous flight and data analysis. The drone industry continues to explore emerging technologies such as drone swarms, autonomous flight, and Beyond-Visual-Line-Of-Sight (BVLOS) operations. Performance requirements for BVLOS operations have been defined in ETSI TS 122 125 [i.14].

The integration of 5G technology with drones opens up new possibilities and revolutionizes the capabilities of UAVs in terms of connectivity, remote operation, and potentially collaboration between drones (drone swarms), etc. Furthermore, using MEC in the 5G edge brings significant value to the drone industry by enabling low latency and high reliability of communication between UAV and UAS Operators (e.g. with Ground Control Stations, UTM), and by providing scalable and efficient processing capabilities for data. It also allows drones to react faster to changing environmental conditions and unexpected events by enabling effective control by UAS operators.

NOTE: Drone to drone direct communication via sidelink is out of scope.

Information and capabilities exposed via the MEC abstracted network information API can contribute to the overall organization and coordination of actors involved in the UTM eco-system (see e.g. the UTM Pilot Program [i.15]).

5.2.2 Use Case 2.1: Safety drones for emergency services

5.2.2.1 Description

Safety drones are drones that are specifically designed and utilized for emergency services. These drones are equipped with various sensors, cameras, and technologies to support emergency services including search and rescue, disaster response, etc. They play a crucial role in enhancing situational awareness (e.g. by collecting information on the disaster situation via sensors or cameras and provide the information to the emergency centre) for facilitating rapid and effective decision-making during emergencies. For this purpose, the use of safety drones has become increasingly prevalent in public safety agencies, disaster response organizations, and other emergency services.

An example for this use case is a deployment of post-emergency call fast-responding safety drones [i.16]. These drones arrive at the scene just minutes after a distress call is received. They provide real-time situational awareness (e.g. based on 4k and thermal imaging that is enriched with AI insights) which helps the commanders to quickly identify the best course of action.

The drones are connected via 5G which allows 360° video streaming and low latency remote control which is expected to continue to work even in case of congestion thanks to the use of prioritization techniques of 5G.

Taking a general view on this use case, integrating safety drones with the 5G network edge cloud and exploiting its exposed capabilities can offer several benefits:

- **Low-latency communication enabling remote control of the safety drones from command centre:** This is crucial for immediate decision-making during emergency situations, such as disaster response or search and rescue operations. Furthermore, it enables remote piloting and monitoring of safety drones from the remote operation centre, allowing UAS operators to control drones from a distance.

- **High bandwidth for the transmission of high-quality imaging:** Safety drones often rely on high-definition cameras. The high bandwidth provided by the 5G network ensures that high-quality imaging data can be transmitted quickly and reliably to the control centre for analysis.

- **Edge computing capabilities:** These allow safety drones to process data in the 5G edge cloud (e.g. near the point of capture), reducing the need to transmit large volumes of raw image data to a central network server. Moreover, integrating Artificial Intelligence (AI) capabilities in the edge cloud allows for AI decision support for the emergency centre. This is particularly beneficial for scenarios that are time-critical, such as identifying hazards, assessing the severity of a situation or responding to safety threats and emergencies.

- **Precision navigation and control of safety drones:** This is essential for flying in challenging environments, avoiding obstacles thanks to accurate location services provided by the 5G network.

- **Interconnectivity with other devices, sensors and safety drones:** Such interconnected network can provide comprehensive data for better situational awareness and coordination during emergencies. Furthermore, safety drones can collaborate to efficiently cover larger areas or address complex situations such as disaster-stricken regions.

- **Secure communication between the safety drones and the command centre:** This is critical to prevent unauthorized access of information used for emergency services.

5.2.2.2 Analysis

The present work item can provide information about the performance of the communication service provided by 5G system, which will allow making the safety drones-based emergency service/application and its provider aware of the network, such that they can react to changes in the network by adapting the service.

Table 5.2.2.2-1: Needed information to enable the use case

Information item	Description
Service throughput	This provides information about the actual and predicted throughput of the communication service provided by the 5G system. This information could be used for the purpose of a second line of defence, which allows the drones to adapt to varying throughput of connectivity.
Service latency	This provides information about the end-to-end latency of the communication service provided by the 5G system. If predicted, it could help the drones to react accordingly.
Service coverage	5G system provides e2e communication service for drones. The service area is the area where the service is available with certain minimum QoS levels. This information could be used in part to generate the so-called coverage maps to optimize the flight planning.

5.3 Industry Segment: Immersive technologies

5.3.1 Description

Immersive technologies allow to create interactive and engaging environments for end-users. The use cases below have been derived from the network requirements for metaverse services as defined by the Metaverse Standards Forum [i.19]. This segment includes VR Cloud gaming which can be hosted on edge servers (e.g. handling computation) and streamed to VR headsets which can enable immersive and high-quality gaming experiences with minimized latency on a limited capacity hardware. The second use case for Immersive Tele-Operated Driving (TOD) involves remote operation with VR devices for the vehicles in hazardous environments that require very low latency and high reliability for processing real-time data. The third use case is Local interaction with offloaded processing with XR devices through which users can interact with physical and virtual elements in a local environment while offloading the processing to edge servers. MEC is an essential aspect for these use cases for achieving real-time interactions and augmented realities for the user with low latency and high data rate requirements. Furthermore, certain uses cases such as TOD additionally require high reliability e.g. for reading remote steering.

Figure 5.3.1-1: Immersive technologies

5.3.2 Use case 3.1 Immersive cloud gaming

5.3.2.1 Description

Cloud gaming uses cloud computing for streaming the visual content to the user's XR headsets. The user can interact with the game through haptic feedback devices or some controllers. By this approach, complex and graphically intense gaming and visual experiences can be virtualized or augmented through a relatively modest hardware. With localized data processing and reduced latency, MEC technology can enhance and ensure the necessary responsiveness which is important for immersive experience for users in XR environments.

5.3.2.2 Analysis

This use case requires real-time communication capabilities which can be supported by MEC to process high-bandwidth video streams closer to the user. For maintaining immersion and competitiveness in fast-paced games, ultra-low latency can ensure that players experience minimal delay and real-time responsiveness.

In addition to exposing the information items defined in table 5.3.2.2-1, the use case needs the capability of the network to support quality on demand and prioritization in case of congestion.

Table 5.3.2.2-1: Information items to support the use case

Information item	Description
Service throughput	The data rate essential for streaming high-quality video content and maintain the immersive visual experience for cloud gaming.
Service latency	Describes the delay characteristics of the communication service which are important for real-time responsiveness for seamless gaming experience.
Service reliability	The ability to meet defined service level requirements for immersive competitive and fast-paced gaming.
Service coverage	Indicates the geographical coverage to meet specific quality parameters for mobile immersive cloud gaming.

5.3.3 Use Case 3.2: Immersive Tele-Operated Driving (TOD)

5.3.3.1 Description

Immersive Tele-Operated Driving facilitates controlling vehicles remotely through providing situational awareness via an XR device supported with haptic feedback. This use case has the potential to be extremely vital for operations in hazardous environments, situations where human presence is unsafe or not practical, or to save driver resources e.g. in rental car door-to-door delivery. MEC can support Immersive TOD with its edge compute capability to allow real-time processing of huge amount of data produced by vehicle, camera, radar etc. This can enable creating virtual representation (e.g. digital twin) of the physical world in the MEC system or in the data network to provide the multi-sensory communication to the remote driver, which can be additionally helpful to conduct safety procedures remotely, on top of the reference use case of tele-operated driving as defined by the automotive sector (clause 5.1.4).

5.3.3.2 Analysis

Low latency and high reliability of network connections, which can be supported by MEC for real-time control and feedback procedures, as well as low-delay video streaming, are vital for the safety procedures and efficacy of remote operations which can ensure that under varying network conditions, an Immersive TOD operator can maintain a robust control over the remote vehicle.

In addition to exposing the information items defined in table 5.3.3.2-1, the use case needs the capability of the network to support quality on demand and prioritization, and to provide accurate location information of the remote vehicle.

Table 5.3.3.2-1: Information items to support the use case

Information item	Description
Service throughput	The data rate essential for the quality and continuity of communication between the vehicle and the immersive TOD operator.
Service latency	Describes the delay characteristics of the communication service important for immersive TOD operations which can include real-time responses and feedback.
Service reliability	The ability to meet defined service level requirements to ensure strict control over the remote vehicle at all times.
Service coverage	The geographical coverage for the communication service to meet specific quality parameters necessary for immersive TOD.
Location	Determining the precise location of a vehicle is essential for the use case. If the network determines the location, information about achieved precision can be part of the exposed network information.

5.3.4 Use Case 3.3: Local interaction with offloaded processing

5.3.4.1 Description

A user can wear a see-through XR headset which can involve interacting with both physical and virtual objects in a real-world environment where the XR device is equipped to perform complex tasks such as data overlay, real-time object detection and environmental mapping, while the processing is offloaded to nearby edge servers. For remote training, emergency assistance and navigation, this setup can facilitate immediate and augmented responses that can be overlaid or extended onto the user's field of view which can enhance their interaction by manipulating the physical and virtual elements according to the demand of the use case.

5.3.4.2 Analysis

This use case requires edge computing capabilities to process data with shorter latency. Offloading the computation to the MEC system also requires the network to provide high-bandwidth and low-latency transmission to ensure timely response. To provide a desirable interactive experience, MEC can ensure that the user's interactions are well integrated with the overlay of virtual enhancements.

In addition to exposing the information items defined in table 5.3.4.2-1, the use case needs the capability of the network to support quality on demand and prioritization, as well as accurate location determination and direction of gaze detection.

Table 5.3.4.2-1: Information items to support the use case

Information item	Description
Service throughput	The data rate essential for streaming high-quality visual overlays and real-time data to the XR client.
Service latency	The latency needed for real-time responsiveness, mixed and augmented reality.
Service reliability	The ability to meet the service level requirements for stable and uninterrupted augmented mixed reality experiences.
Service coverage	The geographical coverage to meet specific quality parameters for augmented and mixed reality.
Location	Determining the precise location within the environment is essential for the use case. If the network determines the location, information about achieved precision can be part of the exposed network information.

5.4 Industry Segment: Gaming and entertainment

5.4.1 Description

The gaming and entertainment industry has undergone a major modernization by advancements in cloud gaming, real-time multiplayer ultra-low latency experiences and advanced Content Delivery Networks (CDNs). Multi-access edge computing can play a crucial role in gaming by enabling real-time data processing, content delivery optimization and optimized cloud workload orchestration. Gaming services can be boosted to provide superior quality of service and scalability during high demand by utilizing MEC. Some examples are presented in [i.20] and [i.21].

5.4.2 Use case 4.1: Gaming

5.4.2.1 Description

The use case explores the use of MEC for meeting the service level needed for real-time multiplayer gaming.

Key aspects of this use case include:

- **Aspect 1 - Game starting aspect:** This strives to achieve the low-latency to connect players at the start of game.
- **Aspect 2 - In-progress game management aspect:** This strives for optimization of gaming quality based on demand and multiplayer location. This aspect follows the game starting aspect previously described. They collaboratively contribute to ensuring the game application to be well-managed during gameplay. It also helps scale the session when more players join or leave without impacting performance.
- **Aspect 3 - In-edge content caching aspect:** This strives to ensure that gaming content is delivered quickly by caching game data in the edge close to the players instead of relying constantly on the content in the cloud. This is essential for real-time game streaming, reducing latency during gameplay.

Together, these aspects deliver smooth, multiplayer gaming with satisfactory latency. MEC is a key enabler of this system, allowing processing and optimization to occur closer to the players for improved performance.

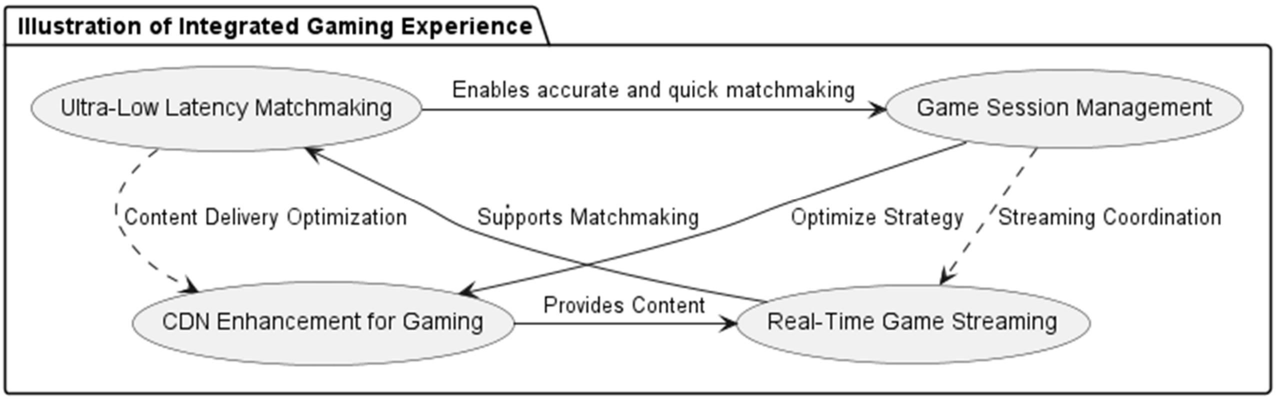

Figure 5.4.2.1-1: Example: Integrated Gaming Experience

Figure 5.4.2.1-1 is an example of how the three aspects could be illustrated. Ultra-Low Latency Matchmaking is an example realization of aspect 1. Game Session Management is an example realization of aspect 2. CDN Enhancement for Gaming is an example realization of aspect 3.

5.4.2.2 Analysis

In order to meet the real-time latency and matchmaking requirements to manage the gaming sessions and content delivery optimization, the abstracted network information which is essential for real-time game streaming and integrity of game sessions without any disruptions is described in table 5.4.2.2-1.

Table 5.4.2.2-1: Information items to support the use case

Information item	Description
Service throughput	The data rate in downlink and uplink necessary to download and upload gaming content between the server and the player's device.
Service latency	Service delay or round-trip time for a user's action represents the two-way latency between sending a gaming service request and receiving the corresponding response on the user's device.
Service reliability	The percentage of loss for the data packets during the streaming of the gaming content which can affect the reliability of the gaming service and the overall quality of real-time gaming experience.
Delay variation	The variation in packet arrival time during transmission, which is to be minimized to prevent inconsistencies in the game and ensure smooth and anticipated gaming experience.

This approach for abstracted network information exposure leverages MEC to create a seamless integrated gaming experience that meets the high quality demands of advanced and modern real-time gaming. This abstracted network information can be applied across multiple aspects of gaming, from matchmaking to content delivery which can ensure a high-quality, ultra-low/balanced latency and scalable service.

5.5 Industry Segment: Industry 4.0

5.5.1 Description

Industry 4.0, also known as the Fourth Industrial Revolution, entails various key features and technologies such as IoT, data driven decision-making, automation, AI, augmented and virtual reality and smart supply chains which can be integrated into traditional industrial production and manufacturing processes. This revolution intends to create so-called "smart factories" where machines autonomously optimize the sourcing, manufacturing, shipping, storage, distribution and delivery.

5.5.2 Use case 5.1: Automated Guided Vehicle (AGV) steering

5.5.2.1 Description

Automated Guided Vehicles (AGVs) are vital for material or products handling in Industry 4.0 manufacturing facilities, warehouses or distribution centres. They can navigate autonomously in production spaces without human intervention. AGVs can utilize low-latency processing capabilities and position prediction for real-time control and speed regulation by leveraging MEC at the network edge. The MEC host can run applications that can monitor the AGV's position, speed and direction using data from sensors at the Industry 4.0 facility and in the AGV, and send steering commands to the vehicle to steer it on a target path. Abstracted network information can provide insights into network conditions, such as latency and throughput which can affect the estimation of position and speed of the AGV. This can enable the system for AGV route optimization, position prediction, position correction and speed regulation based on real-time network conditions to ensure reliable and effective AGV operations in the facility. MEC can play a vital role by enabling low-latency data processing at the edge, network delay estimation and compensation for position prediction and adaptive route optimization. In the events of high service latency or network degradation, the MEC application can predict and correct the AGV's position or regulate its speed and path to maintain safety and efficiency. This can ensure reliable and continuous operation in dynamic facility conditions.

5.5.2.2 Analysis

The end-to-end latency and packet loss are crucial for the AGVs' operational efficiency. A study [i.22] has explored how simulated end-to-end latency and packet loss affect the accuracy of guiding an AGV on a target path, see figure 5.5.2.2-1. The deviation of the AGV from the reference path is called the guide error. A position predictor is hosted at the network edge. The position of the AGV is sent by the AGV to the position predictor through the RAN for which packet loss and delay can be simulated. Because of the uplink delay and packet loss, the position made known to the position predictor represents knowledge from the past. When knowing network uplink and downlink delay information and the currently applied velocity command, the position predictor can predict the future position of the AGV when the next velocity command can arrive at the vehicle, thereby compensating the impact of network delay. Based on the predicted position and the reference path, the controller sends a velocity command to the AGV for changing its position and copies that command to the position predictor. The velocity command to the AGV is again subject to downlink delay and packet loss.

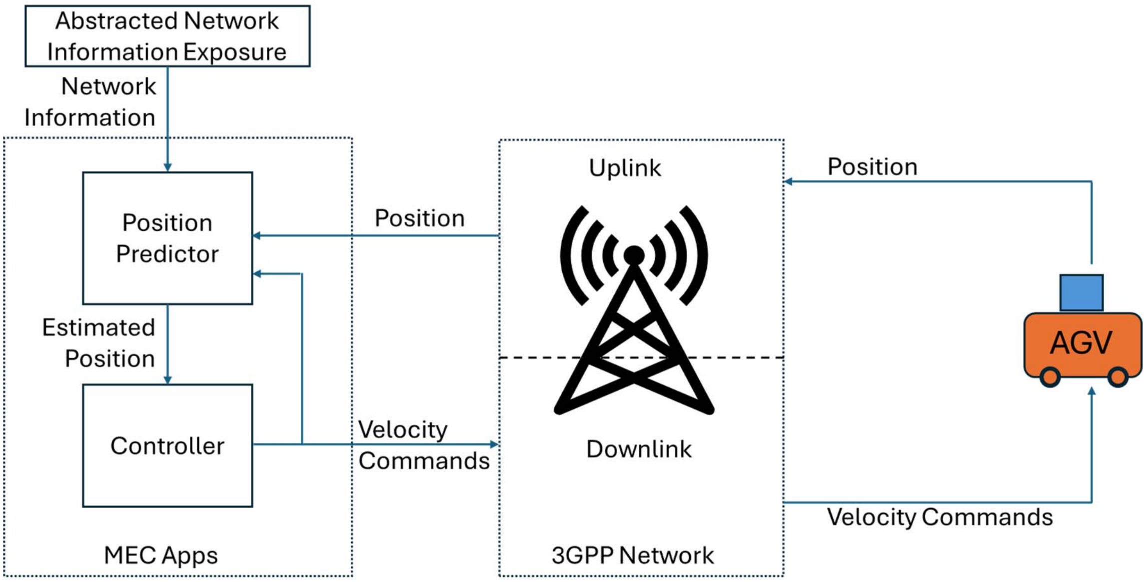

Figure 5.5.2.2-1: Use case of AGV steering with MEC

In the study [i.22], it has been found that one-way channel delays beyond 50 ms have a perceivable impact on the guide error and need to be corrected by the position predictor. Correction needs to consider non-linearities. For packet loss, less than 10 % can be tolerated, 10 % to 30 % have severe negative impact on the guide error, and above 30 % render the service unacceptable, with the AGV losing its trajectory.

Below is the list of abstracted network information items which are essential for AGV operation.

Table 5.5.2.2-1: Needed information to enable the use case

Information item	Description
Service throughput	The available data rate for communication between the AGV and the MEC system. This ensures that the AGV receives accurate velocity commands and transmits pose data without any disruptions. As control commands are small, this is less critical.
Service latency	Represents the latency between the controller and the AGV. Can be represented as uplink latency (time for a message to travel from the AGV to the controller), downlink latency (time for a message to travel from the controller to the AGV) and round-trip time (time interval between the controller sending a message to the AGV and receiving the AGV's response). Low latency ensures real-time responsiveness and accuracy for AGV control; high and varying latency requires corrective measures. As per the use case explored in [i.22], a one-way delay of 50 ms was identified as the limit above which correction is needed.
Service reliability	The percentage of time the radio network maintains the communication quality that is needed for AGV control. In this use case, this relates to the percentage of packets lost, leading to losing velocity commands towards the vehicle or losing position updates from the vehicle. Low reliability, i.e. high packet loss, can degrade AGV performance up to the AGV losing its trajectory.
Delay variation	The variation in packet arrival times during transmission that can affect the consistency of data transmission and real-time AGV control. High delay variation makes delay prediction and compensation less effective.

5.5.3 Use case 5.2: Process automation - closed-loop control

5.5.3.1 Description

Process automation using a closed-loop control system as described in section 4.2 of [i.24] is a key use case in Industry 4.0 which involves sensors and actuators in industrial plants (e.g. plants for chemical processing, food production, energy optimization, etc.). Sensors can measure various parameters of a process (e.g. temperature, force/torque to monitor stress, liquid levels in a tank, speed/velocity for a moving object, etc.) and send them to an edge-based controller application. The controller can compute accurate control signals and send them to actuators which enables the system to steer the process based on the data from sensors and decisions made by the controller.

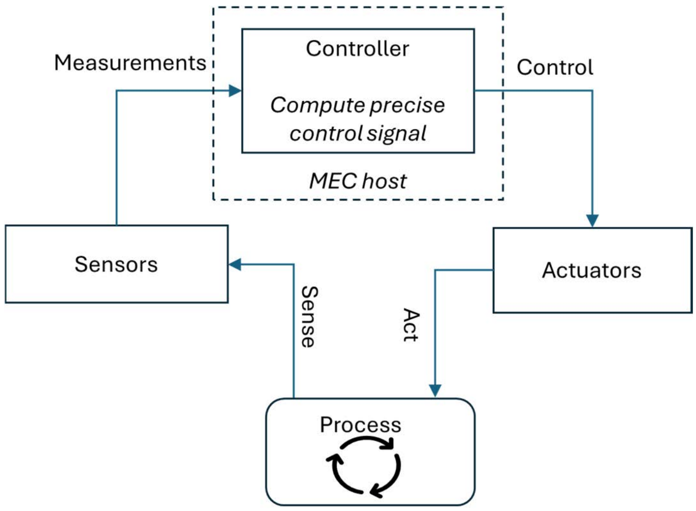

Figure 5.5.3.1-1: Closed-loop control system

As shown in figure 5.5.3.1-1, there are two essential aspects of closed-loop control systems in process automation:

- Feedback mechanism: The closed-loop control system operates with a feedback loop which involves sensors, controllers (i.e. controller applications) and actuators. Sensors continuously send the measurement data to the local edge controller (i.e. controller application deployed in MEC host) such as proportional, integral and derivative controllers (PID), to adjust the control settings for the actuators.

- Edge computing in process automation: Controller application deployed locally in the MEC host can handle localized data processing, storage, computation by the PID controllers to ensure bandwidth efficiency and low latency.

5.5.3.2 Analysis

There are several advantages of hosting the process automation controllers at the local MEC host. Localized processing of sensor data can enable quick decision making for the adjustments that need to be done by the actuators. Sensor data can be stored at the local MEC host for further analysis and processed e.g. for predictive maintenance, eliminating the need to send the data to a centralized cloud data centre. This allows to achieve the strict latency requirements for Industry 4.0 process automation. Hosting process automation controller applications such as PID at the local MEC host can help with enhanced reliability and availability, as it reduces the risks of failures and guarantees the operations continuity. This use case has very stringent requirements for latency and service availability.

Below is the list of abstracted network information items which are essential for closed-loop control.

Table 5.5.3.2-1: Needed information to enable the use case

Information item	Description
Service throughput	The data rate needed by the closed-loop control system as depicted in figure 5.5.3.1-1 to send the measurements and adjusted control signals between the sensors and the actuators.
Service latency	Service latency is the end-to-end latency for the closed-loop control system illustrated in figure 5.5.3.1-1. This latency should be <10 ms for each cycle of the data exchanged between the sensors, controllers and the actuators for an effective closed-loop control mechanical for process automation in Industry 4.0.
Service reliability	The percentage of packet loss for the data packets during the exchange of the control signals and sensor data. This use case is very sensitive to packet loss (target packet loss = 0 %).
Service coverage	The geographical area of coverage for the control loop system as described in table A.2.3.1-1 in [i.25] is typically $\leq 100\ m$ (length) × $100\ m$ (width)× $50\ m$ (height).
Service availability	Service availability refers to the percentage of time the network service is usable by the closed-loop control system, which includes sending the data to the controllers and sending the adjusted control signal to the actuators. As described in table A.2.3.1-1 in [i.25], the service availability is between 99,999 9 to 99,999 999 %.
Delay variation	The variation in packet arrival times from sensors and controllers. To prevent inconsistencies in the closed control loop mechanism, it is usually not larger than 10 % of the target transfer interval which is < 1 ms.

5.6 Industry Segment: Media production

5.6.1 Description

At live events and during the production of news, media are acquired and processed on-site, and contributed via networks to production hubs that generate the final programme for distribution.

Figure 5.6.1-1 illustrates the media production and consumption chain.

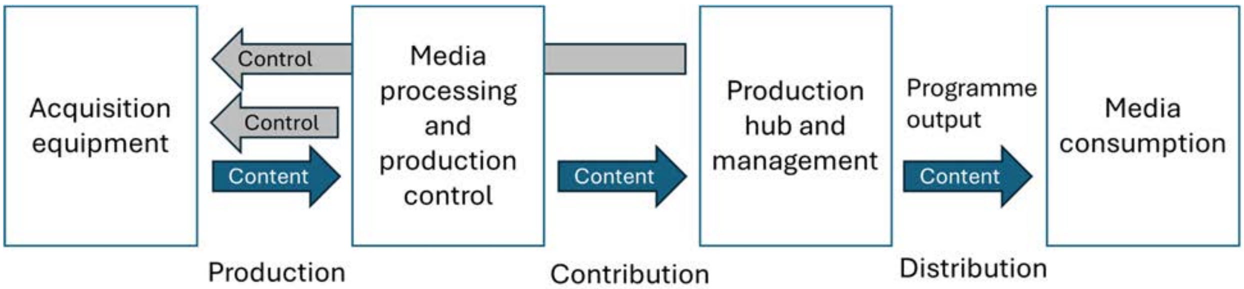

Figure 5.6.1-1: Media production and consumption chain (adapted from [i.39])

While media distribution via public digital networks is state of the art for some time, contribution of media from capture and production sites has long used dedicated private networks, such as leased lines and satellite links.

Since the availability of 5G, media production and contribution via cellular networks gains popularity and importance. In the context of live events or news reporting, the process of media acquisition typically takes place remotely, using 5G-enabled equipment. The process of media processing and production control can take place remotely too, but can also be performed on-site or in a hybrid on-site/remote setting, depending on the requirements of the actual event.

Hosting the media production related applications in MEC hosts closer to the users can fulfil the reliability, bandwidth and latency requirements of these processes. Exposing from the network the information related to the communication service that carries the media streams can support controlling the media streams such that they optimally use the networks, and can assist in planning the distribution of media processing and production control between on-site and remote locations.

The following clauses describe and analyse use cases for network-based media production and contribution.

5.6.2 Use case 6.1: Electronic news gathering

5.6.2.1 Description

5G-MAG has described in [i.26] and [i.39], the use case of Electronic news gathering and uplink contribution, and its requirements to the network. In this use case, a crew on site is capturing and contributing content to an application server in the cloud or remote premises.

5.6.2.2 Analysis

This use case assumes that network connections can be booked with a certain QoS, and that the actual provided QoS can be monitored in real-time and possible violations are notified. Media use cases also need an accurate time base. The detailed information items to enable the use case are listed in table 5.6.2.2-1.

Table 5.6.2.2-1: Needed information to enable the use case

Information item	Description
Service throughput	The production crew monitors in real-time service throughput of the connectivity it has booked with a certain QoS and gets notified when there are issues. This allows them to re-configure the uplink codecs to adapt to network changes.
Service latency	The production crew monitors in real-time service delay of the connections it has booked with a certain QoS and gets notified when there are issues.
Delay variation	In video production, delays are compensated by buffers. The presence of delay variation necessitates larger buffers to prevent buffer underrun, leading to longer buffering times and making precise cuts more difficult or impossible. Therefore, this use case demands the delay to be ideally constant, that means delay variation to be close to zero.
Service coverage	The production crew can book certain network capabilities per location.
Service capability	The production crew queries the available network capabilities and gets notified if a capability becomes unavailable.
Accurate timing	In media use cases, synchronization of several media streams is necessary. For that purpose, accurate timing is needed.

5.6.3 Use Case 6.2: Professional TV production contributions from an off-site, remotely-produced, multi-camera outside broadcast

5.6.3.1 Description

This use case is defined in clause 5.7 of 3GPP TR 22.827 [i.27]. It fits well into the scenario where media production is distributed between off-site content capturing by one or more crews of camera operators, and on-site live media programme production by a programme director who uses the facilities of a production gallery. This use case is assumed to allow for cost-effective live content production as it is not necessary that the whole production crew travels to the off-site location.

The use case assumes three camera operators and two commenters to be present at an off-site sports event. High-quality audiovisual content is streamed from the cameras to the production gallery. For bandwidth saving, only the stream that is currently on air is sent at high quality, whereas every camera in addition sends a low-quality preview stream to be presented to the programme director for decision making. Communication between the programme director and the off-site personnel, as well as between the off-site personnel, needs to be enabled. Besides that, the director can also send control signals to the equipment directly. To provide the off-site crew a view of the programme, compressed audiovisual content also has to be provided downstream from the production gallery to the off-site location. For the audiovisual content, the use case documentation provides two different, contradicting figures. In the scenario description, it is stated that the video can even be uncompressed. In the derived requirements, compressed UHD 4K video at 50 fps is stated as the upper bound.

The use case has tight QoS and reliability requirements (see table 5.3.2.2-1 for details), as the network infrastructure is used to produce high-value content in a live setting. Given the tight requirements, the application has probably not a lot of flexibility to adapt to changing network conditions. Still, network information can be used to monitor whether the necessary QoS is available.

5.6.3.2 Analysis

The detailed information items to enable the use case are listed in table 5.6.3.2-1.

Table 5.6.3.2-1: Needed information to enable the use case

Information item	Description
Service throughput	The throughput of the upstream communication link needs to be high (200 Mbit/s), as multiple video streams are to be transmitted to the production gallery, up to UHD 4K video at 50 fps. Down-stream, the bitrate requirements are smaller (20 Mbit/s).
Service latency	The use case needs low delay communication, with the overall application E2E latency below 20 ms, and the E2E link latency below 6 ms.
Service reliability	The service needs a Quasi Error Free (QEF) link. Retransmission is allowed to ensure this; even at the cost of a longer delay. Being QEF is more important than latency, i.e. longer latency can be accepted to avoid errors.
Service coverage	The area covered by the service is assumed to be less than 1 000 m^2. Handover needs to be smooth, to introduce minimal service disruption.
Delay variation	Not only that the delay needs to be low, it also needs to be constant and predictable over the whole production time (hours to days). Figures for acceptable delay variation were not defined in [i.27]. Latency is to be synchronized to within 5 ms to 20 ms in order to allow video cuts within a frame boundary. A fixed, constant and predictable delay allows for a fixed correction buffer.
Accurate timing	Accurate timing is needed such that the involved devices can synchronize their clocks, facilitating synchronization of the multiple media streams. For that, the Precision Time Protocol is needed to be supported.

5.7 Industry Segment: Satellite-enhanced media delivery

5.7.1 Description

Broadcasters' content and services are delivered over dedicated broadcasting networks and over fixed or wireless broadband networks, using over-the-top models to reach audiences directly via their own apps or via aggregation platforms. This dual distribution strategy remains challenging in terms of costs, complexity and keeping up with technological developments. This clause considers satellite-enhanced video distribution consisting of 5G edge cloud/server/MEC hosts connected through a satellite backhaul.

Using satellite backhaul enables efficient delivery of popular content to end-users by extending media delivery service footprint. With a single transmission over satellite, different markets (i.e. use-cases) can be reached.

5.7.2 Use Case 7.1: "Direct-to-Home"

5.7.2.1 Description

The "Direct-to-Home (DTH)" [i.30] use case class relates to providing media content delivery services directly to end-users' houses. Both the edge gateway and satellite antenna are installed at home. The edge gateway (a Multicast Adaptive Bit Rate (MABR) gateway) receives data from satellite and makes it available to in-home IP client devices using the service applications. Unicast content is to be delivered via the broadband connection at home or via a satellite return channel if no broadband connection is available at home.

The edge gateway contains a local cache, e.g. a small RAM disk, for live streaming and mass storage (possibly in-home NAS) for VOD media and may contain a built-in Wi-Fi access point to allow the end-user devices to connect to it directly if no other local network is available. Most of the wireless routers and access points state they can support about 250 devices connected at once. Realistically, having more than 6 devices connected at once in an average household is highly unlikely.

5.7.2.2 Analysis

This use case assumes that network connections guarantee a certain QoS, and that the actual provided QoS can be monitored in real-time and possible violations are reported. The detailed information items to enable the use case are listed in table 5.7.2.2-1.

Table 5.7.2.2-1: Needed information to enable the use case

Information item	Description
Service throughput	50 Mbps (this would satisfy 6 people all streaming HD video simultaneously, representing the worst-case scenario, where all of them are accessing different content and none of that is already cached locally).
Service latency	The latency of the content delivered to the end user.
Service reliability	The ability of the communication service to achieve the service level requirements expressed as guaranteed service bit rate and service latency for a given time interval, under given conditions.
Service coverage	The region where the communication service is available, achieving some specific combination of service bitrate, latency and reliability.

5.7.3 Use Case 7.2: "Direct-to-Edge"

5.7.3.1 Description

The "Direct-to-Edge (DTE)" [i.30] use case class captures the scenario where the media content is delivered via a Multicast Adaptive Bit Rate gateway deployed at a location closer to the users compared with the point of content origin. Such locations are considered to be close to a 5G base station or a Micro Data Centre (for example, micro data centre can be a CDN point of presence).

Depending on the base station configuration, the content can be delivered to subscribers using the following methods:

- 5G NR Unicast, including possible support of 5G Media Streaming (ETSI TS 126 501 [i.34])
- 5G NR Multicast, supporting 5G Multicast Broadcast Services (ETSI TS 123 247 [i.35])
- 5G Broadcast, leveraging the LTE-based 5G terrestrial broadcast system (ETSI TS 103 720 V1.2.1 [i.36])

5.7.3.2 Analysis

This use case assumes that network connections guarantee a certain QoS, and that the actual provided QoS can be monitored in real-time and possible violations are reported. The detailed information items to enable the use case are listed in table 5.7.3.2-1.

Table 5.7.3.2-1: Needed information to enable the use case

Information item	Description
Service throughput	50 Mbit/s (service offer can be similar to "Direct-to-Home" and "Direct-to-Vehicle" use cases).
Service latency	The latency of the content delivered to the end user.
Service coverage	The region where the communication service is available, achieving some specific combination of service bitrate, latency and reliability.

5.7.4 Use Case 7.3: "Direct-to-Vehicle"

5.7.4.1 Description

The "Direct-to-Vehicle (DTV)" [i.30] use case class relates to providing media content delivery services (e.g. entertainment) in vehicles like cars, buses, ships, and planes. Other services could be added, e.g. traffic information, weather forecast, etc. The Far Edge is in many of these cases connected to the on-board entertainment systems that control the user interaction with the content via in-built terminals. Other connection models allow wireless connections to handhelds of the end-users in the vehicle. From an architecture point of view, this use case is similar to the "Direct-to-Home" use case (see clause 5.7.2).

5.7.4.2 Analysis

This use case assumes that network connections guarantee a certain QoS, and that the actual provided QoS can be monitored in real-time and possible violations are reported. The detailed information items to enable the use case are listed in table 5.7.4.2-1.

Table 5.7.4.2-1: Needed information to enable the use case

Information item	Description
Service throughput	50 Mbit/s. The throughput is indicative depending on the service offer provided to the end users in the vehicle. It is dimensioned considering the video streaming service is provided in HD quality.
Service latency	The latency of the content delivered to the end user.
Service reliability	The ability of the communication service to achieve the service level requirements expressed as guaranteed service bit rate and service latency for a given time interval, under given conditions.
Service coverage	The region where the communication service is available, achieving some specific combination of service bitrate, latency and reliability.
Location	The location of a UE (such as a car) in the service coverage area.

6 Analysis of the information needs

6.1 Overview

Clause 6 collects and analyses related information items from the use cases introduced in clause 5. Table 6.1-1 lists all identified information items and maps them to the different use cases. It is apparent that some information items are needed by a large number of use cases, whereas others are only applicable to some specific cases.

Table 6.1-1: Mapping of the information items to use cases

Information Item	1.1 V2N2X	1.2 LTA	1.3 TOD	2.1 Drones	3.1 Immersive cloud gaming	3.2 Immersive TOD	3.3 Local interaction/offloaded processing	4.1 Gaming	5.1 AGV	5.2 Closed loop control	6.1 Electronic news gathering	6.2 Professional TV production contribution	7.1 "Direct-to-Home"	7.2 "Direct-to-Edge"	7.3 "Direct-to-Vehicle"	Count
Service throughput	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	15
Service latency	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	15
Service reliability	X	X	X	-	X	X	X	X	X	X	-	X	X	-	X	12
Service coverage	X	-	X	X	X	X	X	-	-	X	X	X	X	X	X	12
Service capability	X	-	-	-	-	-	-	-	-	-	X	-	-	-	-	2
Service availability	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	1
Location	X	-	X	-	-	X	X	-	-	-	-	-	-	-	X	5
Delay variation	-	-	-	-	-	-	-	X	X	X	X	X	-	-	-	5
Accurate timing	-	-	-	-	-	-	-	-	-	-	X	X	-	-	-	2

6.2 Information item 1: Service throughput

6.2.1 Description

Service throughput indicates the data rate, also defined as bitrate, that is provided by the communication service. Most use cases distinguish between downlink bitrate (the bitrate in the channel from the network towards the receiving device) and uplink (the bitrate in the channel from the sending device towards the network). Use case 1.1 (V2N2X) differentiates between maximum and guaranteed throughput. Some use cases, such as use cases 1.3 (TOD), 6.1 (Electronic news gathering) and 6.2 (Professional production), have asymmetric throughput requirements (i.e. these differ between uplink and downlink). The satellite use cases refer to downlink throughput. Throughput requirements, if captured in the description of the listed use cases, differ between a few kbits per second (e.g. for control commands) and hundreds of Mbits per second for video and game content. Use case 2.1 (Safety drones) distinguishes between actual and predicted throughput. Support for electronic news gathering (use case 6.1) requires throughput information to be real-time.

Having access to actual and predicted throughput information allows the vertical applications to adapt to varying throughput situations and degrade gracefully.

Table 6.2.1-1: Collected descriptions of the "Service throughput" information item from all captured use cases

Description	Use case
The data rate provided by the communication service. In case of interaction with 3GPP networks according to clause 6.9 of ETSI TS 123 288 [i.4], this can be mapped to a specific value of the guaranteed flow bit rate GFBR, maximum flow bit rate or to radio access UE throughput.	1.1 V2N2X
Service throughput Includes the bitrate in the downlink and in the uplink.	1.2 LTA
The data rate provided by the communication service which is important for the persistence and quality of vehicle and TOD operator communication. 5GAA has defined these values as follows (see clause 6.6 in [i.18]): In the uplink, 32 Mbps are needed for video-only (assuming four streams), or 36 Mbps for video plus data. In the downlink, 400 Kbps are needed to transmit the steering commands.	1.3 TOD
This provides information about the actual and predicted throughput of the communication service provided by the 5G system. This information could be used for the purpose of a second line of defence, which allows the drones to adapt to varying throughput of connectivity.	2.1 Drones
The data rate essential for streaming high-quality video content and maintain the immersive visual experience for cloud gaming.	3.1 Immersive cloud gaming
The data rate essential for the quality and continuity of communication between the vehicle and the immersive TOD operator.	3.2 Immersive TOD
The data rate essential for streaming high-quality visual overlays and real-time data to the XR client.	3.3 Local interaction/offloaded processing
The data rate in downlink and uplink needed to download and upload gaming content from server and the player device.	4.1 Gaming
The available data rate for communication between the AGV and the MEC system. This ensures that the AGV receives accurate velocity commands and transmits pose data without any disruptions. As control commands are small, this is less critical.	5.1 AGV
The data rate needed by the closed-loop control system as described in figure 5.5.3.1-1 to send the measurements and adjusted control signals between the sensors and the actuators.	5.2 Closed loop control
The production crew monitors in real-time service throughput of the connectivity it has booked with a certain QoS and gets notified when there are issues. This allows them to re-configure the uplink codecs to adapt to network changes.	6.1 ENG
The throughput of the upstream communication link needs to be high (200 Mbit/s), as multiple video streams are to be transmitted to the production gallery, up to UHD 4K video at 50fps. Down-stream, the bitrate requirements are smaller (20 Mbit/s).	6.2 Professional production
50 Mbps (this would satisfy 6 people all streaming HD video simultaneously, representing the worst-case scenario, where all of them are accessing different content and none of that is already cached locally).	7.1 "Direct-to-Home"
50 Mbit/s (service offer can be similar to direct-to-home and direct-to-vehicle use cases).	7.2 "Direct-to-Edge"
50 Mbit/s. The throughput is indicative depending on the service offer provided to the end users in the vehicle. It is dimensioned considering the video streaming service is provided in HD quality.	7.3 "Direct-to-Vehicle"

6.2.2 Evaluation

Service throughput is listed by all use cases.

Therefore, it can be considered an information item of general interest and should be provided as part of a general, cross-verticals abstracted network information exposure API.

To support the whole range of use cases, aspects to consider include uplink and downlink, and to enable throughput prediction besides providing information about the actual throughput.

6.3 Information item 2: Service latency

6.3.1 Description

Service latency indicates the delay that is incurred. The captured use cases distinguish between different aspects of latency:

- uplink delay/latency (delay of traffic from the UE towards a defined endpoint within the network, e.g. the 5G UPF);
- downlink delay/latency (delay of traffic from a defined endpoint within the network, e.g. the 5G UPF, towards the UE);
- end-to-end or service-level delay/latency (delay between the service endpoints, i.e. the UE and the server);
- round-trip delay (delay between sending a service request and receiving the related service response).

Most use cases imply measured delay but use case 2.1 also explicitly indicates predicted delay. Even though delay is typically not constant, service latency indicates the average delay. The delay variation, also called delay jitter, is elaborated in clause 6.9.

Table 6.3.1-1: Collected descriptions of the "Service latency" information item from all captured use cases

Description	Use case
The delay characteristics of the communication service. In case of interaction with a 3GPP network, according to clause 6.9 of [i.4], this can be mapped to a specific value of the Packet Delay Budget (PDB).	1.1 V2N2X
Service latency includes the delay in the downlink towards the UE, and in the uplink from the UE.	1.2 LTA
Details the delay characteristics of the communication service which are important for real-time responses in TOD operations. 5GAA has defined these values as follows (see clause 6.5.2.1 in [i.18]): The service-level latency needs to be less than 100 ms in the uplink and less than 20 ms in the downlink.	1.3 TOD
This provides information about the end-to-end latency of the communication service provided by the 5G system. If predicted, it could help the drones to react accordingly.	2.1 Drones
Describes the delay characteristics of the communication service which are important for real-time responsiveness for seamless gaming experience.	3.1 Immersive cloud gaming
Describes the delay characteristics of the communication service important for immersive TOD operations which can include real-time responses and feedback.	3.2 Immersive TOD
The latency needed for real-time responsiveness, mixed and augmented reality.	3.3 Local interaction/offloaded processing
Service delay or round-trip time for a user's action represents the two-way latency between sending a gaming service request and receiving the corresponding response on the user's device.	4.1 Gaming
Represents the latency between the controller and the AGV. Can be represented as uplink latency (time for a message to travel from the AGV to the controller), downlink latency (time for a message to travel from the controller to the AGV) and round-trip time (time interval between the controller sending a message to the AGV and receiving the AGV's response). Low latency ensures real-time responsiveness and accuracy for AGV control; high and varying latency requires corrective measures. As per the use case explored in [i.22], a one-way delay of 50 ms was identified as the limit above which correction is needed.	5.1 AGV
Service latency is the end-to-end latency for the closed-loop control system as illustrated in figure 5.5.3.1-1. This latency should be < 10 ms for each cycle of the data exchanged between the sensors, controllers and the actuators for an effective closed-loop control mechanical for process automation in Industry 4.0.	5.2 Closed loop control
The production crew monitors in real-time service delay of the connections it has booked with a certain QoS and gets notified when there are issues.	6.1 ENG
The use case needs low delay communication, with the overall application E2E latency below 20 ms, and the E2E link latency below 6 ms.	6.2 Professional production
The latency of the content delivered to the end user.	7.1 "Direct-to-Home"
The latency of the content delivered to the end user.	7.2 "Direct-to-Edge"
The latency of the content delivered to the end user.	7.3 "Direct-to-Vehicle"

6.3.2 Evaluation

Service latency is listed by all use cases.

Therefore, it can be considered an information item of general interest and should be provided as part of a general, cross-verticals abstracted network information exposure API.

To support the whole range of use cases, aspects to consider include uplink and downlink delay, end-to-end delay, round-trip delay, and to enable delay prediction besides providing information about the actual delay.

6.4 Information item 3: Service reliability

6.4.1 Description

Service reliability is used in three main meanings, each in a number of use cases. First, it is used to denote the ability to meet the service level requirements in general (use cases 3.1, 3.2, 3.3). Second, more precisely, it is used to define the percentage of the time in which the service level requirements are met (use cases 1.1, 1,3, 5.1). Third, it is coupled with the percentage of failed transmissions, i.e. packet loss (use cases 1.2, 4.1, 5.1, 5.2). There is a link between the last and the first two meanings, as an upper bound to packet loss is typically one of the service level requirements.

Service level requirements typically denote a Quality of Service (QoS) level needed for the service, for instance in terms of Service Level Specifications that consist of Service Level Objectives [i.29] and are part of an Service Level Agreement (SLA).

Table 6.4.1-1: Collected descriptions of the "Service reliability" information item from all captured use cases

Description	Use case
The ability of the communication service to achieve the service level requirements expressed as guaranteed service bit rate and service latency for a given time interval, under given conditions. This information could range from 99,9 % for the vulnerable road user protection use case towards 99,999 % for the group start use-case.	1.1 V2N2X
Service reliability describes the robustness of packet transmission, such as packet loss.	1.2 LTA
Indicates the ability of the communication service to meet the defined service level requirements in a given time period. 5GAA has defined these values as follows (see clause 6.6 in [i.18]): In the uplink, 99 % are needed, whereas in the downlink (e.g. remote steering from remote driver to HV), the requirement is much higher at 99,999 %.	1.3 TOD
The ability to meet defined service level requirements for immersive competitive and fast-paced gaming.	3.1 Immersive cloud gaming
The ability to meet defined service level requirements to ensure strict control over the remote vehicle at all times.	3.2 Immersive TOD
The ability to meet the service level requirements for stable and uninterrupted augmented mixed reality experiences.	3.3 Local interaction/offloaded processing
The percentage of loss for the data packets during the streaming of the gaming content which can affect the reliability of the gaming service and the overall quality of real-time gaming experience.	4.1 Gaming
The percentage of time the radio network maintains the communication quality that is needed for AGV control. In this use case, this relates to the percentage of packets lost, leading to losing velocity commands towards the vehicle or losing position updates from the vehicle. Low reliability, i.e. high packet loss, can degrade AGV performance up to the AGV losing its trajectory.	5.1 AGV
The percentage of packet loss for the data packets during the exchange of the control signals and sensor data. This use case is very sensitive to packet loss (target packet loss = 0 %)	5.2 Closed loop control
The service needs a Quasi Error Free (QEF) link. Retransmission is allowed to ensure this; even at the cost of a longer delay. Being QEF is more important than latency, i.e. longer latency can be accepted to avoid errors.	6.2 Professional production
The ability of the communication service to achieve the service level requirements expressed as guaranteed service bit rate and service latency for a given time interval, under given conditions.	7.1 "Direct-to-Home"

Description	Use case
The ability of the communication service to achieve the service level requirements expressed as guaranteed service bit rate and service latency for a given time interval, under given conditions.	7.3 "Direct-to-Vehicle"

6.4.2 Evaluation

Service reliability is listed by the majority of the use cases.

Therefore, it can be considered an information item of general interest and should be provided as part of a general, cross-verticals abstracted network information exposure API.

To support the whole range of use cases, aspects to consider are the percentage of time during which the service level requirements/service level objectives are met, as well as the reliability of the packet transmission itself, i.e. packet loss, which can be one of the service level requirements.

6.5 Information item 4: Service coverage

6.5.1 Description

Service coverage is usually tied to a certain quality of service, or, for one use case (6.2), to certain service capabilities, being available within a particular geographical reference. Regarding the type of the geographic reference, use cases 1.1, 2.1 and 5.2 refer to an area; use case 6.1 refers to a location, use case 1.3 refers to a trajectory (polyline), and use cases 3.1, 3.2, 3.3, 6.2, 7.1, 7.2 and 7.3 do not make a statement on the type of the geographic reference. Additionally, two use cases (5.2 and 6.2) provide information on the expected size of the service area.

Table 6.5.1-1: Collected descriptions of the "Service coverage" information item from all captured use cases

Description	Use case
The region where the communication service is available, achieving some specific combination of service bitrate, latency and reliability. The service coverage information may be expressed as service range information in the specific region.	1.1 V2N2X
The communication service has to cover the whole trajectory of a planned tele-operated drive, meeting the specified quality parameters.	1.3 TOD
5G system provides e2e communication service for drones. The service area is the area where the service is available with certain minimum QoS levels. This information could be used in part to generate the so-called coverage maps to optimize the flight planning.	2.1 Drones
Indicates the geographical coverage to meet specific quality parameters for mobile immersive cloud gaming.	3.1 Immersive cloud gaming
The geographical coverage for the communication service to meet specific quality parameters necessary for immersive TOD.	3.2 Immersive TOD
The geographical coverage to meet specific quality parameters for augmented and mixed reality.	3.3 Local interaction/offloaded processing
The geographical area of coverage for the control loop system as described in table A.2.3.1-1 in [i.25] is typically $\leq 100\ m$ (length) × $100\ m$ (width)× $50\ m$ (height).	5.2 Closed loop control
The production crew can book certain network capabilities per location.	6.1 ENG
The area covered by the service is assumed to be less than 1 000 m^2. Handover needs to be smooth, to introduce minimal service disruption.	6.2 Professional production
The region where the communication service is available, achieving some specific combination of service bitrate, latency and reliability.	7.1 "Direct-to-Home"
The region where the communication service is available, achieving some specific combination of service bitrate, latency and reliability.	7.2 "Direct-to-Edge"
The region where the communication service is available, achieving some specific combination of service bitrate, latency and reliability.	7.3 "Direct-to-Vehicle"

6.5.2 Evaluation

Service coverage is listed by the majority of the use cases. Therefore, it can be considered an information item of general interest. The handling of service coverage is however not trivial. Two approaches are possible:

1) Service coverage is a network planning parameter, and the network is planned such that a certain minimum quality of service is achieved throughout a projected area of coverage. Based on this, the coverage can be made part of a service contract, or service ordering would allow specifying a service area, and the service order would be refused if the service cannot be provided throughout the area specified. Such, there is no need to expose coverage information, but also no possibility for an application to react, apart from trial and error.

2) Service coverage is known or can be predicted in a particular area, but typically, the needed service quality cannot be met in certain parts of the needed service area all of the time, and the use case foresees adaptation to such situation, for instance through route planning. To support such cases, exposure of certain kinds of service coverage information via a network information exposure API would be needed. However, network operators want to impose control about such coverage information to prevent its use for unauthorized purposes.

Approach (1) is taken currently by most networks.

Approach (2) is favourable for adaptive applications that can react to coverage gaps. Requirements to support one such use case, unmanned aerial systems, are provided in clause 6.2 of ETSI TS 122 125 [i.14]. Specifically, requirements are defined for exposing information about whether the service can be provided at a certain QoS in a certain area and/or at a certain time. A similar requirement is defined for predicting such information. To prevent abuse, the provision of such information controlled by operator policy. 5GAA has focused on the need for predictive QoS in [i.6]. ETSI MEC has also provided means for accessing service coverage information as part of ETSI GS MEC 030 [i.32].

As most of the use cases relate service coverage to QoS, the following analysis focuses on this relationship, and on the mobility situation in which the service is used, with the goal of representing in which geographical location (point, trajectory, area) the needed QoS is available. Related to mobility, different use cases have different assumptions. Whereas in V2X, TOD and Drones use cases, wide area, high speed mobility along a trajectory is key, media production and industry use cases typically involve low-speed mobility in a confined, controllable area. For the gaming, AR-related and satellite-related use cases, mobility needs vary, depending on whether the user is interacting with the service from a stationary position, while walking around or while on board of a vehicle.

Existing standards are available for exposing service coverage information focusing on the related mobility situations, such as ETSI GS MEC 030 [i.32]. Such APIs provide service coverage information tailored to the needs of particular verticals.

As service coverage is referred to by the majority of the use cases, exposure of actual or predicted service coverage information can also be supported related to a service that allows to book connectivity with a certain QoS, or a as part of a service that exposes abstracted information on monitored or predicted service QoS. Because coverage information can be considered sensitive, careful analysis is needed, and the provision of the information needs to be guarded by operator policy.

As part of API design, elaborations are needed on:

1) how a geographic reference is specified to support the use cases, such as in terms of geographic coordinates, in terms of civic addresses, or in terms of administrative references such as district, street number etc.;

2) in which situations to expose service coverage information (related to QoS) as part of a general, cross-verticals abstracted network information exposure API;

3) in which situations to provide service coverage information in an API tailored to a particular vertical.

6.6 Information item 5: Service capability

6.6.1 Description

Service capability is an information item that is only connected to two use cases. In use case 1.1, service capability is tied to the support of certain quality of service levels. In use case 6.1, service capabilities refer to exposed network capabilities, and it is assumed that the set of supported capabilities is dynamic, and notifications are sent when that set changes.

Table 6.6.1-1: Collected description of the information item from all captured use cases

Information item	Description	Use case
Service capability	The possible quality of service in the service coverage area. A level of service is being defined as a combination of service bitrate, latency and reliability.	1.1 V2N2X
Service capability	The production crew queries the available network capabilities and gets notified if a capability becomes unavailable.	6.1 ENG

6.6.2 Evaluation

Service capability is tied to supported properties of certain services, or the actual set of services itself.

The set of supported QoS profiles would typically be related to a QoS ordering service, but also to the information items of service throughput, service delay and service reliability.

The set of available exposed network capabilities can be obtained from a service registry.

To summarize, the set of QoS profiles could be part of a service that allows ordering a certain QoS, but could also be provided as part of a network information exposure service to track whether the actually available connectivity fulfils a certain (requested) QoS profile. Information about the available exposed network capabilities and their changes is available already using service discovery services and related service change announcements, e.g. CAPIF (see ETSI TS 123 222 [i.28]), and does not have to be exposed as part of Abstracted Network Information exposure.

6.7 Information item 6: Service availability

6.7.1 Description

One use case in the area of Industry 4.0 requests information related to the availability of the service, which denotes the percentage of the time the service is usable.

Table 6.7.1-1: Collected descriptions of the "Service availability" information item from all captured use cases

Information item	Description	Use case
Service availability	Service availability refers to the percentage of time the network service is usable by the closed-loop control system, which includes sending the data to the controllers and sending the adjusted control signal to the actuators. As described in table A.2.3.1-1 in [i.25], the service availability is between 99,999 9 to 99,999 999 %.	5.2 Closed loop control

6.7.2 Evaluation

The capability to obtain service availability information is just requested by a single use case. However, the use case puts very high availability requirements that might need additional measures to make the overall network service so highly available. As this is a specific enterprise control use case, there might be even a specific private network set up for such use case.

Availability appears to be rather a KPI than information that is needed to make the application network-aware. In any case, such KPI could be provided, or a dedicated API for exposing availability information could be set up, as part of a specific private network deployment geared towards machine control.

Therefore, service availability is recommended to be left out of scope of a general, cross-verticals network information exposure API.

6.8 Information item 7: Location

6.8.1 Description

Information related to the location of a UE in the service area is requested in five use cases, sometimes with the additional consideration of the precision of the location information.

Table 6.8.1-1: Collected description of the information item "Location" from all captured use cases

Information item	Description	Use case
Location	The location of a UE (such as a car) in the service coverage area. This information could be used by the application layer as a trigger to assess V2N2X use cases deployment in the area.	1.1 V2N2X
Location	Determining the precise location of a vehicle is essential for the use case, but the precision requirements depend on the actual mode (e.g. whether the vehicle is driven based on sensor data or based on video streams). If the network determines the location, information about achieved precision can be part of the exposed network information.	1.3 TOD
Location	Determining the precise location of a vehicle is essential for the use case. If the network determines the location, information about achieved precision can be part of the exposed network information.	3.2 Immersive TOD
Location	Determining the precise location within the environment is essential for the use case. If the network determines the location, information about achieved precision can be part of the exposed network information.	3.3 Local interaction/offloaded processing
Location	The capability to determine the location of a UE (such as a car) in the service coverage area.	7.3 "Direct-to-Vehicle"

6.8.2 Evaluation

The information that is actually exposed by this information item is the location of the UE. Three of the five cases additionally require the location to be "precise", which implies that also the precision of the location information can be an information item of interest.

Location services and related APIs exist already, for example [i.33]. It is suggested that these existing APIs are used to fulfil the use cases, instead of adding location and location precision as information items to a potential general, cross-verticals abstracted network information exposure API.

6.9 Information item 8: Delay variation

6.9.1 Description

Delay variation, also known as delay jitter, measures statistically how much the service latency (see clause 6.3) fluctuates over time. It is mentioned in five use cases, related to gaming, industrial control and professional media production.

Table 6.9.1-1: Collected descriptions of the "Delay variation" information item from all captured use cases

Description	Use case
The variation in packet arrival time during transmission which is to be minimized to prevent inconsistencies in the game and ensure smooth and anticipated gaming experience.	4.1 Gaming
The variation in packet arrival times during transmission that can affect the consistency of data transmission and real-time AGV control. High delay variation makes delay prediction and compensation less effective.	5.1 AGV
The variation in packet arrival times from sensors and controllers. To prevent inconsistencies in the closed control loop mechanism, it is usually not larger than 10 % of the target transfer interval which is < 1 ms.	5.2 Closed loop control
In video production, delays are compensated by buffers. The presence of delay variation necessitates larger buffers to prevent buffer underrun, leading to longer buffering times and making precise cuts more difficult or impossible. Therefore, this use case demands the delay to be ideally constant, that means delay variation to be close to zero.	6.1 ENG
Not only that the delay needs to be low, it also needs to be constant and predictable over the whole production time (hours to days). Figures for acceptable delay variation were not defined in [i.27]. Latency is to be synchronized to within 5 ms to 20 ms in order to allow video cuts within a frame boundary. A fixed, constant and predictable delay allows for a fixed correction buffer.	6.2 Professional production

6.9.2 Evaluation

Delay variation is unwanted in many use cases but appears in packet-based networks for different reasons. The goal is to keep it small, to mitigate its negative impacts:

- In gaming, it affects lag and cross-player delay differences.
- In control, it can lead to oscillations as it adversely affects the prediction and compensation of delays.
- In media production, it increases buffering times and therefore, end-to-end media delay. It can furthermore make frame-accurate cuts difficult or prevent them.

The measurement of "delay variation" typically represents the value of the deviation from the mean delay, i.e. a statistical measure. ETSI TS 122 261 [i.37], which defines the requirements for the 5G system, mentions delay jitter as one example for QoS parameters to be monitored. Via the NEF, the 3GPP Core Network can optionally provide information about the Packet Delay Variation (in uplink, downlink or roundtrip) as part of the AsSessionWithQoS API defined in ETSI TS 129 122 [i.38], see clause 5.14.2.1.6. However, as the AsSessionWithQoS API is very complex, abstraction of the information is needed.

However, it depends on the application area whether delay variation will be processed by the vertical application. As an example, ETSI TS 122 104 [i.25] takes a different approach. That document analyses communication requirements for cyber-physical applications and states that jitter is a measurement to represent the actual "scatter" of the delay, i.e. it represents the observed value of the deviation. In cyber-physical applications, predictable delays are crucial and therefore, ETSI TS 122 104 [i.25] introduces the concept of "timeliness" that allows to define the requirements a network service has related to the value of "time". Earliness and lateness are introduced as boundaries; outside these bounds, the time is assumed to be "invalid", e.g. meaning that a packet with a particular assumed delivery time is treated as "lost". Based on that approach, earliness and lateness are used instead of delay jitter, and measures are defined to react to "unacceptable deviation from target E2E latency" i.e. the time lies outside of the earliness or lateness boundary.

As delay variation is referenced by multiple use cases across verticals, and is optionally available in the network, it is suggested to provide, based on the capabilities of the underlying network, delay variation information as an option in a general, cross-verticals abstracted network information exposure API. Delay variation is always tied to the "service latency" information item and cannot exist on its own. Consequently, delay variation has the same scope as the related service latency information, i.e. it is related to uplink, downlink, round-trip or end-to-end delay, and is, like the delay value itself, either measured or predicted.

In vertical-specific APIs, such as for industrial control, also other information items dealing with the variation of service delay can be provided, such as earliness and lateness figures. However, such APIs are outside the scope of the present document.

6.10 Information item 9: Accurate timing

6.10.1 Description

Within the scope of the present document, accurate timing is needed by two use cases in professional media production to support the synchronization of multiple media streams.

Table 6.10.1-1: Collected description of the "Accurate timing" information item from all captured use cases

Description	Use case
In media use cases, synchronization of several media streams is necessary. For that purpose, accurate timing is needed.	6.1 ENG
Accurate timing is needed such that the involved devices can synchronize their clocks, facilitating synchronization of the multiple media streams. For that, the Precision Time Protocol is needed to be supported.	6.2 Professional production

6.10.2 Evaluation

Typically, this accurate timing information is not provided by an API using common API design styles and technologies such as REST/HTTP/JSON, but a dedicated protocol is used, such as the one mentioned in use case 6.2, to cater for the specific properties of timing and time synchronization.

Because this information item is only needed by a small set of use cases and a protocol already exists, this is recommended to be left out of scope of a general, cross-verticals abstracted network information exposure API.

7 Recommendations and conclusions

The present document has explored use cases where vertical applications can benefit from the exposure of abstracted network information, assuming that such information would be valuable across multiple vertical industries.

A number of information items were identified and analysed in the context of these use cases in clause 5. Further, the needs of the different use cases with respect to each of the information items were compared in clause 6.

Based on these comparisons, this clause summarizes the recommendations as conclusions of the study.

The following information items have been found to be of general applicability and are suggested to be considered as part of a general, cross-verticals abstracted network information exposure API:

- Service throughput
- Service latency
- Service reliability

For the following information item, case-by-case elaborations are needed, and it is suggested to be considered as part of a general, cross-verticals abstracted network information exposure API conditionally:

- Service coverage

In contrast, the following information items are specific to a small number of use cases, and can therefore be considered in the context of vertical-specific APIs, rather than a general, cross verticals abstracted network information exposure API:

- Service capability
- Service availability

For the following information items, dedicated APIs exist already:

- Location
- Accurate timing

For an abstracted network information exposure API for vertical industries, for each information item, table 7-1 summarizes the aspects which are recommended to be considered.

Table 7-1: Recommendations for individual information items to be exposed by an Abstracted Network Information API for Vertical Industries

Information item	Recommendations
Service throughput	Provide uplink and downlink throughput information. Provide measured values, but also predictions.
Service latency	Provide uplink and downlink latency information between defined service end-points, such as UE and server or UE and base station. Provide round-trip delay information between sending a request and receiving a response. Provide measured values, but also predictions. Latency is represented as a delay value (length of a time interval). Optionally, provide statistical information on the variation of the delay value in addition, if the related information is available in the underlying network.
Service reliability	Provide information on the reliability of packet transmission (also known as packet loss). Provide information on the reliability of service quality (probability that the QoS requirements are met). Provide measured values, but also predictions.
Service coverage	Conditionally provide a geographic reference in which the service can be used at the needed QoS level. The geographic reference can represent a location (e.g. coordinates or civic address), a trajectory or an area. The information can be sensitive, and therefore, careful analysis of the situations in which to expose it, and application of operator policy are needed as a condition.

For the communication patterns involved, both request/response patterns (query the information) as well as subscribe/notify (subscribe to notifications related to defined changes of these values, such as threshold crossing, or request periodic delivery of the value) can be foreseen.

Also, assuming a service with dedicated QoS such as a network slice or a session with Quality on Demand, the violation of QoS requirements could also be notified.

Annex A:
Change history

Date	Version	Information about changes
August 2021	V 3.0.1	Initial skeleton proposal for the study
September 2021	V 3.0.2	Incorporates MEC(21)000473
November 2022	V 3.0.3	Incorporates MEC(22)000462R4 but missed to update the Change History annex
November 2022	V 3.0.4	Updates the Change History annex
September 2023	V 3.0.5	Incorporates MEC(23)000294r2
September 2023	V 3.0.6	Incorporates MEC(23)000244r3
October 2023	V 3.0.7	Incorporates MEC(23)000399r2 and MEC(23)000419r1. Also, minor editorials (such as using straight quotes and applying styles).
December 2023	V 3.0.8	Incorporates MEC(23)000443 and MEC(23)000420r3. Also, minor editorials (character styles, removal of active hyperlinks, transforming links in references to NOTEs in line with EDR, removing rapporteur's note, partially re-ordering references to keep related references together)
February 2024	V 4.0.0	Contributions included: MEC(24)000002r2_MEC043_Drone_Industry_Segment MEC(24)000003r4_MEC043_Use_case_-_Safety_Drones MEC(24)000004_MEC043_Fixing_the_structure_of_the_use_case_template MEC(24)000054r1_MEC043_GS_name_and_scope_update Editorials: Change of year
April 2024	V 4.0.1	Contributions included: MEC(24)000106r1_MEC043_Applying_the_new_UC_template MEC(24)000103r4_MEC043_UC_on_Cross-Traffic_Left-Turn_Assist__LTA (reference i.z as it is referenced no-where) MEC(24)000155_MEC043_editorial_refs_update Editorial: Wrong use of reference i.1 corrected and replaced it by i.11; fixes to punctuation, fixed wrong use of colour
September 2024	V 4.0.2	Contributions included: MEC(24)000318r3_MEC043_UC_on_Tele-operated_driving__TOD MEC(24)000331r1_MEC043_UC_on_Immersive_Technologies MEC(24)000358r4_MEC043_UC_on_Integrated_Gaming_Experience Editorials/rapporteur's non-technical changes: Missing table headings added Hyperlinks embedded Minor formatting Removed unused references Made reference to tables 5.1.3.2-1 and 5.4.1.2-1 explicit
October 2024	V 4.0.3	Contributions included: MEC(24)000335r2_MEC043_Address_EN_in_UC1_2_-_Cross-Traffic_Left-Turn_Assist MEC(24)000414r1_MEC043_UC_on_AGV MEC(24)000431_MEC043_update_3GPP_references
December 2024	V 4.0.4	Contributions included: MEC(24)000479r1_MEC043_UC_on_Automation MEC(24)000487r3_MEC043_Media_industry_segment MEC(24)000488r1_MEC043_UC_on_Electronic_news_gathering Editorials: Fixed wrong reference i.x
February 2025	V 4.0.5	Contributions included: MEC(25)000022r1_MEC043_editorials MEC(25)000023r1_MEC043_alignment_of_tables Editorials: Font size and paragraph formatting fixes
March 2025	V 4.0.6	Contributions included: MEC(25)000083_MEC043_Clause_6_Overall_Analysis MEC(25)000084r1_MEC043_Clause_6_Service_throughput MEC(25)000085r1_MEC043_Clause_6_Service_latency MEC(25)000086r1_MEC043_Clause_6_Service_reliability MEC(25)000088r1_MEC043_Clause_6_Service_capability MEC(25)000093r1_MEC043_Structural_updates_from_rapporteur MEC(25)000094r1_MEC043_Media_production_use_case_from_3GPP_22_827

Date	Version	Information about changes
March 2025	V 4.0.7	Contributions included: MEC(25)000105r3_MEC043_Industry_segment_on_satellite_enhanced_media_delivery Editorials: For use case 6.2, fixed the clause numbering and added a reference to the table Fixed hanging paragraphs in clauses 5.5 and 5.6
April 2025	V 4.0.8	Editorials: Created a new packaged version of the present document as the uploaded package of V 4.0.7 was broken. No technical change
April 2025	V 4.0.9	Contributions included: MEC(25)000127r2_MEC043_Adding_new_UCs_to_evaluation_clause MEC(25)000144_MEC043_Abbreviations
April 2025	V 4.0.10	Contributions included: MEC(25)000087r4_MEC043_Clause_6_Service_coverage MEC(25)000089r1_MEC043_Clause_6_Service_availability MEC(25)000090r2_MEC043_Clause_6_Positioning-related_information MEC(25)000091r1_MEC043_Clause_6_Delay_variance MEC(25)000092r2_MEC043_Clause_6_Network_timing MEC(25)000169r1_MEC043_editorial_cleanup MEC(25)000171r1_MEC043_ENs MEC(25)000172r1_MEC043_Clause_7 MEC(25)000199_MEC043_171r1_followup MEC(25)000203_MEC043_Industry_segment_on_satellite_enhanced_media_delivery Editorials: Aligned order of contributions in change history
May 2025	V 4.0.11	Contributions included: MEC(25)000198_MEC043_clean_up_magic_ETSI_words Editorials: Fixed clause numbering
May 2025	V 4.0.12	Stable Draft created based on version 4.0.11 cleaned up by editHelp!
May 2025	V 4.0.13	Contributions included: MEC(25)000197_MEC043_Address_comment_on_scope_of_the_service MEC(25)000200_MEC043_clean_up_evaluation_structure MEC(25)000201_MEC043_Clause_7_address_EN_on_Service_coverage MEC(25)000221_MEC043_latency_sentence_fix MEC(25)000222_MEC043_positioning_clean-up
June 2025	V 4.0.14	Contributions included: MEC(25)000173r1_MEC043_Resolve_ENs_related_to_delay_jitter MEC(25)000220r1_MEC043_clause_7_ENs_delay_variance MEC(25)000279_MEC043_deleting_one_remaining_EN MEC(25)000234r2_MEC043_Addressing_EN_in_5_1_2 Editorials: Aligning the captions of tables 6.x.1-1
July 2025	V 4.0.15	Contributions included to address review comments #1 and #2: MEC(25)000291r1_MEC043_Final_review_-_editorial_clean-up MEC(25)000290_MEC043_Final_review_-_scope_fix Editorials: Fixed the way [i.27] is referenced to address review comment #3

History

Version	Date	Status
V4.1.1	August 2025	Publication