



5G Specifications in 3GPP: North American Needs for the 5G Future

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Abstract

The first full set of 5G specifications was completed in 3Q 2019 in the 3rd Generation Partnership Project (3GPP) Release 15. 3GPP then directed its attention to future releases to further define and enhance the newly established 5G system. The 5G system is intended to enable a complete mobile communications platform. As such, it will support all 4G capabilities except ones related to legacy technology interworking. In addition, 3GPP will continue to enhance 5G to support new markets, improved performance and additional management capabilities. This document reviews the technology and societal drivers to lay out a vision of the 5G technology and market landscape (post Release 16) and identifies areas that will need more in-depth study going forward. Specifically, the report:

- Reviews the global landscape related to future technology innovation.
- Reviews progress on R17 itself and identifies North American priority areas going forward.
- Previews a number of potential future network-related applications and services.

3GPP specifications will continue to evolve 5G networks to become more distributed and customizable. They will support many new applications and usage models with software-driven, dynamic and elastic network functions enabled through virtualization and cloud-based implementations.

Foreword

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1 Executive Summary

1.1 Introduction

Release 15 represents the first full set of 5G specifications. After initial delivery in late 2017 of Non-Stand-Alone (NSA) NR (New Radio) specifications, 3GPP focused on the completion of Release 15, as well as the 3GPP submission toward IMT-2020. With the completion of Release 15 in 3Q 2019, 3GPP directed its attention to future releases to further define and enhance the newly established 5G system.

The 5G system is intended to enable a complete mobile communications platform. As such, it will support all 4G capabilities except ones related to legacy technology interworking. In addition, 3GPP will continue to enhance 5G to support new markets, improved performance and additional management capabilities. This represents a very large body of work that will play out over many 3GPP releases. As 3GPP work on Release 16 is completed during the first half of 2020, the focus will shift to Release 17 and beyond to address the need for continued network evolution.

There are many drivers behind this continual network evolution, including the increasing diversity of connected devices, a multitude of demanding applications and the unprecedented growth in data traffic since the dawn of Internet Protocol (IP) networking over 20 years ago. These factors will in turn drive networks to become more distributed and customizable. They will support many new applications and usage models with software-driven, dynamic and elastic network functions enabled through virtualization and cloud-based implementations. The network will also leverage data-powered, artificial intelligence (AI) driven network automation to support management and monitoring at scale. These network enhancements, along with increased spectrum availability, will enable the 5G NR to meet the needs associated with new high-end applications, ultimately leading to a greatly enhanced user experience.

1.2 Industry and Regional Context

North America, with the U.S. as the largest percentage of that market, will play a leading role in the initial and near-term deployments of 5G. According to GSMA Intelligence forecasts, the U.S. will experience one of the fastest customer migrations to 5G in the

world.¹ North America has, relative to the rest of the world, distinct macro characteristics and projections that will influence subsequent requirements and needs for 5G technologies and standards. These include governmental, financial, consumer, enterprise and industrial factors.

The regulatory environment supports 5G technologies and deployments by making spectrum available, limiting deployment restrictions and creating complementary technologies such as shared spectrum - e.g., Citizens Broadband Radio Service (CBRS). North America will continue to lead in investment for R&D, financing of innovation, new technology company creation and subsequent deployment in enterprise, industrial and consumer offerings.²

Consumer demands are leading to a convergence of the technology, media and telecoms (TMT) industry that will utilize 5G across horizontal markets. At the same time, new 5G-enabled services and solutions (e.g., IoT, mission-critical apps) will create industry-leading companies and entities with vertical market and niche application foci.

Projected capacity constraints from labor and infrastructure will accelerate the adoption of 5G technologies in the enterprise and industrial settings to augment the workforce and facilitate automation. For example, a shortage of trucking and transportation operators will drive investment in autonomous/connected vehicles, automated logistics and alternative delivery means- e.g., drones. North America will also invest in the realization of the fourth industrial revolution with cyber-physical systems that require continually improving connectivity performance. As enterprises and industries experience and adopt 5G technologies, it is projected that they will increasingly contribute to the investment and deployment of connectivity infrastructure and services.

Although the North America leads in most global competitive economic measures, it still competes with other developed countries in social factors such as health care, public safety, environmental sustainability. A combination of public and private investment,

¹ "The 5G era in the US," page 6, <https://www.gsma.com/publicpolicy/wp-content/uploads/2018/03/The-5G-era-in-the-US.pdf>

² "The 5G era in the US," page 5, <https://www.gsma.com/publicpolicy/wp-content/uploads/2018/03/The-5G-era-in-the-US.pdf>

policy and initiatives will further drive demand for medical, security, emergency response and network-resiliency capabilities based on 5G. The shift toward urbanization and aging demographics will continue to put pressure on North America's expansive rural and agricultural areas for productivity gains. Those areas will need increased connectivity, coverage and capacity to meet those demands.

1.3 Goals and Objectives

The primary goal of this report is to lay out a vision of the 5G technology and market landscape (post Release 16) and then to identify areas that will need more in-depth study going forward. Specifically, the report identifies key technologies and markets, along with the transformational societal impacts of these technologies that will drive new requirements.

Section 3 of this report covers the global landscape related to future technology innovation. Work in various standards bodies is considered, including the ITU-T Focus Group Network 2030, IEEE 802.11, oneM2M and 3GPP work in the area of services and applications. New vertical markets have shown to be of high interest given the improved performance attributions of the 5G system. Work on a selected set of vertical markets is also referenced.

Section 4 reviews progress on Release 17 itself and identifies North American priority areas going forward. These areas are of interest to the broad North American service provider domain, many of which support public safety and other regulatory requirements for the region.

Network slicing has been identified as a key enabling technology. Section 5 discusses a number of useful enhancements to network slicing.

Section 6 previews a number of potential future network-related applications and services covering:

- Ultra-enhanced 3D visual communications
- Multi-sensory applications and haptic communications
- Ultra-high-definition positioning
- Context-aware applications
- Intelligence-enabled connectivity

- Enhanced cellular sensing applications
- Content-optimized networks
- Low-energy/zero-energy internet of things (IoT) devices

2 Drivers

2.1 Business Drivers

As the first phase of 5G gets deployed, operators are looking for operational efficiencies to offset the deployment costs. The use of AI and data analytics has been identified as one way to optimize the network and operations. Increased use of such technologies will also position mobile systems toward their next evolutionary phase.

At the same time, competition in the industry is intense, driving operators to look for new business models and revenue streams. So far, mobile broadband has been a cornerstone for 4G services and now for 5G. In this next phase of 5G, services related to several verticals with more stringent network requirements are expected to enter the market. These include not just massive IoT services, but also ultra-low-latency and high-reliability IoT applications such as industrial automation and enterprise networks. In addition, governmental mandates and requirements can provide additional business drivers, such as developing and enhancing mission-critical services.

With the new 5G air interface and network, the industry has begun to address the three major use cases of enhanced Mobile Broadband (eMBB), massive Machine Type Communications (mMTC)/IoT and Ultra-Reliable Low Latency Communications (URLLC). The future will see each of these use cases continue to develop and grow to meet the coming demands.

The 5G NR interface has brought us the capability and flexibility to support improved IoT and MTC applications through enhancements to the existing mobile infrastructure. However, consumer and enterprise demands will soon exceed their current capabilities. Industrial IoT (IIoT) and mMTC need to be fully addressed and developed in their own right, starting at the concept stage for all system aspects.

For years, we have worked toward merging the access to multiple resources, both service and content, in a piecemeal fashion in an attempt to simplify the lives of our users. The true simplicity of universal access is getting closer. Support for fixed wireless Internet

Service Providers (ISP) services, along with the merging of eMBB with broadcast functionality, are essential building blocks to fulfill the vision of 5G.

2.2 Societal Drivers

Like most developed countries, the U.S. has an aging population. By 2030, more than 20 percent of U.S. residents are projected to be aged 65 and over, compared with 13 percent in 2010 and 9.8 percent in 1970.³ In 2012, 62.8 percent of the U.S. population was aged 18 to 64. By 2030, as the baby boomers age, the proportions in these working ages will drop to 57.3 percent.⁴ Labor shortages, constraints and trends towards a tertiary sector workforce (service, knowledge, professional) will drive adoption of industrial automation. Likewise, the ratio shift between the labor force and supported population will drive innovation for elderly in-home care applications such as 5G-enabled augmented reality (AR), virtual reality (VR) and extended reality (XR) for remote health care.

Industry projections estimate a six-fold increase in bandwidth consumption on mobile devices in North America from 2018 to 2024.⁵ In parallel, there are increasing constraints and sensitivity about the societal, environmental and cost impact of the energy that networks consume. Improvements and innovation in network infrastructure energy efficiency will need to continue as 5G matures to align with consumer ideals, service provider operational costs and possible government mandates. As 5G evolves and enables remote and enhanced communication services (e.g., AR, VR, XR, smart grid), it can indirectly reduce energy consumption with reduced travel and more efficient resource utilization.

³ "An Aging Nation: The Older Population in the United States," page 2, <https://www.census.gov/prod/2014pubs/p25-1140.pdf>

⁴ "An Aging Nation: The Older Population in the United States," page 6, <https://www.census.gov/prod/2014pubs/p25-1140.pdf>

⁵ "Ericsson Mobility Report, November 2018," page 17, <https://www.ericsson.com/491e34/assets/local/mobility-report/documents/2018/ericsson-mobility-report-november-2018.pdf>

There has been an increased awareness of climate change and its impact on society. Based on a 2018 Gallup Poll study,⁶ today's younger generations are more concerned about this issue, so they are more open to lifestyle adjustments that can create a more sustainable environment with a reduced carbon footprint. 5G and beyond enhanced communication services in the area of AR/VR/XR can help society in reducing the need for activities that add to global climate change.

Urbanization in the U.S. will continue to outpace overall population growth. Much of this growth will happen outside of traditional urban centers of the Northeast and Upper Midwest. This dichotomy will generate demands to both revitalize established and create new infrastructure with smart city systems. These systems and users will drive requirements for highly dense communication services and massive IoT deployments with associated data collection, analytics, security and privacy support. U.S. cities and metropolitan areas will increasingly compete on the national and global stage to attract for business, industry, visitors and workers. Depth and scale of mobile connectivity are both a necessity for urban efficiency and a measure of city viability and potential.

2.3 End User Drivers

Usage patterns for communication services have changed substantially over the last decade, with more changes expected in the near future. For example, today's teenagers hardly watch linear television programs in the living room. Instead, they consume content via an individualized unicast delivery on a mobile/tablet—anywhere and anytime. Additionally, younger generations are more likely to use AR/VR/XR-type technologies in business environments for cost reduction, for saving time or simply because it is better suited to their lifestyle.

In the last decade, the smartphone has already become more important than the wallet. It now manages user communication services, and in many cases finances, identity, location (mapping) and documentation (imaging). Savvy users are getting used to mobile services implementing AI and intent-based computing. This now is driving the trend toward augmentation of smartphones with other form factor next-gen

⁶ "Global Warming Age Gap: Younger Americans Most Worried," <https://news.gallup.com/poll/234314/global-warming-age-gap-younger-americans-worried.aspx>

communication systems that would use low-latency, high-bandwidth networks. Users expect to be able to add these new services without any disruption to their existing ones.

The end user device environment is increasingly complicated by the addition of new radio technologies (including 5G NR) and spectrum covering a wide range of bands and capabilities. It is essential that users have devices that can easily and autonomously adapt to the radio environment that they are in to deliver information/entertainment services efficiently and with the highest QoS necessary to meet user expectations.

As radio technologies and capabilities advance, the bandwidth, latency and overall quality of the air interface link will increase dramatically. But the air interface is still constrained by many factors that can severely affect communication quality. This means that air interface impediments may increase the variation in quality.

Ultimately, the goal is to provide to the end user a consistent, high-quality, high-functionality communication service across a diverse landscape of conditions. To that end, it is important to:

- Ensure that 4G features and functionality are fully supported by 5G standards.
- Limit generational fallback scenarios except as necessary to provide consistent service.
- 5G should not give the impression to users that it has less functionality, security or quality as compared to previous generations.

2.4 Identified North American Needs in 3GPP

Consistent with the drivers and market dynamics discussed so far, ATIS has identified a baseline set of North American needs. Section 4.3 provides more detail about these needs, which include:

Governmental Needs - 3GPP specifications that enable North American (NA) operators to meet the needs of existing and future anticipated public services, including:

- Vehicle-to-everything (V2X) enhancements applicable to public safety applications.
- Unmanned aerial system (UAS) work related to unmanned aerial vehicles (UAV) connectivity, identification and tracking.

- 5G multicast, broadcast and proximity services for mission-critical situations are of specific interest for FirstNet and other public safety applications.
- Multimedia Priority Service (MPS) enhancements to account for current and anticipated MPS user needs for priority voice, data and video communication capabilities in a 5G network.

Services and Architecture Needs - 3GPP specifications that support the unique market needs of mobile operators related to services and their impact on the mobile core network, including:

- Enhanced 5G support for verticals markets such as agriculture and industrial automation.
- Network automation enhancements to support the application of 5G data analytics for improved network operations.
- Enhancements to network slicing as noted in section 5.

Radio Access Network (RAN) Priorities - 3GPP specifications that support the unique market needs of mobile operators related to RAN and spectrum, including:

- Radio performance enhancements, such as multiple-input, multiple-output (MIMO) enhancements, control channel enhancements, LTE/NR coexistence and coverage enhancements.
- Efficient usage of operator licensed bandwidth when available spectrum does not align with existing standard 5G channel bandwidth options. This priority is described in more detail in annex B of this document.

2.5 Vision of Technology in the 2020s

In the 2020s, we are likely to see continued refinement and deployment of the well-known emerging technologies such as data-driven AI, cloud/virtualization and edge computing. Together, these technologies will enable a more dynamic and distributed network architecture with increased automation and ease of management to enable new, high-performance applications.

Network deployments will increasingly leverage cloud-native virtual network functions (VNFs) that may be designed using disaggregated software components (e.g.,

microservices) all deployed on cloud infrastructure as workloads that can be scheduled on demand by an orchestrator and scale in/out on demand.

Distributed ledger technology (DLT) will likely be used in a variety of areas from authentication and identity management to supply chain security. As a whole, network security will be enhanced through improvements in IoT security, application security and infrastructure security.

New technologies in the 2020s can be segregated into application, device and network domains. As illustrated in Figure 2.1, each of these domains will see significant advancements:

- The application domain will see advancements in such areas as holographic technologies (e.g., advanced holographic displays), brain-computer interfaces and nano-technology applications.
- The device domain will see advancements in robotics, higher resolution displays and personalized surfaces.
- The network domain will see advancements in terahertz communication, quantum communications and potentially new network protocols replacing the existing IP-based networks.

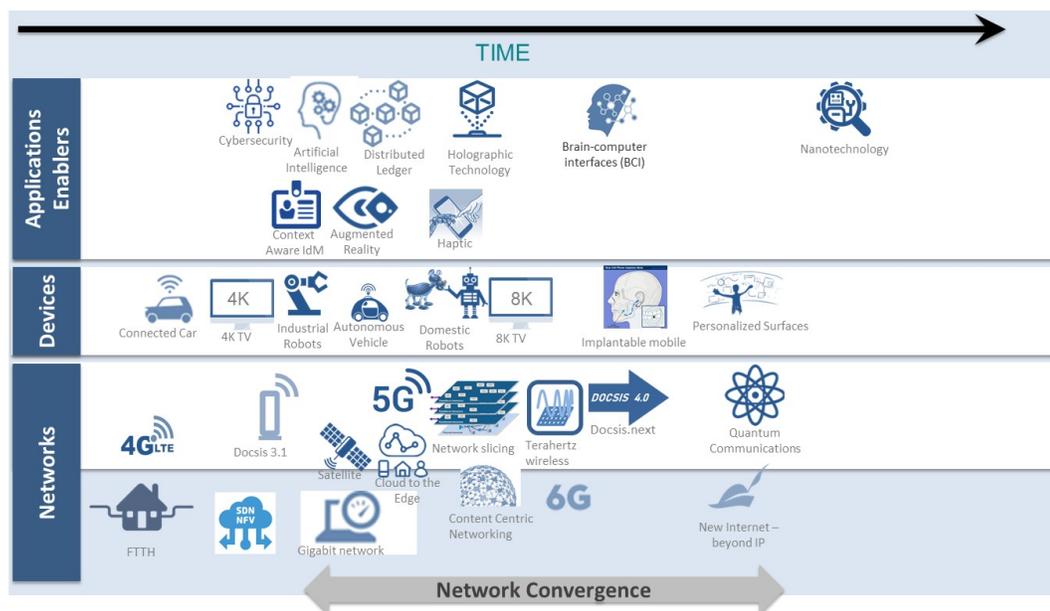


Figure 2.1 Technology Landscape in the 2020s

These technology advancements will place new requirements on the 3GPP network and will likely require new radio and network structures to fully leverage these advances.

3 Landscape

3.1 Standards

3.1.1 *International Telecommunications Union-T (ITU-T) Focus Group Network 2030*

ITU-T “Focus Group (FG) Network 2030” was created to address global data communication needs in 2030 and beyond. The central driving theme of Network 2030 can be summarized simply as the fusion of digital and physical worlds, of machines and humans, across all dimensions for the purpose of enabling services that do not exist today. The scope of the work was partitioned into three areas:

- An exploration of next-gen data services (use cases), along with corresponding networking requirements, that go beyond today’s state of art.
- An investigation of new technologies that would be necessary to support these next-gen data services.
- Network architecture concepts (e.g., post-IP networking) that can provide the underlying intelligent connectivity fabric for sustaining future data communication.

The underlying technical requirements are demanding to say the least. Examples include data rates in the hundreds of GB, ultra-low latency (<1ms), ultra-low jitter, embedded network intelligence, built-in security, fault tolerance, virtualization, integrated access (wired/wireless/space), scale and reach. The ITU-T Focus Group has attempted to address these issues for each new use case considered and identify the technology gaps that exist today. In addition to technology considerations, a key requirement for the success of this effort is a cross-industry/cross-sector/global collaboration with participation by government and research communities without which real progress would not be possible.

The Net2030 Use Cases have been divided into categories that range from the familiar (e.g., IIoT) to more futuristic - e.g., holographic-type communication. A few representative use cases (and “categories”) are listed below:

- Holographic-type communication ("*New Media*") for enabling immersive holographic local rendering of distant objects/artifacts serving the needs of a range of users such as doctors, industrial workers, businesses, trainers/educators and emergency personnel.
- Multi-sensory internet ("*New/Enhanced Network Capability*") for applications that involve not only optical (i.e., video/holograms) and acoustic (audio) sensory inputs, but also touch (tactile), smell and taste. Evolution of this use case could be viewed as first steps towards a form of teleportation: experiencing a distant reality with the full range of human sensory inputs.
- Deep edge services ("*Intelligent Edge*") push network/application service provisioning deep into the access subsystem. The ultimate goal is terminating services one hop away from the end user to reduce latency, improve overall network utilization (e.g., micro data centers) and enable new interaction models (e.g., opportunistic multicast).
- Integrated space-terrestrial ("*New/Converged Network*") deployment and operation scenarios of future converged internet with seamless integration between terrestrial (wired/wireless) network infrastructures and next-generation low earth orbit (LEO) satellite networks.
- Digitized farming for automated agriculture and livestock care ("*New/Enhanced Vertical Industry/Application*") involves a fully connected farming operation (machines, livestock, soil, feed, sensors) where all relevant components can be modeled as digital entities with explicit interactions. A fully digitized farmland operation would enable remote surveillance and control via high-definition video and AR/VR.

Network 2030 is primarily focused on the fixed data communication networks.

3.1.2 *IEEE 802.11/Wi-Fi Alliance*

The IEEE 802 family of standards is widely used around the world. IEEE 802.11 specifies a set of media access control (MAC) and physical layer (PHY) protocols for wireless local area network (WLAN) communication in various frequencies, including but not limited to the 2.4, 5, 5 to 7 GHz and 60 GHz bands.

The 802.11ax standard is expected to be ratified in the second quarter of 2020 and is the basis for the Wi-Fi 6 certification being developed by the Wi-Fi Alliance. Wi-Fi 6 certification is scheduled to be launched in August 2019. The main features of Wi-Fi 6

include improved performance (around 30 percent) from longer orthogonal frequency-division multiplexing (OFDM) symbols (frequency and time efficiency) and 1024 quadrature amplitude modulation (QAM), downlink orthogonal frequency-division multiple access (DL OFDMA), DL multi-user (MU)-MIMO and uplink (UL) OFDMA. The 802.11ax standard supports features for operation in the 6 GHz band, which currently is under regulatory review for license-exempt use. The Wi-Fi Alliance has stated that [5G and Wi-Fi are complementary](#),⁷ where each technology addresses specific use cases and together address the increasing data demand.

The next major development in 802.11 is the Extremely High Throughput (EHT), soon to become 802.11be, which is expected to provide at least 30 Gbps. The main features may include multi-band operation that supports asynchronous channel bonding (or link aggregation), 320 MHz channel operation, and multi access point (AP) cooperative operation that may support fractional frequency reuse, null steering and joint processing.

For high frequency bands (60 GHz), 802.11ay is expected to be ratified in the second quarter of 2020. The main enhancements over 802.11ad include synchronous channel bonding (e.g., two, three or four consecutive 2.16 GHz channels) to further increase performance, with speeds comfortably exceeding 20 Gbps. In addition to short-range usage, 11ay also supports backhaul applications. On positioning, 802.11 currently supports Fine Timing Measurement (FTM), a ranging technique with accuracy of around 3m. 802.11az adds a set of enhancements, including enhanced privacy to prevent tracking and multi-user operation for improved efficiency. The target positioning accuracy is 1 m. For vehicular applications, 802.11bd will be backward compatibility with 802.11p Dedicated Short-Range Communications (DSRC).

3.1.3 3GPP

3GPP has created multiple technical specifications (TS) series and technical reports (TR) series documenting service level requirements for the 5G system. Of primary interest is 3GPP TS 22.261, *Service Requirements for the 5G System*. Completed in February 2017, it was the first 5G specification from 3GPP. This document has been updated to include

⁷ <https://www.fiercewireless.com/wireless/wi-fi-alliance-wi-fi-5g-will-be-complementary>

3GPP Release 16 service level requirements. The most recent version of this document is available [at the 3GPP website](#).⁸

Among other things, TS 22.261 resolved a long debate about definitional aspects of user equipment (UE) vs. IoT devices. Specifically:

- UE is equipment that lets users access network services via 3GPP and/or non-3GPP accesses.
- An IoT device is a type of UE designed for a set of specific use cases or services. It can make use of certain features restricted to this type of UEs.

TS 22.261 also includes an annex about factory/process automation, electricity distribution and intelligent transport use cases.

3GPP has also produced additional 5G TRs available for context about use cases and “building blocks,” which includes:

- [TR 22.891 SMARTER](#), *Feasibility Study on New Services and Markets Technology Enablers*,⁹ broadly covers use cases classified into five categories:
 - eMBB - e.g., mobile broadband, UHD/holograms, high-speed mobility, virtual presence.
 - Critical Communications- e.g., interactive games/sports, industrial control, drones/robots/vehicle, emergency.
 - mMTC - e.g., subway/stadium service, e-health, wearables, inventory control.
 - Network Operation - e.g., network slicing, routing, migration and interworking, energy saving/efficiency.
 - Enhancement of V2X - e.g., autonomous driving, safety and non-safety aspects associated with vehicles.
- [TR 22.861 SMARTER-mIoT](#) discusses requirements for massive Internet of Things (mIoT) use cases, such as tens of thousands of sensors in a factory or millions of wearables. This group of use cases is particularly relevant to the new vertical

⁸ http://www.3gpp.org/ftp/Specs/archive/22_series/22.261/

⁹ <http://www.3gpp.org/DynaReport/22891.htm>

services, such as smart home and city, smart utilities, e-health and smart wearables.¹⁰

- [TR 22.862 SMARTER-CRIC](#) covers mission-critical requirements, industrial automation and tactile internet. The main areas where improvements are needed for critical communications are latency, reliability and availability to enable, for example, industrial control applications and tactile internet. These requirements can be met with an improved radio interface, optimized architecture and dedicated core and radio resources.¹¹
- [TR 22.863 SMARTER-eMBB](#) discusses multiple use case families related to higher data rates, higher density, deployment and coverage, higher user mobility, devices with highly variable user data rates, fixed-mobile convergence and small-cell deployments.¹²
- [TR 22.864 SMARTER-NEO](#) covers network operation (NEO) use cases and addresses the functional system requirements. These include aspects such as flexible functions and capabilities, new value creation, migration and interworking, optimizations and enhancements, and security.¹³

In addition, 3GPP SA1 has initiated for Release 17 a variety of Study Items and related Normative Work Items. These include:

- **TR 22.826** *Feasibility Study on Communication Services for Critical Medical Applications (FS_CMED)*.
- **TR 22.827** *Feasibility Study on Audio-Visual Service Production (FS_AVPROD)* covers enhancements to URLLC and TSN requirements specifically for A/V use.
- **TR 22.829** *Study on Enhancement for UAVs (FS_EAV)*.
- **TR 22.832** *Study on Enhancements for Cyber-Physical Control Applications in Vertical Domains (FS_eCAV)*.
- **TR 22.834** *Study on Support for Multi-USIM Devices (FS_MUSIM)*.
- **TR 22.836** *Study on Asset Tracking Use Cases (FS_5G_ATTRAC)* covers use cases involving shipping containers, wagons and pallets.
- **TR 22.842** *Study on Network Controlled Interactive Service in 5GS (NCIS)*.

¹⁰ <http://www.3gpp.org/DynaReport/22861.htm>

¹¹ <http://www.3gpp.org/DynaReport/22862.htm>

¹² <http://www.3gpp.org/DynaReport/22863.htm>

¹³ <http://www.3gpp.org/DynaReport/22864.htm>

- **TR 22.854** *Feasibility Study on Multimedia Priority Service (MPS) Phase 2 (FS_MPS2)* focuses on voice, DTS and video use cases.
- **TR 22.866** *Study on Enhanced Relays for Energy Efficiency and Extensive Coverage (FS_REFEC)* discusses extending the ProSe UE-to-UE and UE-to-network relays to include multi-hop relay UEs.

3.1.4 oneM2M

oneM2M is the leading global standardization body for IoT and M2M. It specifies the service layer with functionality such as data transport and management, device management, storage and exchange of analytic data, and semantic and security functions. An important feature of oneM2M is its ability to provide interworking between several standards or technologies including 3GPP, leveraging 3GPP's network exposure APIs.

Release 4 Work Items in progress for 2019 and beyond include:

- Support for fog and edge technologies.
- Vehicular domain support enhancements and 3GPP V2X interworking.
- Advanced semantics, reasoning and analytics.
- Enhancements for service subscription, charging and user management.
- Lightweight services and enhanced action triggering.
- Privacy and context-aware authorization.
- Support for heterogeneous identification systems and physical objects.
- Service platform discovery.

This list is likely to be expanded in oneM2M releases following Release 4.

oneM2M work will be an important driver in deployment of IoT services because it provides an extended "exposure function" of the network capabilities, such as leveraging Non-IP Data Delivery (NIDD) and Background Data Transfer (BDT). At the same time, oneM2M requirements can provide an important input into what capabilities underlying networks such as 3GPP should focus on in order to better capture the IoT market. In addition, its certification program can ensure that the high volume of IoT devices in any given deployment have service and resource requirements that are well understood and managed by network operators.

3.2 Academia

With 5G in initial deployment stages, academia and other research organizations have turned their focus to “beyond 5G” studies that may lead to 6G in coming years. For example, in the U.S., NYU Wireless has demonstrated a 140 GHz system and is doing several studies in this frequency range. 5G is currently limited to frequencies below 52.600 GHz. In the U.S., the FCC opened a variety of spectrum bands between 24 GHz to 48 GHz for millimeter-wave 5G use. Thus, spectrum beyond the 52 GHz existing limit provides potential for future wireless evolution.

In Oulu, Finland, 6G research was launched with the “6GFlagship Ecosystem.” 6GFlagship involves the University of Oulu with advanced research in spectrum from 100 to 1000 GHz to handle data rates up to terabit speeds at very low latency.

In addition, many universities are investigating new application areas that can make use of ultra-high spectrum.

3.3 Verticals

3.3.1 5G Automotive Association (5GAA)

The [5GAA](#) brings together companies from automotive, technology and telecommunications industries to develop a global vision for future mobility systems and transportation services. 5GAA has over 80 member companies representing academia, research, public authorities, and both the automotive and information and communication technology (ICT) industries.¹⁴

5GAA has long advocated cellular V2X (C-V2X) based on 3GPP’s LTE technology, and now is advancing the evolution to 5G-based V2X. The original C-V2X based on 3GPP Release 14 supports vehicle-to-vehicle (V2V), vehicle-to-(roadway) infrastructure (V2I) and vehicle-to-pedestrian (V2P) direct communications using a device-to-device approach that does not rely on network infrastructure. Device-to-cell-tower communication can also be supported when network coverage is feasible. The evolution

¹⁴ www.5gaa.org

to 5G will support enhanced vehicular automation with a focus on safety by providing greater throughput and lower latency.

Currently 5GAA has five working groups:

- Use Cases and Technical Requirements develops end-to-end use cases, requirements and KPIs.
- System Architecture and Solution Development develops recommended system architectures to support the requirements and KPIs. It also considers technical options for wireless air interfaces, network models, networked clouds, device management and security.
- Evaluation, Testbeds, and Pilots executes large-scale trials to promote commercialization and standardization.
- Standards and Spectrum provides input to 3GPP, IEEE and other industry standards fora, including spectrum allocation for V2X.
- Business Models and Go-To-Market Strategies develops market plans and business models, including a global approach to mobility solutions.

3.3.2 5GACIA

[5G Alliance for Connected Industries and Automation \(5G-ACIA\)](#) is a joint initiative of the operational technology (OT) and ICT industries.¹⁵

At a high level, the objective of 5G-ACIA is to ensure the best possible applicability of 5G technology for connected industries, particularly the manufacturing and process industries. 5G-ACIA will ensure that the interests and particular aspects of the industrial domain are adequately considered in 5G standardization and regulation. 5G-ACIA will further ensure that the ongoing 5G developments are understood by and transferred to the industrial domain.

Currently there are more than 40 members representing stakeholder groups from the OT industry (e.g., industrial automation, machine builders, end users), the ICT industry (e.g.,

¹⁵ www.5g-acia.org

chip manufacturers, network infrastructure providers, network operators), academia (e.g., universities, research institutes) and other relevant groups (e.g., authorities, associations).

5G-ACIA has five Working Groups.

- WG 1 focuses on use cases and requirements. This group also aims to define and consolidate service requirement input for communication to 3GPP SA1.
- WG 2 works on indentation and definition of spectrum needs for industrial 5G networks (e.g., 5G networks within a plant or factory), as well as regulatory issues.
- WG 3 focuses on the overall architecture and deployment consideration for 5G-enabled industrial connectivity infrastructures, as well as evaluation of key technologies from different SDOs for 5G integration.
- WG 4 is in charge of liaisons and interaction with other organizations.
- WG 5 is set up for dealing with validation and interoperability tests and trials. Horizontal topics such as safety and security, along with pre-consensus building for relevant standardization activities, will be covered in some form or other by all working groups.

3.3.3 Automotive Edge Computing Consortium (AECC)

The AECC drives the global cross-industry evolution of distributed computing and network architecture and infrastructure to support high-volume data and intelligent services in a more efficient way for connected vehicles.

AECC looks to achieve its mission through the following activities:

- Development of use cases and requirements for connected services for emerging mobile devices, with a focus on automobiles.
- Development of technical reports and white papers designed to inform relevant standards and open-source communities. These white papers examine best practices for deploying distributed and layered computing infrastructure, which may be comprised of public and private clouds, telecom networks and mobile devices. In addition, the papers examine use cases and the requirements needed to help accelerate their deployment.
- Discuss and agree on reference architectures, such as for next-generation mobile networks and cloud, that are suitable for automotive-oriented use cases.

The AECC has developed two papers: [General Principle and Vision White Paper](#)¹⁶ and [Use-Case and Requirements Document](#).¹⁷

3.3.4 DIGITALEUROPE

[DIGITALEUROPE](#)¹⁸ is a trade association representing digitally transforming industries in Europe. Its goal is to shape industry policy positions on all relevant legislative matters and contribute to the development and implementation of relevant EU policies.

DIGITALEUROPE membership represents over 35,000 businesses that operate and invest in Europe. It includes 63 corporations that are global leaders in their field, as well as 40 national trade associations from across Europe. The association supports a regulatory environment that enables European businesses and citizens to prosper from digital technologies.

3.3.5 Industrial Internet Consortium (IIC)

The IIC is a global, member-supported organization that promotes the accelerated growth of IIoT by developing the guidance needed to securely connect, control and deploy intelligent systems across devices, fog, edge and cloud. IIC works to enable trustworthy industrial internet systems, where systems and devices are securely connected and controlled to deliver transformational outcomes across multiple industries, which include manufacturing, energy, health care, transportation and communication.

In January 2019, the IIC merged with the OpenFog Consortium. The merged consortiums span 30-plus countries with membership that includes small and large technology innovators, vertical market leaders, researchers, universities and government organizations. The IIC aims to advance the use of IIoT, fog and edge computing by clarifying distributed computing at and near the edge of the IIoT and continue to provide an ecosystem for the advancement of the IIoT.

¹⁶ https://aecc.org/wp-content/uploads/2018/02/AECC_White_Paper.pdf

¹⁷ https://aecc.org/wp-content/uploads/2018/05/AECC_WG1_URD1.0.1_ToC.pdf

¹⁸ <https://www.digitaleurope.org>

The IIC provides an environment for its members to connect with a global IIoT community and gain experience and foster partnerships. It has a growing testbed program where the innovation and opportunities of the industrial internet—new technologies, new applications, new products, new services, new processes—can be initiated, thought through and rigorously tested to ascertain their usefulness and viability before coming to market. The IIC currently has 41 liaison relationship globally with standards organizations, open-source organizations, other consortia and alliances, certification and testing bodies and government entities/agencies. The IIC has published many technical reports and white papers including the *Industrial Internet Reference Architecture (IIRA)*, *Industrial Internet Security Framework (IISF)*, *Industrial Internet Connectivity Framework (IICF)* and the *IoT Security Maturity Model* white paper.

The IIC is not a standards organization. It has developed a reference architecture called the IIC's IIRA. It evaluates existing standards against it, identifies requirements and proposes these requirements to standards organizations.

4 3GPP Release 17 and Beyond: Needs and Progress

The 5G system is intended to enable a complete mobile communications platform. As such, it will support all EPS capabilities (e.g., from TSs 22.011, 22.101, 22.278, 22.185, 22.071, 22.115, 22.153, 22.173) with the following exceptions:

- Circuit-switched (CS) fallback to GERAN or UTRAN will not be supported.
- Seamless handover between 5G-RAN and GERAN will not be supported.
- Seamless handover between 5G-RAN and UTRAN will not be supported.
- Access to a 5G core network via GERAN or UTRAN will not be supported.

In essence, 5G must support almost all capabilities currently available in 4G, as well as the newly defined 5G capabilities. This represents a very large body of work, which will play out over many 3GPP releases.

4.1 Release 16 Status

Release 15 represents the first full set of 5G specifications. After initial delivery in late 2017 of NSA NR specifications, 3GPP focused on the completion of 3GPP Release 15, as well as the 3GPP submission towards IMT-2020. With the completion of 3GPP Release 15

in 3Q 2019, 3GPP directed its attention on committed Release 16 capabilities, along with Release 17 definitional work.

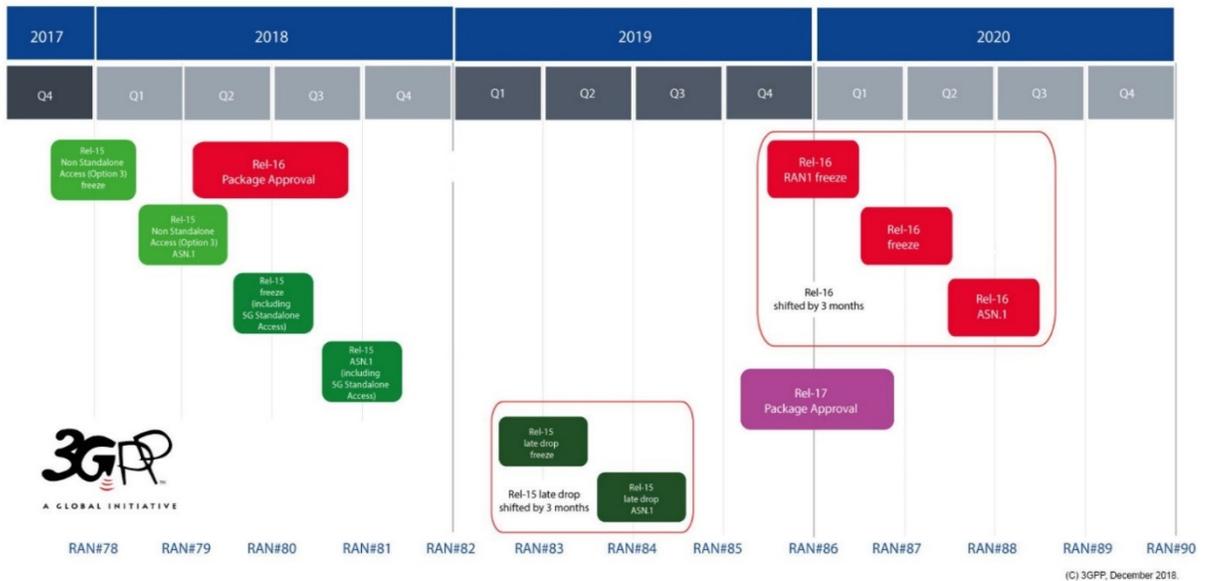


Figure 4.1 Release 16 Timetable

For Release 16, SA1 requirements went into much greater detail on the support for verticals in 5G. Specifically, additional vertical-related topics were addressed, including cyber-physical control applications in vertical domains (CAV), LAN support in 5G (5GLAN), 5G positioning services (HYPOS) and the integration of satellite access in 5G (5GSAT).

3GPP SA also made a decision to focus new work on the 5G system rather than evolving the 4G system further. However, it is expected the selected 4G enhancements will continue to be worked in future releases as necessary. For example, work continued in both 4G and 5G to enable verticals with Remote Identification of Unmanned Aerial Systems (ID_UAS) and Improvement of V2X service Handling (V2XIMP).

Many new 5G features from “verticals” have been included in Release 16, specifically:

- Significant industrial automation enhancements, including input from Germanic factory operators associated with Industrie4.0 and ZVEI (German Electrical and Electronic Manufacturers' Association), as well as electrical grid input coming from China grid operators.

- New key performance indicators (KPIs) and new architecture for non-public networks.
- New requirements, KPIs and accuracy bands for positioning (indoor and outdoor).
- QoS “prediction” and monitoring to support high-reliability systems.
- NR support for unlicensed band operation (in vertical markets).

Additionally, new vertical domains have engaged in 3GPP work covering maritime, audio-visual production, TV distribution, smart cities, water management, waste management and energy services.

4.2 Release 17 and Beyond

At the time this document was published, the 3GPP Technical Specification Group for Service and System Aspects (TSG-SA) had established the initial work priorities as shown in the table below. 3GPP Release 17 SA work priorities include the following areas:

- Enhancement of existing features in support of governmental and public safety needs in a 5G core network.
- Network automation enhancements in support of AI-based network management applications.
- Support for non-public networks.
- Network-slicing enhancements.
- Enhanced support for IIoT and other verticals.
- Enhanced UAV support and satellite access.
- Various network enhancements.

More detailed descriptions of these items are available in Annex A.

Name of the Work/ Study Item	Description	3GPP Document
Study on system enhancement for proximity-based services in 5GS	Identify and evaluate potential enhancements to the 5G System architecture to support proximity-based services based on SA1 requirements defined in TS 22.278 and TS 22.261.	SP-190443
Study on architectural enhancements for 5G multicast-broadcast services	Identify and evaluate potential enhancements to the 5G system architecture to provide multicast-broadcast services, which might be used for public safety and vertical businesses.	SP-190442

Study on enablers for network automation for 5G - phase 2	System enhancements for NWDAF, based on what has been specified in Releases 15 and 16, and will allow 5GS to support network automation.	SP- 190557
Study on enhancement of support for edge computing in 5GC	System enhancements for enhanced edge computing support, and deployment guidelines for typical edge computing use cases.	SP- 190185
Study on enhanced support of non-public networks	Enhancements to 5GS to enable more efficient and simpler support of non-public networks.	SP-190453
Study on Multi-USIM (MUSIM) devices	To address different aspects multi-USIM devices in EPS and 5G system.	SP-190091, SP-190309, SP-190248
Study on enhancement of network slicing phase 2	Identify the gaps in the currently defined 5GS system procedures on support of GST parameters and to study potential solutions that may address these gaps.	SP-190628
Study on enhanced support of IIoT	Enhancements to enable improved support of time-sensitive communication and deterministic applications.	SP-190630
Study on supporting UAS connectivity, identification, tracking and application layer support	Analyze how mechanisms to support UAS in the 3GPP system according to SA WG1 requirements are applicable to 5GS and possibly EPS.	SP-181114, SP-181252
Study on access traffic steering, switch and splitting support in the 5G system architecture	Investigate the different multi-path aspects for UEs that can connect to 5GC over both 3GPP and non-3GPP accesses.	SP-190558
Study on architecture aspects for using satellite access in 5G	Identify key issues of satellite integration in the 5G system architecture as described in TR 22.822.	SP-181253
Study on multimedia priority service (MPS) phase 2, stage 2	Perform a feasibility study to explore solution alternatives to enhance MPS consistent with requirements added to TS 22.153 to support MPS user needs for priority voice, data and video communication capabilities.	SP-190629
Study on enhancement to the 5GC location services-phase 2	Enhance the 5GC LCS architecture and corresponding network functions and procedures to meet the full set of requirements defined in SA1 (e.g., TS 22.261 and TS 22.071).	SP-190452
5G system enhancement for advanced interactive services	Define potential QoS parameters such as new standardized 5QI(s) corresponding to QoS requirements from SA1 NCIS in TS 22.261.	SP-190564

At the time this document published, the 3GPP Technical Specification Group for Radio Access Network (TSG-RAN) had established the initial work priorities as shown in the table below. 3GPP Release 17 RAN work priorities include the following areas:

- Enhancements to existing features in support of governmental and public safety needs in a 5G radio network.
- Radio network performance, coverage and power-saving enhancements.
- Extending 5G radio up to 71 GHz.
- NB-IoT and LTE-MTC enhancements along with other various IoT-related enhancements.
- Enhanced RAN slicing.

More detailed descriptions of these items are available in Annex A.

Name of the Work/Study Item	Description	3GPP Document
Study on NR V2X	Support advanced V2X services beyond LTE Release 15 V2X that require NR enhancements to meet the stringent requirements for low-latency/high-reliability services and with improved capacity and coverage.	RP-190224
Release 17 enhancements on MIMO for NR	Specify the further enhancements identified for NR MIMO.	RP-193133
Proposal for extending NR operation up to 71 GHz	Extend operation up to 71 GHz with the adoption of one or more new numerologies (i.e., larger subcarrier spacings).	RP-193229
NR sidelink enhancement	Specify radio solutions that can enhance NR sidelink for V2X, public safety and commercial use cases.	RP-193257
NR dynamic spectrum sharing (DSS)	As the number of NR devices in a network increases, it is important that sufficient scheduling capacity for NR UEs exists on the shared carriers.	RP-193260
Release 17 enhancements for NB-IoT and LTE-MTC	Specify enhancements to NB-IoT and/or LTE-MTC to support a broader set of use cases.	RP-193264
Solutions for NR to support non-terrestrial networks (NTN)	Specify the enhancements identified for NR NTN, especially LEO and GEO with implicit compatibility to support high-altitude platform station (HAPS) and air-to-ground (ATG) scenarios.	RP-193234
UE power-saving enhancements	Specify enhancements for idle/inactive mode, as well as connected-mode UE power saving, considering system performance aspects.	RP-193239

NR multicast and broadcast services	Specify RAN basic functions for broadcast/multicast for UEs.	RP-193248
Multi-radio dual-connectivity (MR-DC) enhancements	Specify enhancements to MR-DC to address network power consumption issues due to the need for maintaining two radio links simultaneously.	RP-193249
IAB enhancements	Specify enhancements for robustness, degree of load-balancing, spectral efficiency, multi-hop latency and end-to-end performance.	RP-193251
NR small data transmissions in INACTIVE state	Enable small data transmission in RRC_INACTIVE state.	RP-193252
Enhanced eNB(s) architecture evolution for E-UTRAN	Specify the control plane (CP)- user plane (UP) separation and the interface between the CP and UP for eNB and gNB.	RP-193181
SON/MDT for NR	Specify data collection enhancements in NR for self-organizing networks/minimization of drive tests (SON/MDT) purposes.	RP-193255
NB-IOT/eMTC over NTN	Evaluate and confirm that solutions for satellite NB-IoT/eMTC are defined in a complementary manner to terrestrial deployments.	RP-193235
Positioning enhancements for NR	Support for high-accuracy (horizontal and vertical), low-latency, network-efficiency (scalability, RS overhead, etc.) and device-efficiency (power consumption, complexity, etc.) requirements for commercial/IoT positioning use cases.	RP-193237
Support of low-complexity NR-light devices	Identify and study potential UE complexity reduction features in support of low complexity, long battery life IoT and "wearable" applications.	RP-193238
NR coverage enhancement	Study potential coverage-enhancement solutions for specific scenarios for both FR1 and FR2.	RP-193240
Proposal for XR evaluations for NR	Study related to capacity, coverage and mobility needs for XR and cloud gaming applications.	RP-193241
Study item on NR side link relaying	Study coverage extension and power efficiency improvements, considering a wider range of applications and services.	RP-193253

Study on enhancement of RAN Slicing	Enhancement to RAN support of network slicing.	RP-193254
NR QoE management and optimizations for diverse services	Study of the generic mechanisms of triggering, configuration and reporting for QoE measurement collection for a diverse set of services.	RP-193256

4.3 North American Needs for Release 17 and Beyond

The North American region has a number of regional specific needs based on market dynamics, as well as governmental needs. As 5G specifications progress in 3GPP Release 17 and beyond, it is important to keep sight of these specific needs in order to ensure that the future 3GPP specifications can be aligned with these needs.

4.3.1 Governmental Needs

Of specific interest are 3GPP specifications that enable operators within the North American (NA) region to meet the needs of existing and future anticipated public services. Identified NA needs in this category are:

- Enhanced 5G support for select vertical domains that intersect with emerging public and governmental interest. Of particular interest are the V2X enhancements that are applicable to public safety applications and UAS work related to UAV connectivity, identification and tracking. Specific aspects related to UAS include:
 - Remote identification (remote ID) of UAVs.
 - UAV restrictions: providing a technical means to enforce zones where UAVs are not authorized to fly.
 - Integration of UAVs into an aviation traffic management (UTM) system.
 - Support for beyond-line-of-sight control of UAVs.
 - Support for UAV payload communications.
- 5G multicast, broadcast, and proximity services for mission-critical situations are of specific interest for FirstNet and public safety applications.
- Multimedia priority service (MPS) enables national security/emergency preparedness (NS/EP) users to make priority calls/sessions using the public networks during network congestion conditions. Enhancements are needed to account for current and anticipated MPS user needs for priority voice, data and video communication capabilities in a 5G network.

4.3.2 Services and Architecture Needs

This category addresses 3GPP specifications that support the unique NA market needs of mobile operators related to services and their impact on the mobile core network.

Identified NA needs in this category are:

- Enhanced 5G support for verticals markets such as agriculture and industrial automation.
- Network automation enhancements to support the application of 5G data analytics for improved network operations.
- Enhancements to network slicing as noted in section 5 of this document.

4.3.3 RAN Needs

This category addresses 3GPP specifications that support the unique NA market needs of mobile operators related to RAN and spectrum. Identified NA needs in this category are:

- Radio performance enhancements involving MIMO, control channel, LTE/NR co-existence and coverage.
- Efficient usage of operator-licensed bandwidth when available spectrum does not align with existing standard 5G channel bandwidth options. This priority is described in more detail in annex B of this document.

5 Network Slicing: An Enabling Technology

Network slicing is a key component of the 5G architecture, enabling network operators to expand their customer base and offer new, differentiated services. Through network slicing, operators can allocate their network resources based on a precise set of performance requirements. Defining priority capabilities, along with a sufficient number of standardized network slice types, is essential because customers will expect the same level of service no matter where they are.

5.1 Network Slicing Priority Enhancements

5.1.1 Motivation

The network slicing enabler provides a virtualized approach for a flexible allocation and sharing of computing, functional and storage resources, while providing QoS guarantees,

and compatible performance to support for a variety of 5G services, under the broad categories of service types delineated as eMBB, mMTC, URLLC and V2X.

These 5G services are rendered over network slice instances (NSIs) and network slice subnet instances (NSSIs). These provide a logical partitioning of resources across the 5G core network (5GCN) and 5G radio network (5GRN), where the resources consist of virtual and physical entities to support the composition of a network slice required for a given 5G service.

Examples of 5G services include various types of IoT services, multi-access edge computing, industrial automation, health monitoring/diagnostics, surgical mediation, autonomous vehicles and mission-critical communications. Each of these services requires highly diverse allocations of computing, functional and storage resources to support service assurance in terms of performance criteria, and a wide range of QoS guarantees that include ultra-low latency and ultra-high reliability.

To establish a network slice that supports a given 5G service, the requisite resources are arranged based on policies associated with a corresponding administrative domain, together with any negotiated service-level agreements (SLAs) between domains. The behaviors suited for a given service in a certain domain, such as a hosted domain, may need to be replicated in another domain serving as a hosting domain.

With this diversity of 5G services, it is anticipated that services that have the same or different performance demands and QoS guarantees would need to be supported by network slices. An appropriate priority marking also is necessary to enable the 5G management subsystem to appropriately schedule the instantiation of a network slice in the 5G system.

5.1.2 Proposal

The support for a 5G service instance is realized by one or more NSIs, which in turn may consist of NSSIs that provide the requisite resources, whether in the 5GCN, 5GRN or both.¹⁹

A priority marking for the instantiation of a given network slice provides guidance for the orchestrator to appropriately sequence the instantiation of the network slice from among a multitude of network slice instances of the same network slice type or of different network slice types. The provisioning of network slice types in an administrative domain is based on the network slice types supported by the administrative domain, as governed by the service deployment scenarios and the corresponding policies.

A general requirement to include a priority attribute for a network slice instance is stated in TS28.531,²⁰ while further study is anticipated for the inclusion of this priority attribute in the resource model.

The orchestrator in the network management sub-system is responsible for instantiating a network slice to support the demands of any given 5G service that is launched. This proposal consists of an introduction of the following network slice attributes in the resource model to guide the orchestrator for network slice instantiation:

- Priority marking attribute for a network slice for enabling the orchestrator to perform slice prioritization.
- Priority-based sequencing for network slice instantiation.

5.2 New Network Slice for Internet of Things (IoT)

5.2.1 Background

The ATIS IoT Categorization Focus Group has produced a report that defines an IoT classification system. It divides the market into a small number of categories with similar requirements from a network/platform perspective. This report considers the network

¹⁹ 3GPP TR28.801, *Telecommunication management; Study on management and orchestration of network slicing for next generation network*, Release 15.

²⁰ 3GPP TS28.531, *Management and orchestration; Provisioning*, Release 16.

requirements across the multidimensional landscape of IoT devices and applications to identify any additional network slice types that may be defined to ensure consistent service quality across operators. *IOT Categorization: Exploring the Need for Standardizing Additional Network Slices*²¹ was published in September 2019 and is available [on the ATIS website](#).

Network slicing has been devised as a way to structure a network to support diverse classes of services in a guaranteed way on the same network. The objective of the IoT categorization analysis was to determine if additional network slice types are needed to support the varied IoT applications and devices that will connect to the network. Standardized definitions for the most commonly used slice types provide a mechanism for enabling roaming, as well as global interoperability for network slicing across network operators.

The IoT categorization effort assessed the performance requirements for IoT devices and applications against the three standardized slice types: eMBB, URLLC and mMTC. Based on the analysis, it was determined that these three standardized network slices were insufficient.

During the period of the IoT categorization study, 3GPP defined an additional slice type, V2X, that was incorporated into the analysis. This slice addresses the requirements of V2X applications, including ultra-low latency, high bandwidth, highly reliable communication, high mobility and high density. The V2X slice type also meets the performance requirements of the rapidly growing number of UAV applications requiring high mobile broadband data rates, low latency, large system capacity, and robust reliability. With the addition of the V2X slice, the analysis showed that the majority of the IoT applications and devices examined generally map to the four currently defined slice types.

5.2.2 Proposal

However, a smaller subset of the applications and devices exhibited characteristics across multiple slices that were not a perfect match to the currently defined four standardized slice types. As a result, the IoT Categorization Focus Group recommends consideration of an additional standardized slice type to address the performance requirements for this

²¹ https://www.atis.org/01_resources/whitepapers/#iotcat.

subset, which encompasses use cases across industrial automation, robotic surgery and public safety. Industrial automation use cases are emerging, requiring time-critical communication along with collaborative functions of robots, wearables on the manufacturing floor and AR. These functions require the transfer of large blocks of data (e.g., 3D models, sizeable historical data sets) for fast intervention, maintenance or assembly tasks. Remote robotic surgery applications use multimodal communications, such as video, audio and haptics, and demand a high data rate to facilitate good quality and fast visual feedback. Critical public safety applications using real-time video surveillance require high throughput and low latency to ensure high QoS for the video stream.

The proposed new network slice type, High-Performance Machine-Type Communications (HMTC), would be defined by the key performance characteristics common to the applications in the above subset, including low latency, high availability and high data rates. Although similar to the characteristics of the newly defined V2X slice, no mobility or sidelink is required. Below are the key performance characteristics that would typify the HMTC slice:

Table 5.1 Key Performance Characteristics that Typify the HMTC Slice

Performance Characteristic	Range of Values
Latency	Low (<10 ms)
Data Rate	High – very high (≥ 50 Mbps)
Availability	High (up to 99.999%)
Mobility	Fixed position
Density per km	Low (<1000)
Criticality	Mission/safety critical

5G is envisioned to support a wide range of IoT verticals with a diverse set of performance and service requirements. With the addition of the recommended HMTC slice definition, the resulting standardized slice types should address the most commonly used services and associated performance characteristics. Providing this broader set of standard slice types ensures roaming support, as well as global interoperability for network slicing across network operators.

6 Future Network Enhancements

As we look beyond 3G Release 16 to Release 17 and beyond, it is important to take a broad, high-level view of how networks can help enable delivery of new services and applications in the future consumer and enterprise marketplaces. This future landscape will be shaped by the intersection of emerging technologies with societal trends and new business models. The cumulative impact of these three trends will define the path forward and shape the agenda of 3GPP future releases.

Key areas for consideration will include the target market domains noted in figure 6.1 covering key verticals such as industrial automation, transportation, health care and energy, as well as media/entertainment, public safety and smart cities.



Figure 6.1 Emerging Market Domains Addressed by Future 3GPP Releases

The above market domains will be addressed using a variety of application areas as discussed in the next section.

6.1 Ultra-Enhanced 3D Visual Communications

The objective of ultra-enhanced 3D visual communications is to deliver very high-resolution 3D imagery in real-time 360° applications, including dynamic holographic imagery.

Specific applications may include:

- Smart factories
- 3D-assisted surgery
- Remote health care
- Electronic contact lenses
- Tele-positioned user experiences
- Immersive shopping malls
- Virtual museums
- Hyper-precise 3D positioning

New or enhanced 3GPP specifications may be required to address technical challenges associated with this application area, specifically:

- Interactive applications will require very low latency.
- High-resolution, wide viewing perspectives (including holographic display) will require significantly higher bandwidth, potentially in the 1 Tb/s range.
- Bandwidth requirements will be defined by a combination of frames per second and pixels per degree, depending on the application.
- In many cases, it will be necessary to reverse engineer human perception capabilities to maximize natural perception in artificial environments. This may include the use of AI, machine learning (ML) and complex predictive algorithms and systems.

6.2 Multi-Sensory Applications and Haptic Communications

The objective of multi-sensory applications is to combine information from multiple sensory sources to allow humans and machines to interact with their environment on a real-time basis.

Typical applications may include:

- Tactile internet
- Advanced multimedia experiences
- Remote robotic health care
- Exoskeleton-based artificial limbs

- Telesurgery
- Robotics and manufacturing

New or enhanced 3GPP specifications may be required to address technical challenges associated with this application area. These applications involve information-rich interactive communications, so the ability to deliver a continuous user experience will require both high bandwidth and low latency. In addition, the synchronization of sensory information across various sources may place new requirements on the system related to the delivery of timing and synchronization capabilities. Physical limitations surrounding latency for multi-sensory applications may require a high degree of edge cloud compute or fog computing resources.

6.3 Ultra-High Definition Positioning

The objective of ultra-high definition positioning is to collectively utilize a multi-dimensional set of sources, such as space, air and ground communications, to deliver ultra-high definition positioning and imagery. This application area may be used in AR/VR applications to overlay virtual information onto the visual landscape. In these situations, it is necessary to not only recognize the object of interest, but to locate the object in both macro and micro environmental contexts. This combination accurately associates the object with relevant information that can be displayed to the user viewing the object.

Applications may include:

- Precision navigation
- Public safety
- Accurate positioning in complex environments (e.g., underwater, underground)
- Imagery sent to electronic glasses/contact lenses
- Smart agriculture
- Autonomous shipping

New or enhanced 3GPP specifications may be required to address technical challenges associated with this application area, specifically:

- The need for both instantaneous positioning and continuous feedback for tracking.
- Enhanced high-bandwidth coverage to address remote or hard-to-reach areas, such as rural, in-building or underground areas.

6.4 Context-Aware Applications

The objective of context-aware applications is to collect information from a large number of contextual sources and apply it in real-time to applications that leverage the environment surrounding a human or machine. Context has been used in identity-management authentication applications to improve on traditional multi-factor authentication mechanisms. However, context can also be used with other applications to improve overall performance and to provide an enhanced and more personal user experience.

Example applications include:

- Transaction validation, particularly financial or business process related
- Digital identity
- Enhanced multimedia applications
- Retail merchandising
- Remote health care
- IT environments
- Personalized multimedia warning alerts

New or enhanced 3GPP specifications may be required to address technical challenges associated with this application area, specifically:

- The need to acquire real-time targeted retrieval of contextual data on a per-subscriber basis may require new functions and structures within the core architecture.
- This contextual data must be efficiently acquired and aggregated across many domains.
- Consent and privacy policies for locations, profiles and behaviors must be considered.

6.5 Intelligence-Enabled Connectivity

The objective of intelligence-enabled connectivity is to utilize AI, ML, hyper-connectivity and massive data to support the next generation of IoT-enabled intelligent applications. These applications utilize insights derived from network data and context, including ambient intelligence, to derive more localized insight that can then be used to optimize and enhance IoT applications. Supplementing IoT based information with network data allows more efficient resource management for constrained IoT devices in the network.

Typical applications enabled in this category include:

- Edge-enabled applications that enable local optimization of IoT systems and associated networking.
- Privacy and security perimeters established around devices based on AI-assisted assessments.
- Event-driven connectivity to the network to make more efficient use of limited IoT functionality and battery life while reducing costs.

New or enhanced 3GPP specifications may be required to address technical challenges associated with this application area, specifically:

- Many of these applications may integrate and extend AI capabilities in the network and require collective and federated AI.
- This area may be well suited to more complex IoT applications such as industrial IoT, smart utilities and autonomous vehicles, so specific requirements and capabilities may be needed to address those specific verticals.

6.6 Enhanced Cellular Sensing Applications

The objective of enhanced cellular sensing applications is to extend the functions of cellular infrastructure to include a new portfolio of sensing applications that leverage radio frequency (RF) signal effects. As new cellular technologies are deployed to increase coverage and capacity across a large geographical area with support for a very wide range of spectrum (low, mid and high bands), the network's RF attributes may now be utilized for other non-communication-based applications with only incremental additions to the network infrastructure.

Applications include:

- Near-term weather predictions (present local conditions)
- Local proximity mapping based on signal reflection
- Coverage mapping in dense urban environments
- Security applications

New or enhanced 3GPP specifications may be required to address technical challenges associated with this application area, specifically:

- These new non-communication functions may require protocol enhancement, as well as additional processing complexity at base stations.
- New issues may arise associated with interference effects.
- New antenna designs may be required.

6.7 Content-Optimized Networks

The objective for content-optimized networks is to better align mobile network content sources with mobile end-point users. This includes using innovations such as named content architectures to meet the future demands of rapid content discovery and delivery using ICN-based solutions. In addition, new peer-to-peer capabilities that may leverage information-centric aspects may be integrally supported in the network to enable more efficient delivery of high-bandwidth, low-latency content.

Example applications include:

- Network-enabled AR
- Efficient linear video delivery services, such as edge caching
- Anchorless mobility
- Multi-access conferencing
- Ubiquitous and efficient core network broadcast services

New or enhanced 3GPP specifications may be required to address technical challenges associated with this application area, specifically:

- Integration and co-existence of content-addressable data objects with IP-based networks.
- Standardized naming schema for content objects.
- Trust and security model that incorporates content object attributes.

6.8 Low-Energy/Zero-Energy IoT Devices

The objective of low-energy/zero-energy devices is to leverage the environment to extract ambient energy from various local environmental sources, as well as recovering energy from radio waves, to power ultra-low-power sustainable IoT devices.

Possible applications include:

- Wearables
- Implanted devices
- State-only devices
- Event-driven applications
- On-demand wake-up signals

New or enhanced 3GPP specifications may be required to address technical challenges associated with this application area, specifically:

- Tradeoff between stored power vs. incremental complexity to extract energy from the external environment (i.e., RF, heat, light, energy).
- Sustainability based on ambient energy within that environment and other environmental effects.
- The changing environment between indoor and outdoor movement.

7 Conclusion and Recommendations

The 5G system will continue to evolve creating a complete mobile communications platform that not only replaces 4G/LTE, but also enhances the performance and scope of 4G, enabling new services and applications. This effort represents a very large body of work that will play out over many 3GPP releases. This report lays out a vision of the 5G technology and market landscape (post Release 16) and identifies areas that will need more in-depth study going forward. Specifically, the report identifies key technologies and markets along with the transformational societal impacts of these technologies that will drive new requirements.

The 3GPP work on 5G is supplemented by a global ecosystem of standards bodies and fora providing supporting technologies and standards as well as forward looking use cases. These groups include specifications and studies from ITU, IEEE and oneM2M, a closer examination of verticals from groups such as 5GAA, 5GACIA, AECC and IIC, and new research that may lead to 6G from a variety of academic institutions.

North America has a number of regional-specific needs based on market dynamics and governmental needs. As 5G specifications progress in 3GPP Release 17 and beyond, it is important to keep sight of these specific needs in order to ensure that the future 3GPP specifications can be aligned with these needs.

Network slicing is a key component of the 5G architecture, enabling network operators to expand their customer base and offer new, differentiated services. Through network slicing, operators can allocate their network resources based on a precise set of performance requirements. Defining priority capabilities along with a sufficient number of standardized network slice types is essential because customers will expect the same level of service no matter where they are.

5G-enabling technologies include the use of AI and data analytics to optimize the network and operations as the network increasingly transforms to a more virtualized and cloud based distributed architecture.

The landscape in coming years will be shaped by the intersection of emerging technologies with societal trends and new business models. The cumulative impact of these three trends will define the path forward and shape the agenda of 3GPP future releases. Areas for consideration will include key verticals such as industrial, automation,

agriculture, transportation, health care and energy, as well as media/entertainment, public safety and smart cities.

8 Abbreviations

5GCN	5G Core Network
5GRN	5G Radio Network
5GS	5G System
AECC	Automotive Edge Computing Consortium
AI	Artificial Intelligence
ANSI	American National Standards Institute
AR	Augmented Reality
ATG	Air to Ground
ATIS	Alliance for Telecommunications Industry Solutions
BDT	Background Data Transfer
CAV	Communication for Automation in Vertical Do- mains
CBRS	Citizens Broadband Radio Service
CITEL	Inter-American Telecommunication Commission
CP	Control Plane
CS	Circuit Switched
C-V2X	Cellular Vehicle to Everything
DLT	Distributed Ledger Technology
DSDS	Dual SIM Dual Standby
DSRC	Dedicated Short-Range Communications
DSS	Dynamic Spectrum Sharing
EHT	Extremely High Throughput
eMBB	Enhanced Mobile Broadband
eNB	Evolved Node B – LTE / 4G base station
FG	Focus Group
FR1	Frequency Range 1 (FR1) includes sub-7GHz fre- quency bands
FR2	Frequency Range 2 (FR2) includes frequency bands 24.25 GHz and above
FTM	Fine Timing Measurement
gNB	5G base station
HAPS	High Altitude Platform Station
HMTC	High-Performance Machine-Type Communications
IAB	Integrated Access and Backhaul
ICT	Information and Communication Technology
ID_UAS	Identification of Unmanned Aerial Systems
IIC	Industrial Internet Consortium
IICF	Industrial Internet Connectivity Framework

IIRA	Industrial Reference Architecture
IISF	Industrial Internet Security Framework
IoT	Internet of Things
IP	Internet Protocol
ISP	Internet Service Providers
ITU	International Telecommunication Union
LAN	Local Area Network
LEO	Low Earth Orbit
MAC	Media Access Control
MEO	Medium Earth Orbit
mIoT	massive Internet of Things
mMTC	massive Machine Type Communications
MPE	Maximum Permissible Exposure
MPS	Multimedia Priority Service
NA	North American
MDT	Minimization of Drive Tests
NEO	Network Operation
NIDD	Non-IP Data Delivery
NR	New Radio
NS/EP	National Security/ Emergency Preparedness
NSA	Non-Stand-Alone
NSI	Network Slice
NSSI	Network Slice Subnet Instance
NTN	Non-Terrestrial Network
OT	Operational Technology
PHY	Physical Layer
RAN	Radio Access Network
RF	Radio Frequency
SLA	Service Level Agreements
SON	Self-Organizing Networks
TMT	Technology, Media and Telecoms
TR	Technical Report
TS	Technical Specifications
TSC	Time Sensitive Communication
UAS	Unmanned Aerial Systems
UAV	Unmanned Aerial Vehicles
UE	User Equipment
UP	User Plane
URLLC	Ultra-Reliable and Low Latency Communications
UTM	UAV Traffic Management

V2I	Vehicle-to-(Roadway) Infrastructure
V2P	Vehicle-to-Pedestrian
V2V	Vehicle to Vehicle
VR	Virtual Reality
WLAN	Wireless Local Area Network
XR	Extended Reality

ANNEX A

Study on System Enhancement for Proximity-Based Services in 5GS (SP-190443)

Proximity services has been developed in 3GPP starting in Release 12 to support both commercial and public safety services. Proximity Services is a device-to-device (D2D) technology that allows LTE and 5G NR devices to detect each other and to communicate directly. It relies on multiple enhancements to existing LTE standards, including new functional elements and a sidelink air interface for direct connectivity between devices.

Proximity services are expected to be an important system-wide enabler to support various applications and services, particularly in the public safety domain. Nevertheless, prior efforts within 3GPP have identified needed 5G system enhancements to support the proximity-based services with one common architecture to take advantage of economy of scale. Specifically, such architecture can be used for both public safety and commercial proximity services where applicable.

Study on Architectural Enhancements for 5G Multicast-Broadcast services (SP-190442)

3GPP originally developed the multicast/broadcast multimedia subsystem (MBMS) for 3G networks for video broadcasting and streaming services. It later introduced the evolved MBMS (eMBMS) for EPS. In Releases 13 and 14, the MBMS system had been updated to support new services, such as public safety, CIoT and V2X.

The scope of this study is to support multicast use cases described above, as well as dedicated broadcasting requirements/use cases within a 5G context.

Study on Enablers for Network Automation for 5G - Phase 2 (SP-190557)

3GPP Releases 15 and 16 specify a framework to enable data collection and provide analytics to consumers. This involves defining extensions to existing network data analytics function (NWDAF) services to support the analytics that are required for functions such as:

- QoS profile provisioning
- Traffic routing
- Future background data transfer

- Slice SLA, performance improvement and supervision of mIoT terminals
- Support of northbound network status exposure and customizing mobility management

In order to improve the NWDAF-related work initiated in Releases 15 and 16, it is necessary to further investigate solutions for supporting network automation leveraging 5G core information exposure and network data analytics.

Study on Enhancement of Support for Edge Computing in 5GC (SP-190185)

Compared to 4G LTE, the 5G system can provide a low-latency user experience and enhanced data volume with high efficiency. This enables support of the many applications and content types that need to be deployed toward the network edge in a distributed manner.

Edge computing is considered as one key enabler to fulfil this kind of deployment. With edge computing, operators can host their own and/or third-party applications and content close to the user. The UE can access the application/content via (R)AN and a locally deployed user plane function. This fulfills the expectations for the end-to-end user experience and allows the low-latency, to-the-edge applications and the heavy traffic to be offloaded from backbone network to the edge.

To support the edge computing and its deployment together with 5GS, many enablers have been specified in Releases 15 and 16. However, there is still a lack of common understanding how edge computing can be deployed with the 5G system given that the application architecture for edge computing is out of scope of the 5G core architecture specifications.

This study investigates architectural improvements to support the deployment of edge computing/localized access.

Study on Enhanced Support of Non-Public Networks (SP-190453)

3GPP Release 16 normative work to support non-public networks has started. Access to the vertical industries is often divided into an OT domain and an IT domain. Access to the OT domain is often achieved via local on-site technologies, whereas access to the IT domain includes wide-area access technologies, such as the support of mobility outside of the non-public network. Release 16 focuses on support of access to the OT domain

while also providing some basic support for access to IT domain by re-using the principles of untrusted access, which requires limited or no co-operation between the non-public network operator and the PLMN operator. With some level of co-operation between the NPN operators and the PLMN operators, the 5G system could likely support some further enhanced access to the IT domain and to PLMN services.

The goal of this work is to enable more efficient support of non-public networks via increased cooperation in the areas of QoS, network slicing and other shared network capabilities.

Study on MUSIM Devices (SP-190091, SP-190309, SP-190248)

Many commercially deployed devices support more than one USIM card (typically two). MUSIM devices typically address the following two use cases:

- The user has both a personal and a business subscription and wishes to use them both from the same device. This use case has become popular with the BYOD initiatives in the enterprise world.
- The user has multiple personal subscriptions and chooses which one to use based on the selected service (e.g., use one individual subscription and one “family circle” plan).

In either of the two use cases, the USIMs may be from the same or from different MNOs.

In the past, MUSIM devices have been popular in emerging economies but are now spreading to other regions.

Support for MUSIM is currently handled in an implementation-specific manner without any support from 3GPP specifications, resulting in a variety of implementations and UE behaviors. Examples include dual SIM single standby, dual SIM dual standby and dual SIM dual active.

For cost efficiency reasons, a MUSIM device implementation typically uses common radio and baseband components that are shared among the MUSIMs. This can lead to several issues that impact the 3GPP system performance. For example, a MUSIM device that is actively engaged in communication with a 3GPP system will need to manage paging events and behavior potentially across two different mobile core networks.

The impacts caused by dual SIM dual standby devices to the 3GPP system have already been discussed in the past (e.g., see R2-115375), but there was no standardization work that followed.

With the increased complexity of 5G-capable UEs, and with growing demand for MUSIM devices in the market, it becomes important for 3GPP to consider system enhancements that would allow for more cost-efficient implementations in such devices.

Study on Enhancement of Network Slicing Phase 2 (SP-190628)

Network slicing features defined in previous releases enable a great variety of communication services for operators and verticals alike. To enhance the commercial viability of network slicing, GSMA 5GJA has introduced in document NG.116 the concept of a generic slice template from which several network slice types descriptions can be derived. Some of the parameters in the GST point explicitly to the definition of parameters and bounds on the service delivered to the end customer. However, the enforcement of some of these bounds or of some of these parameters is not supported by the 5GS yet.

The objective of this study is to identify the gaps in the currently defined 5GS system procedures defined in SA2 owned TSs to support of GST parameters and to study potential solutions that may address these gaps.

Study on Enhanced Support of Industrial IoT (SP-190630)

3GPP Release 16 normative work was based on the conclusion of the FS_Vertical_LAN study described in TR 23.734. However, some aspects of time-sensitive communication (TSC) could not be agreed to be part of the study conclusion.

Release 16 starts to introduce some generic enablers for native TSC using the 5G system. However, the integration of the 5G system is specifically introduced for IEEE TSN networks only. Furthermore, it relies on the application layer protocol and DS-TT/NW-TT to support certain functionalities (e.g., appropriate routing and delivery of packets, synchronization).

This study will address enhancements to the 5G system that would enable enhanced support of TSC for IIoT and other media-related deterministic applications.

Study on Supporting UAS Connectivity, Identification, Tracking and Application Layer Support (SP-181114, SP-181252)

Due to the strong interest in using cellular connectivity to support UAS, the 3GPP system offers excellent benefits for UAS operation by providing ubiquitous coverage, high reliability, QoS, robust security and seamless mobility. In particular, the 3GPP system can be used to enable UAS identification and tracking, and to support UAS command and control functions.

Regulators are investigating safety and performance standards, and registration and licensing programs to develop a well-functioning private and civil UAS ecosystem. This ensures UAS can safely coexist with commercial air traffic, public and private infrastructure, and the general population. Such solutions require support by the 3GPP system to enable the appropriate communications.

The study item aims to address the above concerns.

Study on Access Traffic Steering, Switch and Splitting Support in the 5G System Architecture (SP-190558)

The access traffic steering, switch and splitting (ATSSS) feature enables UEs to be simultaneously connected to both 3GPP access and non-3GPP access. The 5G system should be able to take advantage of these two accesses in a way that improves the user experience, optimizes the traffic distribution across two accesses and enables the provision of new high-data-rate services.

During the Release 16 study and normative development of ATSSS, certain aspects of the initial scope were not supported, such as traffic splitting support for GBR traffic, more advanced steering modes, additional steering methods and certain roaming scenarios. Additionally, several other potential performance enhancement procedures have been deferred for further study.

The intent of this study is to investigate the deferred features and additional access deployment scenarios as noted above.

Study on Architecture Aspects for Using Satellite Access in 5G (SP-181253)

Terrestrial networks may not be available for both economic reasons and disaster-related reasons. Furthermore, a number of potential users may wish to access 5G services in these “un-served” or “underserved” areas. But they will be prevented from doing so unless 5G satellite access networks provides them with such a service (see FS_5GSAT, TR 22.822).

In order to further elaborate the requirements associated to satellite access for 5G integration, the study on using satellite access in 5G (FS_5GSAT, TR 22.822) has developed a number of use cases and identified potential requirements for the integration of satellite components into the 5G system.

TR 22.822 has been agreed during WG SA1#82 (Dubrovnik, May 2018), as well as a corresponding 5GSAT work item for the corresponding normative phase. It is therefore timely for the SA2 Working Group to initiate a study on the integration of satellite in the 5G system architecture.

Study on NR V2X (RP-190224)

To expand the 3GPP platform to the automotive industry, the initial standard on support of V2V services was completed in September 2016. Enhancements focusing on additional V2X operation scenarios leveraging the cellular infrastructure were completed in March 2017 as 3GPP V2X phase 1 for inclusion in Release 14 LTE. In Release 14 LTE V2X, a basic set of requirements for V2X service in TR 22.885 has been supported, which are considered sufficient for basic road safety service. Vehicles (i.e., UEs supporting V2X applications) can exchange their own status information through sidelink, such as position, speed and heading, with other nearby vehicles, infrastructure nodes and/or pedestrians.

3GPP V2X phase 2 in Release 15 introduced multiple new features in sidelink, including carrier aggregation, high-order modulation, latency reduction. It also included a feasibility study on both transmission diversity and short TTI in sidelink. All these enhanced features in 3GPP V2X phase 2 are primarily based on LTE and require co-existing with Release 14 UE in same resource pool.

SA1 has completed enhancement of 3GPP support for V2X services (enhanced V2X services). The consolidated requirements for each use case group are captured in TR

22.886. A set of the normative requirements is defined in TS 22.186. SA1 has identified 25 use cases for advanced V2X services. They are categorized into four use case groups: vehicles platooning, extended sensors, advanced driving and remote driving.

TSG RAN has already agreed in TR 38.913 that it is not intended for NR V2X to replace the services offered by LTE V2X. Instead, the NR V2X shall complement LTE V2X for advanced V2X services and support interworking with LTE V2X. At least from a 3GPP RAN technology development standpoint, the focus and scope of NR V2X study is to target advanced V2X use cases. However, this does not imply that NR V2X capability is necessarily restricted to advanced services. It is clearly up to the regional regulators and the stakeholders involved (i.e., car OEMs and the automotive ecosystem in general) to decide on the technology of choice for the services and use cases.

NR V2X is destined as 3GPP V2X phase 3 and would support advanced V2X services beyond services supported in LTE Release 15 V2X. The advanced V2X services would require enhanced NR system and new NR sidelink to meet the stringent requirements. The NR V2X system is expected have a flexible design in support of services with low-latency and high-reliability requirements. The NR system also expects to have higher system capacity and better coverage. The flexibility of the NR sidelink framework would allow easy extension of the NR system to support the future development of further advanced V2X services and other services.

Study on Multimedia Priority Service (MPS) Phase 2, Stage 2 (SP-190629)

TR 23.854 (Release 11) evaluated the architectural requirements for MPS, considered the priority service scenarios, and analyzed solution alternatives based on stage 1 requirements specified in TS 22.153 (Release 11). TR 23.854 provided the framework for normative requirements in TS 23.401, TS 23.203, TS 23.228, 23.273, 23.216, 23.237, etc., to support MPS from Release 11 onward. MPS requirements in TS 23.501, TS 23.502 and TS 23.503 for 5GS for Releases 15 and 16 evolved from these earlier TSs.

The scope of MPS until Release 16 mainly focused on voice communications and data transport services using default bearer/QoS flows. MPS users are now relying more heavily on sophisticated services involving data and video communications. Several use cases to account for current and anticipated MPS user needs for priority voice, data and video communication capabilities have been studied, and potential new stage 1 requirements have been identified. SA approved a WID (SP-190305) to update TS 22.153

to include normative stage 1 requirements to support anticipated MPS needs for priority voice, data and video communications based on TR 22.854 in Release 17.

Enhanced services in MPS phase 2 will lead to additional stage 2 impacts to core network specifications. Examples include priority voice/video conferencing, conferencing initiated by a host on the server, priority sessions (voice/video calls, voice/priority teleconferencing) from a public UE (i.e., a UE not subscribed to MPS), priority data sessions to an enterprise network, priority sessions initiated from IoT devices and enterprise network, etc. Downgrading a video call to audio only due to resource constraints and upgrading it back to a video call when resources become available again will result in additional requirements.

A feasibility study (similar to TR 23.854 that provided the framework for MPS requirements in phase 1) is needed to explore stage 2 solutions for the use cases identified in the updated stage 1 requirements in TS 22.153 for Release 17 as applicable for 5GS as well as for EPS.

Study on Enhancement to the 5GC LoCation Services-Phase 2 (SP-190452)

During Release 16, SA2 studied *Enhancement to the 5GC LoCation Services* and agreed conclusions have been specified in TS23.273 *5G System Location Services (LCS)*. However, due to limited time, some key issues and corresponding solutions were not concluded in Release 16's scope. In addition, some other aspects - e.g., EPC-5GC interworking for LCS), have not been fully studied yet. Some SA1 Release 16-defined requirements also have not been studied - e.g., very low latency and very high accuracy for IIoT and other applications, positioning service area, positioning service level). These requirements are specified in TS22.261 and TS22.104.

This study will consider enhances to 5G system location services to satisfy the above requirements.

5G System Enhancement for Advanced Interactive Services (SP-190564)

Interactive services, (e.g., cloud gaming) have become more popular in recent years. For cloud gaming, rendering can be performed in the network. This means that sensor/pose data must be transmitted in the uplink to the network to enable downlink rendered data to the UE.

In uplinks, the sensor/pose data requires treatment within 5G system with low latency and high reliability. In downlinks, the rendered data (i.e., audio and video require low latency) and potential high bandwidth - e.g. 100Mbps though reliability can be less stringent than uplink data.

Cloud gaming services are characteristic of real-time interaction with low-latency requirements, and the required reliability for uplink sensor/pose data and downlink rendered audio/video traffic are asymmetric. Buffered packets exceeding the delay budget are not meaningful for cloud gaming. Meanwhile, to support interactive cloud gaming services, the total delay including both uplink and downlink within 5G systems in two directions should be less than a threshold - e.g., 5ms. However, due to the asymmetry for uplink and downlink, the latency for uplink and downlink may not be equal and static. Existing QoS mechanisms (e.g., 5QIs already defined in 23.501) cannot meet the requirements for this service.

In addition, for UAS, the uplink traffic requires eMBB treatment, while the downlink traffic may require URLLC treatment, which is the opposite of cloud gaming. To support these types of interactive services, the 5G system needs to be enhanced to support the interactive services with different KPIs requirements in the uplink and downlink.

As of the publication of this document, the 3GPP TSG-RAN has established the initial work priorities as follows

Release 17 Enhancements on MIMO for NR (RP-193133)

As NR is in the process of commercialization, various aspects that require further enhancements have been identified from real deployment scenarios. Such aspects include the following:

- Release 16 manages to offer some reduction in overhead and/or latency. But high-speed vehicular scenarios (e.g., a UE traveling at highway speeds) in Frequency Range 2 (FR2), which includes frequency bands from 24.25 GHz to 52.6 GHz), require more aggressive reduction in latency and overhead. This also includes reducing the occurrence of beam failure events.
- While enhancements for enabling panel-specific UL beam selection were investigated in Release 16, there was insufficient time to complete the work. This work offers the potential for increasing UL coverage.

- Maximum Permissible Exposure (MPE) issues may occur on all transmit beams from the panel. Therefore, a solution for MPE mitigation may be needed on a per panel basis to meet the regulatory requirement for scenarios of interest.

Proposal for Extending NR Operation up to 71 GHz (RP-193229)

RAN carried out a Release 16 study on NR beyond 52.6 GHz documented in TR 38.807. From this study, the global availability of bands in the 52.6-71 GHz range became apparent. Moreover, the World Radiocommunication Conference (WRC) 19 recently identified the 66-71GHz frequency range for IMT operation in certain regions.

The proximity of this frequency range (57-71GHz) to FR2 and the imminent commercial opportunities for high data rate communications makes it compelling for 3GPP to address NR operation in this frequency regime.

In order to minimize the specification burden and maximize the leverage of FR2 based implementations, 3GPP has decided to extend FR2 operation up to 71 GHz with the adoption of one or more new numerologies - i.e., larger subcarrier spacings. These new numerologies will be identified by the study on waveform for NR for frequencies greater than 52.6GHz in the first half of 2020. NR-U defined procedures for operation in unlicensed spectrum will also be leveraged for operation in the unlicensed 60 GHz band.

NR Sidelink Enhancement (RP-193257)

3GPP has been developing standards for sidelink as a tool for UE-to-UE direct communication required in various use cases since LTE. The first standard for NR sidelink is to be completed in Release 16 by the work item "5G V2X with NR sidelink," where solutions including NR sidelink are being specified mainly for V2X. They can also be used for public safety when the service requirement can be met.

Meanwhile, the necessity of NR sidelink enhancements have been identified. For V2X and public safety, the service requirements and operation scenarios are not fully supported in Release 16 due to the time limitation, and SA work is ongoing on some enhancements in Release 17. In addition, other commercial use cases related to NR sidelink are being considered in the SA working groups via several work/study items such as Network Controlled Interactive Service (NCIS), Gap Analysis for Railways (MONASTERYEND), Enhanced Relays for Energy efficiency and Extensive Coverage (REFEC) and Audio-Visual Service Production (AVPROD). In order to provide a wider coverage of NR sidelink for

these use cases, and to be able to provide the radio solutions in accordance with the progress in SA working groups, it is necessary to specify enhancements to NR sidelink addressing such areas as:

- Power saving to enable UEs with battery constraints to perform sidelink operations in a power-efficient manner.
- Enhanced reliability and reduced latency enable the support of URLLC-type sidelink use cases in wider operation scenarios.

NR Dynamic Spectrum Sharing (DSS) (RP-193260)

DSS provides a very useful migration path from LTE to NR by allowing LTE and NR to share the same carrier. DSS was included in Release 15 and further enhanced in Release 16. As the number of NR devices in a network increases, it is important that sufficient scheduling capacity for NR UEs exists on the shared carriers.

Release 17 Enhancements for NB-IoT and LTE-MTC (RP-193264)

NB-IoT and LTE-MTC were introduced in Release 13 to provide support for low complexity, deep coverage, mass deployments of LTE IoT devices for low power wide area (LPWA) use cases. Additional IoT support was added in Release 14, such as positioning and multicast, and data rates to suit a broader range of usages. Releases 15 and 16 have enhanced the two technologies further to introduce features that allow reduced signaling and control channel overhead for transmitting messages, extensions to battery life, channel quality reporting to the network and coexistence with NR. In Release 17, the intent is to add or enhance features that support the broadening use cases for cellular LPWA IoT, address lessons drawn from deployments and trials, and support the long-term lifecycle of the two technologies.

Solutions for NR to Support Non-Terrestrial Networks (NTN) (RP-193234)

NTN are networks, or segments of networks, using an airborne or spaceborne vehicle for transmission:

- Spaceborne vehicles: LEO, MEO, GEO and HEO satellites.
- Airborne vehicles: high-altitude platforms (HAPs) encompassing UAS, including lighter-than-air UAS (LTA), heavier-than-air UAS (HTA), all operating in altitudes typically between 8 and 50 km, quasi-stationary.

In 3GPP TS 22.261, use cases for 5G satellite integration, and the corresponding service requirements have been identified. This work will address mobile broadband needs in unserved/underserved areas, as well as public safety needs, maritime (3GPP TS 22.119 *Maritime communication services over 3GPP system*), airplane connectivity and railway communication service requirements applicable to satellite access.

Two activities on NR to support NTN have been successively carried out:

- A first activity, FS_NR_nonterr_nw (see RP-171450), studied the channel model for the NTNs to define deployment scenarios, parameters and identify the key potential impacts on NR.
- A second activity, FS_NR NTN_solutions (see RP-190710), defined and evaluated solutions for the identified key impacts from the first activity.

Additional work may include new specifications to address transparent payload-based scenarios in a variety of use cases.

UE Power-Saving Enhancements (RP-193239)

User experience is key to 5G/NR success, not only in terms of experienced data rates and latency but also importantly UE power consumption. UE power-saving enhancements are therefore vital to the success of 5G/NR. In Release 16, several useful power-saving schemes were specified. These include power-saving signal/DCI as enhancement to connected-mode DRX (cDRX), additional adaptations to maximum MIMO layer number, SCell dormancy behavior and cross-slot scheduling as enhancements to BWP framework, RRM relaxation as enhancements for idle/inactive-mode power consumption and UE assistance information.

In Release 17, additional enhancements are required to address outstanding issues in Release 16, namely idle/inactive-mode power consumption in NR SA deployments, considering both eMBB UEs and reduced-capability NR devices, connected-mode power consumption with FR2 deployments and optimizing network utilization of Release 16 UE assistance information.

NR Multicast and Broadcast Services (RP-193248)

No broadcast/multicast feature support is specified in the first two NR releases (i.e. 15 and 16). Nevertheless, there are important use cases for which broadcast/multicast could

provide substantial improvements, especially regarding system efficiency and user experience.

The use cases identified that could benefit from this feature include public safety and mission critical, V2X applications, transparent IPv4/IPv6 multicast delivery, IPTV, software delivery over wireless, group communications and IoT applications.

Multi-Radio Dual-Connectivity Enhancements (RP-193249)

In Release 16, 3GPP has completed the mobility enhancements to NR and LTE to reduce data transmission interruption during handover and improve handover robustness. Specifically, the dual active protocol stack solution has been specified to achieve 0ms interruption handover, and a conditional handover solution has been specified to deal with the case when the source link deteriorates quickly, and the UE cannot receive the HO command successfully. In Release 16, 3GPP has introduced some enhancements for efficient Multi-Radio Dual Connectivity (MR-DC) configuration and improve MR-DC performance.

However, for Dual Connectivity, the network power consumption is an issue due to the need for maintaining two radio links simultaneously. In some cases, NR UE power consumption is 3-4 times higher than LTE. This issue, along with other identified cleanup work, will be addressed in Release 17.

IAB Enhancements (RP-193251)

Enhancements to Integrated Access and Backhaul (IAB) builds on the Release 16 work, which supports wireless backhauling via NR, enabling flexible and very dense deployment of NR cells while reducing the need for wireline transport infrastructure.

Enhancements to IAB in Release 17 improve on various aspects such as robustness, degree of load-balancing, spectral efficiency, multi-hop latency and end-to-end performance.

NR Small Data Transmissions in INACTIVE state (RP-193252)

NR supports RRC_INACTIVE state, and UEs with infrequent (periodic and/or non-periodic) data transmission are generally maintained by the network in the RRC_INACTIVE state. Until Release 16, the RRC_INACTIVE state didn't support data

transmission. Hence, the UE must resume the connection (i.e., move to RRC_CONNECTED state) for any uplink or downlink data. Connection setup and subsequently release to INACTIVE state happens for each data transmission, regardless of how small and infrequent the data packets are. This results in unnecessary power consumption and signaling overhead.

Specific examples of small and infrequent data traffic include the following use cases:

Smartphone applications:

- Traffic from instant messaging (IM) services.
- Heartbeat/keep-alive traffic from IM/email clients and other apps.
- Push notifications from various applications.

Non-smartphone applications:

- Traffic from wearables (periodic positioning information, etc.).
- Sensors (industrial wireless sensor networks (IWSN) transmitting temperature, pressure readings periodically or in an event triggered manner, etc.).
- Smart meters and smart meter networks sending periodic meter readings.

This work builds on previous work to enable small data transmission in INACTIVE state for NR.

Enhanced eNB(s) Architecture Evolution for E-UTRAN (RP-193181)

This work explores control and user plane split centralization and interfaces across the LTE eNB, next generation eNB and NR-based RAN (gNB).

SON/MDT for NR (RP-193255)

Due to the time constraints, it was impossible to accomplish all the objectives listed in the Release 16 SON and Minimization of Drive Tests (MDT) work item. Some of the leftover features will be considered in Release 17, potentially including PCI selection, energy efficiency, MDT for MR-DC and enhancement to UE reports for mobility optimization.

NB-IOT/eMTC over NTN (RP-193235)

IoT operation is critical in remote areas with low/no cellular connectivity for many different industries, including:

- Transportation (maritime, road, rail, air) and logistics
- Solar, oil and gas harvesting
- Utilities
- Farming
- Environment monitoring
- Mining

The capabilities of NB-IoT and eMTC are a good fit to the above but will require satellite connectivity to provide coverage beyond terrestrial deployments, where IoT connectivity is required. There is an urgent need for a standardized solution allowing global IoT operation anywhere on Earth, in view of other solutions already available. It is important that satellite NB-IoT or eMTC be defined in a complementary manner to terrestrial deployments.

Positioning Enhancements for NR (RP-193237)

Emerging applications relying on high-precision positioning technology in autonomous applications (e.g., automotive) create the need for high integrity and reliability in addition to high accuracy. Integrity is the measure of trust that can be placed in the correctness of information supplied by a navigation system. Integrity includes the ability of a system to provide timely warnings to user receivers in case of failure. The 5G service requirements specified in TS 22.261 include the need to determine the reliability, and the uncertainty or confidence level, of the position-related data.

To address the higher accuracy location requirements resulting from new applications and industry verticals, NR Positioning in Release 17 will evaluate and specify enhancements and solutions to meet the following exemplary performance targets:

- For general commercial use cases (e.g., TS 22.261) - sub-meter level position accuracy (< 1 m).
- For IIoT Use Cases (e.g., TS 22.804) - position accuracy < 0.2 m.

Support of Low-Complexity NR-Light Devices (RP-193238)

One important objective of 5G is to enable connected industries. 5G connectivity can serve as catalyst for the next wave of industrial transformation and digitalization. This will improve flexibility, enhance productivity and efficiency, reduce maintenance costs and improve operational safety. Devices in such environment include pressure sensors, humidity sensors, thermometers, motion sensors, accelerometers and actuators. It is desirable to connect these sensors and actuators to 5G networks. The massive IWSN use cases and requirements described in TR 22.804, TS 22.104, TR 22.832 and TS 22.261 include not only URLLC services with very high requirements, but also relatively low-end services with the requirement of small device form factors, and/or being completely wireless with a battery life of several years. The requirements for these services that are higher than LPWA (i.e., LTE-M/NB-IOT) but lower than URLCC and eMBB.

Similar to connected industries, 5G connectivity can serve as catalyst for the next wave smart city innovations. As an example, TS 22.804 describes smart city use case and requirements for that. The smart city vertical covers data collection and processing to more efficiently monitor and control city resources, and to provide services to city residents. Especially, the deployment of surveillance cameras is an essential part of the smart city, as well as for factories and industries.

Finally, wearables use case includes smart watches, rings, e-health related devices and medical monitoring devices. One characteristic for the use case is that the device is small.

NR Coverage Enhancement (RP-193240)

Coverage is one of the key factors that an operator considers when commercializing cellular communication networks due to its direct impact on service quality, as well as capex and opex. Despite the importance of coverage on the success of NR commercialization, a thorough coverage evaluation and a comparison with legacy radio access technologies considering all NR specification details have not been done up to now.

Compared to LTE, NR is designed to operate at much higher frequencies, such as 28 GHz or 39 GHz in FR2. Furthermore, many countries are making available more spectrum in FR1, such as 3.5 GHz, which is typically in higher frequencies than for LTE or 3G. Due to the higher frequencies, it is inevitable that the wireless channel will be subject to higher

path loss, making it more challenging to maintain an adequate QoS that is at least equal to that of legacy RATs. One mobile application of particular importance is voice service, for which subscribers will always expect ubiquitous coverage wherever they are.

For FR1, NR can be deployed either in newly allocated spectrums, such as 3.5 GHz, or in a spectrum re-farmed from a legacy 3G or 4G network. In either case, coverage will be a critical issue because this spectrum will most likely handle key mobile services such as voice and low-rate data services. For FR2, coverage was not thoroughly evaluated during the self-evaluation campaign toward IMT-2020 submission and not considered in Release 16 enhancements. In these regards, a thorough understanding of NR coverage performance is needed while taking into account the support of latest NR specification.

Proposal for XR Evaluations for NR (RP-193241)

XR and cloud gaming are some of the most important 5G media applications under consideration in the industry. XR is an umbrella term for different types of realities and refers to all real-and-virtual combined environments and human-machine interactions generated by computer technology and wearables. It includes representative forms such as AR, MR and VR, and the areas interpolated among them.

One specific aspect to be considered is the role of edge computing as a network architecture to enable XR and cloud gaming. Edge computing is a concept that enables cloud computing capabilities and service environments to be deployed close to the cellular network. It promises benefits such as lower latency, higher bandwidth, reduced backhaul traffic and prospects for several new services as indicated in the SA6 Study on application architecture for enabling Edge Applications (TR 23.758). Edge applications are expected to take advantage of the low latencies enabled by 5G and the edge network architecture to reduce the end-to-end application-level latencies. Edge computing is a valuable enabler that should be considered to help 5G systems achieve the required performance to enable XR and cloud gaming.

As such, additional study related to capacity, coverage and mobility needs for XR and cloud gaming applications are warranted.

Study Item on NR Sidelink Relaying (RP-193253)

For Release 16, a first version of NR sidelink has been developed. It focuses solely on supporting V2X-related road safety services. The design aims to provide support for

broadcast, groupcast and unicast communications in both out-of-coverage and in-network coverage scenarios.

In addition, sidelink-based relaying functionality needs to be studied in order for sidelink/network coverage extension and power efficiency improvements, considering wider range of applications and services.

Study on Enhancement of RAN Slicing (RP-193254)

Strong demand in wireless communication has been expected in vertical markets, as connectivity and mobility empower the transformation and innovation in industries such as manufacturing, transportation, energy and civil services, healthcare and many more. These diverse vertical services bring about a wide range of performance requirements in throughput, capacity, latency, mobility, reliability and position accuracy. NR technology promises a common RAN platform to meet the challenges of current and future use cases and services, not only for those that we can envision today but also for those that we cannot yet imagine. The work of network slicing in Release 15 further advances network architecture toward more flexibility and higher scalability for a multitude of services of disparate requirements.

While Release 15 specifications can provide the foundation of a common connectivity platform for various services, more efforts should be made in Release 17 for RAN support of network slicing. This additional work will make it a tool that network operators can apply to meet the challenge of opening new source of revenue in addition to the one derived from customer subscription. More particularly, the new work should provide technical tools in RAN for network operators to get application providers involved in customizing RAN design, deployment and operation for better support of the applications providers' businesses. This provides network operators the possibility of benefiting directly from the business success of certain major application providers, generating better investment return than by sustaining the explosion of mobile data from the over-the-top business practices.

NR QoE Management and Optimizations for Diverse Services (RP-193256)

In UTRAN and E-UTRAN, QoE measurement collection for streaming services have been specified. NR is designed for different kinds of services and scenarios, and operators

have strong demand to optimize their network and provide better user experiences with various types of services.

QoE management in 5G will collect the experience parameters of streaming services and consider the typical performance requirements of diverse services (e.g., AR/VR and URLLC). Based on requirements of services, we suggest that Release 17 focus on more adaptive QoE management schemes that enable network intelligent optimization to satisfy user experience for diverse services.

5G network will provide service for various kinds of vertical industries and various kinds of users. But the 5QI service requirements may not enough to provide a good user experience for all the user requirements. Thus, in the 5G network, the RAN also needs to collect the user KPI information- e.g., E2E reliability statistic indicator.

Different types of UEs have different QoE requirements, so resource allocation should be based on the UE's requirements. QoE parameters can be defined as UE-specific and service related. In addition, QoE can be used as a criterion to evaluate network quality. In the past, it normally used metrics such as throughput, capacity and coverage for performance evaluations for network solutions. By using QoE parameters, solutions could be evaluated in different aspects and more related to user and service experience.

This work will study the generic mechanisms of triggering, configuration and reporting for QoE measurement collection, including all relevant entities - e.g., UE, network entities. In addition, the mechanisms need to support 5G existing services, as well as scalable support for emerging services in the future.

ANNEX B

Efficient Usages of Operator-Licensed Bandwidths

Existing 5G NR channel bandwidths have been greatly expanded compared to 4G LTE and include 5, 10, 15, 20, 25, 30, 40, 50, 60, 80, 90 and 100 MHz (from TS38.101-1). However, not all operator spectrum licenses are aligned with these existing NR channel bandwidths.

For example:

- Existing 700 MHz blocks tend to be multiples of 6 MHz (due to legacy TV channel assignments) or 11 MHz.
- Sprint has 7 MHz of Band 26 spectrum. Sprint submitted a WID for NR Band n26 that included 7 MHz channel bandwidth, but RP decided to remove the 7 MHz channel bandwidth from the n26 WID and address the issue of issue in Release 17.
- T-Mobile US included 35 MHz in a WID for adding channel BWs to n25, but the inclusion of 35 MHz was challenged in RAN4 R4-1911518.
- UAE Operator Etisalat also requested 13 MHz for n28 at RAN#85. Although Band 28/n28 is not a U.S. band, it is used in Latin America, including Mexico.

Allocation of new spectrum is a constant issue that is not likely to go away. New spectrum allocations are increasingly difficult to find and as such have increased probability of “not fitting” into existing NR channel bandwidths

Potential North American operator allocations that don't align with existing NR bandwidths:

<u>Band</u>	<u>Bandwidth</u>
n2	35 MHz
n5	11 MHz
n12	12 MHz
n25	35 MHz
n26	7 MHz
n66	35 MHz

In aggregate, spectrum fragmentation wastes significant and increasing amounts of spectrum.

Background of Previous Work

3GPP can always define new UE and BS channel bandwidths as requested by operators. Although this option enables operators to get what they need, this will likely result in a large number of channel bandwidths that must be supported. More channel bandwidths mean greater design complexity and testing in the UE and in some cases may not be technically feasible for implementation in the desired UE form factor and cost point. Specifically, 3GPP Contribution (R4-1911519) suggests that adding new bandwidths will need a redesign of the transceiver and harm the design of the analog filters, create even more complexity and require additional specification work, development and testing. As such, recent requests in 3GPP RAN for new channel bandwidth options have not been successful.

R4-1911519 also proposed the use of resource blocks in the middle of the band, leaving blocks at the end unused. For example, if the allocation was for 7 MHz of spectrum, this proposal suggests the use a 10 MHz channel bandwidth (CBW), with the resource blocks in the middle active, leaving 1.5 MHz of the 10 MHz unused on either side. This can be done by restricting the RB allocation in the air interface scheduler. Using the same guard bands for 7 MHz as they have been specified for 10 MHz would center 35/15 RBs for 15/30kHz subcarrier spacing as the transmit bandwidth out of the 52/24 RBs that are allowed as transmit bandwidth configuration for 10 MHz NR CBW. It is hoped that emission requirements are met. Items such as spectral emission mask are based on the channel bandwidth, not the RB allocation, so FCC emission requirements might not be met. In addition, receiver blocking is a problem if the receiver is using a channel bandwidth wider than the operator's licensed allocation.

Another option discussed was to use existing UE channel bandwidth offsets to cover the operator bandwidth. For example, to cover the channel bandwidth (e.g., 35 MHz), this proposal suggests that the network would assign some UEs to the low 30 MHz and some to the high 30 MHz so the network could manage the load evenly across the allocated spectrum. This option has the advantage that no new UE channel bandwidths are required, but new base station channel bandwidths are still needed. Certainly, a single UE can't use all of the operator's bandwidth. In addition, this option doesn't work for channels smaller than 10 MHz because the 3.6 MHz synchronization signal block (SSB) for 15 kHz sub-carrier spacing (SCS) needs to be covered by the RBs of both of the 5 MHz channels.

Finally, it has been suggested that intra-band carrier aggregation can be used to cover the needed channel bandwidth. This option can cover most cases greater than 10 MHz where operator allocations are a multiple of 5 MHz. However, it does not cover situations where you need to cover channel bandwidths not a multiple of 5 MHz. Additionally, the option:

- Requires new intra-band CA configurations to be designed and tested compared to just adding the channel BW.
- Uplink CA emissions are more challenging than use of a single carrier.
- CA is less efficient, offsetting some of the benefit of going to NR.

More study will be required to determine the best option going forward.