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## TCCA White Paper

# What role will 5G play for Critical Communications users?

### Important Note

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## Executive Summary

This white paper addresses key questions raised by the critical communications community regarding the importance and role of 5G technology, including:

- How it compares to existing 4G Long-Term Evolution (LTE) technology?
- What are the initial use cases that 5G will address for Public Protection and Disaster Relief (PPDR) organisations?
- What are the expected benefits to and impacts on user operations?

Furthermore, it forecasts the market timing and availability of mission-critical 5G equipment and services, and the supported migration paths from existing 4G LTE systems<sup>1</sup>. The paper concludes with a set of recommendations for consideration by TCCA and the wider critical communications community.

### Summary of key points raised by this paper:

- The evolution from mission-critical voice-centric narrowband services to mission-critical information-centric mobile broadband services began with 3GPP Release 12, specifying 4G LTE mobile broadband technology. In addition to information-centric services, a major benefit of adopting 4G LTE (and eventually 5G) standards for critical communications use is the access to a much larger ecosystem of device manufacturers, solution providers and application developers, when compared to previous technologies.
- 4G LTE has proven to be a capable mission-critical broadband technology: secure, reliable, available and able to offer high performance mobile communications over a wide coverage area. New use cases are now supported, focused on the use of mission-critical video and data, as well as voice, delivering clear user benefits. 4G LTE is widely available today across early-adopting countries, with many other countries in the planning phase, particularly in Europe. It will continue to be deployed for the foreseeable future.
- Whilst 4G LTE offered a step change in terms of capabilities for critical communication operators and users versus previous technologies, 5G will provide evolutionary enhancements; the latter arguably more visible to PPDR operators than to end users. As mission-critical 4G LTE networks are deployed, and user adoption of these services grows significantly, this will encourage further innovation and enhancements to 5G and future generations of 3GPP standards.
- 5G technology will essentially deliver improvements to users in two distinct ways: (i) Enhancing use cases initially enabled by 4G LTE e.g. in terms of scaling up these services to more users within a given locality, and (ii) Addressing new and emerging use cases made possible with advancements in technology such as ultra-low latency mobile connectivity. Both will provide important user benefits, ranging from enhanced situational awareness - using advanced video recognition capability, artificial intelligence analysis of data collection and new immersive user applications - to greater use of remote and specialist expert analysis of incident ground environments for first responders.
- 5G networks will provide first responders with fast, robust and high-performance communications. It will give control room dispatchers an accurate view of a situation and allow them to allocate resources better. The information between agencies can be shared more easily via cloud-based application platforms. The net result is that the cooperation between first responders can be more effective and efficient, improving the safety of users and saving the lives of others.
- From a technology perspective, 5G will provide a plethora of new capabilities, most notably enhancing mobile broadband services with ultra-reliable low latency communications and supporting massive machine-type device deployments. Whilst these capabilities will be available across all bands, the benefit of some will be more pronounced at higher frequencies due to correspondingly larger channel bandwidths.
- In 5G networks, the use of a service-based architecture with networking functions built for cloud-native server platforms will allow operators and potentially users to customise network performance to match specific needs at a specific moment in time, allowing both mission-critical and non-mission-critical applications to share the same infrastructure simultaneously – be that public, private or a hybrid mix.

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<sup>1</sup> Interworking considerations between narrowband and broadband systems are outside the scope of this paper.

- 5G covers an array of new capabilities and ways of deploying network services. In general, it will be implemented as a complementary add-on to existing LTE networks, termed Non-Standalone (NSA). Over time, these NSA deployments will gradually transition to full 5G Standalone (SA) networks. Therefore, networks are likely to support dual mode 4G-5G equipment, enabling a smooth migration path from 4G LTE to 5G.
- The global ecosystem committed to 5G will undoubtedly drive further standardisation and development of mission-critical services. Industry is also investing in and delivering solutions capable of providing new ways of monitoring network performance and assuring service levels using complementary software technologies such as automation, analytics, and artificial intelligence.
- To build nationwide 5G services, low, mid and high band spectrum will be required. Low band (<1 GHz) provides ideal geographic coverage in rural areas, mid band (1-6 GHz) is suitable for urban and suburban coverage providing a balance between capacity and coverage. The high band (>6 GHz) is ideally suited for significantly boosting capacity in dense urban areas, including in-building coverage.
- Since 2020, commercial 5G operator services have been available in many countries, however these have been mainly deployed in mid and high spectrum bands; notable exceptions include Switzerland which has rolled out relatively quickly 5G-New Radio (NR) in low bands through software updates only. Given that, it may take several years before nationwide 5G NR coverage is widely available, with 4G LTE more than adequate to address most use cases.
- 5G technology offers highest throughput and lowest latency in the higher bands, where operators and/or agencies typically have 100+ MHz of channel bandwidth in urban and suburban areas, in comparison to low bands used for wide area coverage. Note, combining low and higher bands can substantially increase the coverage of capacity gains from higher bands – typically deployed within suburban areas.
- To meet PPDR user needs with regard to the availability of nationwide mission-critical broadband services, a range of coverage solutions will be necessary using 4G LTE, 5G or a combination of both. These solutions will typically involve “fixed” wide area macro networks - possibly relying on the networks of public operators - as well as rapidly deployable networks, complemented by User Equipment (UE) with Device-to-Device (D2D) communication capability such as use of the Sidelink feature.
- Applications such as video surveillance and mass rollout of sensors across government and critical infrastructure will have increasing importance for critical communications and are likely to have a profound effect on the provision of future PPDR services. Nevertheless, voice will continue to play an important role in mission-critical communications, hence the driving force behind the porting efforts in 3GPP of mission-critical (MC) services (MCX) from 4G LTE to 5G NR. This together with other factors mentioned throughout this paper forecasts that PPDR 5G SA systems, with a comprehensive suite of mission-critical functionality, are likely to surface circa 2025.
- Whilst this paper describes the capabilities and general timing of 5G technology to operators and agencies planning for mission-critical services, the exact implementation and availability of those services will always depend on country-specific conditions.
- Looking beyond, international collaboration on service deployment experiences and sharing of best practice is highly recommended, and TCCA is the ideal organisation in which to discuss this.

# Introduction

## Brief comparison of 4G LTE and 5G technology

Before we begin, it is important to define what we mean by '4G LTE' and '5G'. In simple terms, and throughout this white paper, we will define 4G LTE and 5G in relation to the functionality and capability provided by specific releases of the 3GPP standards. More specifically:

- The set of requirements that need to be fulfilled by a 4G LTE system is defined by the IMT-Advanced specifications. 3GPP implements this in Release 8 through Release 14. It is characterised by the introduction of LTE radio access technology (RAT) and packet-centric network architecture.
- The set of requirements that need to be fulfilled by a 5G system is defined by the IMT-2020 specifications. 3GPP implements this in Release 15 through Release 18 (18 being the latest release in current development at the time of publication of this white paper). It is characterised by the introduction of NR RAT – as well as continued support for LTE RAT - and a 5G Core (5GC).

Whilst 4G LTE offers a step change in terms of capabilities for critical communication operators and users versus previous technologies - and provides considerable benefits already to mission-critical users - 5G will provide evolutionary enhancements in terms of performance, greater breadth of use cases and quality of service network controls. Although not discussed in detail, it's worthwhile to understand the key objectives underpinning development of 5G standards, i.e.

- Enhanced Mobile Broadband (eMBB), providing substantially improved throughput performance and capacity.
- Massive Machine-type Communications (mMTC), connecting sensors and physical assets, enriching device ecosystems, enabling additional use cases and improving situational awareness.
- Ultra-Reliable Low Latency Communications (uRLLC), enabling critical machine-type communications (cMTC).

However, it should be observed that Machine-type Communications are already specified in 4G LTE, i.e. NB-IoT and LTE-M are kept. Furthermore, in the initial 5G releases, the IoT functions make use of the LTE IoT radio interface, adding support in 5G SA mode - details discussed later in this section.

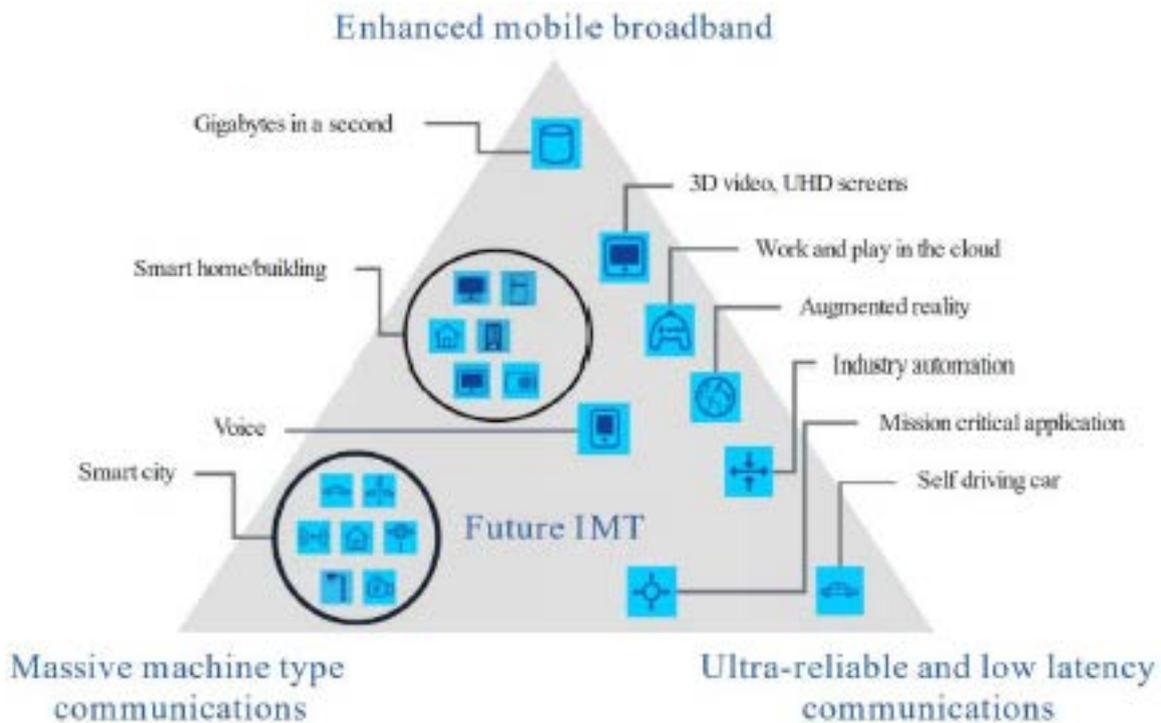


Figure 1 Framework and overall objectives of 5G<sup>2</sup>

<sup>2</sup>Re-printed from Recommendation ITU-R M.2083-0, 'IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond' by ITU-R, 2015, page 12, Figure 2.

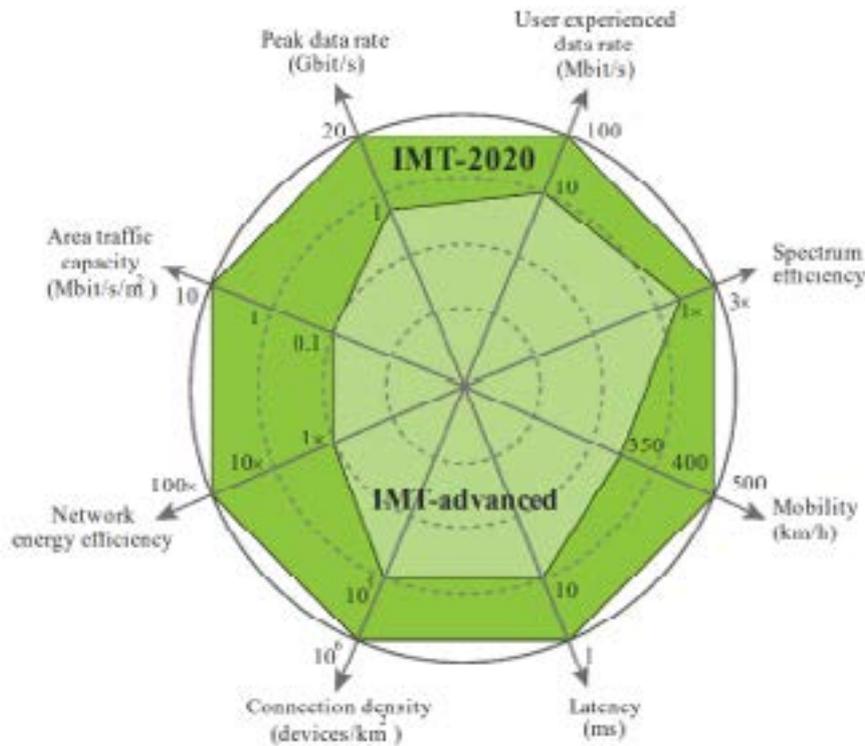


Figure 2 Comparison of key capabilities between 4G LTE ('IMT-Advanced') and 5G NR ('IMT-2020')<sup>3</sup>

Furthermore, the technological aspects that have made this possible include:

1. Support for new spectrum, mainly mid and higher bands delivering Gbps+ data speeds.
2. Extensive use of massive MIMO - up to 64 antenna arrangements.
3. New RF interface techniques combined with edge computing - lowering latency to milliseconds.
4. Enhancements to signalling protocols and antenna diversity – targeting 99.9999% reliability across the radio interface.
5. Adoption of service-based architectures enabling deployment on cloud native platforms - where the cloud environment provides highly scalable and dynamically configurable networks.

The throughput performance of a 5G network very much depends on the spectrum utilised as well as deployment options such as edge computing, minimising transport latency and jitter. Figure 2 shows typical coverage as well as latency targets depending on the frequency bandwidth. By combining multiple carriers, using Dual Connectivity or Carrier Aggregation (CA) features, a combination of good downlink/uplink coverage and high throughput can also be achieved. Note CA involving low and higher bands can substantially increase the coverage of capacity gains from higher bands – typically deployed within suburban areas.

In general, 5G technology is essentially an evolution of 4G LTE. It will be deployed in many different architectural models, which are expected to change over time as the market adapts – see Figure 4 for the two main variants. Critically, however, an evolution path is described within the 5G standard starting from (i) LTE anchored services re-using the existing Evolved Packet Core (EPC) - in what is referred to as NSA architecture – to (ii) a full-blown 5G network with 5G NR as the primary radio access technology and using a service-based 5G Core (5GC) – the latter being referred to as SA architecture.

Given the widespread deployment of 4G LTE networks and services, particularly in the low (coverage) and mid (coverage/capacity) spectrum bands, these networks will evolve from NSA to SA over the long term. Consequently, 4G LTE and 5G (NR) RATs will be tightly integrated, operating in unison and adapting to the varying needs of users and their use cases.

<sup>3</sup> Re-printed from Recommendation ITU-R M.2083-0, 'IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond' by ITU-R, 2015, page 14, Figure 3.

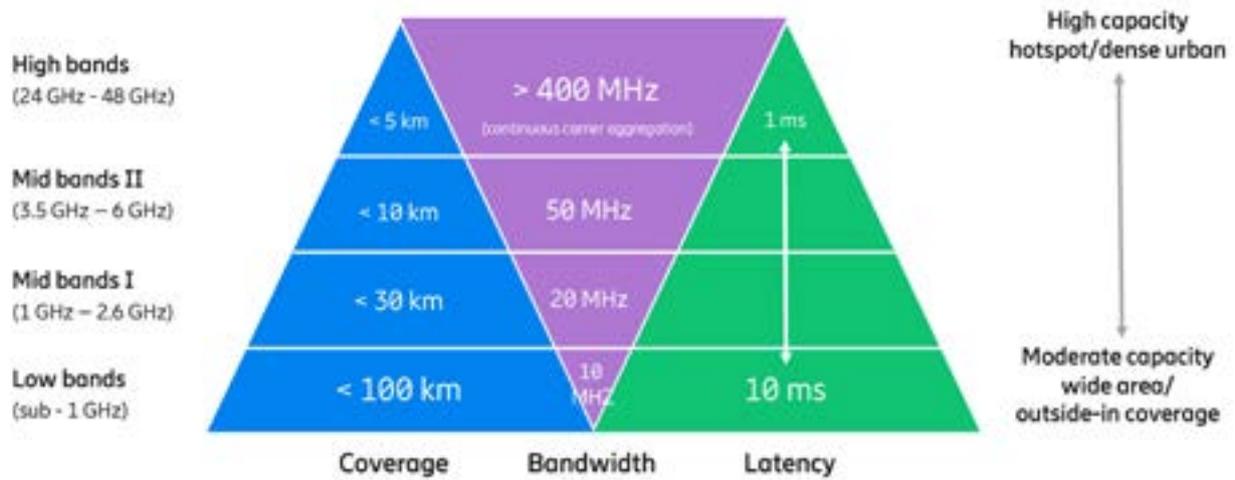


Figure 3 Coverage and latency depending on frequency band<sup>4</sup>

Security has been one of the main considerations in 3GPP standards development, ensuring that the resulting technology is trustworthy. Each generation of 3GPP standards have incorporated security improvements - underpinned by advancements in hardware and software - and against the backdrop of an ever-evolving threat landscape. Hence the security of 5G is a further enhancement over 4G LTE.

5G now permits a single network to offer services and performance similar to a 4G LTE network, whilst at the same time providing a foundation for continuing to offer new services that target very different use cases with often contradictory demands in terms of latency, throughput, battery efficiency and device complexity. This is the embodiment of the 'Network Slicing' concept.

### 5G capabilities most relevant to critical communications

3GPP Releases 15 and 16 have specified functionality and interfaces required to offer 5G networks supporting enhanced Mobile Broadband (eMBB) and Voice-over-New-Radio (VoNR) services. They also laid the foundation for more advanced critical communications services such as massive IoT, critical IoT and MCX over NR.

Release 17 (expected June 2022) is targeting the initial functionality to provide MCX over a 5G SA network. MC functionality comparable to LTE is expected to be finalised in Release 17 for unicast services and Release 18 for multicast/broadcast services; the latter expected to be completed in 1H 2023.

It may be recalled that MCX over 4G LTE have already been specified by 3GPP, thus allowing the delivery of these services over an LTE network.

Although 5G (3GPP Releases 15-18) contains a myriad of new functional capabilities that could be considered relevant to critical communication users, a summary of the ones with greatest impact are as follows:

- **MC Services over 5G:** Principally the porting of all MCX services to 5G NR.
- **5G Multicast & Broadcast Services (5MBS):** Enabling more efficient and effective usage of spectral resources for group-based communications – consisting of mission-critical voice, data and video services – and support for high concentrations of Public Safety users operating in large groups within a small incident area.
- **Device-to-Device Communications using Sidelink:** Enabling the capability for Proximity Services (5G ProSe) and Vehicle-to-X (V2X) services, addressing device-to-device (D2D) short-range communication use cases in environments with limited or non-existent network coverage. The protocol stack and QoS model has evolved from the LTE equivalent, catering for robust MCX in D2D operation. Also, UE-to-UE relaying has been added to increase range of the service.

<sup>4</sup>Adapted from Broadband Library, 2019 (<https://broadbandlibrary.com/5g-low-latency-requirements/>).

### Non-Standalone Architecture (NSA)

NSA was designed to launch 5G services, enabling the use of new 5G spectrum - quickly increasing capacity and throughput - and supporting early adopters of 5G-enabled devices. It can support advanced video streaming, such as AR/VR/XR type of applications, as well as critical IoT use cases. It leverages existing LTE networks, providing mobility management and control signaling, as well as utilizing an enhanced Evolved Packet Core that supports both LTE and 5G NR radio access technologies (RAT).

### Standalone Architecture (SA)

SA is the target architecture for 5G networks, enabling simplified RAN and device operations. It uses a cloud-native 5G Core (5GC) and supports advanced network-slicing functions, facilitating a wider range of use cases involving a plethora of new device types, and requiring higher performance levels including ultra-low latency and/or higher throughputs. This option will also enable the pervasive deployment of 5G NR in low spectrum bands with the same coverage footprint as 4G LTE.

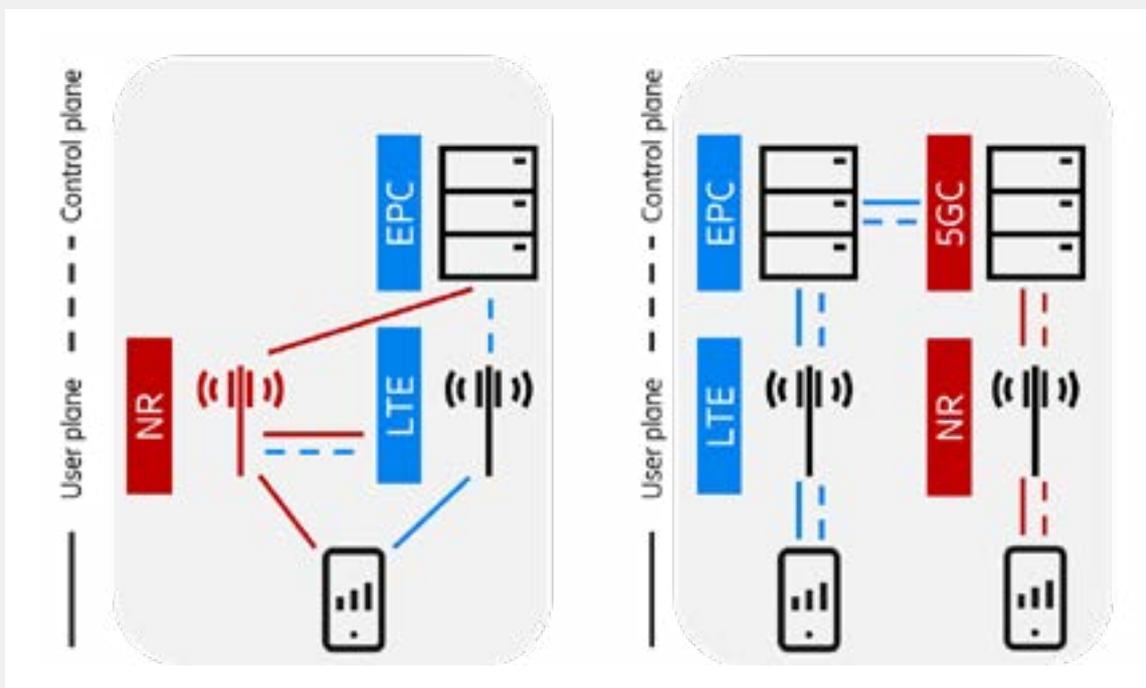


Figure 4 Overview of 4G-5G architectures evolving over time from NSA to SA

- **Network Slicing:** Providing the ability to slice a single physical network into many virtual ‘private’ networks with widely differing network service characteristics. Example implementations include network slices allocated within a dedicated core to different PPDR organisations, or alternatively slices allocated and optimised to specific types of end-to-end applications, such as HD video, drone deployments, IoT sensors, etc.
- **Enhanced Network Security:** Further mechanisms to protect the integrity, confidentiality and availability of the network services and user data, including support for Network Slicing.
- **Isolated Operation for Public Safety (IOPS):** Originally introduced in 3GPP Release 13, enhanced and refined in terms of its security and operational deployment capabilities. IOPS over 5G systems is being defined in Release 17.
- **Advanced Congestion Management:** Improvements to support differentiation of mission-critical users and services during times of peak congestion – such as ‘Access Identity’ and ‘Prioritised Random Access CHannel’ (RACH).

<sup>5</sup> Adapted from “5G-Implementation-Guideline-v2.0-July-2019”, GSMA, 2019

- **Enhancements for Railway Communications:** Driven by the Future Rail Mobile Communications System (FRMCS) initiative, it will enable interworking and future migration of existing rail mobile communications from GSM-R and TETRA, and the provision of new broadband-enabled services.
- **5G Non-Terrestrial Networks (NTN):** Expanding coverage solutions to places with no terrestrial coverage and involving use of satellites as well as networks, or segments of networks, using an airborne or spaceborne vehicle for transmission, such as High-Altitude Platforms (HAPs) and Unmanned Aerial Systems (UAS).

## What role will 5G play for Critical Communications users?

The evolution from mission-critical voice-centric narrowband technologies to mission-critical information-centric mobile broadband services started with functionality introduced in 3GPP Release 12 ('4G LTE'). The use cases addressed by 4G LTE have initially been focused on the use of mission-critical data and video, and received favourable feedback in addressing the initial needs of critical communication users.

With the introduction of 5G, the boundary of mobile broadband networking will be pushed to new levels, with the obvious potential to increase user operational efficiencies further. New 5G capabilities include not only a further development of mission-critical services but also new ways of performance monitoring and service assurance, as well as new 'hybrid' network deployment models that optimise users' experience and adapt to available spectrum, regulation and agencies operational requirements. In summary, these capabilities will deliver improvements in two distinct ways:

- Enhancing use cases currently enabled by 4G LTE
- Create new and emerging use cases, previously not viable with earlier generations

## Use cases enabled by 4G LTE and further enhanced with 5G

With mission-critical 4G LTE, many use cases can already be addressed and deployed (or are being deployed). Common examples are listed here and have been widely discussed amongst TCCA stakeholders and the wider community:

- **Situational Awareness:** Being aware of events related to an incident, in time and space, is a key area where the introduction of broadband will play a pivotal role. Combining enhanced X, Y and Z positioning capability together with 10 to 100 times more connected devices per square kilometre will enable the collection and processing of a large amount of data from a wide variety of mobile-connected sources for real-time pattern matching using big data technologies. In practice, this means for example connecting body-worn cameras and cameras in police cars to command centres to identify what is happening at an incident and to gain an overview of the situation as it unfolds. This will ultimately enhance user operations and planning for future emergency response, collecting data and sharing the required processed information to agencies and users in service, while boosting cooperation and enabling more efficient resource management.
- **Video Surveillance and Analytics:** In addition to cameras hosted in and around emergency services vehicles, cameras can also operate on remotely controlled drones or unmanned vehicles for a better awareness of urgent situations occurring in areas that human beings cannot easily access. Because 5G focuses on massive broadband, it will allow the number of cameras in specific hotspots to be increased where capacity is currently limited by 4G LTE. In addition, higher resolution 4K, 360° cameras or thermal imaging cameras can be used for more precise visual insights.
- **Remote Control and Monitoring:** 5G NR will bring a number of benefits such as ultra-reliable and low-latency communications which can be used by applications and pave the way to assisted driving and unmanned automated vehicles. This capability will also be important for instance in automating a fleet of high-speed drones with real-time centralised coordination that uses sensors, geo-fencing and/or video analytics to avoid collisions.
- **Immersive Applications for First Responders:** The introduction of mobile broadband with low latency combined with edge computing opens new possibilities for deploying command and control capabilities. Usage of augmented reality (AR) and virtual reality (VR) will reduce the amount of desk space used by multiple display screens and allow emergency organisations to equip workers with wearable solutions like smart glasses to access data at the scene of an event.

- **User-Friendly Operations:** Network resource prioritisation, geofencing combined with enhanced parameters for positioning are examples of 5G techniques which can be used by the application layer to automatically connect users in the same area in order to provide more user-friendly operation. This enables more focus on the task at hand and less on the device.
- **eHealth:** The new level of performance provided by 5G networks will be an important enabler for major eHealth and telemedicine applications. Examples include future healthcare and its transformation in terms of preventative, routine and post-operative care. Furthermore, 5G will empower moving ambulances to transmit life-critical data to hospitals, including high-definition video and the outputs of sophisticated medical equipment. These capabilities, combined with real-time video communication with remote doctors, will make it possible for doctors to diagnose and address problems before patients even arrive at the hospital.

## New and emerging 5G use cases

The introduction of mission-critical mobile broadband services combined with low latency will open a new scene of communications and ways of working for Public Safety agencies, with easier and faster access to processed information allowing safer, better, more effective and more efficient decisions. With the arrival of 5G, we can expect to see further influence of technology on the ways of working for Public Safety agencies.

The areas where we will see new use cases likely to emerge are as follows:

- 5G will bring massive Machine Type Communications (mMTC) designed to provide penetration for hundreds of thousands of devices per square kilometre allowing command and control systems to monitor an almost unlimited number of sensors. This data explosion will accelerate and support users' ways of working and decision making when combined with new technologies such as AI and Big Data analytics, providing results in a more comprehensive, consolidated and insightful format.
- 5G will provide the opportunities for first responders to bring coverage with them in a simpler way. IAB (Integrated Access Backhaul) will leverage NR's increased capacity and support of multi-hop backhauling allowing for fast deployment of enhanced coverage – deployable, cell/ system on wheels or tactical networks can be used to expand coverage of the static macro network, such as in rural and mountainous regions.
- 5G infrastructure will deliver the possibility to keep user data local and running advanced applications much closer to end user operations, leveraging edge computing techniques and offloading network traffic. Examples include operating an 8K video stream from a drone, combined with use of advanced analytics which are processed locally. Further, the local breakout of the user plane here has the potential to enhance battery life for devices by allowing them to act as clients.
- 5G will provide first responders with more opportunities to focus on their critical tasks. For instance, at a traffic accident, a swarm of drones from the first unit at the scene is setup, providing a good overview of the situation for the dispatch centre, and helping to identify if more resources should be sent. 5G will enable the coordination of numerous drones thanks to its short latency and enlarged bandwidth. The drone will provide a good view of the traffic situation, giving first responders information they need to prioritise actions.
- 5G will enable enhanced operational flexibility by defining a unified authentication framework supporting Extensible Authentication Protocol (EAP) for enhanced security flexibility allowing advanced mechanisms for shared network implementations to support secure cross-network communications within a country as well as aiding effective co-operation between countries and user organisations.
- 5G will enable the usage of semi-autonomous vehicles for intervention in hostile environments, including UAVs and ground-based vehicles.
- 5G will enable real time augmented reality (AR) content overlay, for example mapping information to firefighters' glasses. AR can also improve how firefighters can see in smoked-filled zero-visibility environment.

## Expected benefits of 5G to user operations

The introduction of 5G will impact network deployment, given the density of cell sites required for high band 5G and operations. The adoption of a new 3GPP-defined service-based architecture with network functions built to exploit the advantages of cloud technology platform will enable end-to-end resource flexibility, robustness, security and stability of operations.

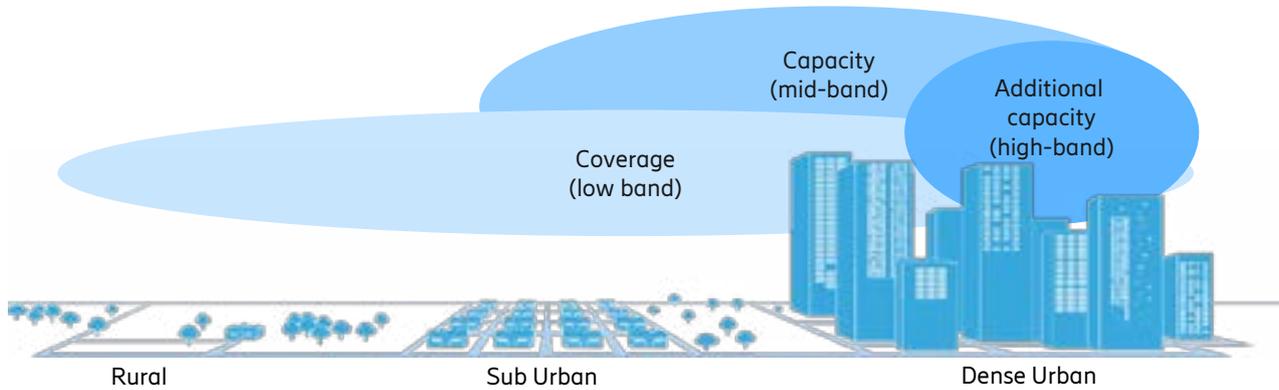


Figure 5: Relative coverage characteristics of different 5G bands

5G infrastructures will provide improvements in network management that drive much higher levels of resilience and robustness, raising the service levels for operating mission-critical applications, and will do this using complementary technologies such as automation, analytics and AI. The service-based architecture will allow operators to customise network performance for users to match specific needs at a specific moment in time, allowing both mission-critical and non-mission-critical applications to share the same infrastructure simultaneously.

5G technologies will provide first responders fast and robust communications. It will give the dispatchers an accurate view of a situation and therefore enable them to better allocate resources. The information between agencies can be more easily shared, complemented by cloud-based applications. The sharing of information between police, fire and rescue services and ambulance service is of vital importance and has had weaknesses in previous approaches. This all means that the cooperation between first responders can be more effective, improve the safety of users and save others' lives.

### What is the likely market timing and availability of 5G Services?

5G is an evolution of the 3GPP-driven standards and, as such, it is possible to gradually transition from 4G LTE to 5G as the ecosystem evolves.

In addition, for critical communications, key enablers need to be in place before 5G can be deployed for field operations, those being:

- Suitable and available spectrum to ensure coverage
- Integration of MC services with the network, assuring the required end-to-end performance versus over-the-top (OTT) implementations
- Fit-for-purpose ecosystem of devices and applications

5G spectrum is categorized into three segments: low band [ $<1$  GHz], mid band [1-6 GHz] and high band (or 'mmWave') [ $>24$  GHz]. The high band represents new spectrum not previously used, while the low-band and mid-band can be either refurbished 2G, 3G or 4G LTE spectrum or new spectrum allocations. To build nationwide 5G services low, mid and high band spectrum will be required. Low band provides ideal geographic coverage in rural areas, mid band is chosen for urban and suburban coverage providing a balance between capacity and coverage, and finally the high band is ideally suited to significantly boost capacity in dense urban areas, including in-building coverage.

Around the world, 5G spectrum has initially been made available to operators to rollout eMBB services, and, more recently, some countries have allocated spectrum for industry-specific use. In general, these early deployments have utilised high and mid bands; notable exceptions to this include early adopters such as Switzerland where both LTE and 5G-NR co-exist in low bands. Commercial services provided by operators have been available since 2020, across many countries. However, it will take several years before operators have enough 5G spectrum available and deployed to provide extensive nationwide coverage. In the meantime, existing 4G LTE spectrum will play an important role for reliable geographic coverage, whilst new 5G NR spectrum will mainly act as a capacity booster.

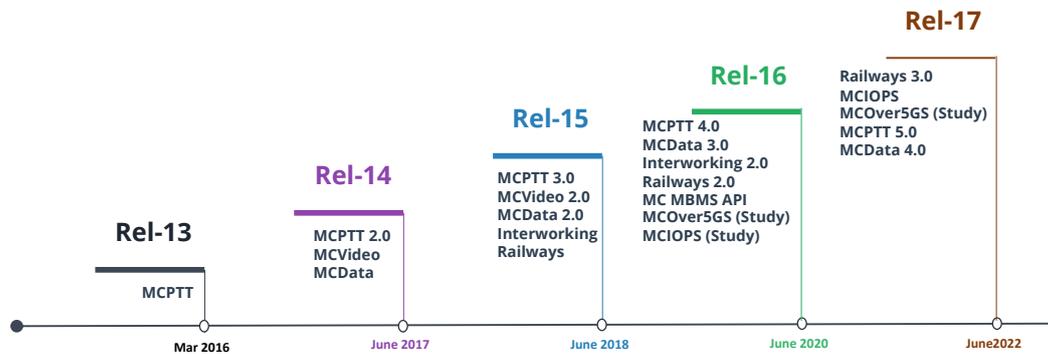


Figure 6: 3GPP Roadmap for Release 13 through 17 with respect to MC functionality

## Summary of 3GPP MC Roadmap Developments related to 5G

- 3GPP Release 15 is the early 5G standard phase focusing on enhanced mobile broadband. This phase usually relies on a 4G foundation including EPC (using non-standalone architecture NSA), with the use of additional spectrum, meaning that subscribers in a 5G coverage area will get higher uplink and downlink throughput. This is the Release typically deployed in networking equipment today for the first 5G commercial launches happening all over the world using the first generation of mass-market commercial 5G terminals.
- 3GPP Release 16: Work for migration and interconnect between MCPTT systems was started and continued in Release 17.
- 3GPP Release 17: This release introduces the key network enablers and initial features for critical communications services.

Similar to 4G LTE adoption, the standards development in 3GPP, device availability and deployment processes of 5G are going to be incremental. Figure 6 shows highlights from the current 3GPP Roadmap. Beware though: once standard Releases are defined, it then takes typically an additional one to two years before these features are commercially available (through network equipment, devices and applications).

How the different mission-critical services must be integrated with the network, and which network enablers to involve, has been extensively specified in 3GPP for 4G LTE networks, and a similar exercise is required for 5G networks in order to ensure the performance levels required for critical communication users.

Several of the network enablers have been specified in Releases 15 and 16, such as the QoS-framework and architecture, however some enablers that may be critical for some use cases, like broadcast and device-to-device communications, are still in development and are currently targeted for Releases 17 and 18. In order to provide the equivalent set of mission-critical services for 5G, completion of these network enablers for 5G is required. The scheduled date for Release 18 is not currently available but is expected to be completed in 1H 2023.

The 5G ecosystem is rapidly evolving, there are already some early 5G devices available and applications relying on 5G performance, such as sub-5 millisecond latency. Because of that, it is likely that devices for critical communications will not be available for another year or two. And while there are applications designed for 5G-networks that would benefit critical communications users, they are not yet mature enough for operational use.

## Implementation timeframe for 5G SA services

An operator planning to deliver 5G services to PPDR users will need 5G technology as described in this paper. The timeframes mentioned herein relate to when the technology will be available to an operator.

It is expected that a nationwide 5G SA network, supporting a comprehensive set of critical communication services for PPDR networks, will be possible from 2025. That said, a subset of critical communication functionality that utilises 5G services – use cases taking advantage of low latency and high throughput - will likely be in use through proof-of-concept trials earlier than this, circa early 2023, relying on 3GPP Release 17 functionality that includes MCX and network slicing amongst other capabilities.

Of course, the expected timings here are also dependent on the ecosystem development as well as operational needs, however if history is anything to go by then neither of these are likely to be the critical path here. Critical communication users have just begun to adapt their operations to using these new technologies, and it is likely that we are several years away from identifying a comprehensive set of use cases that only 5G can address.

## Migration path to 5G

Starting with a critical communications 4G LTE network, the migration path to 5G will be a smooth transition that keeps pace with the ecosystem maturing and appropriate spectrum coming on stream. This process is already underway at the present time in several NSA deployments, which enables both 4G LTE and 5G services. For clarity, in this case, control signalling is conveyed over 4G LTE whilst the user plane data is transmitted over 4G LTE or 5G for different services. This enables critical communication services to use 4G LTE user plane whilst also allowing use of 5G user plane for data offloading in order to free up resources.

By 2022, 5G coverage will be more widely available but still behind that of 4G LTE. Critical communication services using MC Data and MC Video will be in use over 4G and 5G, however in general MCPTT services will largely remain operating over 4G LTE given availability of wide area coverage, broadcast services (where necessary) and the ecosystem of compatible devices. Circa 2025, when critical communication services and network enablers have been standardised over 5G NR, and equipment commercially available and deployed, it will be possible to implement standalone 5G networks suitable for PPDR networks.

Further, more detailed, considerations for the migration path include:

- 5G core network evolution from 4G:** LTE EPC addresses the need for enhanced mobile broadband. New 5G radio access is added by introducing 5G radio via dual connectivity mode with LTE as an anchor. Early adopters can then offer 5G services mainly to address capacity demand in hotspots. This first phase protects the investment of public safety operators who invested in a mission-critical LTE network, while allowing them to offer first responders some 5G benefits. A cloud-native core is fundamental for 5G services, that is a core software that can run in a dynamic and scalable cloud environment. These services include the ability to independently scale control and user-plane resources to meet varying application requirements and service demands — as well as gaining the flexibility to place core resources at the edge of the network for improved network latency and performance.

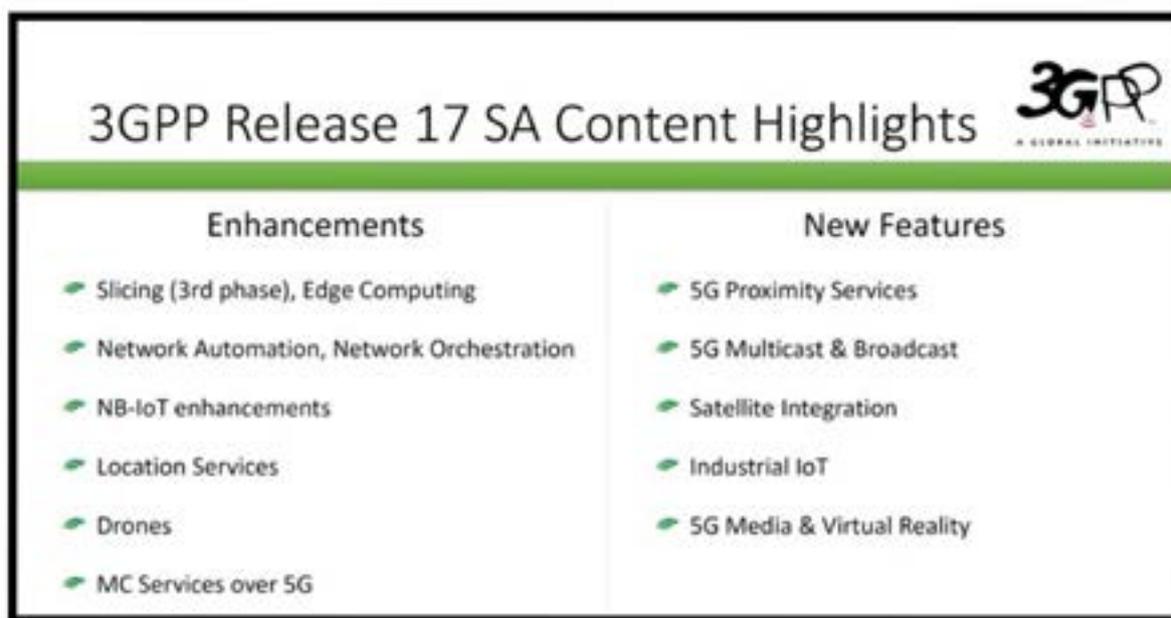


Figure 7: 3GPP Release 17 Content Highlights<sup>6</sup>

<sup>6</sup> Re-printed from '3GPP Progress', 3GPP, Slide 8, Georg Mayer, 2020.

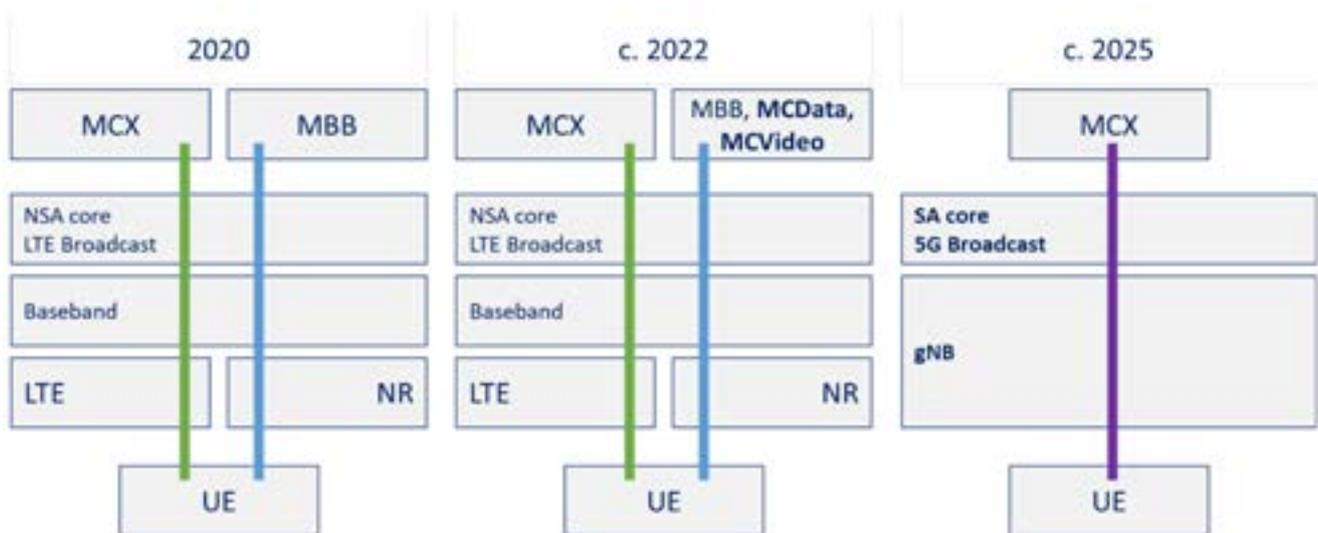


Figure 8: High-level migration path for critical communications from 4G LTE to 5G

- Evolving transport networks for 5G:** Transport networks have played a foundational role in LTE. With the development of the 5G radio network and the 5G core, the transport networks that carry data traffic between them must evolve to meet the increased demands. A specific consideration for public safety is the diverse location of radios required to support new use cases, which need agile transport network services to reach them. These agile transport networks – typically using a mix of wired, microwave and optical technologies – will utilise software-defined networking (SDN)<sup>7</sup> capabilities able to provide the service assurance and optimisation necessary to meet end-to-end SLAs across 5G networks.
- Strengthening network-based security:** 5G networks will facilitate massive adoption of the Internet of life-saving things such as connected defibrillators, connected Early Warning Systems and other sensors and systems used in mission-critical operations. This evolution will likely cause these networks to become greater targets for cyber-attacks. In the 5G era, more than ever, security must be designed and built into the network from day one. The security framework should adapt to address changes in attack vectors and detect these as early as possible for faster responses, using the whole 5G network to do so. The entire security cycle will have to be covered, from prevention to detection, assessment and response.

<sup>7</sup> <https://sdn.ieee.org/>

## Conclusions and recommendations

The main conclusions from this white paper are as follows:

- 4G LTE has proven to be a capable mission-critical broadband technology: secure, reliable, available and able to offer high performance mobile communications over a wide coverage area. New use cases are now supported, focused on the use of mission-critical video and data, as well as voice, delivering clear user benefits. It is widely available today across early-adopting countries, with many other countries in the planning phase particularly in Europe. It will continue to be deployed for the foreseeable future.
- Whilst 4G LTE offered a step change in terms of capabilities for critical communication operators and users versus previous technologies, 5G will provide evolutionary enhancements in terms of greater performance, security, breadth of use cases and quality of service. As mission-critical 4G LTE networks are deployed, and user adoption of these services grows significantly, this will encourage further innovation and enhancements to 5G and future generations of 3GPP Releases.
- From a technology perspective, 5G will provide a plethora of new capabilities, most notably enhanced mobile broadband services with ultra-reliable low latency communications and support massive machine-type device deployments. Whilst these capabilities will be available across all bands, the benefit of some will be more pronounced at higher frequencies due to correspondingly larger channel bandwidths.
- 5G technology will essentially deliver improvements to users in two distinct ways: (i) Enhancing use cases initially enabled by 4G LTE e.g. in terms of scaling up these services to more users within a given locality, and (ii) Address new and emerging use cases made possible with advancements in technology such as ultra-low latency mobile connectivity. Both will provide important user benefits, ranging from enhanced situational awareness - through the use of advanced video recognition capability, artificial intelligence analysis of data collection and new immersive user applications - to greater use of remote and specialist expert analysis of incident ground environments and first responders.
- 5G networks will provide first responders with fast, robust and high-performance communications. They will enable the dispatchers an accurate view of a situation and allow them to better allocate resources. The information between agencies can be shared more easily via cloud-based application platforms. The net result is that the cooperation between first responders can be more effective and efficient, improving the safety of users and saving the lives of others.
- In 5G networks, the use of a service-based architecture with networking functions built for cloud-native server platforms will allow operators and potentially users to customise network performance to match specific needs at a specific moment in time, allowing both mission-critical and non-mission-critical applications to share the same infrastructure simultaneously – be that public, private or a hybrid mix.
- 5G covers an array of new capabilities and ways of deploying network services. In general, it will be implemented as a complementary add-on to existing LTE networks, termed Non-Standalone (NSA). Over time, these NSA deployments will gradually transition to full 5G Standalone (SA) networks. Therefore, networks are likely to support dual mode 4G-5G equipment, enabling a smooth migration path from 4G LTE to 5G.
- The global ecosystem committed to 5G will not only drive further standardisation and development of mission-critical services but industry is also investing and delivering solutions providing new ways of monitoring network performance and assuring service levels using complementary software technologies such as automation, analytics, and artificial intelligence.
- To build nationwide 5G services low, mid and high band spectrum will be required. Low band (<1 GHz) provides ideal geographic coverage in rural areas, mid band (1-6 GHz) is suitable for urban and suburban coverage providing a balance between capacity and coverage, and finally the high band (>6 GHz) is ideally suited to significantly boost capacity in dense urban areas, including in-building coverage.
- Since 2020, commercial 5G operator services have been available in many countries, however these have been mainly deployed in the mid and high bands; notable exceptions include Switzerland which has rolled out relatively quickly 5G-NR in low bands through software updates only. Given that, it may take several years before nationwide 5G NR coverage is widely available, with LTE more than adequate to address most use cases.
- 5G technology offers highest throughput and lowest latency in the higher bands, where operators and/or agencies typically have 100+ MHz of channel bandwidth in urban and suburban areas in comparison to low bands used for wide area coverage. Note, combining low and higher bands can substantially increase the coverage of capacity gains from higher bands – typically deployed within suburban areas.

- To meet PPDR user needs with regard to the availability of nationwide mission-critical broadband services, a range of coverage solutions will be necessary using 4G LTE, 5G or a combination of both. These solutions will typically involve “fixed” wide area macro networks - possibly relying on the networks of public operators - as well as rapidly deployable networks, complemented by User Equipment (UE) with Device-to-Device (D2D) communication capability using the Sidelink feature.
- Applications such as video surveillance and mass rollout of sensors across government and critical infrastructure will have an increasingly greater importance for critical communications and are likely to have a profound effect on the provision of future PPDR services. Nevertheless, voice will continue to play an important role in mission-critical communications, hence the driving force behind the porting efforts in 3GPP of (MCX from 4G LTE to 5G New Radio (NR). This together with other factors mentioned throughout this paper forecasts that PPDR 5G SA systems, with a comprehensive suite of mission-critical functionality, are likely to surface circa 2025.
- Whilst this paper describes the capabilities and general timing of 5G technology to operators and agencies planning for mission-critical services, the exact implementation and availability of those services will always depend on country-specific conditions.

#### **Recommendations for further action:**

Whilst a significant amount of progress has been made by the critical communications community over the past decade - establishing mission-critical broadband spectrum, standards, technology and a competitive marketplace - there is still more to achieve. Listed here are recommendations that should be considered for further action:

- Support, communicate and endorse the continued rollout of mission-critical 4G LTE networks, providing new and vital operational capabilities as well as fuelling ongoing innovation in use cases, applications and communications technologies.
- Continue to target and make use of all available dedicated spectrum, working together as a community to create self-sustaining and competitive ecosystems.
- Expand collaboration efforts with commercial mobile network operators (MNOs) to deliver and enhance mission-critical mobile broadband services for critical communication users, leveraging 3GPP defined capabilities and utilising shared and/or dedicated spectrum.
- Continue to prioritise, resource and support further 3GPP-driven standards definition and testing for the features identified in this paper, and of particular benefit to the critical communications community.
- Identify any new 5G functionality that could be of benefit to those PPDR operators looking to deploy networking solutions involving multiple MNO infrastructures, such as improvements in handover performance, security and interworking in general.
- Continue to build and develop end-to-end ecosystems, including widespread chipset support and device form factors required for PPDR applications, from the traditional to radically new.
- Develop a road map of mission-critical broadband-enabled use cases, working across eco-system partners, to ensure that end-to-end 5G capabilities can be delivered at the earliest opportunity.

Looking forward, international collaboration on service deployment experiences and sharing of best practice is highly recommended, and TCCA is the ideal organisation in which to discuss this.

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## Acronyms and Abbreviations

2G	Second Generation 3GPP Technology Standard
3G	Third Generation 3GPP Technology Standard
3GPP	Third Generation Partnership Project
4G	Fourth Generation 3GPP Technology Standard
4K	Ultra-High Definition Video
5G	Fifth Generation 3GPP Technology Standard
5GC	5G Core (Network)
5MBS	5G Multimedia Broadcast Services
AI	Artificial Intelligence
API	Application Programming Interface
AR	Augmented Reality
CA	Carrier Aggregation
cMTC	Critical Machine-Type Communications
D2D	Device-to-Device Communications
EAS	Extensible Authentication Protocol
eMBB	Enhanced Mobile Broadband
EPC	Evolved Packet Core
FRMCS	Future Rail Mobile Communications System
GSMA	Global System for Mobile Communications Association
GSM-R	GSM for Rail
HAP	High Altitude Platform
IAB	Integrated Access and Backhaul
IMT	International Mobile Telecommunications
IMT-2020	International Mobile Telecommunications standard for 5G Networks
IMT-Advanced	International Mobile Telecommunications standard for 4G LTE Networks
IoT	Internet of Things
IP	Internet Protocol

ITU-R	International Telecommunications Union – Radio Communications
LTE	Long-Term Evolution
MBMS	Multimedia Broadcast and Multicast Services
MC	Mission-Critical
MCData	Mission-Critical Data Services
MCIOPS	Mission-Critical Isolated Operations for Public Safety
MCOver5GS	Mission-Critical over 5G System
MCPTT	Mission-Critical Push-to-Talk
MCVideo	Mission-Critical Video Services
MCX	Mission-Critical Services
MIMO	Multiple-In Multiple-Out
mMTC	Massive Machine-Type Communications
NB-IoT	Narrowband Internet-of-Things Services
NR	New Radio
NSA	Non-Standalone
NTN	Non-Terrestrial Network
OTT	Over-The-Top
PON	Passive Optical Network
ProSe	Proximity Services
QoS	Quality of Service
RACH	Random Access Channel
RAT	Radio Access Technology
SA	Standalone
SDN	Software Defined Network
SLA	Service Level Agreement
TCCA	The Critical Communications Association
TETRA	Terrestrial Trunked Radio
UAS	Unmanned Aerial Systems
UAV	Unmanned Aerial Vehicle
UE	User Equipment
UHD	Ultra-High Definition (aka 4K) Video
uRLLC	Ultra-Low Latency Communications
VoNR	Voice-over-New Radio
VR	Virtual Reality
XR	Extended Reality

## References

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