3GPP TR 22.891 V14.2.0 (2016-09)

Technical Report

3rd Generation Partnership Project;
Technical Specification Group Services and System Aspects;
Feasibility Study on New Services and Markets Technology Enablers;
Stage 1
(Release 14)

Keywords

Fifth, Generation

3GPP

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Contents

Foreword

This Technical Report has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

Version x.y.z

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y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.

z the third digit is incremented when editorial only changes have been incorporated in the document.

1. Scope

The present document aims to identify the market segments and verticals whose needs 3GPP should focus on meeting, and to identify groups of related use cases and requirements that the 3GPP eco-system would need to support in the future. This is a very broad and wide-ranging endeavour. As a result, the work will be organised so that a subset of distinct work/study items with clearly focussed objectives are executed in each stage of the work.

This study will develop several use cases covering various scenarios and identify the related high-level potential requirements which can be derived from them. It will identify and group together use cases with common characteristics and propose a few, e.g. 3-4, use cases (or groups of use cases with common characteristics) for further development in the next stage of the work.

Analysis will also be made on which legacy services and requirements from the existing 3GPP systems need to be included, if fallback mechanisms to them need to be developed, or if fallback is not necessary.

The focus of this work is on the use cases and requirements that cannot be met with EPS. Use cases identified as applicable for EPS are outside the scope of this study and are expected to be progressed independently of it.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[2] NGMN 5G White Paper v1.0

[3] China IMT2020 (5G) Promotion Group white paper "5G Vision and Requirements" May 2014.

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[25] Summary of Deliverable 1.5: Updated scenarios, requirements and KPIs for 5G mobile and wireless system with recommendations for future investigations, May 2015, https://www.metis2020.com/wp-content/uploads/deliverables/METIS_D1.5_Summary.pdf

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[27] Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update 2014-2019 White Paper, Table 6 (http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/white_paper_c11-520862.html)

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[31] 3GPP TR 22.862, "Feasibility Study on New Services and Markets Technology Enablers - Critical Communications; Stage 1"

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3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in 3GPP TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in 3GPP TR 21.905 [1].

Communication efficiency: refers to spectrum efficiency (bits/s/Hz) and/or energy efficiency (bits/J, or vs. LTE) and/or network resource efficiency ([TBD])

Connection density (UEs/km^2): number of UEs connected to the <5G network> over a given area.

End-to-end latency (ms): time it takes to transfer a given piece of information from a source to a destination, measured at the application level, from the moment it is transmitted by the source to the moment it is received at the destination.

Mobility (km/h): Absolute speed of a UE.

Peak data rate (bps): ideal data rate at the radio layer i.e. under ideal radio conditions. Direction (downlink, uplink) to be defined.

Processing time (ms): time it takes to process a given piece of data in a given node, for further action. The node needs to be defined.

Radio Interface Technology (RIT): Type of technology used for radio communication between two or more devices, without limitation to the functional capability or the purpose of the communication. A RIT may be used to provide a traditional access function, a backhaul function, a direct device-to-device (D2D) function between peers, or multiple such functions. A RIT may also support a variety of different communication modes (e.g., unicast, multicast, broadcast) and/or topologies (e.g., point-to-point, star, tree, or mesh).

Reliability (%): the amount of sent network layer packets successfully delivered to a given node within the time constraint required by the targeted service, divided by the total number of sent network layer packets.

Round-trip-time (ms): time it takes to transfer a given piece of data between two nodes, to process the piece of data at the receiving node, and to transfer an acknowledgement status back to the transmitting node, measured from the moment the piece of data is transmitted to the moment the acknowledgement status is received. This does not assume correct reception of either the piece of data or the acknowledgement status. (I.e. it is the sum of transmission delay from the transmitting node to the receiving node, processing time at the receiving node, and transmission delay from the receiving node to the transmitting node). Nodes need to be defined.

Transmission delay (ms): time it takes to transfer a given piece of data between two nodes, measured from the moment it is transmitted to the moment it is received. This does not assume correct reception. Nodes need to be defined.

Traffic density (bps/km^2): total traffic over a given area. Direction (downlink, uplink) to be defined when applicable.

User experienced data rate (bps): data rate averaged over a given duration (to be defined), in a given direction (uplink or downlink), measured at the transport layer or above. Direction (downlink, uplink) to be defined.

3.2 Abbreviations

For the purposes of the present document, the abbreviations given in 3GPP TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in 3GPP TR 21.905 [1].

<ACRONYM> <Explanation>

4 Overview

The proposed use cases can be largely classified into five categories as below.

1) Enhanced Mobile Broadband
   - e.g. Mobile Broadband, UHD / Hologram, High-mobility, Virtual Presence
2) Critical Communications
   - e.g. Interactive Game / Sports, Industrial Control, Drone / Robot / Vehicle, Emergency
3) Massive Machine Type Communications
   - e.g. Subway / Stadium Service, eHealth, Wearables, Inventory Control
4) Network Operation
   - e.g. Network Slicing, Routing, Migration and Interworking, Energy Saving
5) Enhancement of Vehicle-to-Everything
   - e.g. Autonomous Driving, safety and non-safety aspects associated with vehicle

Conceptual diagrams depicting these FS_SMARTER service dimensions appear below. Each of the 5 axes represents the directions of service improvements that FS_SMARTER is proposing.

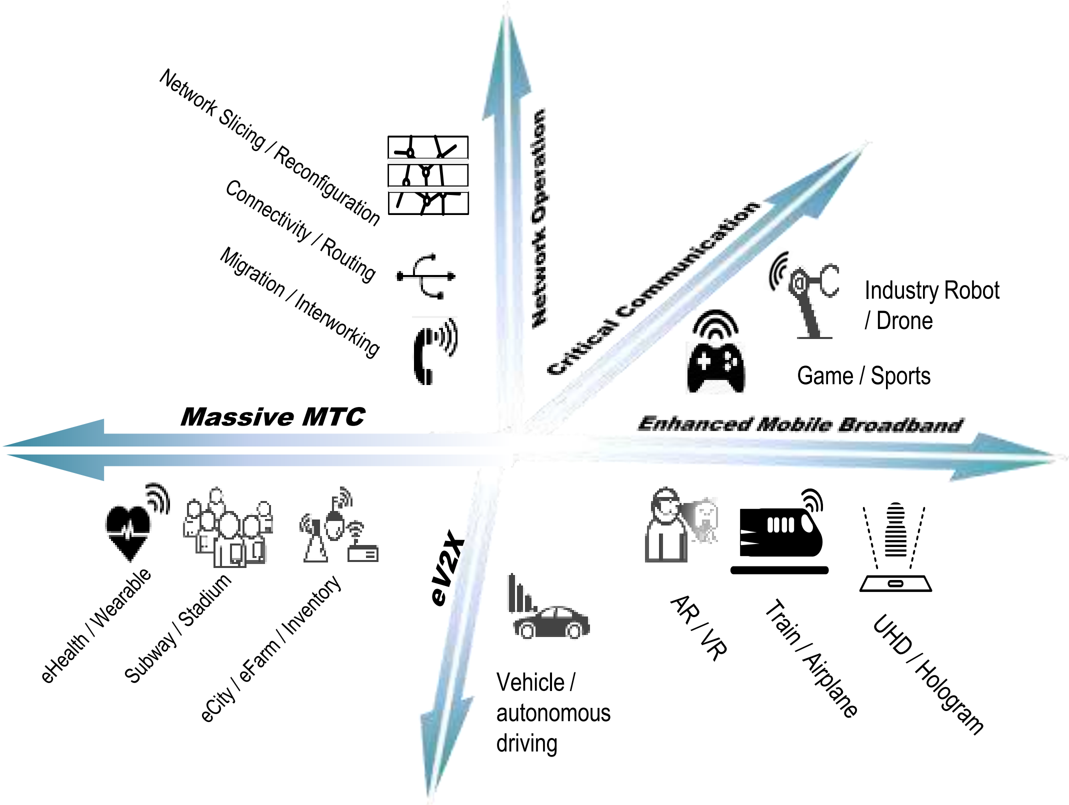

Figure 4-1: FS_SMARTER service dimension

5 Use Cases

5.1 Ultra-reliable communications

5.1.1 Description

In order to enable certain services related to ultra-highly reliable communications, a minimal level of reliability and latency is required to guarantee the user experience and/or enable the service initially. This is especially important in areas like eHealth or for critical infrastructure communications.

Mission critical communication services require preferential handling compared to normal telecommunication services, e.g. in support of police or fire brigade.

Examples of mission critical services include:

- Industrial control systems (from sensor to actuator, very low latency for some applications)
- Mobile Health Care, remote monitoring, diagnosis and treatment (high rates and availability)
- Real time control of vehicles, road traffic, accident prevention (location, vector, context, low Round Trip Time RTT)
- Wide area monitoring and control systems for smart grids
- Communication of critical information with preferential handling for public safety scenarios
- Multimedia Priority Service (MPS) providing priority communications to authorized users for national security and emergency preparedness

Overall, mission critical services are expected to require significant improvements in end-to-end latency, ubiquity, security, robustness, and availability/reliability compared to UMTS/LTE/WiFi.

Pre-conditions

The different substations of a power system are connected to operator A's network to provide automated measurements and automated fault detection to prevent large scale outage.

Service Flows

1. Substations connect to the operator A network
2. Operator A determines this is a mission critical device and configures the network based on the mission critical service requirements
3. Substations report periodic measurements with a given reliability and latency
4. In case of a fault or degraded operation – substation reports fault or degraded operation with a second reliability and latency
5. In the case of a power grid, the power system reacts and may shutdown or divert power from this substation or other substations in the vicinity

Post-conditions

The power system can optimize performance due to periodic measurements. A potential disaster is averted due to the substation reporting in time.

5.1.2 Potential Service Requirements

Services in this category require very low data error rate. Some of them also require very low latency, i.e. for industrial automation with 1ms delay.

5.1.3 Potential Operational Requirements

The 3GPP system shall support efficient multiplexing of mission critical traffic and nominal traffic.

The 3GPP system shall limit the duration of service interruption for mission critical traffic.

The 3GPP system shall support improved reliability and latency as defined in table 5.1-1.

Subject to regional regulatory requirements, the 3GPP system shall support a mechanism to provide end-to-end integrity and confidentiality protection for user data,

The 3GPP system shall provide significant improvements in end-to-end latency, ubiquity, security, and availability/reliability compared to UMTS/EPS/WiFi.

Table 5.1-1: Example mission critical use cases

Sample use case	Description	Critical Requirements
Substation protection and control	Automates fault detection and isolation to prevent large scale power outage For example, Merging Units (MUs) perform periodic measurements of power system components, and send sampled measurement data to a Protection Relay. When the Protection Relay detects a fault, it sends signals to trip circuit breakers.	Latency: as low as 1 ms end-to-end Packet loss rate: as low as 1e-04 Transmission frequency: 80 samples/cycle for protection applications. 256 samples/ cycle for quality analysis & recording Data rate: ~12.5Mbps per MU at 256 samples/cycle Range: provide coverage to the substation
Smart grid system with distributed sensors and management	A smart grid system aims at improving the efficiency of energy distribution and requires prompt reaction in reconfiguring the smart grid network in response to unforeseen events.	Performance requirements are derived from EC FP7 project METIS Deliverable D.1.1: - Throughput: from 200 to 1521 bytes reliably delivered in 8 ms, - One trip time latency between any two communicating points should be less than 8 ms for event-triggered message that may occur anytime. - Device density: dense urban hundreds of UEs per square km; urban: around 15 UEs per square km; populated rural: max 1 UE per squared km.
Public Safety	Operation of first responders in case of fire or other kind of emergency situation.	Public Safety requires preferential handling of its traffic.
Multimedia Priority Service (MPS)	Priority communications to authorized national security and emergency preparedness (NS/EP) users in times of disasters and emergency. Authorized NS/EP users have to rely on public network services when the communication capability of the serving network may be impaired, for example due to congestion or partial network infrastructure outages, perhaps due to a direct or indirect result of the emergency situation and therefore needs preferential handling and priority access to communication resources.	MPS requires preferential handling, and priority treatment.

5.2 Network Slicing

5.2.1 Description

With the new market segments and verticals, as described in the NGMN white paper [2], new diverse use cases will need to be supported by the 3GPP eco system. This needs to be done at the same time as continuing to support the traditional mobile broadband use cases. The new uses cases are expected to come with a high variety of requirements on the network. For example, there will be different requirements on functionality such as charging, policy control, security, mobility etc. Some use cases such as Mobile Broadband (MBB) may require e.g. application specific charging and policy control while other use cases can efficiently be handled with simpler charging or policies. The use cases will also have huge differences in performance requirements.

In order to handle the multitude of segments and verticals in a robust way, there is also a need to isolate the different segments from each other. For example, a scenario where a huge amount of electricity meters are misbehaving in the network should not negatively impact the MBB users or the health and safety applications. In addition, with new verticals supported by the 3GPP community, there will also be a need for independent management and orchestration of segments, as well as providing analytics and service exposure functionality that is tailored to each vertical's or segment's need. The isolation should not be restricted to isolate between different segments but also allow an operator to deploy multiple instances of the same network partition. Furthermore, to support network slices with mission critical services on the same infrastructure, it is required that the isolation can be provided with high assurance. It will enable the 5G system to confine service-specific security/assurance requirements to a single slice, rather than the whole network. Similarly, in the event of a potential cyber-attack, the attack will be confined to a single slice.

The figure below provides a high level illustration of the concept. A network slice is composed of a collection of logical network functions that supports the communication service requirements of particular use case(s). It shall be possible to direct terminals to selected slices in a way that fulfil operator or user needs, e.g. based on subscription or terminal type. The network slicing primarily targets a partition of the core network, but it is not excluded that RAN may need specific functionality to support multiple slices or even partitioning of resources for different network slices.

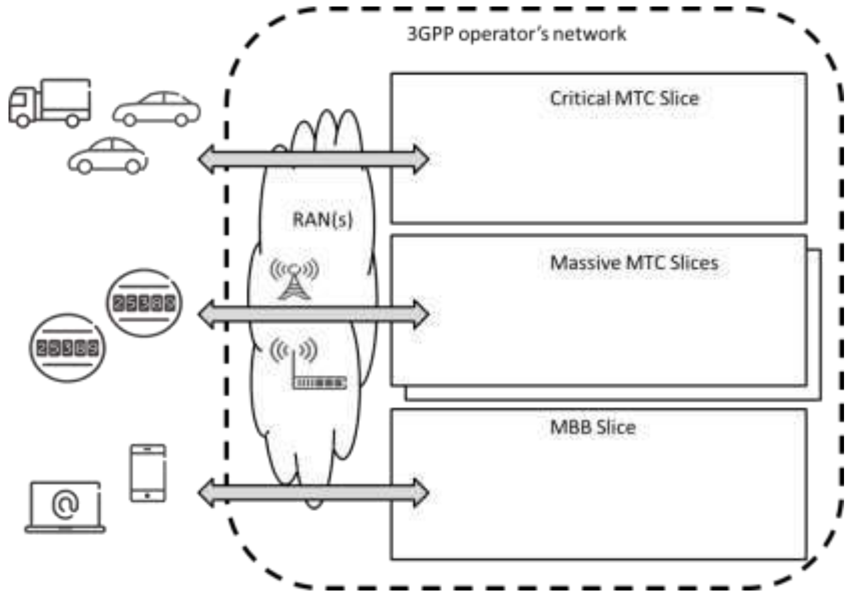

Figure 5.2-1: Network slices that cater for different use cases

This is referring to section 5.4 in the NGMN White Paper [2].

Examples of related use cases are given below:

- Self-automated car in a smart city: Bob starts his self-automated driving car that relies on V2X communication. While sitting in the car, Bob initiates a HD video streaming service through the infotainment system available in the car. In this example, the V2X communication requires a low-latency but not necessarily a high throughput, whereas, the HD video streaming requires a high throughput but is tolerate to the latency.

  Both services are assumed to be provided by the same operator.

- Healthcare robot: A robot that is monitored by the healthcare service provider takes care of elderly people at home. The robot sends a regular report of health status and the activities interacting between the robot and the elderly people to the healthcare operator. The robot also allows the elderly people to do any Internet like services (e.g., web-surfing, hearing streaming music, watching a video) or even making a call to their doctor directly in case of emergency.

Both services are assumed to be provided by the same operator.

5.2.2 Potential Service Requirements

The 3GPP System shall allow the operator to compose network slices, i.e. independent sets of network functions (e.g. potentially from different vendors) and parameter configurations, e.g. for hosting multiple enterprises or MVNOs etc.

The operator shall be able to dynamically create network slice to form a complete, autonomous and fully operational network customised to cater for different diverse market scenarios.

The 3GPP System shall be able to identify certain terminals and subscribers to be associated with a particular network slice.

The 3GPP System shall be able to enable a UE to obtain service from a specific network slice e.g. based on subscription or terminal type.

5.2.3 Potential Operational Requirements

The operator shall be able to create and manage network slices that fulfil required criteria for different market scenarios.

The operator shall be able to operate different network slices in parallel with isolation that e.g. prevents data communication in one slice to negatively impact services in other slices.

The 3GPP System shall have the capability to conform to service-specific security assurance requirements in a single network slice, rather than the whole network.

The 3GPP System shall have the capability to provide a level of isolation between network slices which confines a potential cyber-attack to a single network slice.

The operator shall be able to authorize third parties to create, manage a network slice configuration (e.g. scale slices) via suitable APIs, within the limits set by the network operator.

The 3GPP system shall support elasticity of network slice in term of capacity with no impact on the services of this slice or other slices.

The 3GPP system shall be able to change the slices with minimal impact on the ongoing subscriber's services served by other slices, i.e. new network slice addition, removal of existing network slice, or update of network slice functions or configuration.

The 3GPP System shall be able to support E2E (e.g. RAN, CN) resource management for a network slice.

5.3 Lifeline communications / natural disaster

5.3.1 Description

5G should be able to provide robust communications in case of natural disasters such as earthquakes, tsunamis, floods, hurricanes, etc. Several types of basic communications (e.g., voice, text messages) are needed by those in the disaster area. Survivors should also be able to signal their location/presence so that they can be found quickly. Efficient network and user terminal energy consumptions are critical in emergency cases. Several days of operation should be supported. (NGMN 5G White Paper, section 3.2.1, xi. Natural Disaster) [2]

5.3.2 Potential Service Requirements

Void.

5.3.3 Potential Operational Requirements

Based on operator's policy, the system shall be able to define minimal services necessary in case of disaster that are conditional on e.g. subscriber class (i.e. access class), communication class (i.e. emergency call or not), device type (i.e. Smart phone or IoT device), and application. Examples of those minimal services are communications from specific high priority users, emergency calls, and a disaster-message-board type of application that helps people reconnect with friends and loved ones in the aftermath of disasters.

Those minimal services shall be available in case of disaster.

During the recovery phase of disaster, the service continuity of those minimal services that start being provided should be ensured.

5.4 Migration of Services from earlier generations

5.4.1 Description

In addition to new services derived from the new use cases envisioned for the <5G system>, there exist already today a large number of services in the cellular networks of the current generations.

It is envisioned that some of these existing services could be deemed as required for support in a <5G System> while others are not. In the potential service requirements below services are listed and classified as being either required or not required for support in a <5G system>.

5.4.2 Potential Service Requirements

The <5G system> shall be able to support the following services defined in previous releases of EPS, e.g. to fulfil regulatory requirements:

IMS based Voice, Video and Messaging.

Location services

Public Warning System

Multimedia Priority Service (MPS)

…

Examples of services not required for support in a <5G system>:

CS voice service continuity and/or fallback to GSM or UMTS (i.e. seamless handover)

…

5.4.3 Potential Operational Requirements

The <5G system> shall be able to support the following operational requirement defined in previous releases of EPS:

RAN Sharing

5.5 Mobile broadband for indoor scenario

5.5.1 Descriptions of typical use case in office scenario

In an office scenario, the users and their serving nodes are expected to be deployed indoors. The coverage area per each serving node is small. Ideal backhaul infrastructure should be available and could be optimized.

Users frequently upload and download data from company's servers and they are various in size which could be up to terabit of data. Real-time video meeting within the campus and/or over the internet would be the normal work mode. The productivity is dependent on the efficiency of the system response time and reliability.

5.5.2 Potential Service Requirements

The 3GPP system shall support user experienced data rate up to Gbps of level.

The 3GPP system shall support user peak data rate at tens of Gbps;

The 3GPP system shall support the whole traffic volume in the area at least the level of Tbps/ km^2.

The 3GPP system shall support very low latency for user experienced data exchange.

5.5.3 Potential Operational Requirements

Void.

5.6 Mobile broadband for hotspots scenario

5.6.1 Description

In dense urban areas, users can be either indoor or outdoor. The coverage area is wider than the office scenario. Backhaul availability would be one of the key issues in this scenario, especially if the backhaul is wired. Self wireless backhaul can also be considered which allows flexible deployment of serving nodes and potentially reduces the complexity of the networks. Precise network planning would be difficult, considering the deployment concerns, backhaul capacity and scalability etc. Random or semi-random network planning should be considered.

Given it is a dense urban area, dependent on time of day (e.g. morning, evening, weekday vs. weekend etc.) and the location(e.g. shopping mall, downtown street), there could be high volume and high capacity multi-media traffic upload and download towards internet as well as D2D communications. The traffic volume per cell is very large.

Meanwhile when a user is indoors, it is either stationary or nomadic; however, when a user is outdoor it may travel slowly.

5.6.2 Potential Service Requirements

The 3GPP system shall support the user experienced data rate up to Gbps of level while the user is moving slowly.

The 3GPP system shall support the peak data rate at tens of Gbps while the user is moving slowly.

The 3GPP system shall support the whole traffic volume in the area at least the level of Tbps/ km^2.

5.6.3 Potential Operational Requirements

The 3GPP system shall support flexible and efficient backhaul especially outdoor.

5.7 On-demand Networking

5.7.1 Description

Generally, network areas with high UE density distribution varies with the time and the movement of vehicles or crowds. In these hot spots, network capabilities (e.g., high date rate and low latency) in ultra-high connection density should be provided by operators. On-demand networking should be provided by operators to meet the distribution variation. Use cases include moving areas with high UE density and HD video/photo sharing in stadium/open-air gathering use cases defined in the NGMN 5G white paper [2]. In the use case of HD video/photo sharing in stadium/open-air gathering, operators can get the event information in advance in order to provide the suitable network capability with high date rate and low latency. In moving hot spots, operators may have to analyse historical statistical and recent network data and to track the areas with high UE density in a short time, so as to provide network capabilities to hot spots on demand.

Here are two examples of on-demand networking.

> There is a football match in the Beijing National Stadium this afternoon. Near to ninety thousand audiences will come to watch the match. During the match, audiences may share HD live video with friends who are not at the scene, or post HD photos to the WeChat, a social APP. These applications will require a combination of ultra-high connection density, high date rate and low latency. Operators can provide the network on demand in the stadium area. When the match is over, all the audiences will return home. There is no need to provide high network capability. So the operator should change to very low network capability with the demand variation.

> While moving vehicles or crowds (e.g., moving mass events such as walking/cycling demos or a long red-cycle of a traffic light) will generate capacity variation (from almost stationary to bursty), the hot spots areas can be

tracked and operators can realize dynamic and real-time provision of capacity for these areas with a high density of UEs moving fast.

5.7.2 Potential Service Requirements

The 3GPP system shall provide guaranteed user experience for mobile broadband services like live video in areas with a high UE density which requires user experienced data downlink rate of 300Mbps and uplink rate of 50Mbps in 200-2500 /km^2 connection density.

The 3GPP system shall provide consistent users experience when terminals enter the areas with a high UE density which requires user experienced data downlink rate of 50Mbps and uplink rate of 25Mbps in 2000/km^2 connection density.

5.7.3 Potential Operational Requirements

The 3GPP system shall be able to adjust the network capacities dynamically based on the variation of demand and performance indicators.

5.8 Flexible application traffic routing

5.8.1 Description

As mentioned in China IMT2020 white paper “5G Vision and Requirements” [3], the further development of mobile internet will trigger the growth of mobile traffic by a magnitude of thousands in the future. The immersive services such as augmented reality, virtual reality, ultra-high-definition (UHD) 3D video have critical requirement on transfer bandwidth and delay between the terminals, and the future network shall be able to transfer these data traffic in a flexible and efficient manner.

Pre-conditions

The Service Provider X provides 3D Augmented Reality (AR) service for the users, one user can interact with other user via live 3D Augmented Reality service.

The Service Provider X has a service agreement with an MNO, and the MNO network may optimize the traffic transfer for the live 3D Augmented Reality service in order to realize good user experience.

Service Flows

1. The terminals of Bob and Alice connect to the network via wireless access system. Bob stays in the house, and Alice stays in one bus moving on the city road.

2. Bob connects to the server of Service Provider X and requests to contact with Alice via 3D Augmented Reality service. The server of Service Provider X sets up the connection between Bob’s and Alice’s terminal, and the Augmented Reality control signalling (the “CP” line marked red colour in figure 5.8-1) and the Augmented Reality application data (the “UP” line marked blue colour in figure 5.8-1) are both transferred via the MNO network and the server of Service Provider X.

3. During the communication, the bus that Alice is on keeps changing its location.

4. As a result of the change in location Alice’s terminal use a different base station to access the network. Upon changing base stations the previous user-plane path may become inefficient. To avoid this, the application traffic may be transported via an alternative, more efficient path between Bob’s and Alice’s terminal (the “UP” line marked in green colour in figure 5.8-1)

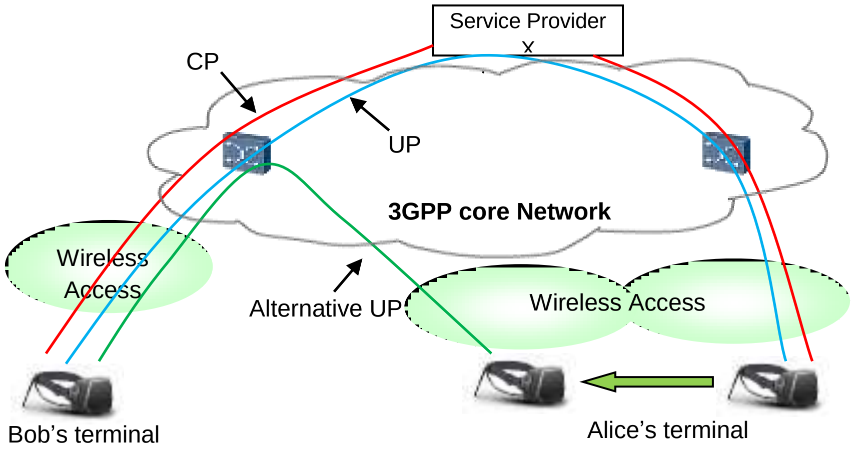

Figure 5.8-1: Application traffic routing after UE mobility

Post-conditions

Data packets are using efficient paths between the involved terminals.

5.8.2 Potential Service Requirements

Void.

5.8.3 Potential Operational Requirements

Subject to operator's policy and/or based on application needs, the 3GPP network shall support efficient user-plane paths between UEs attached to the same network, even if the UEs change their location during communication.

Subject to operator's policy and/or based on application needs, the 3GPP network shall support efficient user-plane paths between a UE attached to the mobile network and communication peers outside of the mobile network (e.g. Internet hosts).

5.9 Flexibility and scalability

5.9.1 Description

Since traffic varies depending on the time of the day and on the day of the week, network deployment decisions based on peak traffic cause waste of resources. In addition, traffic varies also depending on location. It is understood that traffic moves from a location to another in a way, while the total amount of traffic in a wider area is less changed. Therefore it is important that the system can flexibly scale with various levels of control and user-plane demand in order to avoid localized underutilization of resources [2].

Resiliency against congestion and disasters would be also much enhanced by that.

5.9.2 Potential Service Requirements

Void.

5.9.3 Potential Operational Requirements

The system shall be scalable to ensure that different levels of signalling and user plane demand can be handled.

The system shall support dynamic utilization of resources (compute, network and storage resources) in more than one geographic area in order to serve the differing needs of the users in each geographic area, subject to operator policy.

Using resources (compute, network and storage resources) in more than one geographic area by the system shall be supported without requiring manual re-configuration of neighbouring nodes, without service disruption, and while avoiding additional signalling due to unnecessary UE's re-attachments (e.g. due to loss of call state information in the network).

The system shall also support foreseen rapid increases in signalling and user plane demand with a lead time that can be as low as 5 minutes.

NOTE: The lead time of 5 minutes stems from the most severe and unplanned use case i.e. the disaster use case, where the average time until call attempts surge after a disaster occurs is considered 5 minutes.

5.10 Mobile broadband services with seamless wide-area coverage

5.10.1 Description

As a basic scenario of mobile communications, the seamless wide-area coverage scenario aims to provide seamless service to users. In future, mobile broadband services such as mobile cloud office, mobile cloud classroom, online games/videos, and augmented reality, etc. will become more and more popular and helpful. People hope mobile broadband services are provided wherever they go, for example, urban areas, rural areas, high-speed railways and fast ways between cities. That is to say, mobile broadband services are provided in seamless wide-area coverage [3] [4] [5].

Here is an example of this use case.

1. Jack works in an urban city, and today he travels on a business trip. He takes a taxi to the high-speed railway station, and spends 4 hours on the high-speed train. Meanwhile, some urgent work needs to be settled. He continues to work on the taxi and the train using his smart phone or laptop as if he was working in his office. Necessary relevant data (such as document, video, etc.) is obtained from the company's cloud storage server. He can communicate with his colleagues and share the work results with them conveniently and timely.

2. Getting off the train, he arrives at the destination which is in rural areas and meets his customers. He introduces a new product of his company to customers, and at the same time, a video conference by operators' network is held so that his colleagues who are still in their office can also get involved.

3. After the conference, Jack feels tired and goes to the company's guest room which locates beside the factory. It's the evening game time, by connecting to the operators' network; he plays online games with his friends.

4. On the return high-speed train, he watches the football match online that he missed last midnight using his smart phone.

In this case, Jack gets consistent user experience of mobile broadband services on his trip, including on the taxi, the high-speed train, and the rural areas with the assist of operator's network.

However, according to above steps 1 and 4, i.e., when Jack is on high speed train, besides the original requirements, the high speed moving scenario is also required to consider some other necessary issues as follows:

- A high speed moving train usually contains hundreds of passengers (e.g., 500 passengers in a train). Therefore, it may consider that at least hundreds of active UEs may access the internet for different services/applications in a high speed train. Thus, the system shall provide sufficient bandwidth for these active UEs simultaneously at least.

- Some users may use on-line gaming or other real-time applications/services for spending travelling time in the high speed moving train. Therefore, these kinds of applications/services still require stringent delay requirement (e.g., 10 ms E2E delay) such that users can have satisfaction with these applications/services.

5.10.2 Potential Service Requirements

For wide area coverage, the system shall support user experienced data rate for mobile broadband services anytime and anywhere, e.g., 100Mbps.

NOTE: The above requirement assumes reuse of an existing base station site grid.

The system shall support fast-moving end-users, e.g., 500km/h.

The system shall support high connection density for high speed scenarios, e.g., 500 active UEs simultaneously.

The system shall support low latency for high speed scenario.

5.10.3 Potential Operational Requirements

Void.

5.11 Virtual presence

5.11.1 Description

The goal is to provide interactive services for high data rate zones (e.g. Office environments) as described in section 3.2.1 of the NGMN 5G White Paper [2].

A use case can be:

Phil works in a multinational company which has offices in many big cities. He has regular meetings with colleagues based in other countries. He uses to have real time 360° video communications: he wears Virtual Presence glasses, allowing to be merged in a meeting room where he can see all his other colleagues sitting around a table. He can interact with them in real time as if they were just in front of him.

> Phil is alone in his office and wear special glasses. His office is equipped with cameras for transmitting his video to the network.
>
> Phil actives a communication with the virtual presence conference bridge in order to initiate a 360° video communication with all his colleagues.

Another use case can be:

Abigail recently had surgery and cannot attend her classes. Virtual Presence can give her real time 360° video communication with her classmates and teacher.

There is a trade-off between very low latency and modest bandwidth requirement vs. modest latency and high bandwidth requirement pending on where the composing of the virtual meeting stream is located.

5.11.2 Potential Service Requirements

The system shall provide high bandwidth (bidirectional) and low latency. In Office environments, this implies also a full indoor coverage.

The roundtrip delay shall be in the magnitude of 2-4 ms with a bandwidth capable of running an 8k stereo video stream [250Mbps] uplink and downlink.

NOTE: The above requirement is in a virtual presence scenario where composing the “virtual meeting room” is located in the network.

5.11.3 Potential Operational Requirements

Void.

5.12 Connectivity for drones

5.12.1 Description

The objective is to provide use cases concerning connection of drones.

Use cases can be:

Phil is a farm worker who has 55 hectares planted with sensitive cultures. He wants to survey, in real time, the fields and the state of the crops. He uses a drone and a remote control that are both connected to the mobile network. Due to low latency, Phil is able to control the drone and is also able to analyse, in real time, the video and infrared imaging of the fields that are streamed from the cameras and sensors. This provides all necessary information for decision making on irrigation, fertilizer and pesticide distribution

Jack works for a TV station as a cameraman. He uses a drone to live broadcast outdoor events like marathon, F1 auto racing. High quality live video (e.g. Full HD, 4K) is transmitted from the flying drone to the TV station via the mobile network.

In many scenarios, the drone flies in low altitude. The drone needs to maintain continuous connection with the mobile network which requires the network supports continuous wireless coverage in low altitude flight scenarios.

A drone and remote control are connected to the mobile network.

The drone is piloted with remote mode, data being transmitted via the network

The drone transmits video and with other data, such as infrared pictures.

Extreme Real-Time Communications are addressed in the NGMN 5G white paper [2].

Figure 5.12-1 depicts how communication will occur, in this use case communication occurs through the mobile network (WAN). Communication does not occur node to node or through a wireless controller (LAN)

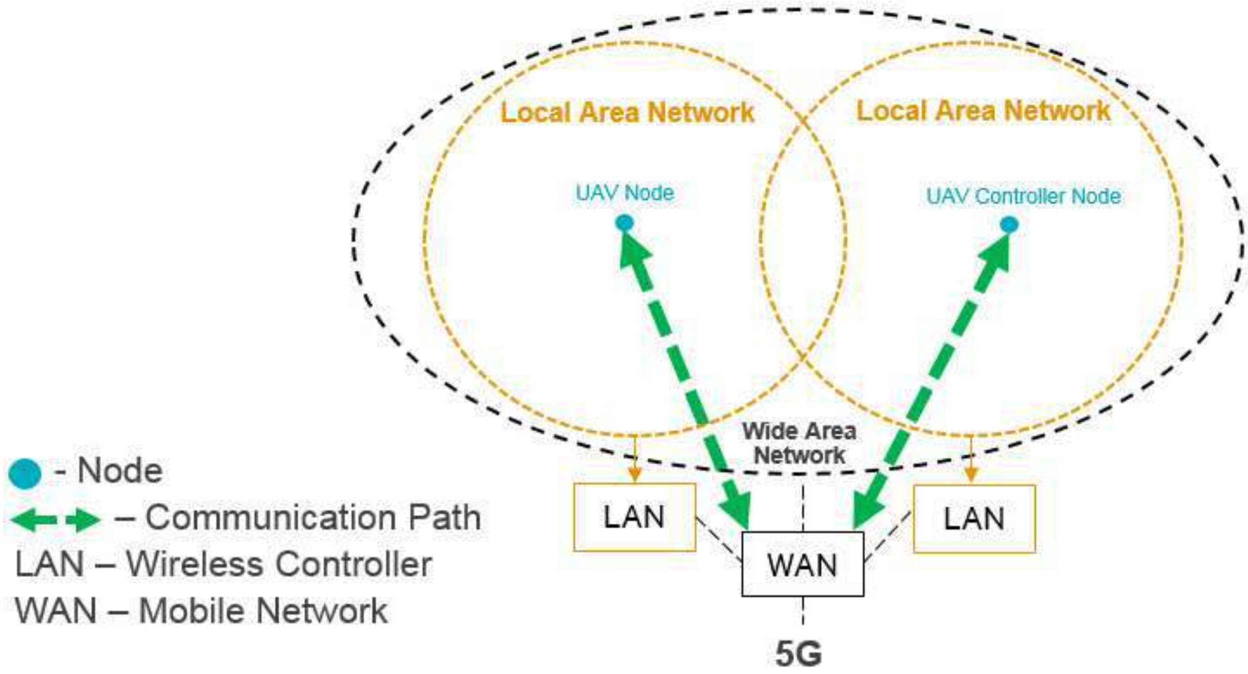

Figure 5.12-1: Communication path

5.12.2 Potential Service Requirements

The 3GPP system shall be able, in the context of Internet of Things, to provide best solutions for applications using, for example drones or robotics. All requirements are for end to end performance, defined as communications sent by source and communication received by target.

The 3GPP system shall support:

- Round trip latency less than [150 ms], including all network components.
- Due to consequences of failure being loss of property or life, reliability goal is [near 100%.]
- Reliability to be at the same level for current aviation Air Traffic Control (ATC). Link supports command and control of vehicles in controlled airspace.
- Priority, Precedence, Preemption (PPP) mechanisms shall be used to ensure sufficient reliability metrics are reached.
- Position accuracy within [10 cm] to avoid damage to property or life in densely populated areas.

- Provide continuous wireless coverage, high speed uplink bandwidth at least [20Mbps], for a flying UE at low altitude of [10-1000] meters with the high speed as maximum as [300km/h].

5.12.3 Potential Operational Requirements

Void.

5.13 Industrial Control

5.13.1 Description

Several industrial control applications require high reliability and very low latency (~1ms) whereas the data rate requirement may be relatively low. In some case also high data rates may be required, e.g., in the uplink, to deliver live video stream to a physical operator, or a computer which then analyses the video and adapts the control to the situation (10s of Mbps per user in a dense environment).

Traditionally industrial control applications have relied on wired connections, or proprietary or tailored wireless solutions. A wired connection, despite the potential of being fast, supporting a high bandwidth, and being reliable, may not be applicable for every situation simply due to the fact that physical wires are subject to tear and wear, and because wiring impacts the mechanical design of the machines to be controlled. Proprietary wireless solutions may suffer from the high prices due to the lack of mass production, and from the lack of globally available frequency bands.

A high-reliability low-latency wireless connection with a high uplink bandwidth fulfils the requirements for industrial control applications.

Reliability can be further enhanced by dedicating the radio interface to the specific industrial control application, and separating the required core network processing from other traffic in the network.

Low latency can be further enhanced by allowing local processing of the traffic.

Related material can be found in

- NGMN 5G White Paper [2]
    - 3.2.1 Use Cases/Ultra-reliable Communications/Extreme Real-Time Communications/x. Tactile Internet
    - 3.2.1 Use Cases/Ultra-reliable Communications/xiii. Collaborative Robots: A Control Network for Robots
- 4G Americas 5G White Paper [6]
    - 2.1.1 SMART GRID AND CRITICAL INFRASTRUCTURE MONITORING
    - 2.4 PUBLIC SAFETY

5.13.2 Potential Service Requirements

The 3GPP system shall support very low latency (~1 ms)

The 3GPP system shall support very high reliability

The 3GPP system shall support very high availability

The 3GPP system shall support high uplink data rate (tens of Mbps per device in a dense environment)

5.13.3 Potential Operational Requirements

Void.

5.14 Tactile Internet

5.14.1 Description

Tactile internet, defined as "*Extremely low latency in combination with high availability, reliability and security will define the character of the Tactile Internet*", makes the cellular network an extension of our human sensory and neural system. Human sensory system requires a millisecond or lower latency to give the impression of immediate response. If the force feedback from a remotely operated tool comes too late, the operation of the tool becomes difficult. If the visual feedback from a virtual or augmented reality headset arrives too late, the human operator may have nausea.

Another important requirement for tactile internet is very high reliability: if the human operator operates a device that interacts with its surroundings, it is very important that he remains in full control of that device all the time. This makes also the security important: the connection must remain intact and secure, without the possibility for outsiders to block, modify, or steal the connection.

Related material can be found in;

- NGMN 5G White Paper [2]
  - 3.2.1 Use Cases/Ultra-reliable Communications/Extreme Real-Time Communications/x. Tactile Internet
- 4G Americas 5G White Paper [6]
  - 2.2 EXTREME VIDEO, VIRTUAL REALITY AND GAMING APPLICATIONS
- 5G & Education [34]
  - Education: Telementoring, Teleteaching, Teleteamworking

5.14.2 Potential Service Requirements

The 3GPP System shall support very low latency (~1 ms)

The 3GPP System shall support very high reliability

The 3GPP System shall support connections that are very difficult to block, modify, or hijack

5.14.3 Potential Operational Requirements

Void.

5.15 Localized real-time control

5.15.1 Description

In Smart factory [3], an extremely restricted requirement of reliability and latency is expected to guarantee the communication between Robots (e.g. automatic precise instruments assemble a car co-ordinately) and the communication between Robot and local Robot-control system.

For an instance, the owner of factory buys “authorized devices (Ads)” from operator A, and deploys Ads in the factory personally. When AD starts up, it connects to the operator A’s network. The service flow would be as follows.

1. Connection among Ads, Robots and Sensors form a local dynamic multi-hop network in the factory to supply data communication service.
2. When Robot starts up, it connects to local robot control system through local dynamic multi-hop network.
3. High-intelligent Robots (e.g. WALLE) communicate with each other directly or through local dynamic multi-hop network and complete cooperation work without any additional central control no matter from robot central control equipment or other equipment connected to operator A’s network.
4. Robot central control equipment connected to operator A network can also support low-intelligent Robots’ operation (e.g. Robotic Arm) in time and precisely.
5. Ads report necessary information of the local dynamic multi-hop network to operator A.

By above procedures, Robot central control equipment guarantees all Robots in factory work properly meanwhile Robots work co-ordinately to complete precision engineering.

5.15.2 Potential Service Requirements

The 3GPP system shall support extremely high reliability and extremely low latency [1-10 ms] for data transmission.

5.15.3 Potential Operational Requirements

The 3GPP system shall support self-organized dynamic networking for multi-hop localized network.

5.16 Coexistence with legacy systems

5.16.1 Description

This use-case is used to collect requirements related to deployment and coexistence with legacy systems.

Several operators expect that the coverage of E-UTRAN will exceed the coverage of GERAN and UTRAN by 2020. In order to support the different use cases and business models with their varying demands it is expected that the <5G system> will include one or more <5G> RAT optimized for different market segments. The support of co-existence of new 5G RAT(s) and an E-UTRAN would cater for a sound migration path.

5.16.2 Potential Service Requirements

5.16.2.1 Interworking with <5G> systems

The <5G system> shall be able to support a UE with a <5G> subscription roaming into a <5G> Visited Mobile Network with roaming agreement with the <5G> Home Mobile Network. The <5G system> shall be able to set up home network provided data connectivity as well as visited network provided data connectivity.

5.16.2.2 Interworking with existing generations systems

The <5G system> shall be able to support a UE with a <5G> subscription roaming into a EPS Visited Mobile Network with roaming agreement with the Home Mobile Network. The <5G system> shall be able to set up home network provided data connectivity as well as visited network provided data connectivity.

The <5G system> shall be able to support seamless handover and Inter System Mobility between<5G> RAT(s) and E-UTRAN.

Seamless Handover between the <5G> RAT(s) and GERAN or UTRAN is not required.

5.16.2.3 Security

The <5G system> shall be able to provide at least the same level of security as EPS (confidentiality and integrity).

5.16.3 Potential Operational Requirements

5.16.3.1 Interworking with existing generations systems

The <5G system> shall be able to support that the operator can limit access to its services for a roaming subscriber with a <5G> capable UE and subscription, i.e. when <5G> SLA is not in place yet.

5.17 Extreme real-time communications and the tactile internet

5.17.1 Description

As mentioned in the NGMN 5G whitepaper [2] and SID for SMARTER, “extreme real-time communications” present tight requirements for communications networks. Another term to describe extreme real-time applications is the “tactile internet” as described by Gerhard Fettweis. Tactile internet applications require extremely low latency and high reliability and security.

Examples of extreme real-time communications include:

Truly immersive, proximal cloud driven virtual reality

Remote control of vehicles and robots, real-time control of flying/driving things

Remote health care, monitoring, diagnosis, treatment, surgery

Target 1ms delay implies endpoints must be physically close. Maximum distance between endpoints depends on delay budget per link.

Pre-conditions

Max is shopping for a new place to live. His real estate agent Charles has lent him a virtual reality headset to preview houses. Charles also provides Max with access to high-resolution 3D files of each property, generated with techniques such as visual odometry to provide dimensionally accurate representations. Charles can also supply a remote controlled drone to allow Max to explore property in real time.

Service Flows

1. Max straps on his goggles and starts shopping. His eyes are presented with life-like images of the subject properties; he can look around the rooms and navigate the property as if he were present. Max can also measure spaces, test if his furniture will fit, etc.

2. For short-listed properties, Charles deploys the drone. In this use case, extreme real-time requirements come into play. Max looks left, drone looks left (naturally and immediately, movement to photons in 10 ms to avoid queasiness.) Max can also communicate and ask questions using the drone. (Drone provides a form of telepresence.)

Post-conditions

Max saves hours by previewing houses using virtual reality. Charles makes more money by not wasting his time showing clients properties that are unsuitable.

5.17.2 Potential Service Requirements

The 3GPP system shall support 1ms one-way delay between mobile devices and devices in the nearby internet.

5.17.3 Potential Operational Requirements

Void.

5.18 Remote Control

5.18.1 Description

In the future, UAV (unmanned aerial vehicle) will be widely used for delivery of packages (e.g. A company plans to use UAVs to deliver goods), which improves delivery efficiency. In a situation where first aid personnel cannot arrive promptly to the scene of an emergency, UAVs could be used to collect video information on site and deliver emergency equipment.

For example, the owners of the UAVs (e.g. Logistics companies or Medical institutions) subscribe to latency and ultra-reliable transmission service from Operator A, and control the UAV remotely through the service. The service flow would be as follows:

1. When an accident happens, a manipulator controls the UAV carrying necessary equipment and medicine.

2. UAV shoots real-time pictures or video along the road and sends the image back to the manipulator.

3. Assisted by the video sent back from UAV, the manipulator controls the UAV away from obstacles through the manipulator.

4. Continuously the manipulator sends the command message to control the velocity of UAV precisely.

5. Besides the real-time image, the UAV in flight also sends back position information and other data from its carried sensor back to the manipulator simultaneously.

Assisted by real-time image and information sent back by UAV, manipulator at the console controls the UAV remotely flying through complex terrain and landing at the exact site where the accident happens.

5.18.2 Potential Service Requirements

All requirements are for end to end performance, defined as communications sent by source and communication received by target. The 3GPP system shall support:

- Round trip latency less than [150 ms], including all network components.
- High reliability for fast-moving end-users (e.g. 120km/h); reliability goal is [near 100%]
- Seamless connection for fast-moving end-users.
- Reliability to be at the same level for current aviation Air Traffic Control (ATC). Link supports command and control of vehicles in controlled airspace.
- Priority, Precedence, Preemption (PPP) mechanisms shall be used to ensure sufficient reliability metrics are reached.
- Position accuracy within [10 cm] to avoid damage to property or life in densely populated areas.

5.18.3 Potential Operational Requirements

Void.

5.19 Light weight device configuration

5.19.1 Description

The new system is expected to support all kinds of devices, ranging from very simple, limited function devices to very complex, sophisticated computing platforms. On the lower end of the device function range, not all such devices may use IMS and may not need to be equipped with an IMS client, and yet it would still be desirable to activate such a device remotely. A light weight configuration mechanism may be used to provide the configuration information to the device.

5.19.2 Potential Service Requirements

The 3GPP System shall be able to support devices (e.g., smart meter) with limited communication requirements and capabilities (e.g., devices without an IMS client).

The 3GPP System shall support a lighter weight signalling for device configuration (i.e., service parameters) than is currently available in EPS.

5.19.3 Potential Operational Requirements

Void.

5.20 Wide area sensor monitoring and event driven alarms

5.20.1 Description

Consider the case of forest fire alarms or wide area outdoor security motion sensors. Sensors would communicate periodic signs of life when not triggered and event information when triggered. Communication would be mission critical and high priority when activated, wide spread, and initiated in the uplink direction. Devices would be low complexity, low powered, battery sensors.

A need arises that requires monitoring a wide area for a particular measured property. The measured property may be, but is not limited to, temperature, motion, vibration, air quality, moisture, or radiation. The need may have been planned (e.g., due to building construction or bridge maintenance) or unplanned (e.g., as a result of a forest fire or other natural/man-made event).

The area to be monitored is “wide” in the sense that it is remote and/or large enough that other wired or wireless network connectivity for the number of sensors deployed is impractical.

Sensors to measure the particular property are deployed in the area of interest. Sensors may be purposefully placed in specific locations (bridge joints, farm field divisions) or randomly dropped (forest fire). Once deployed, sensors are expected to be fixed or not move far. Sensors may be manually or automatically activated when they are deployed in the area to be monitored. Upon activation, each sensor identifies itself with the network and registers with the sensor monitoring service/application. The sensor sends its information unsolicited and infrequently with no expectation of a response from the network.

A method by which large numbers of stationary (or not move far) sensors may be deployed and data may be uploaded while minimizing overhead is vital.

5.20.2 Potential Service Requirements

The 3GPP System shall support efficient transfer of infrequent uplink data for low power devices which only participate in mobile-originated communication scenarios.

The 3GPP System shall support a resource efficient mechanism to provide service parameters and activate groups of low power devices.

The system shall support significantly increased device power efficiency (e.g., battery life up to more than 10 years).

The system shall support efficient data transmission with limited resource and signalling usage.

The system shall support high density massive connections (e.g.1 million connections per square kilometre) in an efficient manner.

The system shall support significant coverage enhancement (e.g., 20dB better coverage than Rel 99 GPRS system).

5.20.3 Potential Operational Requirements

The 3GPP System shall support a mechanism which provides an appropriate and efficient authentication mechanism for low power devices.

The 3GPP System shall support a mechanism which provides appropriate and efficient confidentiality and integrity protection for mobile originated transfer from low power devices.

5.21 IoT Device Initialization

5.21.1 Description

IoT device manufacturers may not know where their devices will eventually be deployed and activated. Consequently, the manufacturer will not be able to pre-provision the devices with PLMN specific and IoT service specific information. The manufacturer will need to know the device is intended for use with 3GPP technology and as such will include a mechanism (e.g., certificate) to securely establish an association with a 3GPP network when the device is activated by an end user.

The device will need to be populated with a preferred PLMN list prior to or during first access attempt. How this is done may be out of scope of 3GPP (e.g., end user accesses a 3rd party website to provide personalized information for the device).

At the first access attempt, the device will use the factory installed mechanism (e.g., certificate) to establish a subscription with the PLMN. Remote provisioning may be used to complete device configuration.

5.21.2 Potential Service Requirements

The 3GPP System shall support a secure mechanism (e.g. a factory installed certificate) that enables a device (e.g. IoT device) that has not been provided with a 3GPP subscription to establish access to a 3GPP network.

The 3GPP network shall support a secure mechanism to remotely provide the device with a particular 3GPP subscription and other, third party provided, device configuration credentials when the device was not previously provided with a 3GPP subscription.

Editor's Note: The above requirements are not agreed and may need further study.

5.21.3 Potential Operational Requirements

Void.

5.22 Subscription security credentials update

5.22.1 Description

To enhance security on IoT devices, it may be desirable to periodically update the subscription security credentials, even for devices that may have very infrequent communication with the network. Additionally, the potential for IoT devices to be compromised poses a risk to the network. As IoT devices proliferate, it will be necessary for the network to be able to identify devices when it determines the security credentials of the device may have been compromised and force an update of their subscription security to maintain security of the network. In either case, the update mechanism could be the same.

Pre-conditions

The network determines that a subscription security credential update is needed for an IoT device with a valid subscription.

Service Flows

The network securely notifies the IoT device that it needs to update its subscription security credentials in a secure manner.

In response to the notice from the core network, the IoT device is provisioned with new proposed subscription security credentials that were exchanged in a secure manner.

Post-conditions

After the subscription security credential update is complete, the IoT device is ready for service.

5.22.2 Potential Requirements

The 3GPP System shall support a secure mechanism to update the subscription security credentials for an IoT device.

The 3GPP System shall support a secure way of storing subscription security credentials in the IoT device.

5.23 Access from less trusted networks

5.23.1 Description

In order to enable more flexible deployments, operators will support access and connectivity via less trusted networks. For example, current core network functions are expected to be deployed nearer the edge and multiple parties may own the network equipment traversed. In these networks, privacy across access networks elements cannot be assumed.

The current 3GPP system requires a UE to provide its IMSI unencrypted over the air during the initial attach. A passive attacker can identify a user from on the IMSI by observing the OTA traffic. This also enables the attacker to track the user while the user roams to another network.

In addition, when the UE is roaming, the UE has provide its IMSI to the serving network for authentication and the IMSI is again stored across the network elements of the roaming network, e.g., in the MME, S-GW, P-GW. This enables the serving network to trace the user.

Example: Angela visits another country and switches on her mobile. The visited PLMN requests her IMSI in order to register. The visited PLMN (and potentially other agencies) are then aware of her visit. 3GPP should consider a method to protect subscribers' identities while roaming.

Pre-conditions

A UE and its home network shall enable the use of an identifier for initial attach.

Service Flows

1. A UE sends an attach request to a serving network using a non-permanent identifier
2. The network requests authentication information for the UE to the UE's home network based on the temporary identifier.
3. The HSS of the user's home network identifies the permanent identifier (i.e., IMSI) associated with the non-permanent identifier provided by the serving network.
4. The HSS provides the authentication information for the UE to the serving network
5. After successful authentication, the serving network may request the UE's permanent identifier to the home network, e.g., for lawful intercept.

Post-conditions

Void.

5.23.2 Potential Requirements

Subject to regulatory requirements, the UE may use a temporary identifier for initial attach that hides its long-term identity. The home network shall be able to associate this temporary identifier to the long-term identity.

5.24 Bio-connectivity

5.24.1 Description

As per the 4G Americas white paper: "Bio-connectivity, which is the continuous and automatic medical telemetry (e.g., temperature, blood pressure, heart-rate, blood glucose) collection via wearable sensors, is another strong emerging trend that will add to the wireless communications requirements" [6].

In order to support the bio-connectivity use case, low complexity and high battery life are two very important requirements for the UE. Other important requirements are reliability and a secure connectivity. High data rates may also be needed in certain cases, such as during a surgery supported by a video stream of the patient internal organs while the surgery is performed by the doctors.

Such UE sensors, when used in operation rooms or near hospital beds, need only to communicate with each other and provide information to a local display equipment for doctors and nurses to monitor. If patients are on the go, these UE sensors may send data to a smart phone or ambulance equipment. They operate seamlessly while the patient is moving within the hospital, at home or on the go. However, these UE sensors do not need to operate standalone. In fact, if there is a massive number of such UEs, it is preferred and also beneficial to have an aggregator to send information to the network. When information needs to be uploaded to a server, for example to update the patient's records, it can be done through a UE-to-network relay. For instance, in the hospital case, this relay could be the patients' monitoring device. 3GPP device to device communication is more efficient for such UEs.

The sensor UEs have 3GPP credentials, an identifier and a subscription, and use 3GPP device to device communication with other UEs and communicates with the network via a UE-to-network relay. By supporting the sensor UE connectivity with the network only via a UE to network relay, that sensor UE can still utilize 3GPP services and the network is able manage that UE and provide authorization, end-to-end secure connectivity, resource management and service provisioning. The advantages are the many optimizations in complexity and power requirements that can be implemented in that UE.

This is the use case for a low power, low complexity UE, which is able to communicate with other UEs, under operator control, using 3GPP device to device communication only. The UE is also able to communicate with the network via a UE-to-network relay. The use case presented here is based on e-health, but the scenario and requirements may apply to other wearable sensors as well. This use case enables 5G to reach the massive IoT market in large scale.

5.24.2 Potential Service Requirements

The 3GPP System shall support a mechanism that provides security, authentication and authorization for UEs which only support 3GPP device-to-device communication.

The 3GPP System shall support efficient transfer of data for UEs which only support 3GPP device-to-device communication.

NOTE: This is especially suited for power-constrained, low complexity UEs. The 3GPP System shall support a mechanism for UEs which only support 3GPP device-to-device communication to communicate with the network via a UE-to-network relay.

The 3GPP system shall support a mechanism that allows the network to be aware of the UEs operating with assistance from a UE-to-network relay.

The 3GPP System shall support a timely, efficient, reliable and secure mechanism to transmit the same information to multiple UEs which only support 3GPP device-to-device communication.

5.24.3 Potential Operational Requirements

Void.

5.25 Wearable Device Communication

5.25.1 Description

This use case describes the scenario of the wearable device communication. The wearable devices can communication the network through the smart phone when the wearable devices are within the short communication range of a smart phone. The wearable devices can directly communicate with the network when the wearable devices are outside the short communication range of the smart phone. The wearable device should have a subscription associated to its own subscriber's identity (e.g. IMSI).

Pre-conditions

John has a smart watch and a smart phone. Each device has a subscription associated to its own subscriber's identity (e.g. IMSI). Each device can independently communicate with network. Compared to the smart phone, the smart watch may have smaller shape, lower power capacity and lower BB&RF capability.

Service Flows

1. When the smart watch is within the short communication range of the smart phone the smart watch is aware of that it's in the coverage of the smart phone. When the smart watch is not nearby the smart phone the smart watch is aware of that it's not in the coverage of the smart phone.

2. John makes a call (e.g. VoLTE) using his smart watch. When the smart watch is out of coverage of John's smart phone, the smart watch directly connects the network by the 3GPP system air interface between the smart watch and network. When the smart watch is in the coverage of John's smart phone, the smart watch connects to the network through the smart phone by the 3GPP system air interface between the smart watch and the smart phone, which is managed and controlled by network.

3. If John moves out of the coverage of his smart phone during the call, the smart watch is aware of that it's out of the coverage of the smart phone and then connects directly to the network by the 3GPP system air interface between the smart watch and the network. The smart watch can maintain the call (e.g. VoLTE) after it connects to the network.

4. If John moves into the coverage of his smart phone during the call (e.g. VoLTE), the smart watch is aware of that it's in the coverage of the smart phone. The smart watch connects to the network through the smart phone by the 3GPP system air interface between the smart watch and the smart phone. The smart watch can maintain the call (e.g. VoLTE) after it connects to the smart phone.

5.25.2 Potential Service Requirements

NOTE 1: Requirements below are for 3GPP RAT case but requirements for non-3GPP RAT case also needs to be studied.

The 3GPP system shall support an UE (e.g., wearable device) to access to the 3GPP network directly, or via an authorized UE (e.g. smart phone) when the two UEs are within a short range communication (e.g., less than [TBD]m).

NOTE 2: The short range communication can work in unlicensed or licensed band supported by 3GPP system.

The 3GPP system shall be able to support service continuity for an UE (e.g. wearable device) when it changes from direct access to indirect access via another UE (e.g. smart phone), and vice versa or when it changes indirect access from UE (e.g. smart phone) to another UE (e.g. smart phone).

The 3GPP system shall optimize the battery consumption of an UE (e.g. wearable device), whether it’s connected to the network directly or via another UE (e.g. smart phone).

The 3GPP system shall support end-to-end integrity protection and confidentiality for data transmitted to/from a UE (e.g. wearable device), when it’s connected to the network via another UE(e.g. smart phone) .

The 3GPP system shall support real time services (e.g. real time voice and/or real time video) for a n UE (e.g. wearable device), whether it’s connected to the network directly or via another UE (e.g. smart phone).

The 3GPP system shall support data transmission services for an UE (e.g. wearable device), whether it’s connected to the network directly or via another UE (e.g. smart phone).

The 3GPP system shall support end to end QoS for an UE (e.g. wearable device), when it’s connected to the network via another UE (e.g. smart phone).

The 3GPP system shall identify an UE (e.g. wearable device), when it’s connected to the network via another UE (e.g. smart phone).

5.25.3 Potential Operational Requirements

The UE of wearable device, which can be connected to the 3GPP network directly or via another UE, should have a subscription associated to its own subscriber’s identity (e.g. IMSI) with mobile operator.

NOTE: The number of IMSIs may be exhausted considering the huge number of subscriptions in the future.

5.26 Best Connection per Traffic Type

5.26.1 Description

As mentioned in the 4G Americas white paper: “With the advent of small cells in indoor environments such as offices, there is a need for some traffic to be routed locally while other traffic needs to access MNO or third-party services” [6].

In this use case a user has two applications running, one voice and one video streaming application. The two applications have very different requirements, as one is generating low volume, real time traffic that needs to access MNO services, and the second requires much higher data rates and access to the closest Content Distribution Network (CDN). If the user is in the coverage area of multiple cells, the best cell for the given application should be used, so that the traffic is routed in optimal manner.

The MNO has a macro cell deployed in an area and several small cells (“booster” cells) under the coverage of the macro cell. Initially, the device is registered with the MNO network and camped on the macro cell. In the figure below this device is referred to as Alice’s device. Alice is in a shopping mall when she decides to call her friend, Bob (see Bob’s device in the figure). The call is routed via the macro cell where Alice is camped on, and from there on to the MNO’s IP multimedia network.

During the communication, Alice receives an advertisement in her device. The advertisement is from a local store in the shopping mall, and it is about a new product the store is releasing. The advertisement has a link to a web page where they have a video with the details of the new product. Alice considers Bob would like the product and tells him to see the video. Meanwhile Alice also decides to stream the video to her own device, while still remaining on the call with Bob.

The network operator has a few small cells deployed in the shopping mall. Alice is under the coverage of one of the small cells. That small cell has the functionality to route packets directly to the Internet using the shopping mall’s Internet access. The video is then routed from the closest CDN (Content Delivery Network) server in the Internet to Alice’s device via the small cell. The data does not transverse the macro cell.

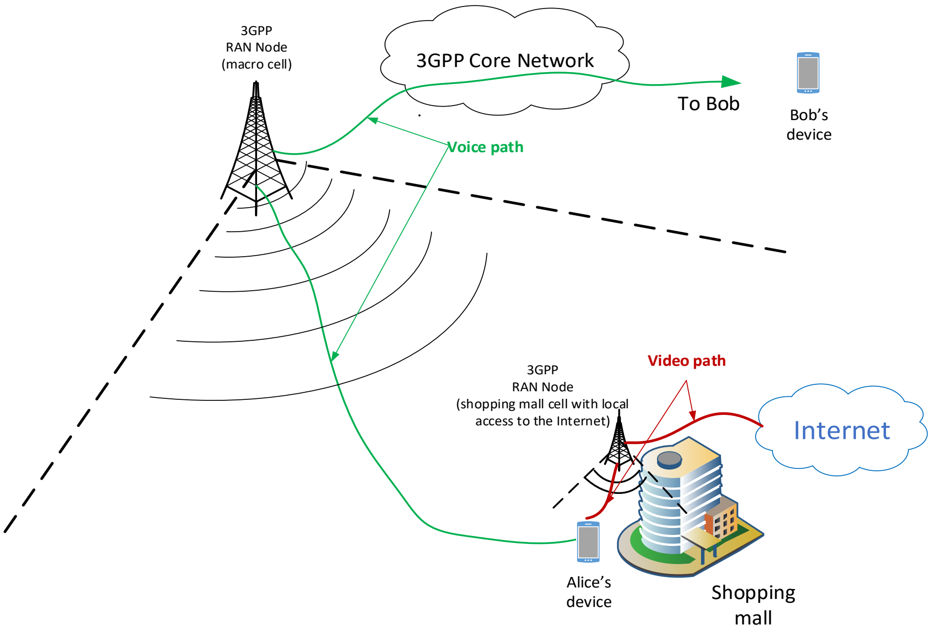

Figure 5.26-1: Application traffic routing for multiple applications

The data packets from the two different applications running in Alice's device are using different RAN nodes. The voice application is routed via the macro cell and through the operator core network. The video streaming is routed directly from a CDN server in the Internet to the small cell and delivered to Alice, without traversing the operator core network or the macro cell node, i.e. by being routed via the shopping mall's Internet access.

NOTE: Today it is possible in the 3GPP system to use dual connectivity in order to take advantage of small cells that can operate as booster cells. The difference between this use case and the existing dual connectivity is that the latter requires that the traffic to/from the booster cell be routed via the macro cell or via the EPC.

5.26.2 Potential Service Requirements

Void.

5.26.3 Potential Operational Requirements

Subject to operator's policy, the 3GPP network shall provide a mechanism such that a specific traffic type (from a specific application or service) to/from a UE can be routed via specific RAN nodes, and traffic in one RAN node can be offloaded towards a defined IP network close to the UE's point of attachment to the access network, while other traffic type to/from that same UE is not offloaded.

5.27 Multi Access network integration

5.27.1 Description

The deployment of different access networks, the broad variety of use cases that future networks will support (such as V2V, CIoT, Mission critical communications…), the broad variety of environments, and the capability of devices to support multiple access technologies, is making the network more and more heterogeneous. So the future network should have the capability to connect to multiple non-3GPP and 3GPP access networks in order to allow the operator to improve the efficiency in the exploitation of the network infrastructure and to provide the best capabilities to end-user.

The 3GPP future system is expected to support at least mobility between 3GPP and non-3GPP networks with optional session continuity, capability for the UE based on network control to select the access to connect to, simultaneous connection to different accesses, capability to access services provided by a 5G network to the UE connected to a non-3GPP access, authentication for accessing a non-3GPP network using 3GPP credential, etc.

The Network operators should be able to increase the user experience and to exploit the available capacity of the most suitable access network. The selection of the access network can depend on both user and operator criteria.

The future network should enable the integration of non-3GPP services (e.g. for office and residential) allowing a broad variety of device and communication scenarios, e.g. to communicate and exchange information in a secure and private manner between them, potentially with internal servers and applications or towards external servers and applications.

Non-3GPP access can extend and/or complement the capabilities of the future network:

- The integration of the fixed line services (e.g. internet connection, streaming service) with a mobile service may be considered.
- The integration of the residential services (e.g. as sharing the fixed infrastructure to visitors) with a mobile service may be considered.

NOTE: The access technology to be considered should not be limited to WLAN and Fixed broadband access, potentially any access could be considered as relevant for a given service.

5.27.2 Potential Service Requirements

The future network shall be able to provide 3GPP services to the UE using various 3GPP and non-3GPP access networks (e.g. WLAN, Fixed broadband access, Bluetooth, etc.).

The future 3GPP system is expected to support at least:

- Inter-system mobility between 3GPP and non-3GPP networks with optional session continuity,
- capability for the UE based on network control to select the access,
- simultaneous connection to different accesses, capability for the UE to access the 3GPP services provided by the 5G network using non-3GPP access e.g. FMSS…,
- authentication to access to future network through a non-3GPP access shall use 3GPP credentials.

Editor's note: this list is not exhaustive.

The future network shall enable the UE to simultaneously connect to the network via different non-3GPP and 3GPP accesses.

The future network shall be able to manage the addition or dropping of the various accesses dynamically during the session according to the quality of the individual connections.

For UEs simultaneously connected to the network via different non-3GPP and 3GPP accesses, the network shall support data transmissions that leverage both types of access.

The future network shall be able to aggregate the UE data transfer via one access or a combination of accesses which may be operated by different mobile network operators.

The future network shall be able to aggregate the UE data transfer via one access or a combination of accesses to provide the best user experience during an ongoing data transmission.

The future network shall be able to support the interworking with fixed broadband network defined by BBF.

NOTE: The specification of fixed broadband access network is outside the scope of 3GPP.Which evolution of fixed broadband access network architecture needs to be considered in stage 2.

The traffic from different subscribers using a non-3GPP access shall be isolated from each other.

The future network shall be able to differentiate charging a subscriber for the same 3GPP service if it is provided to a UE over different 3GPP and non-3GPP accesses.

Based on operator policy, the future network shall be able to dynamically offload part of the traffic from 3GPP RAT to non-3GPP RATs and vice versa, taking into account traffic load.

5.27.3 Potential Operational Requirements

The 3GPP network shall be able to integrate fixed and wireless access management and provide an efficient provision of services over 3GPP and non-3GPP accesses.

5.28 Multiple RAT connectivity and RAT selection

5.28.1 Description

Section 4.4.1 of the NGMN 5G White Paper describes: "*It is expected that a terminal may be connected to several RATs (including both new RATs and LTE) at a given instant, potentially via carrier aggregation, or by layer 2 (or higher) bandwidth aggregation mechanisms.*" And "*The user application should be always connected to the RAT or combination of RATs and/or access point (or other user equipment in case of D2D) or combination of access points providing the best user experience without any user intervention (context-awareness)*" [2].

Multiple RAT connectivity is beneficial for increasing the throughput. And a capability to select which data flow goes over which RAT benefits further. For example, when Bob starts voice call while moving on the backseat of the car, the system might judge that the <5G New RATs> are not necessarily suitable for the voice call due to their small-cell based deployment and that E-UTRA is better to avoid frequent handovers.

The new requirements motivated by the text above will require that the UE has full dual radio capability, i.e. can handle both uplink and downlink radio transmissions on both the <5G New RAT> and the E-UTRA RAT simultaneously. This is expected to be commonly supported by UEs used as e.g. smart phones. Due to the expected large diversity of market segments and type of UEs for the new system, it is also expected that some UEs will target lower complexity segments where single radio capability is preferred.

5.28.2 Potential Service Requirements

Void.

5.28.3 Potential Operational Requirements

The <5G system> shall be able to provide data transmission by using both the <5G New RATs> and E-UTRA RAT simultaneously, i.e. in this case dual radio UE capability is required.

When a UE is both using the <5G New RAT> and E-UTRA RAT simultaneously, the <5G system> shall be able to select a radio access (either a <5G New RAT> or E-UTRA RAT) to assign each data flow, taking into account e.g. service, traffic characteristics, radio characteristics, and UE's moving speed.

The <5G system> shall support UEs with dual radio capability as well as UEs with single radio capability, i.e. a UE that cannot transmit on the <5G New RAT> and the E-UTRA RAT simultaneously.

5.29 Higher User Mobility

5.29.1 Description

Vehicles, trains and aircrafts will demand enhanced connectivity for in-vehicle/on-board entertainment, accessing the internet, enhanced navigation through instant and real-time information, autonomous driving, safety and vehicle diagnostics. Entertainment is a key driver for the increasing need for mobile broadband capacity, including high mobility environments such as trains, cars and airplanes. On the other hand the automotive sector is expected to be a very important new driver for 5G, with many use cases for mobile communications for vehicles. The degree of mobility required (i.e. speed of travel) will depend upon the specific use case.

The example use cases include (as identified in NGMN 5G White Paper) [2]:

- High Speed Train

High speed train is used in various regions for inter-city transport and will further evolve beyond 2020; these high speed trains can reach speeds greater than 500 km/h. While travelling, passengers will use high quality mobile Internet for information, interaction, entertainment or work.

Many on board passengers on these high speed moving trains like to access Internet and other services using their mobile phones and other mobile devices. However, due to different commercial network deployment and surrounding environments (downtown/suburban, tunnel or mountain areas), there exist some issues/scenarios that the current specified requirements are not guaranteed [29]. It is envisioned that when these high speed trains further increase in mobility, e.g. up to 500 km/h in the future, providing mobile services to passengers on board will become more difficult without further improvement in the current network systems. Therefore, it is worth investigating potential requirements to ensure support to various Internet services/applications accessible to users on board high speed moving rail systems.

A high speed moving train usually contains hundreds of passengers. Take Taiwan High Speed Rail (THSR) for example, it can totally take 923 passengers at a fully loaded condition. Therefore, it may consider that at least hundreds of active UEs may access the internet for different services/applications in a high speed train. Thus, the system shall provide sufficient bandwidth for these active UEs simultaneously at least.

In addition, on board passengers may want to watch some HD show or movie, e.g., 4k streaming video, to spend their time on a high speed train. When watching HD videos, it is at least 5Mbps for a user at a time. Therefore, it is envisioned that if many passengers on a high speed train watch HD video almost simultaneously, the system shall provide higher data rate (e.g., 100 Mbps). Not to mention that passengers may multitask, e.g., browsing the Web and texting, for example—while watching HD video. Furthermore, if some end users may use on-line gaming or other real-time applications/services, these kinds of applications/services still require stringent delay requirement (e.g., 10 ms E2E delay) such that end users can have satisfaction with these applications/services.

- Remote Computing

Beyond 2020, remote computing is used on the go and at high speeds (such as vehicles or public transport), in addition to those indicated for stationary or low-mobility scenarios (such as smart office). Moreover, automotive & transportation industry will rely on remote processing to ease vehicle maintenance and to offer novel services to customers with very short time-to-market.

- 3D Connectivity: Aircrafts

Civil aviation will implement commercial connectivity services in 2020+, and the passenger services offered will comprise of similar applications to those available on the ground. Another example for 3D connectivity is support of sporting event live services where the user is moving physically in all 3 dimensions, e.g., balloonists, gliders, or skydivers. In these use cases the licensed mobile frequency bands are used between aircrafts and ground.

5.29.2 Potential Service Requirements

The 3GPP system shall support enhanced mobile broadband services in fast moving vehicles (e.g. up to 500 km/h) with enhanced user experience.

The 3GPP system shall support enhanced connectivity services in fast moving airplanes (e.g. up to 1000 km/h) with enhanced user experience.

5.29.3 Potential Operational Requirements

The 3GPP system shall be able to provide the mobile broadband service in fast moving vehicles with enhanced system experience.

The 3GPP system shall be able to provide the airplanes connectivity service with enhanced system experience.

5.30 Connectivity Everywhere

5.30.1 Description

The new communication system is expected to efficiently provide connectivity services beyond conventional locations. Thus, the area where connectivity is not provided will be dramatically reduced. At locations where connectivity is newly provided, communication among new types of devices is also conceivable. Example of scenarios include following:

- Commercial or recreational UAVs (Unmanned Aeronautical Vehicle) will be controlled by various control centres such as local/federal agency or owner of the UAVs. Depending on the deployment scenario and city skylines, the distance between the UAV and control centre can be up to several hundred meters. In addition, for the safety measure such as collision avoidance, the UAVs from different organizations should be able to communicate for safe flying either directly or indirectly.

- UAVs are agile and quickly deployable. Thus, it can be the first one to arrive at the emergency scene, or the only node able to set up back-haul link to macro cell when no connection link can be setup directly from the ground to macro cell.

- As economy grows, amount of air travel will explode. Because people are accustomed to being always connected to mobile broadband internet service, demand for high speed internet during flight will also explode in the next decade. Considering the number of private, commercial and military aircraft in the future, efficient way of connectivity service should be provided in the next generation of communication system.

- Ships located within several hundred kilometres from seashore are provided with mobile broadband connectivity. Passengers on board cruise liners enjoy broadband services such as watching live sports events, playing on-line gaming or making video calls to families. Broadband connectivity on the sea also helps increased public safety so that emergency rescue operations to maritime accidents are improved. Because installing cell towers on the sea is not desirable, mesh-network by vessels would be desirable.

5.30.2 Potential Service Requirements

The 3GPP system shall be able to provide aerial object with reliable mobile broadband connectivity.

NOTE 1: The altitude up to which connectivity is provided is subject to regulatory constraints.

The 3GPP system shall be able to provide nautical object with reliable mobile broadband connectivity.

NOTE 2: The distance from seashore up to which connectivity is provided is subject to regulatory constraints.

The 3GPP system shall be able to provide reliable low-latency connectivity between aerial objects.

5.30.3 Potential Operational Requirements

Void.

5.31 Temporary Service for Users of Other Operators in Emergency Case

5.31.1 Description

This use case is related to "Resilience and High Availability" (refer to NGMN 5G White Paper, section 4.4.4) [2]. Although it might be difficult for each operator to achieve high network availability in some emergency cases (e.g. large disaster), the cooperation among operators makes it higher.

As an example, when a specific operator's network becomes out of service in a disaster area, time to network recovery can become faster if other operators temporarily provide the communication services for the users of the specific operator in the area until the specific operator network can be recovered (i.e. Operator *A* and Operator *B* supports network recovery of Operator *C*).

The other example is, in case all operators' networks become out of service in vast areas, time to network recovery can become faster if each operator can concentrate on recovering different areas (i.e. Operator *A* recovers area *1*, Operator *B* recovers area *2* and Operator *C* recovers area *3*, at first). Each operator temporarily provides the communication services for the users of the other operators in different recovered areas until network recovery of whole area can be achieved.

Pre-conditions

When a disaster happens in an area, Operator *A*'s network keeps active or recovers from out of service and Operator *B*'s network keeps out of service.

Akiko is Operator *B*'s user who locates in the disaster area and wants to communicate with Yusuke.

Yusuke is Operator *B*'s user who locates outside of the disaster area.

Service Flows

1. Akiko is aware that she cannot use the communication services by Operator B's network. And Operator B detects that its own users cannot use the communication services in the disaster area.

2. Operator B requests Operator A to provide the communication services for Operator B's users who locate in the disaster area.

3. Operator A changes the configuration of its own network in the disaster area in order to provide the communication services for Operator B's users.

4. After changing the configuration, Operator A's network sends a notification to all the terminals in the disaster area.

5. When Akiko's terminal detects the notification, it sends an access request message to Operator A's network.

6. Operator A's network identifies Akiko's terminal is one of Operator B's user based on the access request message and makes temporary service provision as a temporary user.

7. After successful temporary service provision, Operator A's network notifies that each temporary user can temporarily use the communication services by its own network.

8. With the notification, Akiko knows that and makes a voice call to Yusuke.

Post-conditions

Akiko can use the communication services by Operator *A*'s network and make a call to Yusuke.

5.31.2 Potential Service Requirements

Void.

5.31.3 Potential Operational Requirements

Subject to regulatory requirements, 3GPP system shall be able to support temporary service for users of other than home operators as temporary users in emergency case by serving operator policy.

Subject to regulatory requirements, 3GPP system shall be able to support defining the limited set of necessary communication services and acceptable terminal features for temporary users by serving operator policy.

3GPP system shall maintain an appropriate level of communications security for temporary service.

5.32 Improvement of network capabilities for vehicular case

5.32.1 Description

The use case will study how to bring high-rate services seamlessly to users in moving cars and buses in a dense urban environment. There are two ways to provide support service to vehicular users. If a vehicle is equipped with a vehicular base station (or a relay), the cellular network should be able to provide a high-rate link to a car or a bus. If such equipment is not available, the moving user equipment must have direct link to the cellular network. As the car / bus rates are aggregates of those for a single user, the rate requirement is higher for links serving them.

Pre-conditions

There are multiple user applications which need to be supported: High Definition Video (streaming/non-real-time), High Definition Video (conversational/real-time), Cloud Computer Games – Low Latency Applications. It is assumed that majority of the game computations occur in the cloud and only video rendering is performed by the user device (thin client).

Users of these applications are located in cars and buses moving up to 60 km/h in dense urban environment. The streets in this use case have 6 lanes (counting both directions).

Looking from the view of specific applications, table 5.32-1 gives the average needed values. These are taken as the basis for further use case definition. The ratio between e2e and air latency has been assumed as 5 to 1.

Table 5.32-1: KPIs for three possible services

Application	Average End User Throughput	Latency (end-to-end)	Latency (over the air)
High Definition Video 8K (streaming)	< 100 Mbps (DL) [7]	< 1 s [8]	< 200 ms
High Definition Video (conversational)	< 10 Mbps [7] (DL/UL)	< 150 ms [8]	< 30 ms
Cloud Computer Games with 4K 3D graphics – Low Latency Applications	< 50 Mbps (DL/UL) [9] (UL is needed for multiplayer game computation in user device)	< 7.5 ms (10 times less than in [8] for real time games)	< 1.5 ms

Scenario

Video/gaming services to vehicular (up to 60 km/h) users (cars or buses) in city centre, driving on a six lanes in a street canyon surrounded by at least six-story buildings. User terminals are either directly connected mobile network(s) through a wireless radio link or through a relay in the car or bus. The mobile network deployment can be either macro or micro cellular, or ultra-dense network (UDN). For this use case, we assume that 1/3 of the active users are engaged in real-time video (4K), 1/3 in non-real-time (8K video) and 1/3 in gaming (which includes a 3D 4K video).

Each car: 1 active user [range 0.5-2].

Density of cars per lane: 5 cars per 100 m lane on four lanes (car lanes). For simplicity, all cars are assumed to move at constant 60 km/h.

Each bus: 20 active users [range 10-30].

Density of buses per lane: 3 buses per 100 m of lane on two lanes (bus lanes). For simplicity, all buses are assumed to move at constant 60 km/h.

Post-conditions

In both scenarios, 90% of the active mobile users should reach the QoS required to support their service seamlessly.

5.32.2 Potential Service Requirements

The network shall be able to support the High Definition Video 8K (streaming) service for users in vehicles with following performance indicators:

- Average End User Throughput is [100] Mbps (DL)
- Latency (end-to-end) is less than [1] s
- Latency (over the air) is less than [200] ms
- Speed is up to 100 km/h (from [4] Dense Urban)

Editor's Note 1: The jitter for the high definition video is FFS.

The network shall be able to support the High Definition Video (conversational) service for users in vehicles with following performance indicators:

- Average End User Throughput greater than [10] Mbps (DL and UL)
- Latency (end-to-end) less than [150] ms
- Latency (over the air) less than [30] ms
- Speed up to 100 km/h

Editor's Note 2: The jitter for the high definition video is FFS.

The network shall be able to support 4K/8K immersive interaction and 3D Cloud Computer Games service for users in vehicles with following performance indicators:

- Average End User Throughput greater than [50-120] Mbps (DL or UL)
- Latency (end-to-end) less than [7.5] ms
- Latency (over the air) less than [1.5] ms
- Speed is up to 100 km/h.

Editor's Note 3: The jitter for the high definition video is FFS.

Editor's Note 4: Power efficiency in the infrastructure and terminal needs to be taken into consideration.

5.32.3 Potential Operational Requirements

Void.

5.33 Connected vehicles

5.33.1 Description

As mentioned in [10], if full-autonomous vehicles are deployed, further reduction of the potential human error is expected as long as the road information and controlling messages can be exchanged between adjacent vehicles with very low latency (e.g., 1 millisecond) and high reliability, which can't be supported by legacy 3GPP system. Furthermore, an autonomous vehicle would need to be driverless in all geographies, thus would require full road network coverage (e.g., nearly 100% availability) with nearly 100% reliability to avoid accident.

Besides, in some scenarios, video information between vehicles and infrastructure is needed to further enhance the efficiency and safety, where higher data rate between vehicles, and between vehicles and infrastructure is required. The required uplink data rate per vehicle is tens of Mbps.

Another big challenge in connected vehicles is high mobility, especially for those vehicles running in opposite directions, which makes reliable communication between vehicles more challenging due to larger Doppler shift and spread. Furthermore, high moving speed also leads to varying topology as the relative positions of vehicles change all the time, which requires that the network is flexible and scalable enough to manage the dynamic topology and connectivity.

NOTE: Service requirements in autonomous driving are much higher than those in LTE V2X scenarios especially in safety related applications. For example, in TR 22.885, the maximal allowed latency of V2XLTE is typically 100ms, and no explicit requirement on reliability is given yet. However, for connected vehicles in SMARTER, 1 millisecond end-to-end latency and nearly 100% reliability are required.

5.33.2 Potential Service Requirements

The 3GPP system shall support very low latency (e.g., 1 millisecond end-to-end latency).

The 3GPP system shall support very high reliability (e.g., nearly 100%).

The 3GPP system shall support high uplink data rate per vehicle even in a dense environment (e.g., tens of Mbps per device in a dense environment).

The 3GPP system shall support high downlink data rates (e.g., tens of Mbps per device in a dense environment).

The 3GPP system shall support very high mobility (e.g., absolute speed more than 200 km/h while relative speed more than 400 km/h).

The 3GPP system shall support data transmission from one point to multipoint (e.g. multicast and/or broadcast).

The 3GPP system shall support high positioning accuracy (e.g. 0.1 meters)

The 3GPP system shall support high density of connections for vehicles (e.g. the number of vehicles can exceed 10000 in scenarios with multiple lanes and multiple levels and types of roads)

5.33.3 Potential Operational Requirements

Void.

5.34 Mobility on demand

5.34.1 Description

As illustrated in both the 4G Americas whitepaper on 5G [6] and the NGMN white paper on 5G [2], 5G is expected to address very different requirements on mobility support.

While some UEs will be accessing the network while moving at very high speeds, other UEs are expected to follow nomadic patterns or will be entirely stationary when accessing the network.

At the same time requirements on mobility support also vary based on the applications and services used. While some services require the network to hide mobility events from the application layer to avoid interruptions in service delivery, other applications have application specific means to ensure service continuity. Hiding mobility events includes aspects such as minimizing interruption time and packet loss or maintaining the same IP address during intra- or inter-RAT cell changes.

It is worth noting that different applications may require different levels of mobility hiding support. While for instance some applications may not require the network to maintain the same IP address during mobility events, the applications may however still require the network to minimize interruption times so that they can continue to communicate quickly to ensure that their application-specific means of addressing mobility events work effectively.

For these reasons the NGMN whitepaper on 5G suggests to "not assume mobility support for all devices and services but rather provide mobility on demand only to those devices and services that need it." [2].

In line with this related service requirements are proposed below.

5.34.2 Potential Service Requirements

The 3GPP system shall enable operators to define different levels of mobility support for different UEs.

Mobility support consists of providing none, any one or any combination of the following:

- minimizing packet loss during inter- and/or intra-RAT cell changes,
- maintaining the same IP address assigned to a UE across different cells,
- minimizing interruption time until a UE can continue to communicate with a potentially different IP address (in case the same IP address is not maintained during a mobility event).
- avoiding network congestion and minimizing interference due to handover of multiple users in a high mobility scenario (disconnecting and reconnecting at the same time many users from one cell to another may increase RAN and network congestion).

Editor's note: This list is not exhaustive. Other aspects may be added in future meetings.

The 3GPP system shall enable operators to update the level of mobility support provided for a UE.

5.34.3 Potential Operational Requirements

Void.

5.35 Context Awareness to support network elasticity

5.35.1 Description

Context awareness could enable rapid network configuration and provide the expected experience for the multiple services/applications.

Today's UEs are typically implemented as smartphones. From hardware point of view, smartphones are equipped with variety of sensors such as accelerometer, gyroscope, magnetometer, barometer, proximity sensor, GPS and etc. In addition, they supports different kinds of connectivity technologies such Bluetooth, WIFI, NFC and etc. The information gathered by these sensors and connectivity technologies can be not only useful to the Apps installed in the smartphone but also to the networking technologies. Following examples can be considered:

- The exact location information of UE can be used by network node to optimally select the cell that the UE should be connected to. If network nodes can utilize the speed and heading information of UE, which can be computed by using accelerometer or gyroscope, the network node can optimally configure which cells to monitor for handover or when to perform handover.
- User data of application such as navigation App can be used. If the destination and the calculated route information can be shared to the network, the network nodes can optimize parameters for handover configuration. In addition, the network nodes may be able to predict when radio resource from which cell should be reserved to serve the UE.
- Based on the information regarding the social network of a user group and their schedule, network can control when and how to configure small/CSG cells.

5.35.2 Potential Service Requirements

Void.

5.35.3 Potential Operational Requirements

The 3GPP system shall enable elastic configuration of the network based on system information, including:

- Instantaneous network conditions, such as serving RATs (macro cell, small cell, WiFi), network load information and congestion levels;
- Application's user characteristics, such as mobility type (high mobility, low mobility, no mobility), expected traffic over time, location)
- When allowed by a user, UE context information, such as sensor-level information (e.g. direction, speed, power status, display status, other sensor information installed in the UE), application-level information (e.g. foreground applications, running background application, application data, user settings, etc.)

The system shall support a secure mechanism to collect system information while ensuring end-user and application privacy.

The system shall support a mechanism to collect the information in a timely manner to enable optimized network elasticity regarding resource use based on accurate context information.

5.36 In-network and device caching

5.36.1 Description

Video based services and applications have been instrumental for the massive growth in mobile broadband traffic. The forecast for mobile data traffic [27] seems to suggest that the video services will continue to remain a key driver for future growth in mobile data traffic; by 2019, as much as 70% of the total mobile data traffic is expected to be video based. Simultaneously, over the last decade, advances in the semiconductor technologies have driven down the unit cost and volume of storage devices, thereby allowing for a flexible and cost effective deployment of in-network content caching entities at the edge of the network. In-network caching is an effective way to deliver video, webpages, etc.

Deploying in-network content caching at the edge is an effective way to deliver video, webpages, etc. and;

1) provides a better user experience (lower latencies and channel switching times) for the end-user,

2) allows the operators to dimension their network and backhaul more cost-effectively and

3) in some scenarios, efficiently utilize its limited radio resources.

This use case is related to the use case category #14 in Annex A of the NGMN white paper [2] and to the technology building blocks, "UE centric network" and "smart edge node", in Annex D of the paper.

Pre-conditions

Wireless operator A has deployed a 3GPP system.

Three types of broadcast content caching entities, X, Y and Z have been deployed within the network.

Entity X is co-located with the integrated terminal/set-top box. Entity Y is co-located with the radio site M. Entity Z is located at a local aggregation point.

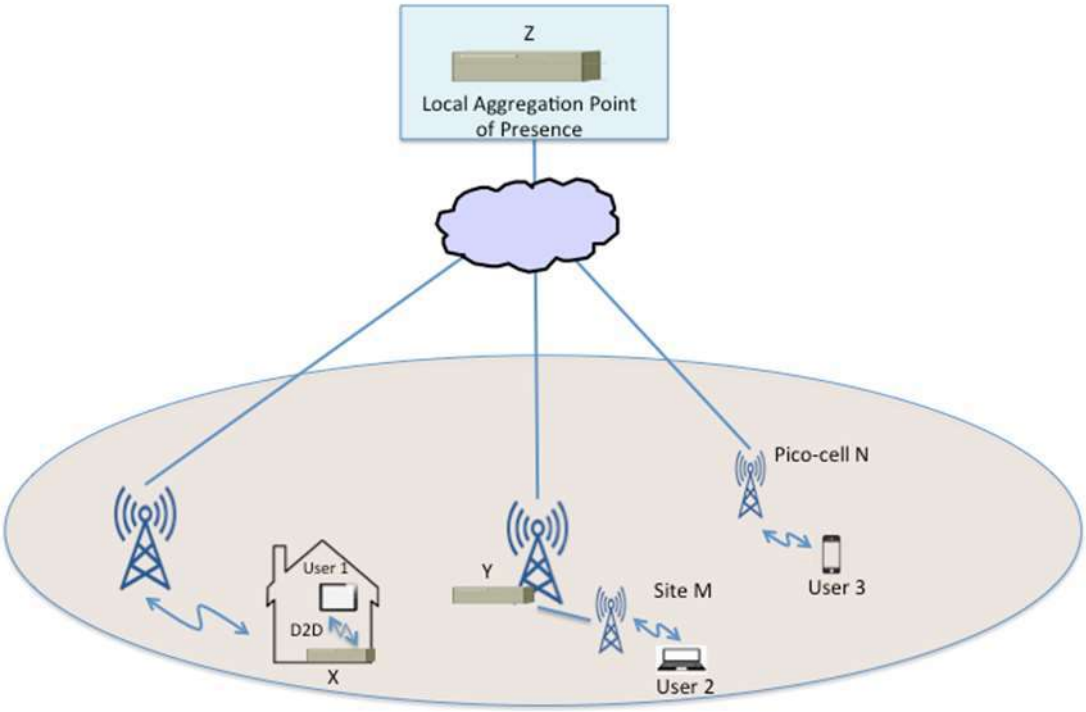

Figure 5.36-1: Example network deployment with three types of broadcast content caching entities

Service Flows

Wireless operator A decides to deliver popular video content using the multicast / broadcast function of the 3GPP system.

The content caching entities X, Y and Z receive and store the broadcast/multicast content.

User 1 is at home and accesses the video content on a personal device via a device to device (D2D) interface from content caching entity X located in the 3GPP enabled set-top box. Note that D2D interface could be 3GPP based D2D interface or it could be non-3GPP RAT based (e.g. WiFi, Bluetooth, etc.).

User 2 is at the local coffee shop and served by site M. User 2 accesses the video content via content caching entity Y.

User 3 is walking in an urban area and is being served by the Pico-cell N. User 3 accesses the video content via content caching entity Z located at the local aggregation point.

Post-conditions

Users 1, 2 and 3 are able to watch the video content of interest, previously broadcasted, from a content caching entity through efficient utilization of network and radio resources.

5.36.2 Potential Service Requirements

The 3GPP network shall be able to efficiently deliver or forward content from in-network entities controlled by the operator.

The 3GPP system shall provide charging, Lawful Interception (LI) and QoS differentiation for content delivered from an in-network caching entity.

The 3GPP system shall enable a flexible deployment of content caching entity located at multiple locations within the network (e.g. at various radio sites and local aggregation points).

The 3GPP system shall support a content caching entity that is capable of being integrated within a device under the control of the operator.

The authorized UE shall be able to receive cached content broadcasted by content caching entity.

The 3GPP system shall enable efficient delivery of content from an appropriate caching entity, e.g. a cache located close to the user.

5.36.3 Potential Operational Requirements

Void.

5.37 Routing path optimization when server changes

5.37.1 Description

As mentioned in [3], the further development of mobile internet will trigger the growth of mobile traffic by a magnitude of thousands in the future. The immersive services such as augmented reality, virtual reality, ultra-high-definition (UHD) 3D video have critical requirement on transfer bandwidth and delay.

In order to ensure good user experience, the server near to the end-user may be utilized to serve these types of services, and the operator network needs to ensure optimized data path between end-user and server to address the immersive services requirement on delay, for example, based on the terminal and server location.

Pre-conditions

One service provider provides an application for enterprise users, and the enterprise users may run the application on their terminal and access server.

In order to ensure good service experience, the service provider may deploy the application in multiple servers in order to keep the active application as near as possible to the user when the user moves.

The service provider signs service agreement with the operator. The operator network may re-route path for the user's application traffic when the application location changes to another server closer to the end-user's UE.

Service Flows

1. The user's terminal runs the enterprise application, and the related application server resides in one server near the user.

2. The user moves.

3. The service provider decides to activate application on another server closer to the new user location to ensure consistent user experience.

4. When a new closer server is ready to serve the user's application, the operator network selects one optimized routing path based on the UE location, the new server location and operator policy.

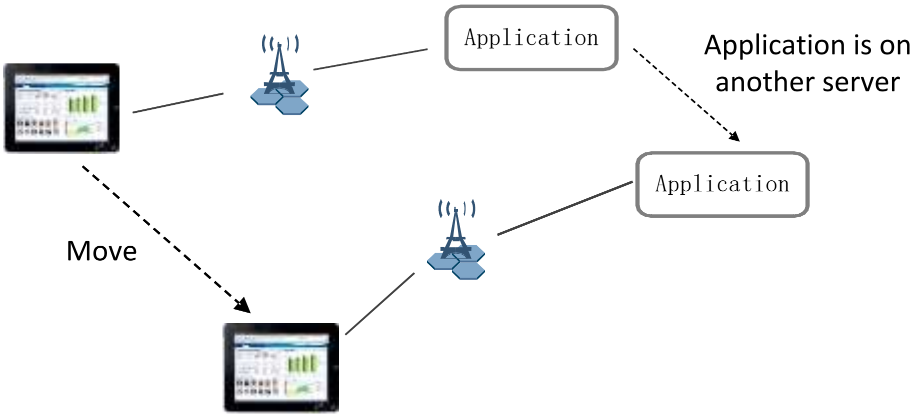

Figure 5.37-1: Routing path optimization when server location changes

Post-conditions

The application on the user's terminal communicates with the application server residing in the new server via the optimized path.

5.37.2 Potential Service Requirements

Subject to the service agreement between the operator and the service provider, the 3GPP network shall enable hosting of services (including both MNO provided services and 3rd party provided services) closer to the end user to improve user experience and save backhaul resources.

The 3GPP network shall be able to support routing of data traffic to the entity hosting services closer to the end user for specific services of a UE.

The 3GPP network shall support efficient user-plane paths between a UE and the entity hosting the service closer to the end user even if the UE changes its location during communication.

The 3GPP network shall be able to support charging, QoS, and Lawful Interception (LI) for services hosted closer to the end user.

5.37.3 Potential Operational Requirements

Void.

5.38 ICN Based Content Retrieval

5.38.1 Description

Information Centric Networks (ICN) and Content Centric Networks (CCN) that enable discovery, routing and caching based on named content have been researched and developed in academic circles for over 15 years.

The principles include managing content by named data networking and extensive support of dynamic intelligent caching.

The benefits to the 3GPP system users are as follows:

- Latency reduction. Content can be delivered from ICN caches located at e.g. edge nodes, which avoids retrieval from the source node and hence reduces latency. Latency can be reduced even further due to the multi-path delivery feature of ICN/CCN (which could for instance be used to fetch separate chunks of content via different RATs in parallel).

- Bandwidth savings on backhaul and core transport links. Due to dynamic caching using ICN/CCN at edge nodes, multiple transmissions of the same popular content across core transport and backhaul links can be avoided.

- Flexible caching. In comparison to static CDN caches, ICN/CCN's in-network caching feature and its support for dynamic caching strategies supports flexible caching without prior cumbersome planning of cache placement.

- Security. Integrity protection of content is an integral part of ICN/CCN to ensure the authenticity of cached content.

Today, proprietary adoption of ICN/CCN (whilst adding benefit on a case by case basis) is not generating the network and inter-network volume traffic optimisations that could be possible in a future 3GPP network. Future 3GPP networks could benefit greatly by natively supporting ICN/CCN protocols.

Pre-conditions

ICN/CCN protocols are operated over the 3GPP system and edge nodes are user content cache enabled.

Service Flows

1. A user makes a request for ContentID=X to the network by sending an ICN/CCN content request to its nearest ICN/CCN node.
2. The closest edge node checks if the content is available at its own cache and responds accordingly with the content. If the node does not have the content then the content request is forwarded to the next content system enabled node and so on.
3. If the content search is not resolved in a given time or to a given set of bounding criteria, then, by node request, default access to the content by direct internet may be used.

Post-conditions

Void.

5.38.2 Potential Impacts or Interactions with Existing Services/Features

Void.

5.38.3 Potential Requirements

The 3GPP system shall efficiently support a mobile optimised ICN/CCN protocol.

The 3GPP system shall support flexible placement of ICN/CCN caches by enabling flexible user-plane termination (including user-plane termination at the base station).

The 3GPP system shall support efficient transport of a mobile optimised ICN/CCN protocol via the 5G and evolved LTE radio.

The 3GPP system shall provide charging, LI and QoS support for the ICN/CCN protocol.

5.39 Wireless Briefcase

5.39.1 Description

This use case provides a user with Personal Content Management (PeCM) of all of their traditionally stored HDD information in the form of a Flat Distributed Personal Cloud (FDPeC) facilitated over the 3GPP communications network.

Today there are many single-stop cloud providers but they are all centralised and have notable latency even when accessed by fast communications links to the internet.

What is proposed here is a ‘distributed cloud’ accessed over the 3GPP communications network and always aware of the latest changes that a user is making to their personal information and stored files.

A user would need to carry only their 3GPP communications device in order to access any of their personal content information/files.

The FDPeC comprises multiple ‘distributed’ storage locations: i) at the 3GPP device, ii) at the 3GPP edge node cache that they are currently camped on and iii) at the user’s nominated Internet Cloud store.

The users Most Recently Used (MRU) information/files are stored at the 3GPP device and/or at the 3GPP edge node cache

The Least Recently Used (LRU) information/files are stored at the Internet Cloud store.

Over time the user's information/files are all stored at the Internet Cloud store.

As the user moves, his information is stored at different parts of the composite FDPeC in order to minimise latency and manage the cloud across the available communications options that the user can access at this time and in this environment.

Such a service could also provide a student wireless backpack, where students can resume their work through the same or a different device at a time convenient to them, with very fast response times from the network.

Pre-conditions

The user has subscribed to an Internet Cloud store

The user has subscribed to an operator's or service provider's FDPeC

Service Flows

1. A user is at work; his 3GPP device is on the desk and operates as a communication bridge to a local machine that has 3GPP/WiFi connectivity, a human interface and a processor with a set of local applications and the user's FDPeC.
2. The user's 3GPP device has automatically security validated that the applications on the local machine are valid for this user and enabled them for access to the FDPeC whilst the user is in short range of the local machine.
3. The user walks away from the desk and takes his 3GPP device with him.
4. The FDPeC system tracks the user/3GPP device with all of his MRU and open documents/information ported on his device and ends the security validation with the local machine on the desk.
5. The user/device moves to another location in the car or at home and moves into range of the new local machine and security validates with this new set of equipment (if the user has previously camped on this equipment)
6. In this way the user can move around to different local machines and has to carry only his device with him.
7. Initial validation of the user's device with a particular local machine is enabled by operating a simple security software application running on the local machine and validating the device to it using the device and SIM security as the security anchor.

Post-conditions

Void.

5.39.2 Potential Impacts or Interactions with Existing Services/Features

Void.

5.39.3 Potential Requirements

The 3GPP system shall support the ability to securely store the personal data information/files of a user in such a way that they are retrievable with no perceptible delay to the user.

The 3GPP System shall support a mechanism to control the upload and download of personal information/files between the 3GPP device and a server in the network (e.g., Flat Distributed Personal Cloud).

NOTE: A suitable control system (e.g. FDPec control system) can be standardised for use as part of the 3GPP system evolution.

5.40 Devices with variable data

5.40.1 Description

A device is installed and activated at a street corner that includes a camera, some on board processing capability, as well as the ability to send information to the authorities. The device periodically sends a small amount of information to the authorities indicating conditions are normal. When the device detects an incident out of the ordinary, it sends a good quality video to the authorities. In a similar manner, smartphones have multiple applications which frequently exchange small amounts of data with the server side of the application. Larger amounts of data are needed only e.g. when a user is interested in it.

For both cases, the event of a large amount of data is expected to happen only occasionally but nevertheless the network needs to support it. The network needs to be efficient for both frequent and infrequent short data bursts as well as large amounts of data (e.g. video) since having two separate modems on the device for two technologies increases device complexity.

As sensor and monitoring devices are deployed more extensively, there will be a need to support devices that send data packages ranging in size from a small status update in a few bits to streaming video. The network will need the flexibility to provide efficient service to the device, regardless of when it sends data and regardless of how much data is sent in a given transmission.

Specifically, to support short data bursts, the network will need the ability to operate in a connectionless mode where there is no need to establish and teardown connections when small amounts of data need to be sent. The system will therefore accept data transmission without a lengthy and signalling intensive bearer establishment and authentication procedure. The system will, as a result, avoid both a negative impact to battery life for the device and using more signalling resources than actual data transport resources.

The same device will need to establish a connection when it needs to transmit a large amount of data (e.g., video).

5.40.2 Potential Service Requirements

The 3GPP System shall be efficient and flexible for both low throughput short data bursts and high throughput data transmissions (e.g., streaming video) from the same device.

The 3GPP system shall support efficient signalling mechanisms (e.g., signalling is less than payload).

The 3GPP system shall reduce signalling overhead for security needed for short data burst transmission, without reducing the security protection provided by 4G 3GPP Systems.

5.41 Domestic Home Monitoring

5.41.1 Description

With the advent of bespoke home monitoring systems provided by utility companies for monitoring utility resource usage and home security vendors providing burglar and video monitoring systems, there is a proven market for these IoT systems. Many of these systems provide remote access over Wi-Fi or Ethernet /local control unit and some provide WiFi/Smartphone interconnection.

However, these systems do not directly interface with 3GPP mobile systems and are in effect ‘capillary IoT inputs to the basic IP interface provided by 3GPP mobile systems and often use the 3GPP system in a notably inefficient manner. Also such capillary IoT systems do not interwork together across vendors.

What is required is some form of integrated IoT concentrator capability at the smartphone device that integrates/interworks and normalises the information from these devices at the home in a standardised manner and is able to relay this information to another mobile for use/ remote control of the home.

This use case proposes the introduction of a category of device and/ or feature additions to a standard smartphone device that is 3GPP system capable to enable a local fixed, potentially mains powered device or battery powered mobile device to interwork with existing capillary IoT systems, consolidate and selectively forward information towards either another fully functioning mobile device or a home minding head end application.

It is envisaged that such a capability would enable a remote homeowner to operate a use case that efficiently remotely monitors and controls their home in an efficient, fast, efficient manner using a static mobile IoT concentrator which connects to 3GPP systems.

Further, as the ‘IoT Home Concentrator’ is static and only communicates low volumes of data then the device could operate a low maintenance group connection towards the network on potentially a low bit rate link with moderate latency.

Today the context of such a device is not standardised so a complex home system is usually notably inefficient (as a system) when operated without a concentrator with each IoT stream operated as a separate communications stream over the 3GPP system.

Pre-conditions

Local low complexity mobile deployed in the home with a concentrator application running to interface to capillary systems.

Remote head end application 'home minder' and or personal mobile application interface towards the concentrator static mobile.

Service Flows

1. The subscriber purchases Off-The-Shelf (OTS) IoT devices and systems as today.
2. The subscriber purchases a 3GPP home IoT concentrator/IoT bridge device
3. The subscriber configures their concentrator device
4. The Subscriber obtains a 3GPP home concentrator interface enabled application for their mobile device
5. The subscriber may monitor or control all of their home IoT systems for sensing and actuation.
6. Additionally, when in the house the subscriber may control all devices that connect to their home controller 3GPP device, potentially making use of the "local control UC" already detailed in the SMARTER specification.
7. Additionally, when the user is out of the house they can delegate to another application potentially hosted at the network operator or by one of the utility companies (to which the mobile subscriber has subscribed) an application to manage their home when they are away on business/ holiday through a delegation of authority control capability.

Post-conditions

Void.

5.41.2 Potential Impacts or Interactions with Existing Services/Features

The system should interconnect with existing IoT systems

The system should enable mobiles that can operate as static concentrators of IoT capillary traffic towards 3GPP networks

The system shall support the integration of mobile, IoT capillary concentrator systems into Home Base stations

5.41.3 Potential Requirements

The 3GPP system shall provide for the support of a UE connected to remote monitoring (that suits home monitoring/control) and includes: Static mobile, Group connection, Normal data service and service for low volume, low frequency updates.

The low volume, low frequency update service shall allow messages up to 256 octets per message.

IoT Security is provided only by the connected UE. Further security measures are for implementation at the IoT level applications.

5.42 Low mobility devices

5.42.1 Description

Many sensor type devices will be stationary, or have very low mobility. For example, devices may be embedded in a building, bridge, or other structure to monitor for motion, air quality, moisture, etc. These sensors may be manually or automatically activated when they are deployed in the area to be monitored. Upon activation, the device is authenticated and registered with the network and registers with the sensor monitoring service/application.

Each sensor sends its information infrequently. The application can request information from a sensor as needed.

A method by which large numbers of stationary sensors may be deployed and managed while minimizing overhead is vital.

5.42.2 Potential Service Requirements

The 3GPP System shall support a mechanism to accept information from large numbers of stationary devices with reduced mobility management (e.g., handover support, idle mode mobility management).

The 3GPP System shall support a resource efficient mechanism to provide information to a stationary device.

5.42.3 Potential Operational Requirements

The 3GPP System shall provide resource efficient support for stationary devices with reduced mobility management (e.g., handover support, idle mode mobility management).

5.43 Materials and inventory management and location tracking

5.43.1 Description

Consider the case of a warehouse, package delivery system, supplies registry, or equipment tracker. Each item being tracked would need a periodic identification indication communicated to a tracking application. A sensor would be associated (e.g., physically attached) with each item. Sensors may be manually or automatically activated when they are associated to the item. Upon activation, each sensor identifies itself with the network and registers with the sensor monitoring service/application. The communication from each sensor would need to be reliable but not necessarily of high priority. Communication would be predominately uplink, although some downlink acknowledgements and/or commands may be sent. The tracking devices would below complexity, low powered, battery-powered sensors. Further, the sensors configuration may vary from stationary and dense (e.g., in a warehouse) to wide-spread and mobile but locally dense (e.g., delivery trucks). The sensor should support multiple radio access technologies to ensure reachability as it crosses access coverage boundaries, e.g. from the warehouse to the delivery truck to the delivery location.

Due to the low data rate and low duty cycle of the tracking information, signalling overhead must be minimized in spite of mobility. Because the devices are low power, sufficient coverage is needed to ensure accessibility. Also, due to the possible device density, a method for resource sharing by a large number of devices is necessary. As the device moves, e.g., in a delivery truck, it will use whatever access technology is available at the time it attempts to access the network.

The current 3GPP access model requires a UE to attach to a network and establish a bearer for data communication. In the case of a large number of devices with low data throughput such as sensors, this places undue strain on the network resources. Provisioning and state information is required for each device, and signalling overhead can eclipse the amount of data being sent.

A method by which large numbers of possibly mobile sensors may be deployed and data may be uploaded while avoiding unnecessary network attachment and bearer management signalling overhead is vital. To minimize resources used in support of these devices when they are not moving, a method for avoiding the use of mobility management resources for these large numbers of devices in a stationary state is also required.

Use of network connected devices for materials and inventory management and location tracking could address limitations in existing, manual, systems of inventory management. Such an approach would need to be less labour intensive, provide transparent location tracking across broad tracking areas and multiple access technologies, and scale when items are locally dense.

5.43.2 Potential Service Requirements

The 3GPP System shall support a resource efficient mechanism to accept information from large numbers of locally dense devices, possibly simultaneously.

The 3GPP System shall support mechanisms to enable sufficient indoor and outdoor coverage (e.g., 20dB better coverage than legacy Rel 99 GPRS system) for a large number of locally dense low power devices.

The 3GPP System shall support a mechanism to manage resource (e.g., radio resources) sharing by large numbers of locally dense devices efficiently.

The 3GPP system shall support communication service for high density of devices up to (e.g., 1 million devices per km^2), with high mobility at minimum of 100 km/h and with reduced battery consumption.

The 3GPP system shall support high positioning accuracy in both outdoor and indoor scenarios (e.g., 0.5m).

5.43.3 Potential Operational Requirements

The 3GPP System shall support a mechanism which provides efficient authentication for low power devices.

The 3GPP System shall support a mechanism which provides appropriate confidentiality and integrity protection for data from low power devices.

The 3GPP System shall support a mechanism to efficiently manage one or more devices associated with a service (e.g., inventory tracking service).

The 3GPP System shall support roaming.

5.44 Cloud Robotics

5.44.1 Description

Rather than viewing robots and automated machines as isolated systems with limited computation and memory, Cloud Robotics considers a new paradigm where robots and automation systems exchange data and perform computation via networks. Cloud robotics would allow robots to offload compute-intensive tasks like image processing and voice recognition and even download new skills instantly.

For instance, a robot that finds an object that it's never seen or used before (e.g. a plastic cup). The robot could simply send an image of the cup to the cloud and receive back the object’s name, a 3-D model, and instructions on how to use it.

A robot would send video/audio of what it is seeing/hearing and data collected to the cloud in real time, receiving in return detailed information about the environment and action instructions. Using the cloud, a robot could improve capabilities such as speech recognition, language translation, autonomous car, path planning, and 3D mapping.

It is supposed that cloud robotics will be widely used in future for industry and living, for example, each family has one or several cloud robotics that are connected to the 3GPP network. In addition, robots can play an important role in assisting people with disabilities, e.g. helping students with special needs to interact with their educational environment and people around them.

5.44.2 Potential Service Requirements

The 3GPP system shall support UEs of high density distribution to upload synchronized audio, video and data in real time.

The 3GPP system shall support end to end latency lower than [10ms].

5.44.3 Potential Operational Requirements

Void.

5.45 Industrial Factory Automation

5.45.1 Description

Factory automation requires communications for closed-loop control applications. Examples for such applications are robot manufacturing, round-table production, machine tools, packaging and printing machines. In these applications, a controller interacts with large number of sensors and actuators (up to 300), typically confined to a rather small manufacturing unit (e.g. 10m x 10m x 3m). The resulting S/A density is often very high (up to $1/m^3$). Many of such manufacturing units may have to be supported within close proximity within a factory (e.g. up to 100 in assembly line production, car industry).

In the closed-loop control application, the controller periodically submits instructions to a set of S/A devices, which return a response within a cycle time. The messages, referred to as telegrams, typically have small size (<50Bytes). The cycle time ranges between 2 and 20ms setting stringent latency constraints on to telegram forwarding (<1ms to10ms). Additional constraints on isochronous telegram delivery add tight constraints on jitter (10-100us). Transport is also subject to stringent reliability requirements measured by the fraction of events where the cycle time could not be met ($<10^{-9}$). In addition, S/A power consumption is often critical.

Traditionally closed-loop control applications rely on wired connections using proprietary or standardized field bus technologies. Often, sliding contacts or inductive mechanisms are used to interconnect to moving S/A devices (robot arms, printer heads, etc.). Further, the high spatial density of sensors poses challenges to wiring.

WSAN-FA, which has been derived from ABB's proprietary WISA technology and builds on top of 802.15.1 (Bluetooth), is a wireless air interface specification that is targeted at this use case. WSAN-FA claims to reliably meet latency targets below 10-15ms with a residual error rate of $<10^{-9}$. WSAN-FA uses the unlicensed ISM 2.4 band and is therefore vulnerable to in-band interference from other unlicensed technologies (WiFi, ZigBee, etc.).

To meet the stringent requirements of closed-loop factory automation, the following considerations may have to be taken:

- Limitation to short range communications between controller and sensors/actuators.
- Allocation of licensed spectrum for closed-loop control operations. Licensed spectrum may further be used as a complement to unlicensed spectrum, e.g. to enhance reliability.
- Reservation of dedicated air-interface resources for each link.
- Combining of multiple diversity techniques to approach the high reliability target within stringent latency constraints such as frequency-, antenna-, and various forms of spatial diversity, e.g. via relaying, etc.
- Utilizing OTA time synchronization to satisfy jitter constraints for isochronous operation.
- Network access security used in an industrial factory deployment is provided and managed by the factory owner with its ID management, authentication, confidentiality and integrity.

Related material can be found in [11], [12], [13], and [14].

Pre-conditions

Void.

Service Flows

A typical industrial closed-loop control application is based on individual control events. Each closed-loop control event consists of a downlink transaction followed by a synchronous uplink transaction both of which are executed within a cycle time, T_{cycle}. Control events within a manufacturing unit may have to occur isochronously.

1. Controller requests from sensor to take a measurement (or from actuator to conduct actuation).
2. Sensor sends measurement information (or acknowledges actuation) to controller.

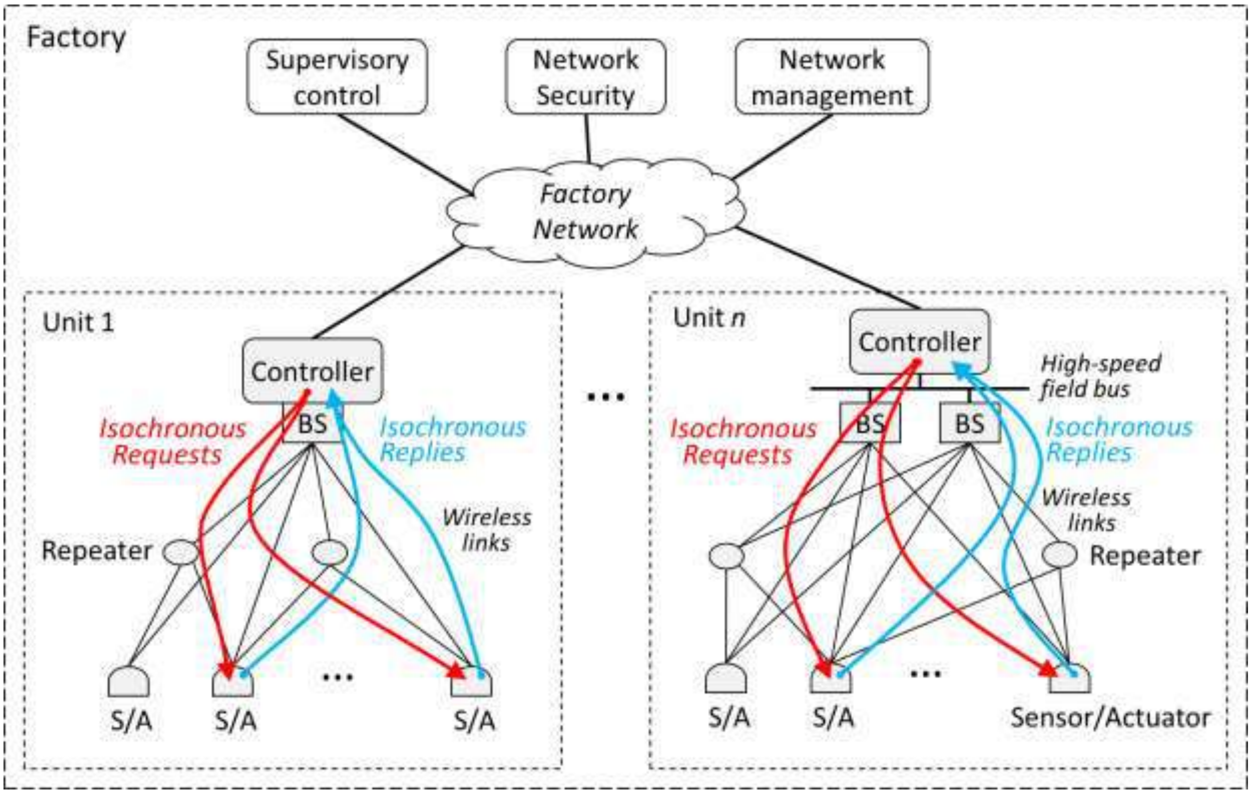

Figure 5.45-1: Communication path for isochronous control cycles within factory units

Figure 5.45-1 depicts how communication will occur in factory automation. In this use case, communication is confined to local controller-to-S/A interaction within each manufacturing unit. Repeaters may provide spatial diversity to enhance reliability.

Post-conditions

Void.

5.45.2 Potential Service Requirements

The 3GPP system shall support cycle times of [1ms to 2ms.] Within the cycle time, both uplink and downlink transactions must be executed. Additional margin is needed for the sensor/actuator to process the request.

Transaction jitter should be [below 10usecs.]

Reliability, measured as the fractions of transactions that cannot meet the latency or jitter constraints, should remain [below 10^{-9}.]

Each transaction should support a payload of 50 to 100 Bytes

For factory automation, required range is up to [10-20m.]

All transactions should be sufficiently integrity- and confidentiality- protected.

NOTE: The above requirements are for end to end performance, defined as communications sent by source and communication received by target.

5.45.3 Potential Operational Requirements

The 3GPP system shall support industrial factory deployment where network access security is provided and managed by the factory owner with its ID management, authentication, confidentiality and integrity.

The 3GPP system shall support an authentication process that can handle alternative authentication methods with different types of credentials to allow for different deployment scenarios such as industrial factory automation.

5.46 Industrial Process Automation

5.46.1 Description

Process automation requires communications for supervisory- and open-loop control applications, process monitoring and tracking operations on field level inside an industrial plant. In these applications, a large number of sensors (~10k) are distributed over the plant forward measurement data to process controllers on a periodic and/or event-driven base. Traditionally, wireline field bus technologies have been used to interconnect sensors and control equipment. Due to the sizable extension of the plant (~10km^2), the large number of sensors and the high deployment complexity of wired infrastructure, wireless solution have made inroads into industrial process automation. Presently, high growth rates are expected in the migration from wireline to wireless solutions for industrial process manufacturing.

The use case requires support of a large number of sensor devices (10k) per plant as well as highly reliable transport (packet loss rate <10^{-5}). Further, power consumption is critical since most sensor devices are battery-powered with a targeted battery lifetimes of several years while providing measurement updates every few seconds. Also, range becomes a critical factor due to the low transmit power levels of the sensors, the large size of the plant and the high reliability requirements on transport. Latency requirements typically range between 100ms and 1s. Data rates can be rather low since each transaction typically comprises less than 100B.

The existing wireless technologies (e.g. WirelessHART and ISA100.11a) rely on unlicensed technologies (802.15.4) operating in the ISM 2.4 band. Transport is therefore vulnerable to interference caused by other technologies (e.g. WiFi, Bluetooth). This sensitivity can be more significant given the low transmit power level of the sensors. With the stringent requirements on transport reliability, such interference is detrimental to proper operation.

The use of licensed spectrum could overcome the vulnerability to same-band interference and therefore enable higher reliability. Utilization of licensed spectrum can be confined to those events where high interference bursts in unlicensed bands jeopardizes reliability and latency constraints. This allows sharing the licensed spectrum between process automation and conventional mobile services.

Further, multi-hop topologies can provide range extension and mesh topologies can increase reliability through path redundancy. Time synchronization will be highly beneficial since it enables more power-efficient sensor operation and mesh forwarding.

Related material can be found in [15], [16], [17], [18], [19], and [20].

Pre-conditions

Void.

Service Flows

A typical process control application supports downstream and upstream flows between process controllers and S/As which consist of individual transactions. The process controller resides in the plant network. This network interconnects via base stations to the wireless (mesh-) network which hosts the S/A devices. Typically, each transaction uses less than 100B. A controller-initiated transaction creates the following service flow:

1. The process controller requests from sensor to take a measurement (or from actuator to conduct actuation). The request is forwarded via the plant network and the wireless mesh to the S/A.

2. The S/A processes the request and sends a replay in upstream direction to the controller. This reply may contain an acknowledgement or a measurement reading.

An S/A-device initiated transaction creates the following service flow:

1. The sensor sends measurement reading to the process controller. The request is forwarded via the wireless mesh and the plant network.

2. The process controller may send an acknowledgement in opposite direction.

For both controller- and S/A-initiated service flows, upstream and downstream transactions usually occur asynchronously.

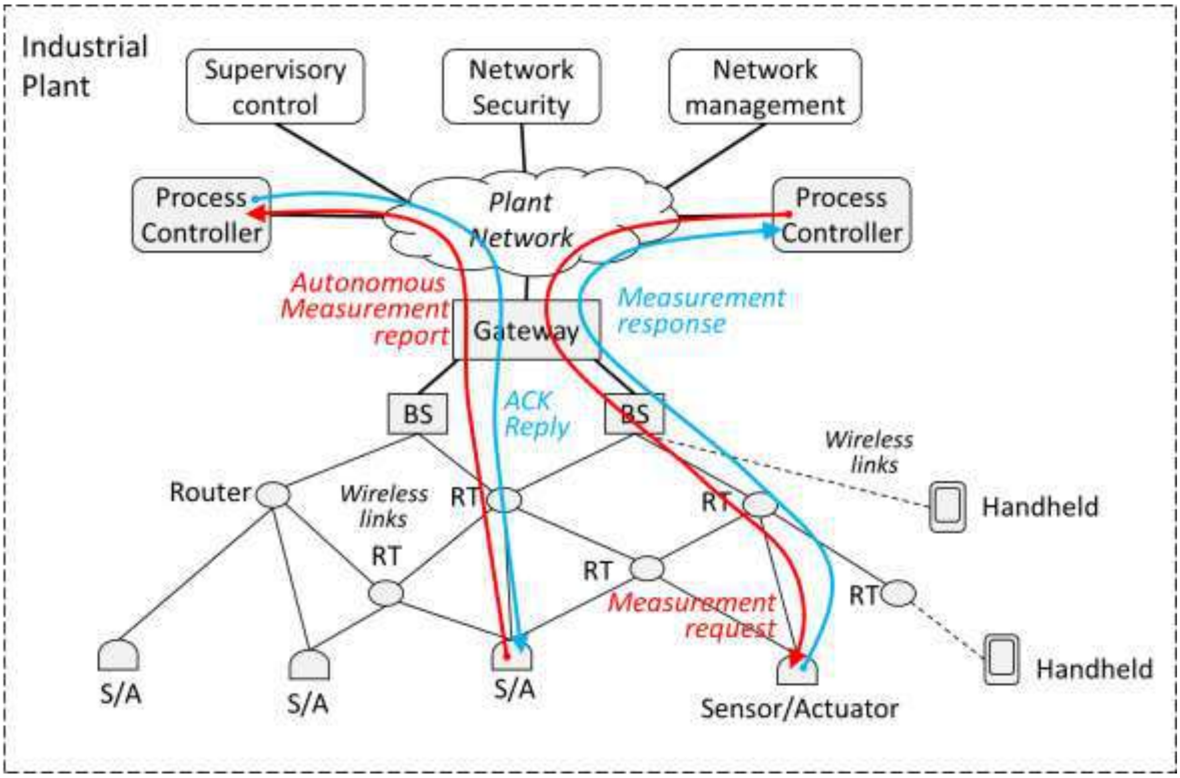

Figure 5.46-1: Communication path for service flows between process controllers and S/A devices

Figure 5.46-1 depicts how communication will occur in process automation. In this use case, communication runs between process controller and S/A device via the plant network and the wireless mesh network. The wireless mesh may also support access for handheld devices for supervisory control or process monitoring purposes.

Post-conditions

Void.

5.46.2 Potential Service Requirements

The 3GPP system shall support [10k sensor nodes within an area of 10sqkm.]

Reliability for the transport of transactions, measured as the fractions of packet losses, should remain [below 10^{-5}.]

The 3GPP system shall support a [transaction latency of 50-100ms], defined as the overall cycle time between a sensor reading and action from process controller.

The 3GPP system shall allow a battery powered sensor lifetime of multiple years while enabling a transaction rate of one every few seconds

Transactions should be sufficiently integrity- and confidentiality- protected.

NOTE: The above requirements are for end to end performance, defined as communications sent by source and communication received by target.

5.46.3 Potential Operational Requirements

Void.

5.47 SMARTER Service Continuity

5.47.1 Description

Service continuity in mobile networks is often perceived as being synonymous with IP address preservation. To enable service continuity today, the mobile device is typically assigned an IP address that is hosted at an “IP anchor” node residing sufficiently deep inside the core network. The traffic between the mobile device and the IP anchor node is tunnelled, whereas IP routing is used only within the packet data network that starts at the IP anchor node. Even though this tunnelled data path may lead to very inefficient resource use in certain scenarios (e.g. two UEs under the same eNB communicating with each other via a long hairpin), this is still done in order to support the IP address preservation.

However, many applications today can survive an IP address change. One example are SIP (Session Initiation Protocol) based applications, where a “SIP reINVITE” message is sent in order to update the remote party of the new IP address that will be used as the contact address for future user plane traffic. Another example are DASH (Dynamic Adaptive Streaming over HTTP) based applications which not only can survive a change in IP address, but can also resume with content delivery from a different content distribution server. This is enabled by associating the content segments with a globally unique transport-independent labels (URLs), so that the streaming client can always determine the next-in-line content segment and request it from the content distribution network (including from a different server).

With the ever-increasing multimedia broadband (MBB) data volumes, it would be beneficial if the 3GPP system could select an IP anchor node that is located close to the radio access network edge and to the current UE location. This would allow for offloading of the IP traffic from the 3GPP system user plane onto traditional IP routing networks close to the network edge, which minimises the tunnelled part and maximises the IP routed part. This in turn has the following advantages:

- Increased scalability of the 3GPP system user plane nodes.
- Optimization of the end-to-end communication path by avoidance of triangular routing via the IP anchor node.
- Content delivery is resumed from a geographically closer content distribution server, which further reduces the traffic load on the 3GPP network.
- Lower end-to-end latency of data transmission.
- Better user experience.

Figure 5.47-1 depicts an example of a UE which starts receiving content from server CDN A and, at some point, having determined that the current IP anchor is suboptimal, the system decides to establish an optimal PDN connection for the same service using a different IP anchor node. When the network IP anchor node changes, there may be an interruption in the service, and it is desired that this interruption time be minimized.

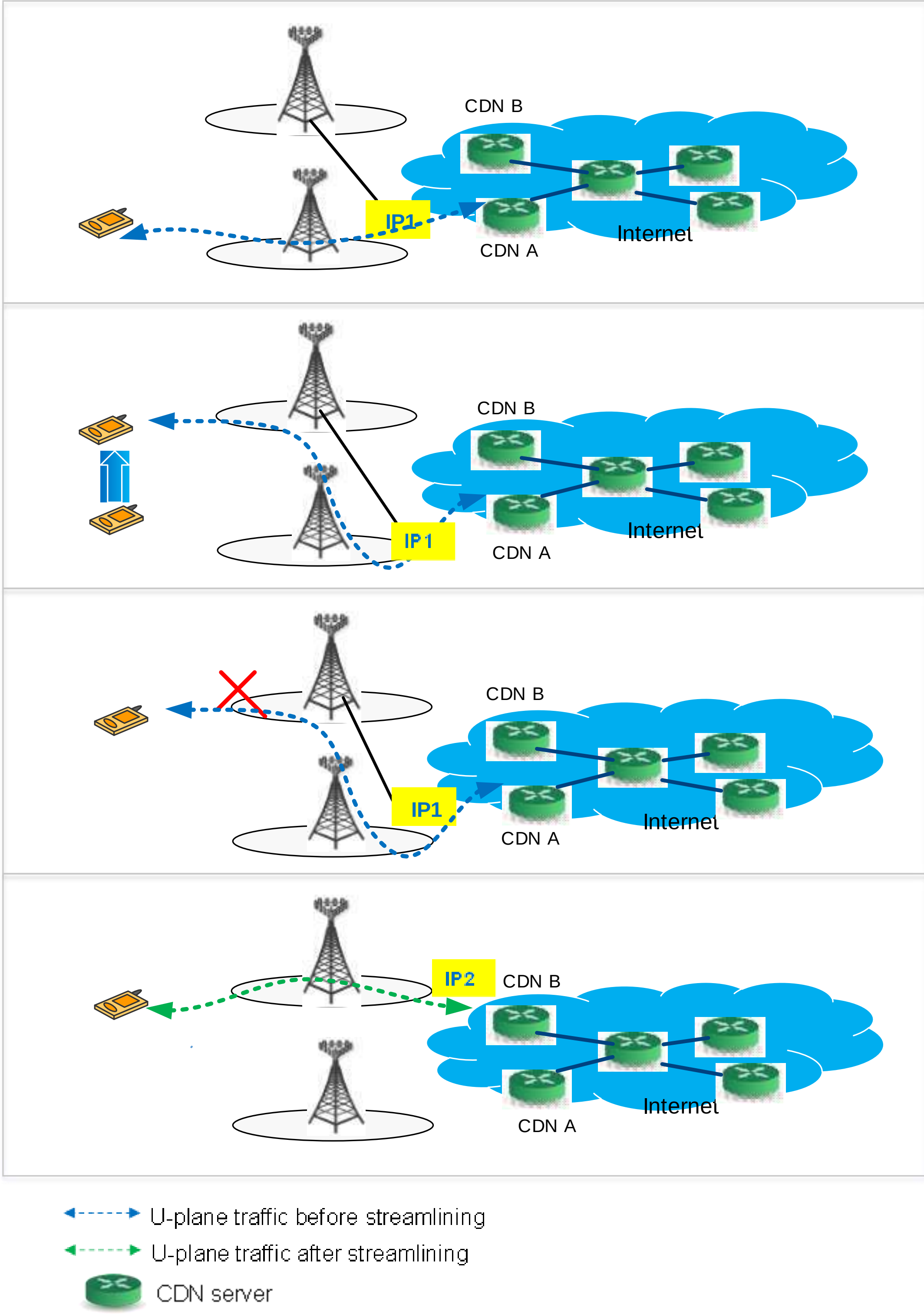

Figure 5.47-1: Example of change in IP anchor node for a given service

5.47.2 Potential Service Requirements

Void.

5.47.3 Potential Operational Requirements

Subject to operator's policy, the 3GPP system shall be able to change the IP anchoring point for a UE with minimal impact on the user experience.

5.48 Provision of essential services for very low-ARPU areas

5.48.1 Description

The objective is to provide access to the network in low-ARPU areas where there is a need for providing access to essential services with a basic Internet access (e.g. Basic broadband speeds, relaxed latency requirements).

A use case can be the following:

Amadi lives in a small village in a scarcely populated region of central Africa. Before going into town to sell the results of the cereal harvest, he gets market prices of crops and cattle from many markets in the country from his device (terminal or user equipment). Amadi's device (terminal or user equipment) gives also access to other critical services about social relationships, administrative process, banking services, health monitoring, education services, news and knowledge.

5.48.2 Potential Service Requirements

The 3GPP system shall support network sharing with capabilities for operators to set parameters for resource sharing both on demand and dynamically.

The 3GPP system shall provide efficient support for low or no mobility UEs (e.g. up to 50 km/h).

The 3GPP system shall support very efficient use of the control plane (e.g., cooperation between services to minimize overall signalling between a UE and the network).

The 3GPP system shall support efficient use of the data plane (e.g., packaging data from multiple applications and sending it on a periodic basis rather than an on demand basis).

The 3GPP system shall support APIs that provide network status information to applications (e.g., to allow applications to use network resources efficiently).

The 3GPP system shall be optimised to minimise as much as possible the traffic (Data and signalling) on the interfaces between the access network and the core network in order to reduce the amount of backhaul traffic.

The 3GPP system shall be optimised to support UEs with minimal functionality (e.g. user experienced data rate of 10 Mbps at DL and 10 Mbps at UL with E2E latency of 50 ms).

The 3GPP system shall be optimised to facilitate very large cells (e.g.: link budget better than 160 dB, relaxed timing on random access and other procedures to enable very long range beyond 50km).

5.48.3 Potential Operational Requirements

The base station shall support an energy saving mode with the following characteristics:

- The energy saving mode may be activated/deactivated either manually (e.g., on demand), or automatically (e.g., reaching a threshold).
- The transmit power may be reduced when the energy saving mode is activated.
- The latency requirements may be reduced when the energy saving mode is activated.
- Service may be restricted to authorized users.
- The base station may be in listen mode.

The 3GPP system shall support centralized network automation and remote management in order to reduce local management tasks.

The data rate transfer should be enhanced at the cell edge for very large cells.

The access network shall be able to inform UEs what capabilities are supported (e.g., to allow UEs to determine if the network provides the required capabilities).

The 3GPP system shall be able to provide the essential services with connection density of 16 / km^2.

The 3GPP system shall be able to provide the essential services with traffic density of 16 Mbps / km^2.

5.49 Network capability exposure

5.49.1 Description

Network capability exposure technology is to provide the network capabilities to the 3rd party ISP/ICP. Service providers can be capable of configuring and managing the service via e.g. open API, while operators will have the option to manage and evolve the network. This feature will arrange a highly efficient coordination between the service and the network. The operator network works together with the 3rd party, improving user's experience and benefiting the industry.

Based on 3GPP SEES, the operator can provide the network information and control the capability with specific demand to the third party users. However, with the advent of 5G, some new network capabilities need to be considered to be exposed to the 3rd party, such as the network slicing capability.

Related material can be found in [21].

5.49.2 Potential Service Requirements

The 3GPP system shall be able to support the existing network capability exposure.

The 3GPP System shall be able to support to expose the 5G network information and capabilities to the 3rd party, such as the network slicing capability.

NOTE: The specific network slicing capability which is needed to be exposed should be defined after the slicing definition is completed.

5.49.3 Potential Operational Requirements

Void.

5.50 Low-delay speech and video coding

5.50.1 Description

Current speech codecs have an inherent coding delay of 20-40 ms. Such a coding delay is not a problem during a phone call because even a 400 ms one-way delay between speakers does not seriously impair an interactive discussion. Moreover, most systems, at least if the speakers are not on different continents, offer a relatively short transmission delay between speakers. The advantage with a higher coding delay (i.e., 20-40 ms) is that it makes it easier to compress the speech signal, either to reduce the bandwidth or to transmit a higher-quality signal.

When voice is used in a highly interactive environment, e.g., a multiplayer game or a virtual reality meeting, the requirements on the speech coding delay become tougher to meet, and current coding delays are too high. To support interactivity, the one-way delay for speech should be 10 ms (or lower).

Augmented reality, virtual reality, three-dimensional (3D) services will be among the services which play an increasingly significant role in the 2020+ timeframe. That is, video will be used more broadly. These scenarios have critical requirement on transfer bandwidth and delay to guarantee good user experience compared to current video service.

Frame rates, resolution and bandwidth are different aspects of video codec.

The higher the frame rates (frames per second) the better the video quality, virtual reality may require the capability of displaying content at frame rates of 120 fps or more.

In order to fulfil the performance (e.g. latency) requirement of future video usage, there is trade-off between complexity and bandwidth usage. But, more complexity (e.g. more complicated compression improvement) implies higher performance processors are required to fulfil the latency requirement.

5.50.2 Potential Service Requirements

The 3GPP system shall support speech with very low one-way service latency [10 ms]

The 3GPP system shall be able to support video with frame rate of [120 fps] and very low one-way service latency [10 ms]

5.50.3 Potential Operational Requirements

Void.

5.51 Network enhancements to support scalability and automation

5.51.1 Description

The future mobile network will be able to automatically and dynamically control and allocate the network resources, such as the network function setting up, capacity expansion / contraction and removal. The capacity of network elements could be flexibly adjusted according to the load status and other factors defined by the operator, which allows the operator to deploy services on demand and adjust the deployment automatically. However, the network scalability and automation may cause some potential impacts or interactions with existing services or features.

For example, when the congestion happens to one network function, the network decides to add a new network function automatically, then the 3GPP network needs to have the policies for the load migration in order to minimize the service impact on the original network function, especially for the low latency tolerant services (e.g. VoLTE) which need to be protected in order to guarantee the user's experience. Moreover, there is also a need to enhance the network function selection mechanism; otherwise, this newly added network function can't treat the traffic bringing the congestion effectively.

As a result, the 3GPP system shall be able to guarantee the service experience of the subscribers during the network scaling and automation operation. Moreover, the existing mechanisms (e.g. load balancing, network function selection) which are closely related with the effect of the network scalability and automation operation need to be enhanced.

5.51.2 Potential Service Requirements

The system shall be able to guarantee the service experience of the subscribers when performing the network scaling and automation operation.

The system shall be able to enhance the existing mechanisms, e.g. load balancing, network function selection, which are highly related with the effect of the network scalability and automation operation.

5.51.3 Potential Operational Requirements

Void.

5.52 Wireless Self-Backhauling

5.52.1 Description

The increasingly high densification of access nodes needed to meet future performance objectives, poses considerable challenges in deployment and management. The use of wireless backhaul for such access nodes helps to address some of the challenges. Wireless self-backhauling may be particularly useful for higher frequency bands, where range may be limited and beam forming can help to minimize interference and increase spectrum reuse.

As an example of wireless self-backhauling, we consider an early deployment of millimetre wave access nodes with the aim of providing coverage over a given geographic area that is larger than the range of a single access node (e.g., an urban-centre deployment). Wireless self-backhauling can enable simpler deployment and incremental rollout by reducing the reliance on the availability of wired backhaul at each access node location. The millimetre wave access nodes can be interconnected wirelessly such that only a subset of the access nodes requires a wired backhaul. Network planning and installation efforts can be reduced by leveraging plug & play type features—self-configuration, self-organizing, and self-optimization. Wireless self-backhauling can enable incremental growth planning by adapting deployment of managed backhaul capacity to the increase of traffic demand as the number of users within the service grows over time (i.e., wired backhaul connectivity can be added to a greater fraction of the access nodes over time). The example described here mentions millimetre wave spectrum but wireless backhauling is not limited to those bands.

Pre-conditions

An operator is deploying a new millimetre wave technology in an urban centre. Access node density and installation locations have been pre-determined based on coverage requirements and other deployment considerations. A subset of the identified access node locations simply cannot be practically connected to infrastructure with wired backhaul. It is also anticipated that the expected initial subscriber demand does not warrant the complexity of providing a wired backhaul to each access node for initial system launch. Thus, some access nodes will be wirelessly backhauled to infrastructure via other neighbouring access nodes that have wired backhaul.

Service Flows

1. Access nodes are deployed at the identified locations.
2. A subset of the deployed access nodes is connected to the operator's infrastructure using wired or fiber backhaul.
3. Access nodes are enabled for infrastructure and wireless self-backhauling operations.
4. Access nodes discover neighbouring access nodes and exchange information regarding their function and reachability to the operator's infrastructure (e.g., direct or via path through neighbouring nodes if/when established).
5. Access nodes integrate into operator infrastructure as paths are determined.
6. Access nodes are enabled for subscriber access operations and begin providing service.

Post-conditions

The new millimetre wave system is fully operational and providing ubiquitous service to subscribers throughout the target urban centre. Since subscriber density is initially low and the millimetre systems achieves a high degree of spectrum reuse and low interference (e.g., due to beam forming), subscribers obtain high performance service. As subscriber density increases over time, the operator may incrementally deploy wired backhaul to additional access nodes (i.e., some that are presently served by wireless backhaul through neighbouring access nodes), thereby increasing the overall service capacity of the network.

5.52.2 Potential Service Requirements

Void.

5.52.3 Potential Operational Requirements

5G Radio Interface Technology (RIT) shall be designed with features and optimizations to provide a backhaul function.

The system shall support flexible partitioning of resources between access and backhaul functions when supported in a common band, including quasi-static provisioning of separate access and backhaul resources, and dynamic allocation of access and backhaul resources, e.g., based on current local conditions.

The system shall support autonomous neighbour discovery and link setup, self configuration of addressing and forwarding plane, and autonomous integration into core/OAM.

The system shall support use of multiple RITs to increase service availability and network resiliency.

The system shall support multi-hop wireless network topologies.

The system shall support network topologies with redundant connectivity and paths to minimize service disruptions due to network dynamics.

The system shall support dynamic adaptation to topology changes (e.g., due to node additions, node failures, link fluctuations.)

5.53 Vehicular Internet & Infotainment

5.53.1 Description

This Use Case describes the provision of internet to the vehicle and its use for general browsing and infotainment. A high quality data connection and good coverage makes possible the reliable delivery of media and internet to a vehicle. This facilitates the provision of infotainment by internet as a standard feature of vehicles in the future.

As well as infotainment from the general internet, dedicated infotainment suppliers for vehicles may become available.

Pre-conditions

Built-in, dedicated vehicular UE registered to a network with an active data connection OR Portable UE tethered to the vehicle and registered to a network with an active data connection.

Vehicle entertainment system linked to a dedicated or tethered UE.

Service Flows

A passenger in the vehicle accesses the internet using the vehicle's entertainment system.

The passenger is able to use the internet while the vehicle is in motion up to at least 200km/h. The passenger accesses web sites, uses social media and downloads files/apps in the same way as on a device at home.

The passenger then selects an internet radio station and plays music in the vehicle that is streamed over the internet.

After a while, the passenger decides to select an Infotainment supplier to which he is registered. The passenger signs into the supplier and selects a movie. This is streamed to the passenger over the internet.

After the movie has finished, the driver of the vehicle accesses traffic information for the next stage of the journey.

The connection is maintained throughout the journey. Short interruptions are tolerated by the in-vehicle system that has sufficient buffering to ensure a smooth presentation of the media.

Post-conditions

The vehicle remains connected to the internet while the entertainment system and the UE (either built-in or tethered) are still operating.

5.53.2 Potential Impacts or Interactions with Existing Services/Features

There is little perceived interaction with existing services and features. The provision of infotainment is "over the top" of an existing data connection. The data connection has to be of the appropriate quality and speed to sustain the service.

Such a service will need to be provided by at least a 4G network.

5.53.3 Potential Requirements

The 3GPP system shall provide a consistent data rate that is high enough to support the chosen media:

- For internet browsing and general information at least [0.5Mb/sec]
- For high quality music streaming at least [1Mb/sec]
- For standard quality video streaming at least [5Mb/sec]
- For high quality (up to UHD) video streaming at least [15 Mb/sec]

Low latency is not critical for media streaming, however, a latency of no more than [100ms] for internet browsing shall be provided.

The 3GPP system shall be able to deliver the required connection quality up to 200km/hr.

The 3GPP system shall be capable of providing the required connection quality in densely populated roads where up to [2000] vehicles in a given service area [1km^2] will be accessing data. The vehicles could be moving at speeds ranging from 0km/h (e.g. in a traffic jam) to 200km/h.

5.54 Local UAV Collaboration

5.54.1 Description

Unmanned aerial vehicles (UAVs) local vehicle collaboration can act as a mobile sensor network to autonomously execute sensing tasks in uncertain and dynamic environments while being controlled by a single user. Accuracy in sensing tasks is increased when deploying a team of UAVs versus just one as there are multiple vantage points using multiple sensors. Examples of uses for deploying a team of UAVs include:

- Searching for an intruder or suspect
- Continual monitoring of natural disasters
- Performing autonomous mapping
- Collaborative manipulation of an object (e.g. picking up corners of a net or picking up a log)

The 3 subsequent sections will describe a use case where a team of UAVs is deployed in order to search for a suspect.

Pre-conditions

1. One UAV Controller has the ability to control 4 UAVs
2. UAVs have the ability to autonomously create flight formations
3. UAVs have direct links to each other and do not need to go back to a controller
4. One of the UAVs is deemed the ‘lead’ UAV the 3 other UAVs are considered ‘follower’ UAVs
5. One UAV is beyond line of sight and operating independently of 4 UAVs previously mentioned
6. Route for UAVs has been determined

Service Flows

Communication to be node to node (includes mesh) unless beyond line of sight. If beyond line of sight the mobile network will be utilized for communication.

1. UAV Controller launches search UAVs
2. The lead UAV shares its current position with the follower UAVs
3. Follower UAVs calculate control changes necessary to reach the desired position in order to create a flight formation
4. UAV Controller monitors health status of UAVs while UAVs are in route to search area
5. One UAV spots a suspect and sends target alert to other 3 UAVs and UAV Controller
6. Other UAVs create a perimeter around suspect ensuring he/she can’t evade UAVs
7. Lead UAV notifies a UAV beyond line of sight, by sending communication through the mobile network (WAN), indicating there is a suspect being pursued 3 miles south of the UAV’s current location
8. As suspect moves UAVs collaboratively adjust to maintain appropriate perimeter
9. UAV Controller notifies authorities

Figure 5.54-1 depicts how communication will occur in UAV local vehicle collaboration. In this use case communication occurs node to node, when UAV is beyond line of sight communication occurs through the mobile network (WAN). Communication does not occur through a wireless controller (LAN) in this use case.

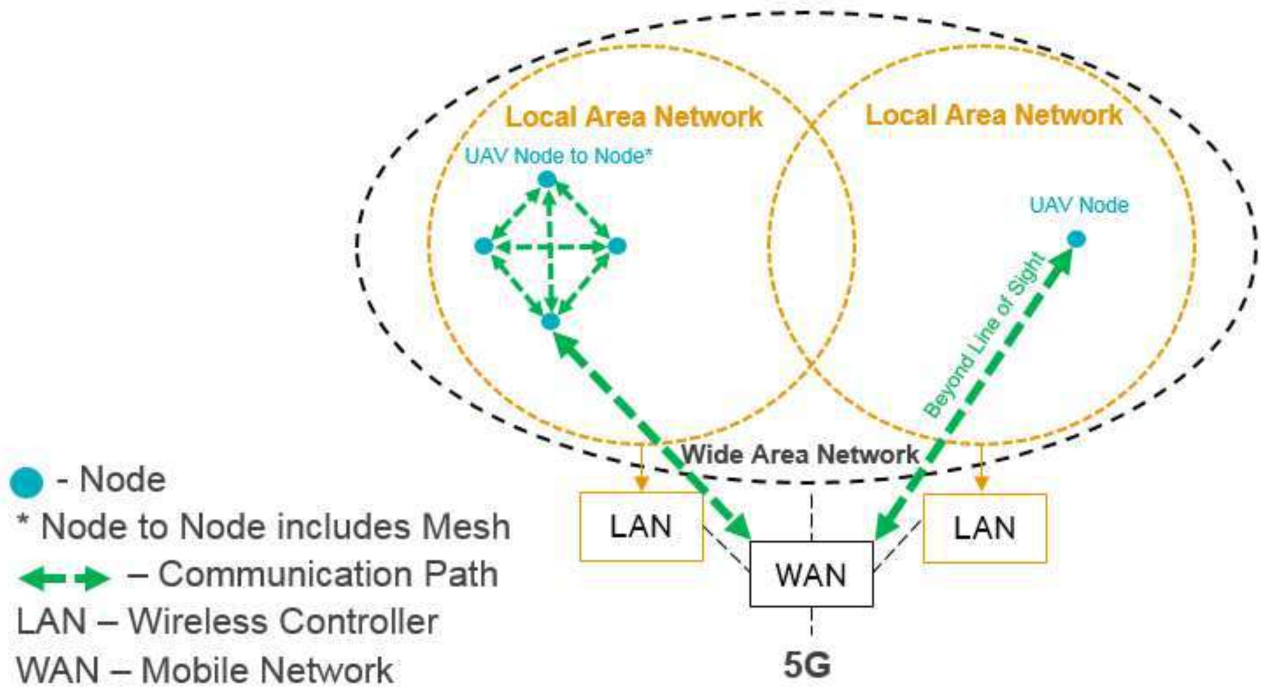

Figure 5.54-1: Communication path

Post-conditions

- Suspect is detained
- UAV Controller instructs all 4 UAVs to return to the base

5.54.2 Potential Service Requirements

Void.

5.54.3 Potential Operational Requirements

The 3GPP system shall support:

- Latency of [10 ms] as collaboration requires vehicle altitude and position control loops to synchronize. Latency is required on the order of the control loop bandwidths.
- Near [100%] reliability as instability and crashing of UAV could result from loss of communications. Control functions depend on this communication.
- Security to be provided at the level for current aviation Air Traffic Control (ATC) for command and control of vehicles in controlled airspace.
- Priority, Precedence, Preemption (PPP) needed as failure to transmit communications in reliable and timely manner could result in loss of property or life.
- Position accuracy within [10 cm] due to multiple UAVs that may need to collaborate in close proximity to one another.

5.55 High Accuracy Enhanced Positioning (ePositioning)

5.55.1 Description

Next generation high accuracy positioning will require the level of accuracy less than [1m] in more than [95%] of service area, including indoor, outdoor and urban environment. Specifically, network based positioning in three-dimensional space should be supported with accuracy from [10 m] to [<1 m] at [80%] of occasions, and better than [1 m] for indoor deployments [2].

High accuracy positioning service in 5G network should be supported in areas of traffic roads, tunnel, underground car-park or indoor environment. The figure below provides an example of network supporting high accuracy positioning.

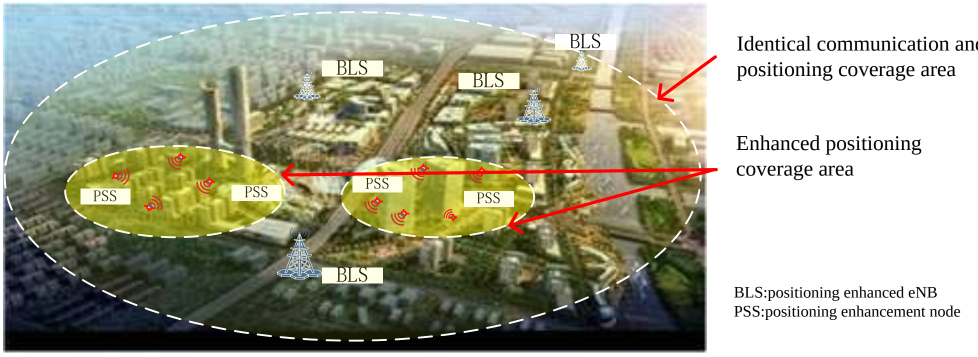

Figure 5.55-1: An example of network supporting high accuracy positioning

A fast-moving car is assumed to move at ~280 km/h, and a fast-moving robot at ~40 km/h. When a 3GPP system is used to control their movement, the time to determine their position and the reaction time must be short to avoid collisions with its surroundings.

The positioning can rely on the 3GPP system completely, partly, or not at all, but the action based on the position must be acted upon fast. If we assume that the required accuracy for car's position must be 1 meter, and for the robot 10 cm, the two-way delay for positioning is 10-15 ms.

Pre-conditions

In the scenario presented below, it is assumed that positioning nodes are coordinated with enhanced cellular communication base stations to form a carrier-grade telecommunication and positioning network. For example, vehicles are navigating using the enhanced positioning signal transmitted by the next-generation base stations. Since the vehicles are guided along the invisible lanes marked by the positioning signal, there is no painted line, crosswalk line or even traffic lights in the intersection. However in the driver vision, the information of driveway, safety marks, pedestrians and other objects are clearly shown through augmented reality wind screen display.

Service Flows

1. Jack rides on an autonomous driving vehicle A and goes to a large shopping mall.

2. At the intersection of a city surrounded by high-rise buildings, another vehicle B is approaching with a speed of 60Km/h. The two vehicles are aware of the potential crash since the coarse location information was exchanged using V2X communication. The vehicles schedule the course, speed and passing order at the intersection in millisecond unit.

3. Before the vehicles meet at the intersection, the vehicles start measuring the location in 1m accuracy at every 100msec and exchange the information via V2V communication. The vehicles constantly calculate the course and adjust the speed. At the crossing point, the two vehicles safely pass the intersection at the time difference of 1 second, which is only 17m gap in the vehicle speed of 60Km/h.

4. Jack's vehicle continues to drives into a large shopping mall and finds a parking place in underground parking lot. With a location-based service, nearby available parking places can be precisely located with the accuracy <1m.

5. When Jack walks around in the shopping mall, he can get instantaneously multimedia discounts information of specific shop pushed by 3GPP network.

6. After finish shopping, Jack can get his car's precise location with the location based service. And the recommended route from his location to the car helps him find his car.

Post-conditions

Jack pays for high-accuracy location and V2X service in monthly or annual fee base.

5.55.2 Potential Service Requirements

The 3GPP system shall support higher accuracy location capability less than [3 m] at [80%] of occasions.

NOTE: [80%] of occasions means the probability of achieving the accuracy in total sampling.

The 3GPP system shall support different configuration for accuracy according to different service requirements.

Initial position fix time of UE shall be less than [10] seconds, and subsequent position fixes shall take no longer than [10~15ms], if required.

The two-way delay for positioning shall be no more than [10-15 ms].

Power consumption due to the continuous use of positioning service shall be minimized.

5.55.3 Potential Operational Requirements

The 3GPP system shall support co-existence with legacy 3GPP positioning service and migration to higher accuracy positioning service.

5.56 Broadcasting Support

5.56.1 Description

The system shall be able to support an enhanced form of MBMS that includes transmission of scheduled linear time Audio and Audio &Video programmes.

Pre-conditions

Both Mobile and Network support an enhanced and flexible form of MBMS.

The Network has previously allocated MBMS resources.

Service Flows

1. A 3GPP device accesses an advertised MBMS service for broadcast information via a broadcast management system.
2. The mobile downloads the 3GPP resource group nomination (e.g. a channel code) for the cell that they are camped on for this broadcast channel from the broadcast management system.
3. The User keys in the channel code and starts receiving the broadcast channel subject to any authorisation.

Post-conditions

Void.

5.56.2 Potential Impacts or Interactions with Existing Services/Features

Void.

5.56.3 Potential Service Requirements

The 3GPP system shall support an interface from external Broadcasters' management systems.

The 3GPP system shall be able to reserve groups of resources for Broadcast channels

The 3GPP system shall be able to support broadcast of lossless state of the art video streams such as 4k UHD.

The 3GPP device shall be able elect to receive a reduced quality version of the broadcast for display on their device screen (typically less than 12") or a full quality version of the same channel for presentation to a video presentation monitor (typically much larger than their device , ie:32" to 72"screen size)

The 3GPP System shall allow the UE to receive broadcasts selected by the user (from the Broadcaster's management system) in accordance with any appropriate authorisations by the Broadcaster.

NOTE: UHD: 3840 x 2160, 50FPS, AVC ~300Mbit/s, UHD: 3840 x 2160, 50FPS, HEVC ~ 150Mbit/s

5.57 Ad-Hoc Broadcasting

5.57.1 Description

MBMS and eMBMS have been defined in UMTS and LTE. However take-up has been poor. There are established terrestrial and satellite digital broadcast capabilities as well as evolving IP-TV content delivery systems whether linear or replay based. There is also a thriving video blog market via IP.

However, there is a demand for good quality event based content broadcasting over and above IP web pages and video snippets.

This use case proposes the ability to setup event based video content broadcasting, using a slice of the local or temporary 3GPP system in the environ of the event.

The event in this context may not be limited to purely sporting or entertainment, but may be a truly ad-hoc video broadcast that interested parties want to see based on a social web advert.

The envisaged difference for this use case for future 3GPP systems as compared to today is that the video content in this case, may be live and may not ever be stored on a video server in the network but may be only transmitted as a 'one-off' by either a broadcast organisation or an individual.

It is envisaged that in order to support this capability, a future mobile unit is operated to provide the video source content and then a DEDICATED resource budget is allocated in a given area or area(s) to enable multicast broadcast to other mobiles when their users elect to receive the content via a 3GPP Ad-Hoc MBMS service.

The benefits are that this is a dynamic way to efficiently broadcast video content on an ad-hoc basis as opposed to a user uploading and then each user separately downloading from a server or group communications point.

Pre-conditions

The source broadcasting mobile has an internet connection over the 3GPP system and video camera/codec capabilities on their phone.

The recipient broadcast received mobiles have the ability to connect to an Ad-Hoc MBMS group.

Service Flows

1. A fixed or mobile 3GPP device user (individual and/or organisation) makes a request that they want to broadcast a video via an Ad-Hoc-MBMS social/operator provided broadcast request management system. The requester specifies the title, description, duration, format and 'scope' of the broadcast. Scope is specified in terms of locale and radius of desired broadcast coverage and mapped at the service centre to a single cell or number of cells that support the requested locale/range.

2. Alternatively the broadcast requester may be another type of device that is fixed connected to the internet and has access to the broadcast request management system.

3. The Ad-Hoc-MBMS application is operated by a host machine or sub-system which has a new interface towards the 3GPP system to make a request for ad-hoc resources for broadcasting the content. (N.B: this service could be chargeable).

4. The operator network element responsible for ad-hoc broadcast requests responds to the broadcaster request and if possible allocates local resources scheduled at a future time to broadcast the content as a 'broadcast opportunity window'.

5. The broadcast requester accepts the opportunity and the operator network element schedules MBMS resources for a given area scope specified in the original request.

6. The broadcast event is added to the ad-hoc broadcast channel programme guide (e.g. on a web page) that is part of the Ad-hoc MBMS service manager. Each broadcast event is given a code for the broadcast receiving devices to select to identify the MBMS resources to 'tune in to' to listen to the ad-hoc broadcast.

7. If the broadcast is for a single cell ad-hoc broadcast then, at the broadcast opportunity start time, the mobile broadcast requester broadcasts the ad-hoc broadcast content to the users in the locale directly, on the resources scheduled by the network earlier.

8. For multiple cell ad-hoc broadcasts, the cell that the broadcast requester is camped-on, also receives the broadcast and relays the stream to other adjacent cells listed in the scope request over the core network for rebroadcast on the resources identified at each adjacent cell in the list.

Post-conditions

Resources operated to support the Ad-Hoc MBMS broadcast are released back into the pool for each cell where the ad-hoc broadcast was staged.

5.57.2 Potential Impacts or Interactions with Existing Services/Features

Void.

5.57.3 Potential Service Requirements

The 3GPP system shall support an interface from an external Ad-Hoc Broadcast management system that manages broadcast requests.

The 3GPP system shall be able to reserve groups of resources temporarily for scheduled Ad-Hoc Broadcasts.

The 3GPP System shall allow the UE to receive broadcasts selected by the user (from the Ad-Hoc Broadcast management system) in accordance with any appropriate authorisations.

5.58 Green Radio

5.58.1 Description

The carbon discharge caused by networks in the 4G communication environment accounts for about 2% of the global carbon discharge. It is anticipated to increase up to 10-15% in the future due to the 5G network-based services, massive amount of connective devices and increased data traffic. One of the IMT-2020 key capabilities of 5G network is to enhance energy efficiency by 100 times compared to 4G network. As 5G network is likely to utilize higher spectrum compared to legacy 3GPP networks including mmWave, it is expected that more base stations are needed to cover the same area covered by legacy 3GPP networks. This would cause higher operational complexity for operators which may be a big burden for the operators in developing countries where power is limited. 5G network should consider technology to maximize energy efficiency.

5.58.2 Potential Service Requirements

The 3GPP system shall be capable of achieving [1000] times energy efficiency compared to legacy system.

5.58.3 Potential Operational Requirements

Void.

5.59 Massive Internet of Things M2M and device identification

5.59.1 Description

The vision of 2020 and beyond includes a great deal of use cases with massive number of devices (e.g. sensors, actuators and cameras) with a wide range of characteristics and demands. This family will include both low-complexity/long-range/low-power MTC as well as broadband MTC. All these devices are communicating with each other and with (servers/applications on) the network. Together this forms the Internet-of-Things.

A typical example of the Internet-of-Things would be a building climate control system. There is a climate control server that communicates with all kinds of sensors/actuators (temperature, humidity, valves, et cetera) in the building. The climate control server may also communicate with sensors/actuators used by other systems (e.g. door sensors can be used for the security system and for climate control), it may use external sensors (e.g. local weather sensors), and it will communicate with external devices for notifications and remote control (e.g. with the building manager’s phone).

Another relevant example is Wearable Devices. The NGMN 5G Whitepaper mentions: “Fitness-related applications, such as activity and body monitoring applications that track walking, running, and biking activities, metabolic rate, cardiovascular fitness, sleep quality, etc. will constitute a significant vertical market in M2M services. Some of these applications will utilize body or personal area networks to collect biometric information and then use cellular networks to transmit it back to centralized data acquisition sites”.

Within the Internet-of-Things there will be very high densities of connections. NGMN mentions an active connection density of 200,000 / $km^{2.}$ 5G-PPP mentions a device density of 1 M / km^2.

Devices in the Internet-of-Things need to be able to communicate with servers/applications in the network and with other devices. In order for the devices to be reachable, they need to be identifiable and addressable.

Different scenarios may have an impact on how devices can be reached and addressed:

- Some devices are always connected and are not very mobile. These are always reachable and may e.g. have a permanent IP address.
- Some devices are always connected but mobile. These are always reachable, but due to their mobility have dynamic IP addresses.
- Some devices are connected via a gateway device. These devices may be always reachable, but have to be addressed via their gateway.
- Some devices are not always connected (e.g. because of power constraints). These devices may be ‘reachable’ via a virtual representation in the network (e.g. an API on a network server through which the latest measurements from the sensor are available).

NOTE: In 5G architecture, these ‘virtual representations’ can be located on any virtual machine in the network. They will also need to be found.

- Sometimes a device may reach another device via direct radio communication. This may also take the form of ad-hoc networking.

In order for the Internet-of-Things not to become a collection of Intranets-of-Things, reachability and addressability should be ensured across different domains. There ideally should be an easy / common way to identify a particular device and then use that identifier to reach and address the device, independently from how the device is connected. If originating servers/applications or devices have to use different ways of identification and addressing dependent on how a device is connected, the Internet-of-Things is unlikely to come to fruition.

Related material can be found in;

- NGMN 5G White Paper [2]
  - Use Cases/ Massive Internet of Things (IoT)
  - Connection Density
- 5G-PPP whitepaper [22]
  - Figure 2, radar diagram on 5G disruptive capabilities

5.59.2 Potential Service Requirements

The 3GPP system shall support network servers/applications and devices to identify, address and reach other devices, in a consistent manner independently of how these devices are connected.

NOTE: Device here does not necessarily imply a UE. A device may or may not have a subscription for 3GPP radio access, however it can be identified by the 3GPP system. Definition of device is FFS.

5.59.3 Potential Operational Requirements

The 3GPP system shall support connection densities of [200,000 / km^2]. Here connection density reflects active devices that are exchanging data, assuming a single operator in the considered area.

NOTE: This requirement is applicable for device that is mobile with low to moderate speeds [e.g. 50 km/h] and requires bit rates up to [e.g. 1 Mb/s].

5.60 Light weight device communication

5.60.1 Description

As connectivity modules become cheaper, more devices from diversified industries are connected online and can be controlled remotely. In general, the connected devices can benefit users for various reasons. However, the following can be observed in the current market:

- The connected devices from different manufacturers cannot communicate with each other in most cases. For example, a connected vehicle from manufacturer A cannot transmit/receive any message to/from an air conditioner of manufacturer B.
- Specific applications provided by the device manufacturers should be used to control the connected devices remotely. In most cases, smartphone and specific App is the only interface to control the devices.
- In some cases, through the use of a common IoT platform, devices from different vendors are somehow able to exchange information. However, software developers have to provide applications for each OS platform and have to provide its own server for interworking between devices operating on different OS platforms.

In the future, as the number of connected devices explosively increases, the number of interactions between human and the devices and/or between devices and devices will also increase. To effectively handle the interaction involving connected devices, the above observations have to be solved by efficient mechanisms. Simple light-weight messaging can be one of the convenient ways to control IoT devices

Following is example service flow:

1. Air conditioner A includes a low-end light-weight connectivity module which does not support IP-based communication. The air conditioner can interpret messages and act based on the messages. Air conditioner A is located at home and the owner is at office.
2. The air conditioner attaches to serving network and is ready to receive messages.
3. At 6:00 PM, the owner leaves his office and drives home.
4. Because the temperature near the office went up to 35 ℃, he decides to turn on the air conditioner in his home.
   He sends a message to set the air conditioner A to 24 ℃, using easy-to-use identifier.
5. The air conditioner receives the message and starts working.
6. The owner receives a notification from the operator that the message was successfully sent.
7. On the other hand, someone in other area tries to send a message “stop” to his air conditioner B. However, he accidently mistyped the target identifier and sends the message to air conditioner A.
8. After receiving the request for message delivery, the network checks whether the sender is allowed to send the message to air conditioner A. Eventually the network refuses to deliver the message.

5.60.2 Potential Service Requirements

The 3GPP System shall be able to provide means for efficient light-weight communication to/from IoT devices (e.g. air conditioner).

5.60.3 Potential Operational Requirements

Void.

5.61 Fronthaul/Backhaul Network Sharing

5.61.1 Description

Network sharing can also imply sharing of fronthaul/backhaul network resources by using emerging 5G method (e.g., network slicing) or existing method (e.g., NFV). Fronthaul/backhaul networks can be deployed by multiple operators. This will allow network operators to benefit by reducing deployment cost and provide better Quality of Service (QoS), increase in revenue e.g. by optimally sharing network resources with other operators when considering traffic conditions, peak hours, etc.

NOTE: Fronthaul network is referred to e.g., the network between Remote Radio Head (RRH) and Baseband Unit (BBU) whereas backhaul network is referred to the network e.g., between BBU and the core network.

5.61.2 Potential Service Requirements

The 3GPP system shall be able to provide fronthaul/backhaul network sharing information and capabilities to other network operators.

5.61.3 Potential Operational Requirements

The 3GPP system shall allow network operators to be able to share fronthaul/backhaul network resources.

5.62 Device Theft Preventions / Stolen Device Recovery

5.62.1 Description

Smartphones and other high value devices such as drones and unmanned aerial vehicles potentially lead to increased numbers of devices with communications capability being stolen and modified to prevent tracing and recovery by civil authorities.

There are two facets employed for reducing device theft rates: theft prevention and stolen device recovery. Theft prevention involves disabling normal smartphone operation, preventing its illegal reuse, repurpose or resale, and deleting user sensitive data. Stolen device recovery involves identifying a recovered smartphone (by the user or civil authorities), verifying that it is stolen, and potentially restoring the smartphone to normal operation.

Unique device identifiers in the 5G system are needed that are stored in a secure and tamper resistant manner on the device. When a stolen device is recovered, the civil authority has a need to retrieve the device identity but may not have sufficiently detailed knowledge of the specifics of the device's user interface. These protected device identifiers can then be used to reliably identify a recovered smartphone as stolen, as well as support the tracing of illegal reuse, repurpose or resale of stolen smartphones.

5.62.2 Potential Service Requirements

The <5G system> shall support a secure mechanism allowing a legitimate entity to disable from normal operation of a device reported as stolen.

The <5G system> shall support a secure mechanism allowing a legitimate entity to re-enable a recovered stolen device to normal operation.

5.62.3 Potential Operational Requirements

5G devices shall store device identities in a secure and tamper resistant way in order to prevent device identification tampering, when required.

5G devices shall display the device identity in a consistent manner, not requiring detailed knowledge of the device's user interface, when required.

5.63 Diversified Connectivity

5.63.1 Description

In the future, the way one can be connected to the Internet will be more diversified. As the number of connected devices of one user increases, the number of interactions that each user has to deal with will increase too. While some of the interaction may simultaneously occur, some of the interactions may occur in a mutually exclusively manner. Due to the possibility that devices are not owned by a specific single user, it may be difficult to assume that one device’s connectivity is statically associated to one user. Because what a user wants is contents and services, connectivity service needs to provide simple service provisioning.

Following needs to be considered for various type of connectivity:

- A user can be connected to the Internet via smartphone, watches, glasses, home appliances, furniture, car, etc. As the number of connected devices for one user dramatically increases, provision of connectivity to each device needs to be simple and straight-forward. For example, because watches are considered as one of fashion items, a user may possess several smart watches and may not use the same watch every day. In this case, it is desirable that a user is not required to make a separate subscription for each watch. Rather, it is desirable that the authorized device for the user can be dynamically changed..

- Infrastructure or physical resources can be shared among people. Already in the market, there are businesses based on sharing economy. As sharing becomes a common phenomenon, the new model of providing connectivity may be needed. For example, when a car is used by different people at different time, it should be possible to dynamically change the authorized user of the connectivity module in the car. In other words, the Internet connection used by the car is associated to John's subscription during John is behind wheel and to Michael's subscription when Michael is driving. Thus, connectivity may need to be defined by who is using the connection, not by the device. Because a device can be used by multiple users, the network should be able to prevent fraudulent access from unauthorized users.

- On-demand temporal provision of connectivity can benefit user convenience. Today, some users buy prepaid SIM cards for their temporary communication use (e.g. during their oversea travel) and make some effort to activate the cards. However, in case of WiFi, a user can purchase connection on the spot by opening a web browser and entering some payment information. If similar mechanism is implemented for 3GPP access, people will have more connectivity opportunities. This on-demand mechanism may provide users with a simple procedure to activate on-the-spot connectivity while providing operators with identification and security tools for the provided connectivity.

- Content-aware control over provided connectivity service can also serve various business model or user benefit. For example, a contents provider may be willing to pay for the cost of any type of connectivity used for the contents delivery without requiring a user to use specific Apps or connectivity technology. In other cases, advertiser may be willing to pay the connectivity charge used for the automatically downloaded multimedia advertisement contents embedded in websites, or the user may even want the network operator to block such contents from flowing first place.

Considering various scenarios listed above, more efficient options for authentication, authorization and charging can be considered in the next generation of communication system. External UICC information based authentication [23] and biometric information based authentication can be examples. Following is an example service flow for biometric information based authentication.

1. Ayumu is a user who has a biometric authentication wearable device and a UICC-less tablet and subscribes to a mobile operator.

2. To use the tablet, she synchronizes the device with the tablet by her intuitive action like 'touching devices'.

3. After the synchronization, the device scans biometric information from her.

4. The biometric information is sent as security information from the device to the tablet.

5. The tablet attempts biometric information based authentication to the mobile operator network.

6. After the successful authentication, she is provided with data communication service for the tablet based on her subscription.

5.63.2 Potential Service Requirements

The 3GPP system shall be able to provide means to dynamically and seamlessly change the association between a user and a device.

5.63.3 Potential Operational Requirements

The 3GPP system shall be able to support enhanced authentication, authorization and charging mechanisms to support various types of connectivity (e.g. subscribed, on-demand or content-aware connectivity).

Enhanced authentication mechanism shall be able to provide efficient means to authenticate a user and a device (e.g. using biometric information).

Enhanced authorization mechanism shall be able to provide a user and a device with on-demand connectivity based on operator policy.

Enhanced charging mechanism shall be able to collect charging-related information for enhanced authentication mechanism and enhanced authorization mechanism.

5.64 User Multi-Connectivity across operators

5.64.1 Description

The next generation 3GPP system is expected to include capabilities to meet a wide set of disparate requirements (e.g. low latency, higher speeds, critical communications, etc.), catering to multiple vertical markets/industries. Given the multitude of use cases for new verticals and services, each operator, based on its business model, may deploy capabilities to serve only a subset of the vertical industries and services. However, this should not prevent end-user to be able to access new services and capabilities that will be part of the next generation 3GPP system.

As described in sections 3.2.2 and 4.5 of the NGMN White paper [2], network operators could contemplate a variety of sharing business models and partnership between service providers and other network operators, to enable users to enjoy services via multiple networks simultaneously in order to provide a better user experience.

Consider a scenario where operator A has deployed a 3GPP system that can support V2X, critical communications and broadband services. Operator B has deployed a 3GPP system that can support high quality video (broadcast and multicast) and broadband services. Operator A forges partnership with Operator B to provide a broadcast/multicast services to its users and Operator B has similar deal on V2X for their consumers. Each user has a relationship with a single operator (home operator). For the broadband service, the access of the service from the home 3GPP system will be prioritized, and the partner operator's 3GPP system for the service will be utilized only if there is no coverage from the home network or if the home 3GPP system directs the subscriber terminal to use the partner operator's 3GPP system.

Joe relies on V2X communication for his self-automated driving car. During family trips, his son wants to watch live sports on the vehicle infotainment. However a single operator in the region doesn't have a network designed to support both the services. In this scenario, the vehicle communicates with two independent networks simultaneously to provide the required services to Joe's family- Operator A for V2X and Operator B for Mobile Video. Joe can simultaneously receive broadband data, V2X and broadcast/multicast services. Joe will continue to receive the broadband service from Operator A unless directed by operator A's 3GPP system to utilize operator B's 3GPP system.

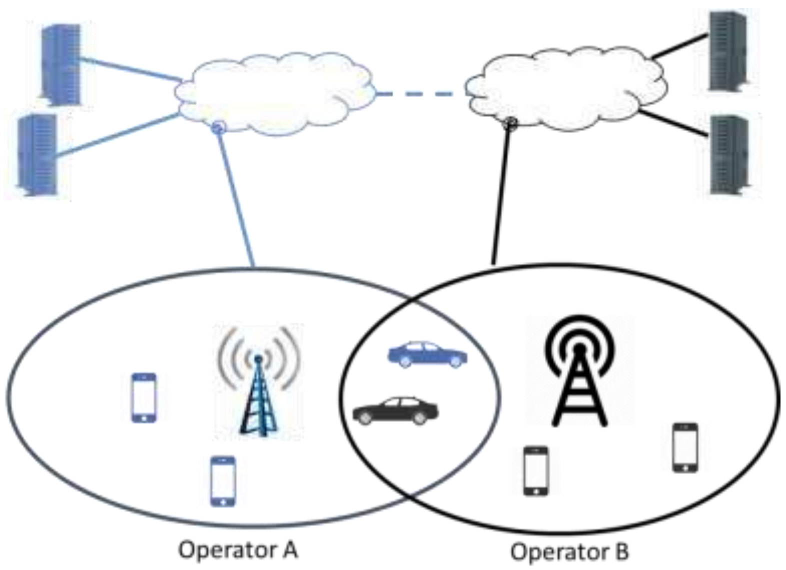

Figure 5.64-1: An example deployment scenario

5.64.2 Potential Service Requirements

The 3GPP System shall enable the operator to deploy networks to serve specific vertical markets and use cases.

The 3GPP System shall enable users to obtain services from more than one network simultaneously on an on-demand basis.

The use of multiple serving networks to deliver services to a given user shall be under the control of one operator who maintains the business relationship with the user (home operator).

In the event of the same service being offered by multiple operators, unless directed by its home 3GPP system or because of lack of coverage, the user shall be prioritized to receive subscribed services from the 3GPP system of the his/her operator.

5.64.3 Potential Operational Requirements

Void.

5.65 Moving ambulance and bio-connectivity

5.65.1 Description

The survival of a patient during pre-hospital time is critical, especially in emergencies such as car accidents and heart attacks when the ambulance moves from a remote location to the hospital.

To permit early triage and treatment while transporting the patient to the hospital, the paramedics must transmit the patient's medical data including high resolution images, diagnostic sound and high quality diagnostic video [24]. It may also be useful to provide two-way video-conferencing between the ambulance personnel and the hospital staff. In order to provide enhanced diagnosis of the patient's health, the medical equipment and the machines in the ambulance may interface directly with the telemedicine tools located at the hospital. With the availability of the patient's vital signs in real-time, it may be feasible to provide remote therapeutics that assist the ambulance personnel in administering medicine and controlling the medical equipment.

In order to support advanced telemedicine techniques, cloud-based services can be used to provide anytime and anywhere access to patient medical records [25], which makes security related issues more important. Additionally, the computing resources available through the cloud are expected to support advanced diagnostics and facilitate remote examinations of patients in high mobility scenarios.

Since the ambulance may be dispatched to a remote location that does not have the same coverage and available RATs as in an urban environment (location of the hospital), fast and seamless handover between different technologies is crucial. Furthermore, if the different RATs belong to the same operator, the handover must be completed while maintaining a connection to the same network. If the ambulance moves from one operator's domain to another then the mHealth service must seamlessly switch/handover from one domain to another.

Since the route to the hospital is known or can be predicted, such real word information can be exploited by the network to further reduce the communications delay by moving the computing functions closer to the edge.

High reliability of communications should be achieved.

5.65.2 Potential Service Requirements

The 3GPP system shall support low latency and high throughput (100 Mbps) even in the high mobility scenario (e.g. greater than 120 km/h).

The 3GPP system shall support seamless handover between suitable RATs without introducing much complexity.

The 3GPP system shall support ultra-high reliability even in the high mobility scenario.

The 3GPP system shall support high availability.

The 3GPP system shall support low end-to-end latency ranging from 1 ms up to 10 ms even in the high mobility scenario.

The 3GPP system shall provide appropriate level of security to ensure the data is not compromised.

5.65.3 Potential Operational Requirements

The 3GPP system shall support on-demand dynamic resource utilization (compute, storage, network and radio), which can be configured in realtime during network service provisioning for a given UE and based on information such as UE location, application characteristics.

5.66 Broadband Direct Air to Ground Communications (DA2GC)

5.66.1 Description

This use cases describes a broadband Direct-Air-to-Ground Communications (DA2GC) system consisting of applications for various types of telecommunication services, such as voice/video call, internet access and mobile multimedia services, during flights [26].

Pre-conditions

A service access network infrastructure, e.g. eNB and WiFi AP (both already certified for on-board implementation) is provided in an airplane to offer passengers in-flight mobile voice and broadband data communication services.

During a flight, the aircraft flew with speeds between 500 km/h and up to [900 km/h] at different altitudes between 4000 meters and 10000 meters.

Service Flows

During the flight;

Mary wants to surf the Web.

Jason wants to make phone calls with his children.

Grace wants to participate in a video conference meeting with her colleagues.

John wants watch a Full HD streaming live video of PyeongChang 2018 or Tokyo 2020 on his tablet on his tablet.

Alice wants watch a Full HD streaming movie.

Bob wants to make a video call with his wife.

Post-conditions

Afterwards;

Mary starts to surf the Web.

Jason initials a phone call with his children.

Grace participates a video conference meeting.

John watches a Full HD streaming live video on his tablet.

Due to bandwidth limitation of Direct-Air-to-Ground Communications (DA2GC) system;

Alice might not be able to watch his Full HD streaming live video.

Bob might start a video call with reduced quality such as lower resolution or voice-only.

5.66.2 Potential Service Requirements

The 3GPP system shall provide Direct Air to Ground Communications (DA2GC).

5.66.3 Potential Operational Requirements

Void.

5.67 Wearable Device Charging

5.67.1 Description

This use case describes the scenarios for the wearable device charging issue. The wearable device should have a subscription associated to its own subscriber's identity (e.g. IMSI). When the wearable device communicates with network directly, the 3GPP system will be able to collect charging data for the wearable device. When the wearable device communicates with network via a smart phone, there are several scenarios for the wearable device charging issue.

Pre-conditions

John has a smart watch and a smart phone. Tom has a smart phone. John and Tom are friends. Each device has a subscription associated to its own subscriber's identity (e.g. IMSI). Each device can independently communicate with network and the smart watch can connect with the network via a smart phone. Compared to the smart phone, the smart watch has smaller shape, lower power capacity and lower BB&RF capability.

Service Flows

For the direct link scenario, John makes a call using his smart watch. The smart watch directly connects the network of PLMN A. The 3GPP system of PLMN A will collect charging data for John's smart watch.

For the indirect link scenario, there are 4 scenarios for the wearable device charging issue.

1. John's smart watch and John's smart phone have subscriptions associated with each other in the same PLMN A. John makes a call using his smart watch. John's smart watch connects to the network through his smart phone, which is managed and controlled by network of PLMN A. The 3GPP system of PLMN A will collect charging data for both of his wearable device and his smart phone together.

2. John's smart watch and John's smart phone have different subscriptions, which belong to the same PLMN A. John makes a call using his smart watch. John's smart watch connects to the network through his smart phone, which is managed and controlled by network of PLMN A.

    2.1 The 3GPP system of PLMN A will collect charging data of his smart watch and the smart phone both for his smart phone's subscription.

    2.2 The 3GPP system of PLMN A will collect charging data of his smart watch for his smart watch's subscription.

3. John's smart watch and John's smart phone have different subscriptions, which belong to the different PLMNs. John's smart watch belongs to the PLMN A and John's smart phone belongs to the PLMN B. John makes a call using his smart watch. John's smart watch connects to the network through his smart phone, which is managed and controlled by network of PLMN B. The 3GPP system of PLMN B will collect charging data of his smart watch for his smart watch's subscription. This charging case for the smart watch is in the roaming case.

4. John's smart watch and Tom's smart phone have different subscriptions.

    4.1 John's smart watch and Tom's smart phone belong to the same PLMN A. John makes a call using his smart watch. John's smart watch connects to the network through Tom's smart phone, which is managed and controlled by network of PLMN A, when Tom permits his smart phone to relay the traffic data of John's smart watch to the network. The 3GPP system of PLMN A will collect charging data of John's smart watch for his smart watch's subscription.

    4.2 John's smart watch and Tom's smart phone belong to the different PLMNs. John's smart watch belongs to the PLMN A and John's smart phone belongs to the PLMN B. John makes a call using his smart watch. John's smart watch connects to the network through Tom's smart phone, which is managed and controlled by network of PLMN B, when Tom permits his smart phone to relay the traffic data of John's smart watch to the network. The 3GPP system of PLMN B will collect charging data of John's smart watch for his smart watch's subscription. This charging case for the smart watch is in the roaming case.

5.67.2 Potential Service Requirements

NOTE. The following requirements also apply in the roaming case.

The 3GPP system shall support online and offline charging for an UE (e.g., wearable device), whether it's connected to the network directly or via another UE (e.g., smart phone).

The 3GPP system shall be able to separate the charging data of a first UE (e.g., wearable device) from the charging data of a second UE (e.g., smart phone), when the first UE (e.g., wearable device) is connected to the network via the second UE (e.g., smart phone).

5.67.3 Potential Operational Requirements

Void.

5.68 Telemedicine Support

5.68.1 Description

One of the applications where IoT devices are useful is telemedicine. Telemedicine is the use of telecommunication and information technologies in order to provide health care at a distance. It helps eliminate distance barriers and can improve access to medical services that would often not be consistently available in distant rural communities. It is also used to save lives in critical care and emergency situations.

There are several factors for the growth of telehealth devices. As the number of senior citizens grows steadily and life expectancies get longer, the number of potential patients who need consistent monitoring increases. In addition, patients with chronical diseases are required to regularly keep track of their health during their normal life activities. Due to lack of time, space and fund, government policy in some countries also drives growth in telehealth. Actually, many private companies are jumping into this business area.

To properly support telehealth service, when the service is provided by a private service provider, a critical event detected by a telehealth monitoring device should get preferential treatment. Currently, this type of devices cannot be categorized into special access classes. Furthermore, if this device does not support voice call service, emergency call is neither used.

5.68.2 Potential Service Requirements

The 3GPP system shall be able to provide UE with prioritized access for transport of critical service data (e.g., data for healthcare).

The 3GPP system shall be able to provide means to verify whether a UE is authorized to use prioritized access for transport of critical service data.

The 3GPP system shall be able to provide UEs with relevant QoS for transport of critical service data.

5.68.3 Potential Operational Requirements

Void.

5.69 Network Slicing – Roaming

5.69.1 Description

Network slicing allows the operator to provide dedicated logical networks with customer specific functionality, without losing the economies of scale of a common infrastructure. As such a big variety of use cases with diverging requirements can be fulfilled (see Use Case 5.2).

To guarantee a consistent user experience and support of services in case of roaming, slices composed of the same network functions should be available for the user in the VPLMN. To keep the operational effort for the operator low a few network slices that cover most of the use cases could be agreed among operators.

Other network slices can be composed by operators as needed. They will consist of mainly 3GPP defined functions but could also include proprietary functions that are provided by different operators or 3rd parties. Configuration of network slices and provision of proprietary functions will be based on agreements between operators.

The roaming users may need to be assigned to a network slice in the VPLMN that provides the same or similar functionality as the HPLMN slice. Different criteria can be used to associate UEs including pre-5G UEs with a particular slice.

5.69.2 Potential Service Requirements

Void.

5.69.3 Potential Operational Requirements

The 3GPP system shall enable operators to define and identify network slices with common functionality to be available for home and roaming users.

The 3GPP system shall support composing of network slices from 3GPP defined functions as well as from proprietary 3rd party or other operator provided functions.

The 3GPP system shall support to associate the user in a VPLMN to the network slice that provides the required functionality for this user (e.g. the same functionality as the associated network slice in the HPLMN). If no corresponding slice has been defined the user should be assigned to a default network slice, as defined by the VPLMN.

5.70 Broadcast/Multicast Services using a Dedicated Radio Carrier

5.70.1 Description

The massive growth in mobile broadband services over the last few years has caused regulatory bodies across the world to consider re-allocating some of the UHF spectrum, because of its superior propagation characteristics, for mobile broadband services. This could potentially cause displacement of smaller/rural TV broadcasters and make them look at alternate delivery models (e.g. channel sharing, delivery via mobile broadband, etc.). The NGMN white-paper [2] has considered that 5G systems could substitute or complement radio/television broadcast services.

As a potential new business opportunity, wireless operators could deploy an overlay 3GPP network using dedicated spectrum for the broadcast service to serve the customers affected by displacement of smaller broadcasters within a geographic area.

Alternatively, a new wireless entrant could deliver a stand-alone broadcast/multicast only service over a large geographic area by deploying less number of sites with greater coverage area.

Consider a use case where Operator A has deployed a 3GPP system using frequency f1 in urban geographic area where demand for the mobile broadband service, and therefore the capacity need is the highest. Operator A decides to introduce a new broadcast/multicast service either on its own or in partnership with another broadcast/multicast service provider. The service is expected to be made available over a much wider area than its existing 3GPP system.

Wireless operator A deploys an overlay over its existing 3GPP system to create a single frequency network with few sites, each covering a wide geographic area. In order to ensure it can accommodate a wide variety of broadcast/multicast content simultaneously, wireless operator A uses a dedicated frequency, f2, to deploy the broadcast/multicast service.

As a result of this overlay deployment users in urban area X can simultaneously receive existing broadband data services (on f1) as well as the new broadcast/multicast service (on f2). Users in suburban/rural areas Y and Z only receive the new broadcast/multicast service.

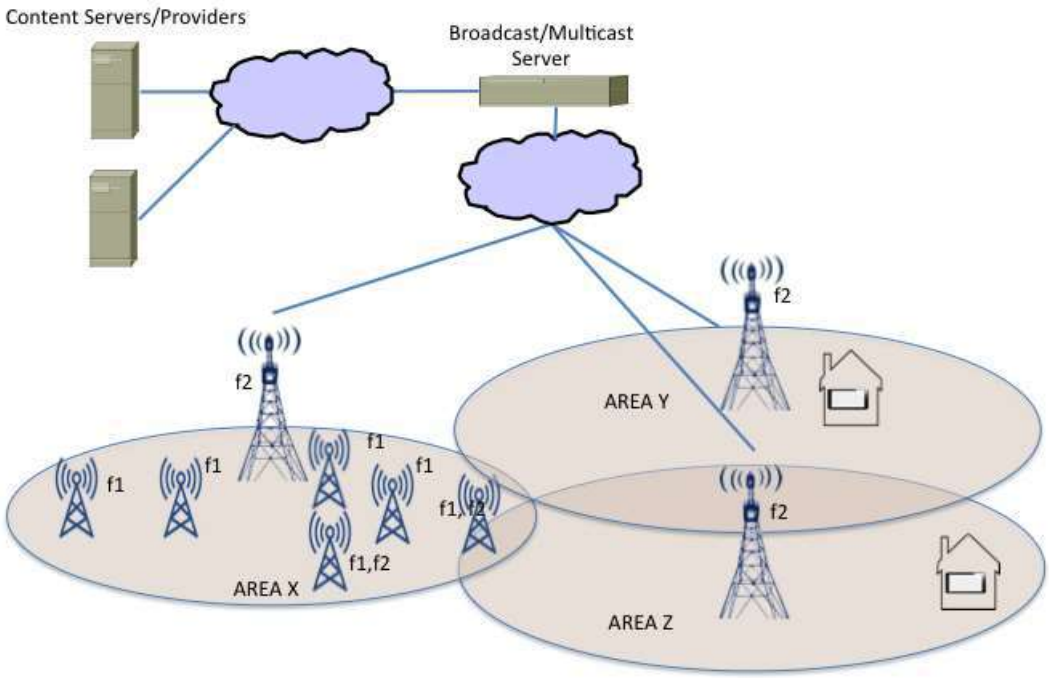

Figure 5.70-1: An example deployment scenario

5.70.2 Potential Service Requirements

The 3GPP system shall enable the operator to deploy a stand-alone 3GPP based broadcast/multicast system by forming a multicast/broadcast single frequency

The 3GPP system shall enable the operator to have the flexibility to allocate 0% to 100% of radio resources of a radio carrier for the delivery of broadcast/multicast content.

Depending on the capability of the terminal and the services subscribed, the user shall be able to receive the broadcast/multicast content via the broadcast/multicast radio carrier while a concurrent data session is going on over another radio carrier.

The 3GPP based broadcast/multicast system shall efficiently utilize the available resources to maximize the amount of content that can be delivered over a dedicated radio carrier network with cell coverage radius of up to 50 km.

5.70.3 Potential Operational Requirements

Void.

5.71 Wireless Local Loop

5.71.1 Description

The delivery of plain of telephone (POTS) and internet services to households requires cabling, either over copper cables, or today often over optical fibre. Many homes may be near a fibre connection but the deployment of the last mile of the cabling, e.g., FTTP (Fibre To The Premises) can be very expensive and not necessarily cost-effective. The addition of new subscribers, or households, may be very expensive, if new cables need to be installed. It may also require the operator to support two distinct systems, each with its own subscription management, for wired and wireless subscribers.

To address this problem, delivering the last mile wirelessly may be a viable option. Such solutions are known as WLL (Wireless Local Loop), where the last mile is delivered wirelessly.

The subscribers of the WLL service could be either delivered a service where the telephone looks like a regular fixed telephone, connected to a wall socket, at least for power, or the telephone could look like a cordless phone, whose use would be limited to the immediate vicinity of the home. The same would be true for the internet service, and the service perception would be similar to a WLAN access point at home. This limited service area could be achieved by not allowing handovers at all, by limiting the service to a small set of cells, or even geofencing.

To make the WLL service appealing to subscribers, and to take advantage of the capabilities of future 3GPP systems, it should offer a wide set of services, comparable to normal MBB users. The voice quality should be excellent and bandwidths up to 1 Gbps be offered to compete with modern wired offerings. The WLL service does not have extreme requirements for latency, speed, or connection density. There may be some additional security requirements to enforce the service policy, limiting the use to around the home, and possible some pre-defined areas (e.g., shopping mall, office, school, and vacation home)

5.71.2 Potential Service Requirements

The 3GPP system shall support WLL deployment with high peak and experienced data rates.

5.71.3 Potential Operational Requirements

The 3GPP system shall support WLL deployment and limit the service area to a pre-defined geographic area.

5.72 5G Connectivity Using Satellites

5.72.1 Description

One of the key requirements across various industry white papers is ensuring high availability and service reliability via ubiquitous coverage. For a 100% geographic coverage requirement case, satellites are ideal in covering areas that cannot be covered by terrestrial networks. As part of wide area coverage, the ARIB's 5G white paper [28] and 5GMF's presentation at the 3GPP RAN 5G workshop also referenced satellite-terrestrial cooperation as part of the mobile networks of 2020 and beyond. The ARIB 5G whitepaper called for a high degree of commonality between the terrestrial and satellite radio interfaces. Similarly, the NGMN white paper [2], as part of its technology candidate analysis, has also listed satellites as an example of an emerging technology that could be relevant as part of 5G.

There are several use cases that can only be served by satellites, and there are other use cases for which satellites provide a more efficient solution. These use cases are described below:

- Areas where it is not possible to deploy terrestrial towers: For example, maritime services, coverage on lakes, islands, mountains or other recreational areas that can only be covered by the satellites
- Disaster relief: During natural disasters or other unforeseen events that entirely disable the terrestrial network, satellites are the only option.
- Emergency response: Besides wide scale natural disasters, there are specific emergency situations in areas where there is no terrestrial coverage. For example a public safety uses case of an accident in a power plant.
- Secondary/backup connection (limited in capability) in the event of the primary connection failure or for connected cars
- Connectivity in rural areas that are hard to cover using terrestrial networks
- Connectivity for remotely deployed sensors, e.g. farms, substations, gas pipelines, digital signage, remote road alerts, etc.
- Low bit-rate broadcast services: Satellites can broadcast wide area emergency messages at a more efficient rate than terrestrial networks.

Standards based satellite specifications have been developed across multiple forums. Typically, these satellite standards are modifications or enhancements of existing terrestrial specifications. Some examples of this are: GMR (GEO-Mobile Radio Interface) which is an ETSI standard derived from 3GPP GSM/UMTS, xHRPD (Extended Cell High Rate Packet Data) which is a 3GPP2 standard derived from EV-DO Rev A, and LTE over satellite specifications which is another ETSI standard.

5.72.2 Potential Service Requirements

The 3GPP system shall support highly available and reliable connectivity using satellites for use cases such as ubiquitous coverage, disaster relief, public safety requirements, emergency response, remote sensor connectivity, broadcast service, etc.

The 3GPP system shall support up to 100% geographic coverage.

The 3GPP system shall support an air-interface with latency of up to 275 ms when satellite connection is involved.

The 3GPP system shall support seamless mobility between terrestrial and satellite based networks with widely varying latencies.

5.72.3 Potential Operational Requirements

Void.

5.73 Delivery Assurance for High Latency Tolerant Services

5.73.1 Description

In addition to high reliability and low latency use cases, there are use cases which require reliability and are tolerant to high latency. Some examples of these use cases include billing information aggregation, repository updates, search engine updates, download of a software upgrade to 3GPP devices etc.

In 5G systems, there may be massive number of devices with diverse data, transmission and bandwidth requirements. The network may not always be capable to handle a massive burst of information and may have to prioritize the traffic. It may not be acceptable for certain data to be lost as the devices may not have the capability to regenerate the data. Therefore, network must be able to ensure delivery of this information. In many instances, it is not vital to transmit this information immediately but the information must eventually reach its destination within the service specified timeframe.

For these services, latency is not an issue but the information must be communicated reliably. This is important for many use cases which rely on the eventual consistency paradigm.

5.73.2 Potential Service Requirements

The 3GPP system shall ensure delivery of information within the service specified timeframe.

5.73.3 Potential Operational Requirements

Void.

5.74 Priority, QoS and Policy Control

5.74.1 Description

5G network will be supporting massive number of devices with various data, transmission and bandwidth requirements. Due to a wide range of devices, services targeted for 5G can be very different from existing services in terms of amount, type and pattern of data exchange over the network. In order to cope with diverse service requirements, it is imperative that intelligent decisions are made at the network such as allocation of resources, scheduling of resources and adapt the network to meet these service requirements.

Many devices in a 5G network such as metering devices and monitoring sensors are expected to operate unattended. A large number of such devices may not be capable to alter their behaviour and adapt their participation as required to meet diverse service requirements. It is therefore vital for the network to assist these devices to operate such that services are able to utilize these resources and alter their behaviour when necessary to do so.

The 5G network will also be supporting many commercial (e.g., medical) and regional/national regulatory specific (e.g., MPS, emergency services) critical communications applications with requirements for priority treatment. During certain events (e.g., disaster events and network congestion), relative priority decisions will need to be made based on priority characteristics as:

- efficient and rapid execution of the needed priority is desired without alteration of the underlying QoS specification,
- the priority of a particular application may need to be different (higher or lower) during a crisis event from that normally adopted by the system, and
- the priority of any given application may need to be different, e.g., elevated, for a particular user of that application based on operational needs and regional/national regulations.

The network must offer a means to provide high reliability, predictable latency and ability to adapt and when necessary prioritize resources to meet specific service requirements. Existing QoS and policy frameworks merely handle predictable latency and improving reliability by traffic engineering. In order to support diverse 5G service requirements, it is necessary for the network to offer QoS and policy control for reliable communication with predictable latency and also enable the resource adaptations as necessary.

The network also need to support flexible means to make relative priority decisions based on the state of the network (e.g., during disaster events and network congestion) recognizing that the priority needs may change in time during a crisis event. Since it is outside the scope of specifications to provide a specific ranking of priority amongst services, flexibility needs to be provided to conform to operator objectives and regional/national regulatory requirements.

The following example depicts a scenario involving MTC devices used for a sample healthcare monitoring service. The upper figure shows that periodic health monitoring reports are sent for a patient every six hours to a health monitoring system. These reports are communicated using a best effort QoS classification since it is not critical for the service operation.

In the middle of one of these reporting periods, the patient falls down and starts having health complications. This scenario is shown in the lower figure. A sensor detects this catastrophic event and reports it to the service. The service now needs additional health monitoring reports urgently. Moreover, depending on the initial reported problem, the service may direct the network to coordinate group conversations involving appropriate health facilities and designated individuals associated with the patient. Some aspects of this communication may require the network to directly adapt existing communication and setup new resources to meet service requirement. The behaviour of monitoring sensors must be altered such that they deliver their reports more aggressively, in great details and to a larger audience. The service may further request network to tune the QoS depending on the patient’s subscription type.

This example shows that the network must offer flexible means to adjust QoS and priority treatment and alter its behaviour based on service state. Such adaptive measures can be feasible only if the network can adjust its behaviour to accommodate the QoS and priority treatment requirements.

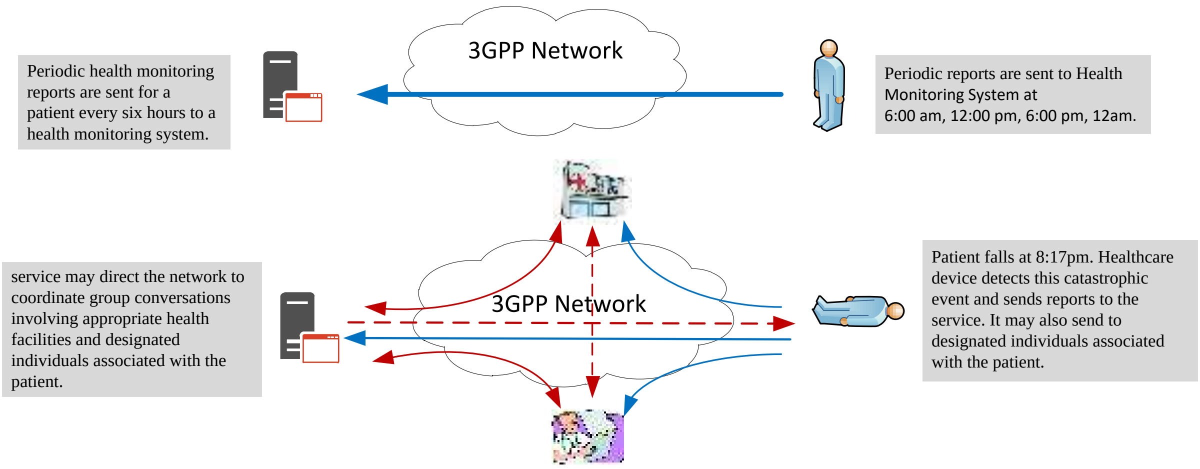

Figure 5.74-1: Example showing different QoS/Policy requirements based on service execution status

Also, as 5G network is expected to operate in a heterogeneous environment with multiple access technologies, multiple types of devices, etc., it should support a QoS and policy framework that applies across multiple accesses.

Further, for existing EPC, QoS control only covers RAN and core network, but for 5G network E2E QoS (e.g. RAN, backhaul, CN, backbone) is needed to achieve the 5G user experience (e.g. ultra low latency, ultra high bandwidth, etc).

5.74.2 Potential Service Requirements

The 3GPP system shall be able to provide high reliability, and latency required for an application to adapt and prioritize resources when necessary.

The 3GPP system shall allow flexible means to make and enforce relative priority decisions among the different application services.

The 3GPP system shall be able to support QoS adjustments based on an application needs.

5.74.3 Potential Operational Requirements

The 3GPP system shall be able to support a QoS and policy framework across multiple accesses.

The 3GPP system shall be able to support E2E (e.g. UE to UE) QoS for a service.

NOTE: E2E QoS needs to consider QoS in RAN, Backhaul, CN, & Backbone.

6 Considerations

6.1 Considerations on security

Considerations on security can be found in TR 22.861 [30], TR 22.862 [31], TR 22.863 [32], and TR 22.864 [33], and consolidated into TR 22.864 [33].

NOTE: The use cases related to eV2X have not been included in the listed TRs. The documentation of security considerations related to them is for further study.

6.2 Considerations on grouping of use cases

The use cases in Clause 5 can be grouped in the following categories;

enhanced Mobile Broadband (eMBB)

Higher Data Rates

5.5 Mobile broadband for indoor scenario

5.6 Mobile broadband for hotspots scenario (duplicate with NEO)

5.56 Broadcasting Support (duplicate with NEO)

5.71 Wireless Local Loop (duplicate with NEO)

Higher Density

5.5 Mobile broadband for indoor scenario

5.6 Mobile broadband for hotspots scenario (duplicate with NEO)

5.7 On-demand networking (duplicate with NEO)

5.32 Improvement of network capabilities for vehicular case (duplicate with eV2X)

Deployment and Coverage

5.5 Mobile broadband for indoor scenario

5.10 Mobile broadband services with seamless wide-area coverage (duplicate with eV2X)

5.11 Virtual presence (duplicate in CriC)

5.30 Connectivity Everywhere

5.66 Broadband Direct Air to Ground Communications (DA2GC)

5.71 Wireless Local Loop (duplicate with NEO)

5.72 5G Connectivity Using Satellites (duplicate with NEO & CriC)

Higher User Mobility

5.6 Mobile broadband for hotspots scenario

5.10 Mobile broadband services with seamless wide-area coverage (duplicate with eV2X)

5.29 Higher User Mobility5.53 Vehicular Internet & Infotainment

5.66 Broadband Direct Air to Ground Communications (DA2GC)

Critical communications (CriC)

Higher reliability and lower latency

5.1 Ultra reliable communication

5.11 Virtual presence (duplicate in eMBB)

5.18 Remote control

5.44 Cloud Robotics

5.45 Industrial Factory Automation

5.46 Industrial Process Automation

5.50 Low-delay speech coding

5.54 Local UAV Collaboration

5.68 Telemedicine Support

Higher reliability, higher availability and lower latency

5.12 Connectivity for drones

5.13 Industrial control

5.65 Moving ambulance and bio-connectivity

Very low latency

5.14 Tactile internet

5.15 Localized real-time control

5.17 Extreme real-time communications and the tactile Internet

Higher accuracy positioning

5.12 Connectivity for drones

5.18 Remote control

5.43 Materials and inventory management and location tracking (duplicate with mIoT)

5.54 Local UAV Collaboration

5.55 High Accuracy Enhanced Positioning (ePositioning) (duplicate with NEO)

Higher availability

5.72 5G Connectivity Using Satellites (duplicate with eMBB & NEO)

Mission critical services

5.1 Ultra reliable communication

5.2 Network Slicing

5.3 Lifeline communications / natural disaster

5.12 Connectivity for drones

5.31 Temporary Service for Users of Other Operators in Emergency Case

5.54 Local UAV Collaboration

5.65 Moving ambulance and bio-connectivity

5.68 Telemedicine Support

5.72 5G Connectivity Using Satellites

Massive Internet of Things (MIoT)

Operational Aspects

5.19 Light weight device configuration

5.21 IoT Device Initialization

5.22 Subscription security credentials update

5.24 Bio-connectivity

5.25 Wearable Device Communication

5.40 Devices with variable data

5.41 Domestic Home Monitoring

5.59 Massive Internet of Things M2M and device identification

5.63 Diversified Connectivity

5.67 Wearable Device Charging

Connectivity Aspects

5.24 Bio-connectivity

5.25 Wearable Device Communication

Resource Efficiency Aspects

5.20 Wide area monitoring and event driven alarms

5.24 Bio-connectivity

5.25 Wearable Device Communication

5.40 Devices with variable data

5.41 Domestic Home Monitoring

5.42 Low mobility devices (duplicate with NEO)

5.43 Materials and inventory management and location tracking

5.60 Light weight device communication

Network operation (NEO)

System flexibility

5.2 Network slicing

5.8 Flexible application traffic routing

5.37 Routing path optimization when server changes

5.48 Provision of essential services for very low-ARPU areas

5.49 Network capability exposure

5.56 Broadcasting Support (duplicate with eMBB)

5.57 Ad-Hoc Broadcasting

5.64 User Multi-Connectivity across operators

5.69 Network Slicing – Roaming

5.70 Broadcast/Multicast Services using a Dedicated Radio Carrier

5.73 Delivery Assurance for High Latency Tolerant Services

5.74 Priority, QoS and Policy Control

Scalability

5.7 On-demand networking (duplicate with eMBB)

5.9 Flexibility and scalability

5.35 Context Awareness to support network elasticity

5.51 Network enhancements to support scalability and automation

Mobility support

5.34 Mobility on demand

5.47 SMARTER Service Continuity

5.42 Low mobility devices (duplicate with mIoT)

Efficient content delivery

5.36 In-network & device caching

5.38 ICN Based Content Retrieval

5.39 Wireless Briefcase

Self-backhauling

5.6 Mobile broadband for hotspots scenario (duplicate with eMBB)

5.52 Wireless Self-Backhauling

5.61 Fronthaul/Backhaul Network Sharing

Access

5.3 Lifeline communications / natural disaster

5.23 Access from less trusted networks

5.26 Best Connection per Traffic Type

5.27 Multi Access network integration

5.28 Multiple RAT connectivity and RAT selection

5.31 Temporary Service for Users of Other Operators in Emergency Case

5.55 High Accuracy Enhanced Positioning (ePositioning) (duplicate with CriC)

5.58 Green Radio

5.71 Wireless Local Loop (duplicate with eMBB)

5.72 5G Connectivity Using Satellites (duplicate with eMBB & CriC)

Security

5.62 Device Theft Preventions / Stolen Device Recovery

Migration and interworking

5.4 Migration of services from earlier generations

5.16 Coexistence with legacy systems

eV2X

5.10 Mobile broadband services with seamless wide-area coverage (duplicate with eMBB)

5.32 Improvement of network capabilities for vehicular case (duplicate with eMBB)

5.33 Connected vehicles

6.3 Considerations on grouping of potential requirements

6.3.1 Overview

In clause 6.2, the use cases in this TR have been grouped into five groups, which have been further subgrouped into related families based on similar requirements. In a few cases, use cases have been identified as being relevant to more than one of the primary groups. The potential requirements associated with the use cases can be considered as mapping to the same groupings, such that in those cases where a use case maps to multiple primary groups, the requirements may be split between the primary groups.

The first three groups, eMBB, CriC, and MIoT, are based on commonality of requirements in support of a vertical service or market. The group NEO includes requirements for the horizontal system aspects for the new 5G System. The families reflect the variances in each group relative to the spider diagram found in [2] and other industry white papers. These spider diagrams illustrate the need for a 5G system to be able to support optimized configurations for a diverse set of requirements, which may be in opposition. For example, some configurations require support for high reliability and low latency while other configurations require support for support for low reliability and high latency.

Unlike previous 3GPP systems which attempted to provide a 'one size fits all' system, the 5G system is expected to be able to simultaneously provide optimized support for these different configurations through various means such as NFV, SDN, and network slicing. This flexibility and adaptability is a key distinguishing feature of a 5G system.

6.3.2 Potential requirements for vertical groups (eMBB, MIOT, CriC, eV2X)

The following table collects potential service requirements from use cases related to verticals as examples to illustrate the main difference between verticals.

Table 6.3.2 Summary of potential requirements from each vertical group of use cases

Vertical group	Data Rate	Latency	Reliability	Comm. efficiency	Traffic density	Conn. density	Mobility	Position accuracy	Remarks
Group eMBB	Very High data rate (e.g. peak rate 10 Gbps, up to 10 Gbps when the user is moving slowly, DL 300Mbps with DL 50Mbps, 100Mbps)	Very low latency, low latency for high speed, reliable low-latency connectivity between aerial objects			High traffic density (e.g Tbps/ km2）	High density for UE (e.g. 200-2500 /km2, 2000/km2, 50 active UEs simultaneously)	0km/h to 500km/h ([1000km/ h])		Characterised by very high traffic, high bit rate. No Reliability needed, no accuracy need
Group CriC		Realtime low latency (e.g. as low as 1 ms end-to-end; the case “Smart grid system”: less than 8 ms, Round trip latency	Ultra high Reliability, high availability (e.g. limit the duration of service interruption for mission critical traffic, Packet loss rate: as low as 1e-04; delivered in 8 ms, Reliability with Priority,		high density distribution (e.g. 10k sensor /10sqkm)			Precise position within [10 cm] in densely populated areas.	Characterised by low latency, ultra high reliability

		less than [150 ms], low latency (~1 ms), UE-UE latency: low latency [1-10 ms], 0.5ms one-way delay, Round trip latency less than [150 ms])	Precedence, Preemption (PPP) mechanisms)						
Group MIOT				Coverage enhancement, Efficient resource and signalling to support low power, support devices (e.g., smart meter) with limited communication requirements and capabilities	High density massive connections (e.g.1 million connections per square kilometre), to accept information from large numbers of locally dense devices, possibly simultaneously	Low mobility (for majority of MTC cases except for inventory)		High positioning accuracy in both outdoor and indoor scenarios (e.g., 0.5m)	Difference with CC is: No low Latency
Group eV2X	Medium Rate (10 of Mbps per device)	Low latency (e.g. 1 millisecond end-to-end latency)	High Reliability (nearly 100%)		Medium traffic density	Medium connection Density (e.g. the number of vehicles can exceed 10000 in scenarios with multiple lanes and multiple levels and types of roads)	High mobility(e.g. up to 500 KM/h, absolute speed more than 200 km/h while relative speed more than 400 km/h).	High positioning accuracy (e.g. 0.1 meters)	V2X differs from eMBB due to its high reliability , lower rate , high speed and high positioning accuracy

7 Conclusion and Recommendations

This TR contains more than 70 use cases which have been grouped into 5 categories. Conclusion and recommendations on four of these categories can be found in TR 22.861 [30], TR 22.862 [31], TR 22.863 [32], and TR 22.864 [33].

NOTE: The use cases related to eV2X have not been included in the listed TRs. The documentation of conclusion and recommendations related to them is for further study.

Annex A (informative): Time Delay analysis

A.1 Time Delay Scenarios

There are several cases for the E2E delay definition in the local communication scenario (e.g. with ultra-low latency requirement) as shown in figure A.1-1. Note that the numbers in the figure indicate the component links of a communication path, for example, 1 refers to the link from a UE to an eNB.

a) via 1, 8 (in red): RTT (round-trip-time) for Uu interface

b) via 1, 6,7,8 (in blue): E2E communication. Normally it doubles the time delay in case a).

c) via 1,2, 3, 4,5,8 (in yellow): from UE to the APP Server

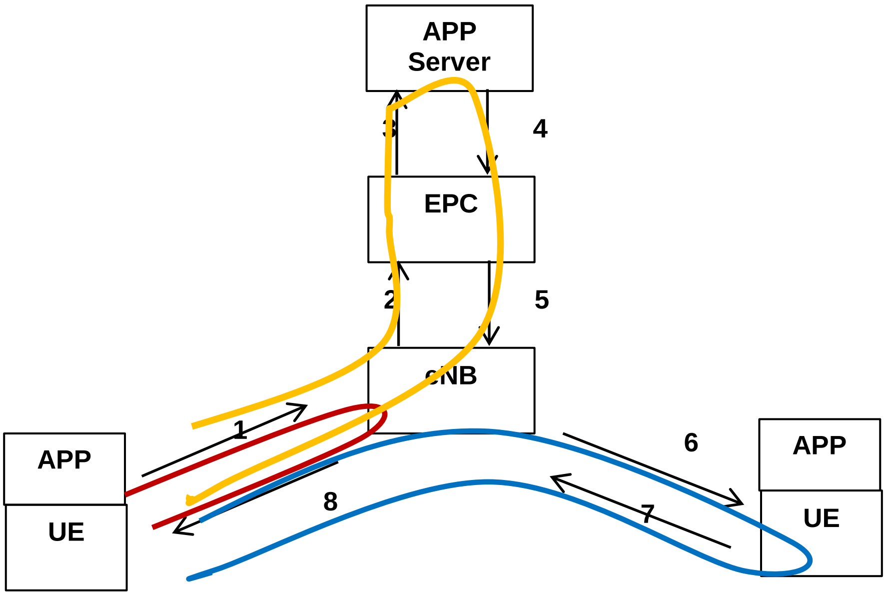

Figure A.1-1: Time delay definition for Local scenario

There are several cases for the E2E delay definition in the remote scenario (e.g. with low latency requirement) as shown in figure A.1-2 below:

d) via 1,2,5,8,9,10,11,12,13,14 (in blue): E2E communication via different EPCs in remote cities.

e) via 1,2, 3', 4',13,14 (in yellow): from UE to APP Server (Client-Server). In this case but the APP Server is far away from EPC1.

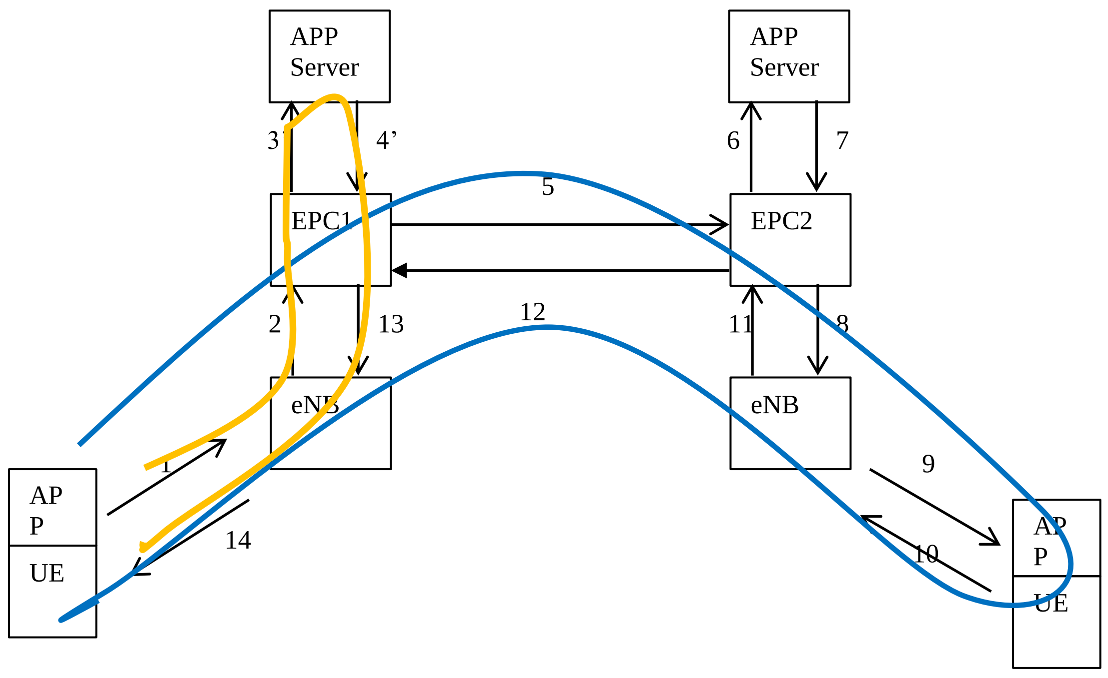

Figure A.1-2: Time delay definition for Remote scenario

The E2E time delay will be longer if we consider the processing delay in each node.

A.2 Physical limit

The propagation delay is limited by physics, i.e. the speed of light (299 792 458 meters per second) in air and 2/3 of the speed of light in fibre connection. With these limits, 1ms one way transmission latency can be mapped to 300 km air propagation or 200 km for fibre based transmission as shown in figure A.1-3. Note that the propagation delay also depends on the wavelength (reflection index from around 1.4 to 1.6).

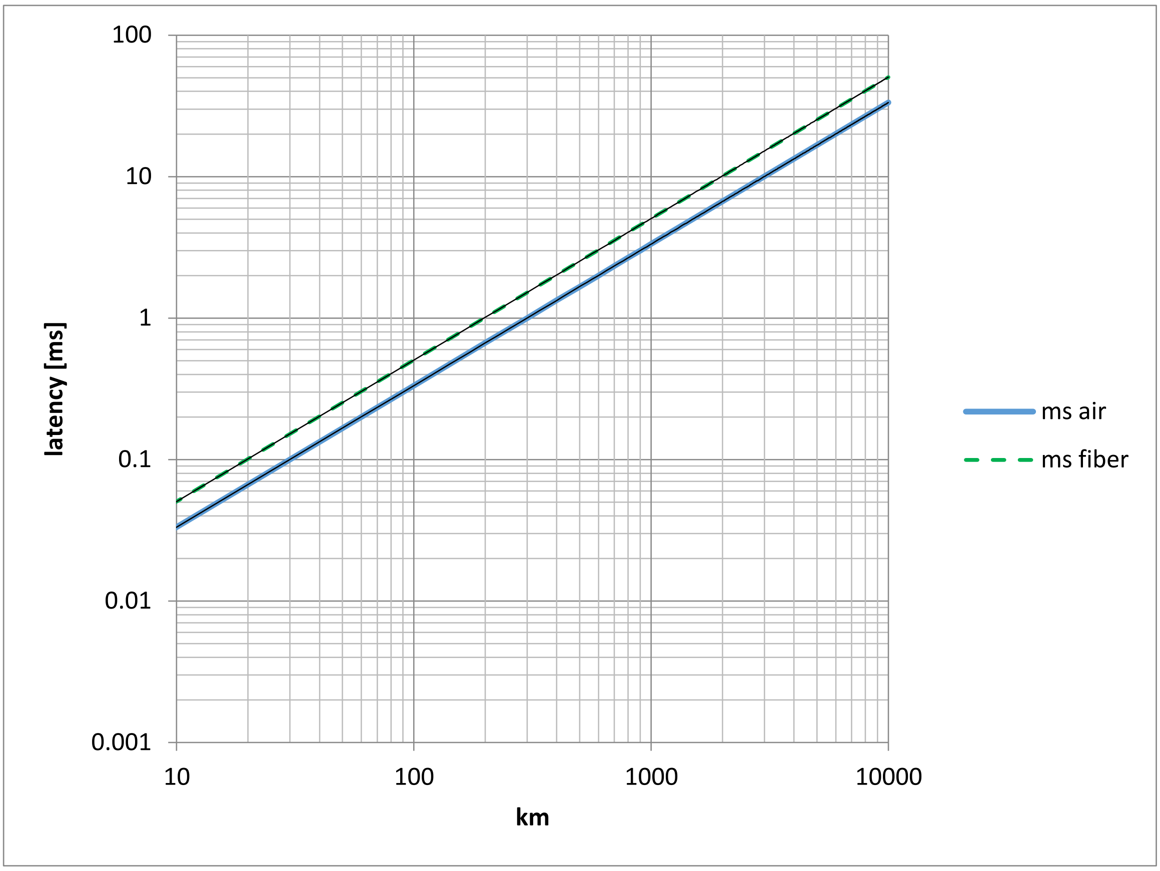

Figure A.1-3: Latency per distance for free air propagation and fibre

The current deployment of the fibre system is depicted by submarine cable map (http://www.submarinecablemap.com). The intercontinental connection goes beyond several thousand kilometres and correspondingly the latency over the intercontinental fibre is around several 10s of ms.

A.3 Conclusions

1. Local Communication: E2E time delay cannot be less than 1ms.
2. Remote Communication: E2E time delay cannot be less than 10ms.

Annex B (informative): Change history

Change history											
TSG SA#	**SA Doc.**	**SA1 Doc**	**Spec**	**CR**	**Rev**	**Rel**	**Cat**	**Subject/Comment**	**Old**	**New**	**Work Item**
SP-71	SP-160118							Raised to v.14.0.0 following SA approval	2.0.0	14.0.0	
SP-72	SP-160365	S1-161320	22.891	1		Rel-14	F	Education Use Cases for 5G	14.0.0	14.1.0	FS_SMARTER
SP-72	SP-160365	S1-161322	22.891	3		Rel-14	D	Cleanup -- Editorial	14.0.0	14.1.0	FS_SMARTER
SP-73	SP-160550	S1-162031	22.891	0004		Rel-14	F	Updated reference for education use cases	14.1.0	14.2.0	FS_SMARTER