

Received: 12 June 2025

Document 5D/699-E
12 June 2025
English only

GENERAL ASPECTS

IAFI¹

PROPOSAL TO REVISE AND UPDATE REPORT ITU-R M.2291-2 – THE USE OF INTERNATIONAL MOBILE TELECOMMUNICATIONS (IMT) FOR BROADBAND PUBLIC PROTECTION AND DISASTER RELIEF (PPDR) APPLICATIONS

1 Background

Report ITU-R M.2291-2 addresses the current and possible future use of International Mobile Telecommunications (IMT) including the use of Long-Term Evolution (LTE)¹ and IMT-2020 in support of broadband public protection and disaster relief (PPDR) communications as outlined in relevant ITU-R Resolutions, Recommendations and Reports. The Report further provides examples for deploying IMT for PPDR radiocommunications, and case studies and scenarios of IMT systems to support broadband PPDR applications, such as data and video. This Report describes the features and benefits that make IMT particularly suitable for PPDR applications as compared to traditional PPDR systems. Annex 1 of the Report provides PPDR requirements drawing from the Report ITU-R M.2377 and describes the capabilities of systems based on IMT technologies to meet these requirements. In addition, case studies have been provided in various Annexes that offer real-world examples of ways in which administrations are leveraging IMT to support broadband PPDR applications. The current version of the Report was finalized in 2021, when IMT-2020 was in the initial phase of development. It is therefore critical to review and update the content of this report to accurately reflect current status and latest developments on this critical subject.

2 Justification for revision and updating Report ITU-R M.2291-2

Given the rapid advancements in MCPTT technology, the growing demand for enhanced public safety communications, and the ongoing standardization efforts by the 3GPP, it is imperative that the Report ITU-R M.2291-2 be revised and updated. This update will ensure that the report remains relevant, providing the latest guidelines and recommendations for the effective deployment and use of broadband public safety communication systems. The areas in which M.2291 needs to be updated include:

¹ [IAFI](#) – ITU-APT Foundation of India is a sector member of ITU-R.

2.1 Significant technological advancements since 2021

Since the publication of ITU-R M.2291-2 in 2021, there have been substantial advancements in the area of Mission Critical Push-to-Talk (MCPTT) services. The 3GPP has continued to evolve MCPTT standards through multiple releases, including Releases 14, 15, 16, and 17. These updates have introduced new features and enhancements that significantly improve the functionality and reliability of MCPTT services for critical communications.

2.2 Growing demand for enhanced public safety communications

The need for robust, secure, and interoperable public safety communication systems has increased due to recent catastrophic events and the growing reliance on real-time data and multimedia capabilities. The shift towards broadband mobile technologies, such as IMT-2020, has accelerated, necessitating updated guidelines and recommendations to ensure these advanced communication capabilities are fully leveraged to enhance public protection and disaster relief efforts.

2.3 Standardization and conformance testing

The 3GPP has made significant progress in standardizing MCPTT services, leading to the development of conformance testing frameworks. This has enabled test laboratories to issue conformance marks, ensuring that MCPTT applications meet the required standards for public safety use. The availability of standardized and tested MCPTT solutions has increased their adoption and reliability.

2.4 Integration with emerging technologies

The integration of MCPTT with emerging technologies such as the Internet of Life-Saving Things (IoLST), including wearables, smartphones, and drones, has expanded the scope of public safety communications. These technologies enable rapid data collection, analysis, and transmission, enhancing the effectiveness of emergency response operations.

2.5 Spectrum outlook and implementation strategies

The ITU-R M.2291-2 report needs to incorporate the latest developments in spectrum management for public safety communications. The harmonization of radio frequency spectrum for broadband Public Protection and Disaster Relief (PPDR) applications is crucial for ensuring seamless interoperability and most efficient use of valuable spectrum resources in times of crisis and for day-to-day public safety operations.

2.6 Global adoption and commercial rollouts

There has been a significant increase in the global adoption of 3GPP-based MCX services, with commercial rollouts of nationwide broadband critical communication deployments in several leading markets. This trend highlights the need for updated guidelines to support the continued growth and integration of these services.

2.7 Interoperability and security challenges

Recent developments in MCPTT have focused on addressing interoperability issues across diverse public safety networks and enhancing security through stronger encryption methods. The updated report should reflect these advancements to ensure that public safety agencies can effectively communicate and coordinate during critical situations.

2.8 Real-time video surveillance and monitoring

One of the most significant applications of IMT technologies in law enforcement is the ability to provide real-time video surveillance. With the advent of 5G networks, high-definition video can be

transmitted seamlessly from CCTV cameras, drones, and body-worn cameras to centralized command centers. This technology enables officers to monitor urban and rural environments in real time, providing a comprehensive view of unfolding situations and improving their ability to respond swiftly and appropriately to incidents. The high-speed, low latency data transmission enabled by 5G networks further supports the simultaneous streaming of multiple video feeds, enhancing surveillance capabilities in high-density areas.

Example: In smart cities, extensive networks of 5G-connected surveillance cameras provide continuous streams of data to central monitoring stations. AI-driven systems analyze these streams to detect anomalies such as suspicious movements, unusual vehicle activities or rapid formation of large crowds, alerting law enforcement to potential security threats, enabling proactive and more efficient intervention.

2.9 Body-worn cameras and live streaming

Body-worn cameras (BWCs) are essential tools for ensuring accountability and transparency in law enforcement. The integration of IMT technologies with these cameras allows for live streaming capabilities, enabling officers in the field to transmit real-time video back to command centers. The low latency and high bandwidth of IMT(5G) networks allow officers to maintain an uninterrupted connection, providing valuable situational data that can be used for decision-making, investigations, or as evidence in legal proceedings. This helps in live video streaming from body-worn cameras ensures that officers remain accountable, improves public trust, and provides immediate oversight of operations.

2.10 Smart policing and predictive analytics

The integration of smart policing practices, powered by IMT technologies, allows law enforcement agencies to leverage real-time data and analytics to prevent crime and allocate resources efficiently. With IMT networks, agencies can utilize IoT sensors, GPS data, and crime databases to predict criminal activity and identify areas at risk. These tools help law enforcement anticipate problems before they escalate and deploy resources in a more targeted and effective manner.

Example: Using predictive analytics, police departments can forecast crime hotspots based on historical data and current trends, allowing them to allocate personnel in anticipation of potential criminal activity.

2.11 Mobile and field communication systems

Effective communication is essential for law enforcement officers working in the field, and IMT technologies provide the necessary tools to stay connected, even in challenging environments. Whether accessing criminal databases, sharing multimedia files such as photographs or videos, or communicating with colleagues, officers benefit from high-speed mobile communication and reliable data transmission. IMT-2020's low latency ensures that officers can make quick decisions based on real-time information, which is critical in high-pressure situations. IMT-based mobile communication systems enable faster information sharing and more efficient decision-making, improving response times and operational coordination during emergencies.

2.12 Emergency response coordination

When large-scale emergencies, or civil unrest occur, maintaining reliable communication between first responders is crucial. IMT technologies offer a solution by enabling deployable 5G base stations that provide emergency responders with seamless connectivity, even in areas where conventional infrastructure has been damaged. These mobile base stations help ensure that law enforcement and emergency services remain coordinated, allowing for timely and effective responses during crises.

In the aftermath of a disaster, 5G-enabled portable stations can be quickly deployed, providing immediate connectivity to rescue teams, allowing them to share real-time information and coordinate relief efforts.

3 Proposal

The impact of IMT technologies on public safety and law enforcement is profound, with real-time surveillance, predictive policing, and mobile communication transforming how agencies protect citizens and maintain order. These advancements contribute to a more efficient, responsive, and transparent law enforcement framework. As IMT networks continue to evolve at a fast pace, it is therefore essential that WP 5D initiate a preliminary review and comprehensive revision of the Report ITU-R M.2291-2. The proposed review and updating of Report ITU-R M.2291-2 will ensure that the report accurately reflects the latest technological developments of IMT and their implications for public protection and disaster relief.

An initial draft work plan for updating of Report ITU-R M.2291-2 (Attachment 1) and a draft working document towards a preliminary draft revision of Report ITU-R M.2291-2 (Attachment 2) are attached.

Attachments: 2

ATTACHMENT 1

Detailed work plan for revision of Report ITU-R M.2291-2

NOTE – The finalization date in this work plan is of indicative nature as it will depend on the progress of work and the extent of any possible contributions. This work plan may therefore be adjusted at each meeting.

Title	The use of International Mobile Telecommunications (IMT) for broadband Public Protection and Disaster Relief (PPDR) applications
Identifier	Report
WP 5D Lead Group	WG General Aspects
SWG Chair	Mr Jitendra Singh; jitendra@qti.qualcomm.com
DG Chair	TBD
Focus for scope and work	Specific industrial and enterprise applications, their usages, functionalities, technical & operational aspects and capabilities supported by IMT
Related documents	Question ITU-R 262/5 – Usage of the terrestrial component of IMT systems for specific applications. (Copy reproduced in Attachment 2). Report ITU-R M.2527 – Applications of the terrestrial component of International Mobile Telecommunications for specific societal, industrial and other usages Recommendation ITU-R M.2083 – Framework and overall objectives of the future development of IMT for 2020 and beyond.
Milestones	<p><u>Meeting No. 49 (Japan, 24 June – 3 July 2025)</u></p> <ol style="list-style-type: none">1 Consider input contributions;2 Develop work plan as necessary;3 Develop working document. <p><u>Meeting No. 50 (Geneva, 7-16 October 2025)</u></p> <ol style="list-style-type: none">1 Consider input contributions;2 Continue updating the working document and upgrade it to preliminary draft revision of (PDR) Report;3 Send liaison statements.4 Review and revise work plan as necessary. <p><u>Meeting No. 51 (India, 3-12 February 2026)</u></p> <ol style="list-style-type: none">1 Consider input contributions;2 Continue updating the working document and upgrade it to preliminary draft revision of (PDR) Report;3 Send further liaison statements, if necessary;4 Review and revise work plan as necessary. <p><u>Meeting No. 52 (TBD)</u></p> <ol style="list-style-type: none">1 Consider input contributions;2 Further update the working document and upgrade it to preliminary draft revision of (PDR) Report;3 Review and revise work plan as necessary. <p><u>Meeting No. 53 (TBD)</u></p> <ol style="list-style-type: none">1 Consider the received contributions;2 Finalize the working document and elevate it to draft revision of (DR) Report and send to SG 5.

ATTACHMENT 2

WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT REVISION OF REPORT ITU-R M.2291-2 – THE USE OF INTERNATIONAL MOBILE TELECOMMUNICATIONS (IMT) FOR BROADBAND PUBLIC PROTECTION AND DISASTER RELIEF (PPDR) APPLICATIONS

(Question ITU-R 229-5/5)

(2013-2016-2021)

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1 Introduction

This Report addresses the current and possible future use of International Mobile Telecommunications (IMT) including the use of Long Term Evolution (LTE)² and IMT-2020³ in support of broadband public protection and disaster relief (PPDR) communications as outlined in relevant ITU-R Resolutions, Recommendations and Reports. The Report further provides examples for deploying IMT for PPDR radiocommunications, and case studies and scenarios of IMT systems to support broadband PPDR applications, such as data and video.

This Report describes the features and benefits that make IMT particularly suitable for PPDR applications as compared to traditional PPDR systems. These features and benefits include:

- enhanced interoperability;
- better performance;
- simplified IP-based architecture;
- low latency;
- enhanced security;
- enhanced network sharing;
- enhanced quality of service and prioritization;
- bandwidth flexibility;
- greater economies of scale;
- simultaneous use of multiple applications, and
- enhanced spectrum efficiency.

Annex 1 of the Report provides PPDR requirements from Report ITU-R M.2377 and describes the capabilities of systems based on IMT technologies to meet these requirements. In addition, case

² LTE and LTE-Advanced also known as Evolved Universal Terrestrial Radio Access Network (E-UTRAN) is an IMT terrestrial radio interface in Recommendation ITU-R M.1457, §§ 5.1 and 5.3, and Recommendation [ITU-R M.2012](#), Annex 1. Throughout this Report (including the Annexes), the term ‘LTE’ has been used to refer to both LTE and LTE-Advanced.

³ “IMT-2020” refers to the radio interfaces specified in Recommendation [ITU-R M.2150](#).

studies have been provided in Annexes 2 to 6 that offer real-world examples of ways in which administrations are employing IMT to support broadband PPDR applications.

Public protection and disaster relief (PPDR) is a combination of the terms ‘public protection radiocommunication’ and ‘disaster relief radiocommunication’, which are defined in Resolution **646 (Rev.WRC-19)**. The first term ‘PP’ is defined as “radiocommunications used by agencies and organizations responsible for the maintenance of law and order, protection of life and property and emergency situations”. The second term ‘DR’ is defined as “radiocommunications used by agencies and organizations dealing with a serious disruption of the functioning of society, posing a significant widespread threat to human life, health, property or the environment, whether caused by accident, natural phenomena or human activity, and whether developing suddenly or as a result of complex, long-term processes”. A number of studies of PPDR radiocommunications have been carried out within the ITU, based on Resolution **646 (Rev.WRC-19)** as well as in external agencies. References for these studies are provided in § 9.

2 Background

Advances in the global mobile communications landscape have brought the general consumer broadband access and new advanced applications making use of information databases, media content, and general Internet capabilities.

Public safety radiocommunications and other governmental mission critical communications have traditionally relied on narrowband systems. However, public safety organizations are also demanding ubiquitous coverage, mobile video, data-rich applications, and increased reliability of “voice-over-Internet protocol (IP)” (VoIP) for use in the field.

To respond to the increasing data demand on mobile broadband networks, network operators are deploying spectrally efficient advanced radio technologies to increase capacity, and advanced systems that will operate anywhere the first responder happens to be. If broadband PPDR applications use IMT systems, then there may be a benefit from increased economies of scale and more rapid technology evolution.

It is also useful to understand how IMT-based specifications and standards can play a vital role by enabling broadband PPDR applications. PPDR communications are predominantly mission critical because these aid in the protection and safety of life or property on a day-to-day basis as well as in response, rescue, and recovery efforts before, during, and after emergencies and disasters. The ability of PPDR agencies to react quickly, inter-communicate and work together in close coordination with each other, as well as their ability to communicate with resources that are farther away, will heavily influence the outcome of an emergency, whether it be a forest fire, a traffic accident or a terrorist threat. With the ever-increasing scale of responses to emergency situations and increased number of responding agencies and authorities, administrations have increasingly recognized how new PPDR applications based on IMT systems may be able to serve or support broadband PPDR communications. The use of IMT for broadband PPDR applications could open up new ways of working, increase the effectiveness of emergency management and improve interaction within and across PPDR organizations. Section 3 details the existing and planned capabilities of IMT that support broadband PPDR applications. Section 4 introduces some of the planned capabilities of IMT-2020 to support broadband PPDR applications.

PPDR applications could be supported on commercial IMT networks to either complement the dedicated PPDR networks in certain areas where dedicated networks may not be economically viable or directly integrate PPDR applications, so as to reduce the overall cost of deploying a dedicated PPDR network. Section 5 details some approaches for supporting broadband PPDR applications using IMT.

3 Capabilities of IMT that support broadband PPDR applications

IMT supports higher data-rates, reliability, resiliency, and capacity of mobile networks in comparison to legacy communications networks. The term ‘IMT’ is the root name that encompasses all of IMT-2000, IMT-Advanced and IMT-2020 collectively⁴. LTE and LTE-Advanced systems have attractive capabilities of providing a broadband Internet Protocol (IP)-based network supporting voice, data and video. This section describes capabilities and key features of LTE as an example of an IMT system for supporting broadband PPDR applications.

Other IMT radio interfaces described in Recommendation ITU-R M.1457 and Recommendation ITU-R M.2012 may also support some PPDR applications.

3.1 Capabilities of IMT systems

Annex 1 describes IMT capabilities that can be used as a base to develop broadband mission critical applications. It shows the relationship between the requirements in Report ITU-R M.2377 and the capabilities of IMT-Advanced and/or IMT-2020 systems. Section 4 outlines capabilities that are currently supported and those that will be made available in IMT-2020.

It should be noted that the IMT specifications are continually being enhanced through new releases. New capabilities or enhancements to existing capabilities may be under consideration that could enhance the capability and/or performance of IMT when utilized in a PPDR application. Annexes 2 to 6 provide case studies and example scenarios of using IMT to support broadband PPDR applications.

3.2 Advantages of IMT systems for PPDR agencies

The following features and benefits make IMT particularly suitable for PPDR applications as compared to traditional PPDR systems and provide unprecedented capabilities for public safety.

3.2.1 Better performance

The numerous technology advances of IMT bring better overall performance. End users will certainly notice an improved experience, and the technology itself will be more reliable. Multiple-input multiple-output (MIMO) technology, for example, is used with LTE.

MIMO puts several antennas – rather than one – on a single tower and on the devices. With more antennas working for the same communication, performance (coverage and capacity) is significantly improved without the need for additional bandwidth or increased transmitting power. Recently, studies have been initiated on 3D MIMO. This additional ability for the network to detect elevation may also enhance the existing location services in IMT to provide a z-axis element to public safety. This would greatly enhance the ability to locate first responders at an incident scene.

Orthogonal frequency division multiple access (OFDMA) is another technology that is used with IMT. It maximizes the use of available spectrum far better than previous technologies. This is a key attribute because there is a finite amount of spectrum available for use. The improved spectral efficiency lets the system optimize bandwidth data capacity, number of users, and user experience.

For public safety, a category of UE that supports higher output power is also an example of how the end user may experience improved performance.

⁴ Resolution [ITU-R 56-2](#), “Naming for International Mobile Telecommunications”.

What this means for public safety agencies: Improved situational awareness; increased coverage and capacity

Two-way voice (MCPTT, VoLTE), real-time high-definition video, device to device (D2D) and large data file distribution integrated with incident management databases, including Geographic Information Systems (GIS), provide for immediate, dependable communications during incident response, where the responder needs it. With LTE, voluminous amounts of information can be exchanged from anywhere, instantly, in many ways. Collaboration utilizing these tools ensures effective sharing of information in task force operations.

3.2.2 Simplified, IP-based architecture

The all-IP architecture of an LTE network requires fewer elements, which reduces complexity and results in lower capital expenditure (CAPEX) and operational expenditure (OPEX) as well as lower latency. LTE is also extremely scalable, which makes it easy to accommodate a significant number of users. All-IP architecture is also more flexible, making it easy to inter-connect nodes, build pathways between nodes for increased resiliency and availability, and automatically change the logical paths between nodes if needed.

In today's commercial marketplace, operators are reducing network complexity and cost by leveraging a common IP architecture for their fixed and mobile needs. Public safety agencies can benefit from the same efficiencies. Best of breed technologies and solutions from the commercial sector – augmented with public safety specific features, such as ruggedized devices for first responders – will provide reduced cost, reduced complexity, and superior service for the public safety market. The IP architecture that may be deployed will be also capable of extensions for specific operator needs such as SON.

What this means for public safety agencies: Unified communications and enhanced day-to-day operations

Voice, video, and data on one end-to-end IP network results in reduced complexity and lower costs through greater efficiency. LTE supports telemetry and remote diagnostics, which means information, may be sent automatically to mobile devices and analysed remotely. As a result, first responder personnel have instant remote access virtually anywhere to databases to access vehicle records or suspect's files, for example, or to submit reports electronically. Public safety personnel can be more effective when paperwork and waiting times are reduced, anywhere they happen to be.

3.2.3 Low latency and low packet loss

Low latency and low packet loss are particularly important for services such as conversational voice (including VoIP and Push to Talk), conversational video (including live streaming) and real time interactive applications with fast call set up.

The LTE architecture has been designed to provide for low latency, and low packet loss. It additionally includes quality of service (QoS) management with up to nine service classes defining a wide range of priority, budget and error loss rates to support these and other applications. Also see § 3.2.7.

With LTE users typically experience a low latency in certain defined QoS classes applicable to the services indicated above. Too much latency degrades the quality of service and application performance and can frustrate the end user.

What this means for public safety agencies: Streaming video

LTE gives new meaning to the phrase “a picture is worth a thousand words”. Seeing what is happening at an incident scene – while the situation is unfolding – is much more helpful than

hearing about it. LTE provides real-time transmission of high-definition video, as well as detailed images of crime and disaster scenes, suspects, and more.

If an officer is not responding by radio, a dispatcher can instruct the squad car to activate and/or remotely control a camera and autonomously transmit video to the dispatcher.

3.2.4 Greater interoperability

LTE has a number of advantages related to roaming partner network interoperability: commercially standardized protocols and interfaces mean that more public safety personnel can talk to one another, agencies and individuals can be on the same communications platform, and there is support for an open device ecosystem.

What this means for public safety agencies:

- enhanced cooperation and lower costs;
- move away from ‘special’ or proprietary and expensive technologies;
- allow roaming onto commercial networks when necessary, facilitating broad partnerships between public safety and commercial carriers;
- communicate seamlessly with other emergency responders. When other first responders join on a public safety LTE network, inter-agency communications are greatly enhanced;
- leverage growing amounts of information – text, images, and video – received by Public service answering points (PSAPs) from the public through mobile devices.

3.2.5 Network security

LTE makes use of some of the most advanced mechanisms available for air interface and network security. Air interface security features and capabilities protect the LTE device, network elements, and traffic from attacks originating over the air interface. Network security features and capabilities protect the LTE network elements and traffic from security attacks generated in the wireline transport network and external devices connected to the Evolved Universal Terrestrial Radio Access Network (E-UTRAN) and the evolved packet core (EPC) network.

End-to-end security is achieved with strong data encryption in the devices and network. This includes encryption at the base stations which provides over-the-air ciphering and integrity validation as well as security over land lines connecting the base stations to the EPC using IPSec. Mutual authentication between the network and devices ensures system integrity.

If further security enhancements are required, LTE could accommodate them.

What this means for public safety agencies:

- communicate securely and reliably;
- enables secure communication;
- enables security between network elements for an end-to-end security policy;
- eliminates tampering with over-the-air information;
- throughput capability enables implementation of additional end-to-end security layers, if needed;
- mutual authentication means rogue devices will not jeopardize operations;
- provides the basis for a secure and reliable communication between devices and data centres.

3.2.6 Network sharing

The concurrent use of the network by multiple entities with distinct functions and roles means asset-sharing must be done in a manner amenable to all parties. Standard network-sharing methods are available to ensure multiple entities have access to their fair share of resources without hindering each other's operations.

What this means for public safety agencies: Share resources

- spectrum resources can be concurrently used;
- spectrum-sharing can be tailored based on mutual agreements;
- distinct encryption levels can be provided;
- traffic can be segregated.

3.2.7 Quality of service and prioritization

With its all-IP architecture, the LTE network must rely on QoS controls to handle different types of services and prevent congestion. In that regard, QoS functions are spread across the whole LTE network domain, including the user equipment (UE), base station, EPC, and IP/multiprotocol label switching (MPLS) backhaul/backbone segments. LTE standards define a comprehensive framework to support end-to-end QoS – from the terminal to the edge of the EPC. Each user and each application per user can be translated into a set of QoS parameters (data rate, latency, packet loss rate and priority) to enable guaranteed and differentiated delivery of each individual application end-to-end. Further, LTE introduces priority mechanisms, including pre-emption, to distinguish between higher and lower priority sessions and UEs. In the event of congestion, this enables the network to prioritize the most critical services/users by pre-empting resources from less critical applications/users. Finally, the rules of QoS can be changed dynamically, ensuring for instance that a group assigned to an incident will have priority over other first responders that may also be in the incident area but that are not part of the response team. QoS continuity when roaming is ensured subject to local policies.

What this means for public safety agencies:

- assure QoS for mission-critical activities;
- intelligent sharing of air resources and network capacity;
- traffic prioritization, especially critical during incidents;
- enable quality of experience.

3.2.8 Bandwidth flexibility

LTE can be flexibly deployed with a wide range of channel sizes, or carrier bandwidths. These can range from 1.4 MHz wide up to 20 MHz. LTE works well at any level within this range. In the future evolution of LTE (LTE-Advanced, first defined in 3GPP Release 10), it is possible to aggregate multiple bandwidths to achieve transmission bandwidth in excess of 20 MHz (up to 100 MHz).

What this means for public safety agencies:

- flexibility and scalability;
- flexibility to fit in existing but disparate spectrum slices (e.g. at 400 MHz);
- system performance scalability as additional spectrum becomes available.

3.2.9 Simultaneous use of multiple applications and grade of service

IMT systems will allow operators to modify their networks for a variety of unique services. For example, voice services require low latency and jitter unlike bandwidth-hungry data and video streaming media applications. Because IMT systems tightly control latency and jitter on links used for voice, while appropriately adjusting for various other types of data, IMT has the ability to deliver both voice and data services on the same network infrastructure. On the downlink, the base station directly controls the scheduling of traffic and the allocation of network resources and through appropriate scheduling the operator can optimize use of the downlink bandwidth. On the uplink, there are several scheduling methods available to the operator, depending upon the QoS requirements for the service flow.

3.2.10 Coverage and spectrum usage/management

Multiple-input multiple-output (MIMO) is a technique for multi-antenna communication systems that relies on the presence of multiple, independent radio-frequency chains and antenna, both at the base station site, and on the subscriber device. For a given bandwidth and overall transmission power, MIMO technology provides a significant increase in throughput and range. In general, MIMO technology increases the spectral efficiency of a wireless communication system and exploits environmental phenomena. For example, MIMO systems exploit multipath propagation to increase data throughput and range and reduce bit error rates. Experts consider MIMO to be a form of smart antenna technology. MIMO and single-input single-output (SISO) are both supported in IMT systems. SISO employs a single antenna on the mobile set and at the base station. MIMO can facilitate the deployment of networks that meet the high coverage and reliability requirements of PPDR.

3.2.11 Capabilities (e.g. talk group configuration)

LMR systems use a broadcast method for talk groups, where multiple mobile stations share a common downlink channel. Multicasting, a similar capability, has been defined for IMT systems to support video and audio conferencing, gaming, and other applications. This type of transmission permits multiple mobile stations in a network to share a common downlink channel.

LTE provides features relevant for PPDR group communications as shown in the Table 1 below. LTE standard includes features such as group voice call services and ensures that the new functionalities will meet the required security targets.

TABLE 1

System features and radio layer features

System features	Group communication service enablers
	Proximity services
Radio layer features	Frequency band support
	Power level support
	Radio enablers for system features

Group Communication Service Enablers (GCSE) in LTE provides basic platform support for group communications such as multicasting and group management. That is, group voice calls require a group call application in the terminals and a respective application server in the network on top of the GCSE support. Similarly, other group communication functions may require an application (the same or a different one).

Proximity Services (ProSe) is direct terminal to terminal communications in LTE, which enables the direct mode operations (DMO) similar to DMO in narrowband networks. Both ‘in-band’ and ‘out of band’ options of ProSe are being studied in 3GPP, referring to operating in the same band as the IMT network (outside the coverage or within coverage requiring some cooperation from the network) or in a separate band. ProSe operation in a separate band requires to identify such dedicated spectrum with associated usage conditions.

3.3 Other IMT capabilities

LTE supports Public Warning System (PWS), which enables the public to receive timely and accurate alerts, warnings and critical information regarding disasters and other emergencies. As has been learned from disasters such as earthquakes, tsunamis, hurricanes and wildfires, such a capability is essential to enable the public to take appropriate action to protect their families and themselves from serious injury, or loss of life or property.

LTE operates in a number of frequency bands, particularly in some of the bands listed for PPDR in Resolution **646 (Rev.WRC-19)**. For one of these bands, a high-power UE capability is being defined to meet the needs of PPDR agencies in this band.

4 Planned capabilities of IMT-2020 to support broadband PPDR applications

Many of the IMT-2020 use cases defined in Recommendation ITU-R M.2083 will require very high data rate communications, a large number of connected devices, and ultra-low latency and high reliability applications. These critical capabilities of IMT-2020 could have important advantages for public safety applications.

4.1 IMT-2020 usage scenario from Recommendation ITU-R M.2083 and its application for PPDR: Enhanced Mobile Broadband (eMBB)

Public safety users will expect mission critical experience at major events such as mass rallies, processions, games and events in the presence of a large number of concurrent users. In such areas, there would be the presence of a large crowd with a high traffic density per unit area and a large number of handsets and machines/devices per unit area. Police, fire brigades, and ambulances need highly reliable audio visual connectivity in crowded environments and machine-centric devices.

During a high-speed chase of criminals on highways and in cities, public safety agencies need mission critical voice and video applications with high mobility. IMT-2020 is expected to offer robust and reliable connectivity solutions to such highly mobile users and communicating machine devices.

4.2 IMT-2020 usage scenario from Recommendation ITU-R M.2083 and its application for PPDR: Ultra-reliable and low latency communications (URLLC)

Public safety agencies need instantaneous and highly reliable connectivity. The low latency and high reliability communications of IMT-2020 is the most important enabler for the future development of new human centric applications in public safety, such as mission critical video.

4.3 IMT-2020 usage scenario from Recommendation ITU-R M.2083 and its application for PPDR: Massive machine-type communications (Massive MTC)

Real-time robotic devices to diffuse explosive devices, to handle dangerous substances, or to control industrial fires need the design of new applications based on machine-to-machine (M2M) communication with real-time constraints. Such applications require much higher reliability and latency than what is envisaged in today’s human-centric communication systems. Real-time traffic

control optimization, emergency and disaster response are other examples of where low latency and high reliability can support public safety agencies.

4.4 Example applications of IMT-2020 technologies for public safety agencies.

The following three areas represent initial examples of how IMT-2020 could be used by public safety agencies.

4.4.1 Application example 1: Connected emergency responders

The Connected Officer has the power to stream video, access information and collaborate in real time. Situational awareness and real-time collaboration increase with interoperable voice and mobile data applications. Officers with mission-critical voice and data, updated threat warnings and automatic health and status monitoring may be in a safer environment. By completing work tasks in the field, efficiency increases, costs are reduced, and communities are potentially safer. In the future, emergency responders and police personnel will have a number of connected devices on their person and will benefit from being connected as shown in the figure below.

These connected devices on an emergency responder could include:

- 1 Officer POV Camera
- 2 360 degrees Body Worn Cameras
- 3 Augmented Reality visual display
- 4 Multi-stream Audio Communication
- 5 Virtual Partner
- 6 Biometrics
- 7 Gun Holster sensor
- 8 Integrated Power Management
- 9 etc.

A significant number of such connected devices are expected to use IMT-2020 systems.

4.4.2 Application Example 2: Next generation public safety vehicle

The emergency vehicle of the future will include multiple high-resolution cameras for recording video and scanning license plates on every side, and an integrated console that controls lights, radio, sirens, PA system, gun holster sensors/alert and digital video recorder activation. Everything supports one purpose – to make the officer safer, smarter, faster and ready for what is next.

Pulling vehicles over is safer with license plate scanning, streaming video back to dispatch or backup, and the ability to switch on lights and sirens remotely. In a major incident, the officer would be able to stream video from the scene, plot nearby sensitive locations, coordinate a multi-agency response and share information with everyone who needs it – in real-time.

All the devices on board a connected vehicle will be able to talk to each other, and also with the control centre, and exchange data and videos using IMT-2020 technologies.



4.4.3 Application Example 3: Connected drones and unmanned aerial vehicles

Drones and unmanned aerial vehicles are becoming a key enabler of public safety activities. High resolution video feeds of a large area can be shared instantly with command centres using a high capacity IMT-2020 mobile network. These can deploy video analytics and other next generation policing tools to manage public safety situations proactively. Drone technology will improve situational awareness and response during incidents in a large way and be deployed more widely when IMT-2020 becomes available.

5 Approaches for supporting broadband PPDR applications using IMT

5.1 IMT offers a high degree of flexibility for supporting broadband PPDR applications. In particular, there are a number of different approaches in relation to accommodating the broadband communications needs of PPDR agencies including:

- deployment of a dedicated PPDR network owned and operated by the PPDR agency or controlling entity, based on IMT systems;
- deployment of a dedicated PPDR network owned and operated by a commercial entity under negotiated contract arrangements for the PPDR organization, based on IMT systems;
- a combination of a dedicated PPDR network owned and operated by the PPDR agency (or entity) and commercial network services, based on a common IMT system, to facilitate roaming where the PPDR agency as a preferential subscriber with suitable assigned priority, under negotiated contract arrangements;
- integrating PPDR as an application on a public network, either sharing the commercial IMT network operator's IMT infrastructure as a closed/private sub-network (e.g. as a virtual private network (VPN)) under specific contract arrangements, or as a preferential subscriber with suitable assigned priority.

5.2 There may also be a need for ruggedized IMT user devices and other special arrangements to meet various PPDR deployment situations.

5.3 During disaster situations, some infrastructure may be affected, but others may still be operational. The surviving infrastructure can be important to support PPDR operations. In the case of IMT, the dynamic use of commercial infrastructure would be a great advantage of the

harmonized use of commercial IMT technologies by PPDR systems. The traffic on a PPDR network is likely to be higher at times of emergency such as natural disasters and major public disorder than at 'normal times'. At these times, it is possible to add extra IMT channels to the PPDR network or increase the width of channels already in use. This could, for example, enable spectrum to be used for PPDR at times of emergency that cannot be made available on a permanent basis.

6 Case studies of applications of IMT to broadband PPDR

Annexes 2 to 6 provide case studies offering real-world examples of ways in which administrations are employing IMT to support broadband PPDR applications:

- 6.1** Case studies of approaches in various countries are outlined in Annexes 2, 3 and 4.
- 6.2** An example scenario of using LTE for PPDR at a chemical factory fire is given in Annex 5.
- 6.3** A case study of a PPDR deployment utilizing partitioning of the service capacity on a national IMT network is given in Annex 6.

7 Summary

This Report has considered how the use of IMT can support current and possible future PPDR applications. The broadband PPDR communication applications are detailed in various ITU-R Resolutions, Recommendations and Reports; and this Report has assessed the IMT capabilities to support these applications. This Report has also considered the benefits that can be realized when standardized radio interfaces technical features, and functional capabilities, are employed to address communications needs of public safety agencies.

8 Acronyms, abbreviations

3GPP	Third Generation Partnership Project
BB-PPDR	Broadband Public Protection and Disaster Relief
BS	Base station
CAD	Computer aided dispatch
CAI	Common air interface
CAPEX	Capital expenditure
D2D	Device to device
DMO	Direct Mode Operation
ECC	European Electronic Communications Committee
EMC	Electromagnetic compatibility
EMI	Electro Magnetic Interference
EMP	Electromagnetic Pulse Protection
EPC	Evolved packet core
ESD	Electrostatic-sensitive device
E-UTRAN	Evolved Universal Terrestrial Radio Access Network
GIS	Geographic Information Systems

HAZMAT	Hazardous materials
IMT	International Mobile Telecommunications
IP	Internet protocol
IPSec	Internet protocol security
LMR	Land mobile radio
LTE	Long term evolution
MCPTT	Mission Critical Push-To-Talk
MCX	Mission Critical Services, which includes Mission Critical Push to Talk (MCPTT), Mission Critical Data (MCData) and Mission Critical Video (MCVideo)
MIMO	Multiple-input multiple-output
MPLS	Multi-protocol label switching
MS	Mobile station
MTC	Machine Type Communications
NR	New Radio (IMT-2020)
OAM	Operation, administration and maintenance
OFDMA	Orthogonal frequency division multiple access
OPEX	Operational expenditure
P25	Project 25
PLMN	Public Land Mobile Network
POV	Point of view
PPDR	Public protection and disaster relief
ProSe	Proximity Services
PSAP	Public service answering points
PWS	Public Warning System
QoS	Quality of service
RAN	Radio Access Network
SISO	Single-input single-output
SON	Self-organizing network
TETRA	TErrestrial Trunked RAdio system.
UE	User equipment
VoIP	Voice-over-Internet protocol
VoLTE	Voice over LTE
VPN	Virtual private network

9 References

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Annex 1

IMT technology capabilities which can be used as a base to develop mission critical applications

Tables 2, 3 and 4 herein provide details of the IMT specifications that support the PPDR requirements outlined in Annexes 4 and 5 of Report ITU-R M.2377. As broadband PPDR applications need to provide the capabilities of earlier narrowband and wideband applications, the separate tables in Report ITU-R M.2377 have been consolidated here to reflect the overall capabilities of IMT systems.

The use of the term ‘enabled’ in the column entitled “Support by 3GPP LTE and Release Number”, in the Tables 2, 3 and 4 below, indicates that the specifications make it possible for an implementation to provide the functionality described, although this functionality is not listed in the specifications. Further, functionality under development but for which specifications have not been completed is listed as ‘not supported’. Some ‘not supported’ functionality and additional functionality not listed in the tables below will be added in successive releases.

In this Annex, the term ‘3GPP NR’ refers to New Radio interface of 3GPP as specified in Recommendation ITU-R M.2150.

The use of the expression “Support is expected in Rel.17 or beyond” in the last column in Tables 2, 3 and 4 indicates that 3GPP MCX Stage 1 requirements are available for IMT-2020 in Rel.17 and MCX Stage 2 IMT-2020 work is ongoing in Rel.17. MCX applications supported for unicast LTE-based communication are applicable for IMT-2020 RAN.

TABLE 2
PPDR applications and examples⁵

Application	Feature	PPDR example	Support by 3GPP LTE and Release number	Support by 3GPP NR and Release number
Voice	Person-to-person	Selective calling and addressing	Supported; Rel. Independent	Support is expected in Rel.17 or beyond
	One-to-many	Dispatch and group communication	Supported in R13	Support is expected in Rel.17 or beyond
	Talk-round / direct mode operation	Groups of portable to portable/mobile-mobile in close proximity without infrastructure	Supported in R13	Support is expected in Rel.17 or beyond
	Push-to-talk	Push-to-talk	Supported in R13	Support is expected in Rel.17 or beyond

⁵ This Table 2 combines the requirements listed in Report ITU-R M.2377-0 in Table A4-1 “Generic/narrowband part”, Table A4-2 “Additional wideband part”, and Table A4-3 “Additional broadband part”.

Application	Feature	PPDR example	Support by 3GPP LTE and Release number	Support by 3GPP NR and Release number
	Instantaneous access to voice path	Push-to-talk and selective priority access	Supported in R13	Support is expected in Rel.17 or beyond
	Phone interconnect	Telephone call from/to radio subscriber	Supported; Rel. Independent	Support is expected in Rel.17 or beyond
		Dispatcher terminal	Supported; Rel. Independent	Support is expected in Rel.17 or beyond
		Multi select	Supported; Rel. Independent	Support is expected in Rel.17 or beyond
	CAD	Computer aided dispatch	Supported; Rel. Independent	Support is expected in Rel.17 or beyond
	Security	Voice encryption/scrambling	Supported; Rel. Independent	Support is expected in Rel.17 or beyond
Facsimile	Person-to-person	Status, short message	Supported; Rel. Independent	Support is expected in Rel.17 or beyond
	Emergency alert	Pressing the emergency button causes alert at the TG or dispatcher	Supported; Rel. Independent	Support is expected in Rel.17 or beyond
	Security	Data encryption/scrambling	Supported; Rel. Independent	Support is expected in Rel.17 or beyond
	One-to-many (broadcasting)	Initial dispatch alert (e.g. address, incident status)	Supported; Rel. Independent	Support is expected in Rel.17 or beyond
Messages	Person-to-person	Status, short message, short e-mail	Supported; Rel. Independent	Support is expected in Rel.17 or beyond
	One-to-many (broadcasting)	Initial dispatch alert (e.g. address, incident status)	Supported; Rel. Independent	Support is expected in Rel.17 or beyond

TABLE 2 (CONTINUED)

Application	Feature	PPDR example	Support by 3GPP LTE and Release number	Support by 3GPP NR and Release number
Security	Priority/instantaneous access	Man down alarm button	Supported; Rel. Independent	Support is expected in Rel.17 or beyond
	Emergency alert	Pressing the emergency button causes alert at the TG or dispatcher	Supported in R13	Support is expected in Rel.17 or beyond

Application	Feature	PPDR example	Support by 3GPP LTE and Release number	Support by 3GPP NR and Release number
	Emergency call	Priority voice call caused by pressing the emergency button	Supported in R13	Support is expected in Rel.17 or beyond
Location Telemetry	Location status	GPS latitude and longitude information	Supported; Rel. Independent	Support is expected in Rel.17 or beyond
	Sensory data	Vehicle telemetry/status	Supported; Rel. Independent	Support is expected in Rel.17 or beyond ⁴
		EKG (electrocardiograph) in field	Supported; Rel. Independent	Support is expected in Rel.17 or beyond ⁴
		Environmental information including sensory data on air quality, temperature, contamination, radiation levels etc.	Supported; Rel. Independent	Support is expected in Rel.17 or beyond ⁴
Database interaction (minimal record size)	Forms based records query	Accessing vehicle license records	Supported; Rel. Independent	Support is expected in Rel.17 or beyond ⁴
		Accessing criminal records/missing person	Supported; Rel. Independent	Support is expected in Rel.17 or beyond
		Computer aided dispatch directly to field resources	Supported; Rel. Independent	Support is expected in Rel.17 or beyond
	Forms based incident Report	Filing field Report	Supported; Rel. Independent	Support is expected in Rel.17 or beyond
Messages	E-mail possibly with attachments	Routine e-mail message	Supported; Rel. Independent	Support is expected in Rel.17 or beyond
Privacy	Security	Data encryption/scrambling	Supported in R13	Support is expected in Rel.17 or beyond
Data Talk-around/direct mode operation	Direct unit to unit communication without additional infrastructure	Direct handset to handset, on-scene localized communications	Supported in R12 (enabled via L3 network) Fully supported in R13	Support is expected in Rel.17 or beyond
Database interaction (medium record size)	Forms and records query	Accessing medical records	Supported; Rel. Independent	Support is expected in Rel.17 or beyond
		Lists of identified person/missing person	Supported; Rel. Independent	Support is expected in Rel.17 or beyond
		Computer aided dispatch directly to field resources	Supported; Rel. Independent	Support is expected in Rel.17 or beyond

Application	Feature	PPDR example	Support by 3GPP LTE and Release number	Support by 3GPP NR and Release number
		Computer aided dispatch directly to field resources	Supported; Rel. Independent	Support is expected in Rel.17 or beyond

TABLE 2 (CONTINUED)

Application	Feature	PPDR example	Support by 3GPP LTE and Release number	Support by 3GPP NR and Release number
		GIS (geographical information systems)	Supported; Rel. Independent	Support is expected in Rel.17 or beyond
Text file transfer	Data transfer	Filing report from scene of incident	Supported; Rel. Independent	Support is expected in Rel.17 or beyond
		Records management system information on offenders	Supported; Rel. Independent	Support is expected in Rel.17 or beyond
		Downloading legislative information	Supported; Rel. Independent	Support is expected in Rel.17 or beyond
Image transfer	Download/ upload of compressed still images	Biometrics (fingerprints, facial recognition)	Supported; Rel. Independent	Support is expected in Rel.17 or beyond
		ID picture (car number plate recognition)	Supported; Rel. Independent	Support is expected in Rel.17 or beyond
		Building layout maps	Supported; Rel. Independent	Support is expected in Rel.17 or beyond
Telemetry	Location status and sensory data	Vehicle status	Supported; Rel. Independent	Support is expected in Rel.17 or beyond
OTAP	Over the air programming	UE programming through the air	Supported in R13	Support is expected in Rel.17 or beyond
Security	Priority access	Critical care	Supported; Rel. Independent	Support is expected in Rel.17 or beyond
Video	Download/ upload compressed video	Video clips	Supported; Rel. Independent	Support is expected in Rel.17 or beyond
		Patient monitoring (may require dedicated link)	Supported; Rel. Independent	Support is expected in Rel.17 or beyond
		Video feed of in-progress incident	Supported; Rel. Independent	Support is expected in Rel.17 or beyond
Interactive	Location determination	2-way system	Supported; Rel. Independent	Support is expected in Rel.17 or beyond

Application	Feature	PPDR example	Support by 3GPP LTE and Release number	Support by 3GPP NR and Release number
		Interactive location data	Supported; Rel. Independent	Support is expected in Rel.17 or beyond
Direct mode operation of video and data	Direct unit to unit video and data communication without infrastructure	Direct handset to handset, on-scene localized command and control	Supported in R14	Support is expected in Rel.17 or beyond
Privacy	Security	Data encryption/scrambling	Supported in R13	Support is expected in Rel.17 or beyond

TABLE 2 (END)

Application	Feature	PPDR example	Support by 3GPP LTE and Release number	Support by 3GPP NR and Release number
Database access	Intranet/Internet access	Accessing architectural plans of buildings, location of hazardous materials	Supported; Rel. Independent	Supported; Rel. Independent
	Web browsing	Browsing directory of PPDR organization for phone number	Supported; Rel. Independent	Supported; Rel. Independent
Robotics control	Remote control of robotic devices	Bomb retrieval robots, imaging/video robots	Supported; Rel. Independent	Supported; Rel. Independent
Video	Video streaming, live video feed, Download/upload of video clips, Video Conferencing	Video communications from wireless clip-on cameras used by in building fire rescue	Supported; Rel. Independent	Support is expected in Rel.17 or beyond
		Image or video to assist remote medical support	Supported; Rel. Independent	Support is expected in Rel.17 or beyond
		Surveillance of incident scene by fixed or remote controlled robotic devices	Supported; Rel. Independent	Support is expected in Rel.17 or beyond
		Assessment of fire/flood scenes from airborne platforms	Supported; Rel. Independent	Support is expected in Rel.17 or beyond
		Multi-scene video dispatch	Supported in R14	Support is expected in Rel.17 or beyond
		Multicast of Multimedia from a BS to multiple users in a given area (e.g. Pt to MPt/Broadcast)	Supported in R14	Support is expected in Rel.17 or beyond

Application	Feature	PPDR example	Support by 3GPP LTE and Release number	Support by 3GPP NR and Release number
		Video conferencing 1 to 1, 1 to many, etc.	Supported in R14	Support is expected in Rel.17 or beyond
		Encrypted video streaming	Supported in R14	Support is expected in Rel.17 or beyond
Real-time multimedia intelligence	Real time optimization of video or other multimedia content	Optimize the use of allocated bandwidth to support multiple video streams	Supported in R14	Support is expected in Rel.17 or beyond
Imagery	Download/upload High resolution imagery	Downloading Earth exploration-satellite images	Supported; Rel. Independent	Supported; Rel. Independent
		Real-time medical imaging	Supported; Rel. Independent	Supported; Rel. Independent

TABLE 3
PPDR requirements⁶

User requirement	Specifics	Support by 3GPP LTE and Release number	Support by 3GPP NR and Release number
1 System			
Support and integration of multiple applications	Integration of multiple applications (e.g. voice and low/medium speed data) at high speed network to service localized areas with intensive in scene activity.	Supported; Rel. Independent	Supported; Rel. Independent
Simultaneous use of multiple applications	Voice and data	Supported; Rel. Independent	Supported; Rel. Independent
	Multicast and unicast services	Supported; Rel. Independent	System: Supported; Rel. Independent Radio: Full support expected in Rel.17 or beyond
	Real time instant messaging	Supported; Rel. Independent	Supported; Rel. Independent
	Mobile office functions	Enabled (there is no specific office function 3GPP standard); Rel. Independent	Enabled (there is no specific office function 3GPP standard); Rel. Independent
	VPN services	Supported; Rel. Independent	Supported; Rel. Independent

⁶ This Table 3 combines the requirements listed in Report ITU-R M.2377-0 in Table A5-1, “Generic user requirements supported by PPDR narrow-, wide-, and broadband communications” and Table A5-2, “Table of additional requirements for PPDR broadband communications”.

User requirement	Specifics	Support by 3GPP LTE and Release number	Support by 3GPP NR and Release number
	Telemetry	Enabled (there is no specific telemetry function 3GPP standard); Rel. Independent	Enabled; Rel. Independent.
	Remote control	Enabled (there is no specific remote-control function in 3GPP standard); Rel. Independent	Enabled (there is no specific remote-control function in 3GPP standard); Rel. Independent
	Location of terminals	Supported; Rel. Independent	Supported; Rel. Independent.
Priority access	Manage high priority and low priority traffic load shedding during high traffic.	Supported; Rel. Independent	Supported; Rel. Independent
	Accommodate increased traffic loading during major operations and emergencies.	Supported; Rel. Independent	Supported; Rel. Independent
	Exclusive use of frequencies or equivalent high priority access to other systems.	Supported; Rel. Independent	Supported; Rel. Independent

TABLE 3 (CONTINUED)

User requirement	Specifics	Support by 3GPP LTE and Release Number	Support by 3GPP NR and Release Number
Grade of service	Suitable grade of service	Supported; Rel. Independent	Supported; Rel. Independent
Quality of service	Quality of service	Supported; Rel. Independent	Supported; Rel. Independent
	Reduced response times of accessing network and information directly at the scene of incidence, including fast subscriber/network authentication	Supported; Rel. Independent	Supported; Rel. Independent
Reliability	Stable and resilient working platform	Supported; Rel. Independent	Supported; Rel. Independent
	Stable and easily operated management system	Supported; Rel. Independent	Supported; Rel. Independent
	Resilient service delivery	Supported; Rel. Independent	Supported; Rel. Independent
	High level of availability	Supported; Rel. Independent	Supported; Rel. Independent
	Localized communication services (e.g. isolated base stations, relayed mode operation, direct mode operation (DMO), Device-to-Device (D2D))	Relaying supported in R10; DMO and D2D Supported in R12; Isolated base stations supported in R13	System: Support expected in Rel.17 or beyond Radio: DMO, D2D and IAB relay Supported in Rel.16; Full Support expected in Rel.17 or beyond

User requirement	Specifics	Support by 3GPP LTE and Release Number	Support by 3GPP NR and Release Number
Coverage	PPDR system should provide complete coverage within relevant jurisdiction and/or operation	Supported; Rel. Independent	Supported; Rel. Independent Enhancements from Rel.17 onward
	Coverage of relevant jurisdiction and/or operation of PPDR organization whether at national, provincial/state or at local level	Supported; Rel. Independent	Supported; Rel. Independent
	Systems designed for peak loads and wide fluctuations in use	Supported; Rel. Independent	Supported; Rel. Independent
	Enhancing system capacity during PP emergency or DR by techniques such as reconfiguration of networks with intensive use of direct mode operation	DMO and D2D Supported in R12; Isolated base stations and Relayed Mode Operation supported in R13	DMO and D2D Supported in Rel.16; Multi-hop IAB relay support in Rel.16; UE relay mode operation, and isolated base stations and full support are expected in Rel.17 or beyond
	Standalone transportable site in order to support local site operation	Supported in R13	Multi-hop IAB supported in Rel.16, isolated base stations are expected for later releases

TABLE 3 (CONTINUED)

User requirement	Specifics	Support by 3GPP LTE and Release Number	Support by 3GPP NR and Release Number
	Mobile site in standalone mode or wide area mode in order to increase coverage/to enhance capacity	Supported in R13	Enabled; Rel. Independent
	Air-to-ground communication	Supported; In Rel. Independent	Enabled; Rel. Independent
	Vehicular repeaters (NB and WB) for coverage of localized areas/transportable site	Supported; Rel. Independent	Supported; Rel. Independent
	Reliable indoor/outdoor coverage including bi-directional amplifier (BDA)	Supported; Rel. Independent	Supported; Rel. Independent
	Coverage of remote areas, underground and inaccessible areas including bi-directional amplifier (BDA)	Supported; Rel. Independent	Supported; Rel. Independent
	Appropriate redundancy to continue operations, when equipment/infrastructure fails – Standalone site services	Supported in R13	Isolated base stations are expected for later releases and full support expected in Rel.17 or beyond

User requirement	Specifics	Support by 3GPP LTE and Release Number	Support by 3GPP NR and Release Number
Capabilities	Rapid dynamic reconfiguration of system	Supported in R13	Supported; Rel. Independent
	Control of communications including centralized dispatch, access control, dispatch (talk) group configuration, priority levels and pre-emption	Supported in R13	Support expected in Rel.17 or beyond
	Robust OAM offering status and dynamic reconfiguration	Supported; Rel. Independent	Supported; Rel. Independent
	Internet Protocol compatibility (complete system or interface with)	Supported; Rel. Independent	Supported; Rel. Independent
	Robust equipment (hardware, software, operational and maintenance aspects)	Supported; Rel. Independent	Supported; Rel. Independent
	Portable equipment (equipment that can transmit while in motion)	Supported; Rel. Independent	Supported; Rel. Independent
	Equipment requiring special features such as high audio output, unique accessories (e.g. special microphones, operation while wearing gloves, operation in hostile environments and long battery life)	Supported; Rel. Independent	Supported; Rel. Independent

TABLE 3 (CONTINUED)

User requirement	Specifics	Support by 3GPP LTE and Release Number	Support by 3GPP NR and Release Number
	Fast call set-up and instant push-to-talk (PTT) group call operation	Supported in R13	Support expected in Rel.17 or beyond
	Location services	Supported; Rel. Independent	Supported; Rel. Independent
	Communications to aircraft and marine equipment, control of robotic devices	Supported; Rel. Independent	Supported; Rel. Independent
	One touch broadcasting/group call/ATG – announcement to all or some of talk groups and session establishment	Supported; R13	Support expected in Rel.17 or beyond
	Terminal-to-terminal communications without infrastructure (e.g. direct mode operations/talk-around), vehicular repeaters	Supported; R13	Supported; Rel.16
	Emergency alert – Pressing the emergency button causes alert at the TG or dispatcher	Supported in R13	Support expected in Rel.17 or beyond

User requirement	Specifics	Support by 3GPP LTE and Release Number	Support by 3GPP NR and Release Number
	Emergency call – Priority voice call caused by pressing the emergency button	Supported in R13	Support expected in Rel.17 or beyond
	Recording and monitoring of audio and video transmissions for evidential purpose, for safety reasons and lessons learned	Enabled by R13	Support expected in Rel.17 or beyond
	Multi select TG's – Ability to aggregate several TG's and establish one call for all of them	Supported; in R13	Support expected in Rel.17 or beyond
	Appropriate levels of interconnection to public telecommunication network(s)	Supported; Rel. Independent	Supported; Rel. Independent
	Stable and easy to operate management system	Supported; Rel. Independent	Supported; Rel. Independent
2 Security related requirements	End-to-end encrypted communications for mobile-mobile, dispatch and/or group calls communications (Voice and Data)	Supported; R13	Support expected in Rel.17 or beyond
3 Cost related	Open standards	Supported	Supported
	Cost effective solution and applications	Supported	Supported
	Competitive marketplace for supply of equipment and terminals	Supported	Supported
	Reduction in deployment of permanent network infrastructure due to availability and commonality of equipment	Supported	Supported

TABLE 3 (CONTINUED)

User requirement	Specifics	Support by 3GPP LTE and Release Number	Support by 3GPP NR and Release Number
4 EMC	PPDR systems operation in accordance with national EMC regulations	Supported	Supported
Scenario	Support operation of PPDR communications in any environment	Supported	Supported
	Implementable by public and/or private operator for PPDR applications	Supported	Supported
	Rapid deployment of systems and equipment for large emergencies, public events and disasters (e.g. large fires, Olympics, peacekeeping)	Supported	Supported

User requirement	Specifics	Support by 3GPP LTE and Release Number	Support by 3GPP NR and Release Number
	Information to flow to/from units in the field to the operational control centre and specialist knowledge centres	Supported	Supported
	Greater safety of personnel through improved communications	Supported	Supported
Compatibility	End-user to end-user connectivity	Supported; Rel. Independent	Supported; Rel. Independent
	Compatible with existing networks used for PPDR communications (e.g. trunked radio)	Supported in Rel.15	Support expected in Rel.17 or beyond
Interoperability	Intra-system: Facilitate the use of common network channels and/or talk groups	Supported in R13	Support expected in Rel.17 or beyond
	Inter-system: Promote and facilitate the options common between systems	Supported in Rel.16	Support expected in Rel.17 or beyond
	Coordinate tactical communications between on-scene or incident commanders of the multiple PPDR agencies	Supported in Rel.16	Support expected in Rel.17 or beyond
5 Spectrum usage and management	Share with other terrestrial mobile users	Supported; Rel. Independent	Supported
	Suitable spectrum availability (NB, WB, BB channels)	Supported	Supported
	Minimize interference to PPDR systems	Supported	Supported
	Increased efficiency in use of spectrum	Supported	Supported
	Appropriate channel spacing between mobile and base station frequencies	Supported	Supported

TABLE 3 (CONTINUED)

User requirement	Specifics	Support by 3GPP LTE and Release Number	Support by 3GPP NR and Release Number
6 Regulatory compliance	Comply with relevant national regulations	Supported	Supported
	Coordination of frequencies in border areas	Supported	Supported
	Provide capability of PPDR system to support extended coverage into neighbouring country (subject to agreements)	Supported	Supported
	Ensure flexibility to use various types of systems in other Services (e.g. HF, satellites, amateur) at the scene of large emergency	Supported	Supported

User requirement	Specifics	Support by 3GPP LTE and Release Number	Support by 3GPP NR and Release Number
	Adherence to principles of the Tampere Convention	Supported	Supported
7 Planning	Reduce reliance on dependencies (e.g. power supply, batteries, fuel, antennas, etc.)	Supported	Supported
	As required, have readily available equipment (inventoried or through facilitation of greater quantities of equipment)	Supported	Supported
	Provision to have national, state/provincial and local (e.g. municipal) systems	Supported	Supported
	Pre-coordination and pre-planning activities (e.g. specific channels identified for use during disaster relief operation, not on a permanent, exclusive basis, but on a priority basis during periods of need)	Supported	Supported
	Maintain accurate and detailed information so that PPDR users can access this information at the scene	Supported	Supported
Integration and Simultaneous use of multiple applications	Integration of multiple applications (e.g. Voice, data and video) on high speed network to service localized areas with intensive “at scene” activity	Supported; Rel. Independent	Supported; Rel. Independent
	Scene video transmission	Supported; Rel. Independent	Supported; Rel. Independent
Quality of service (see Table 4 below)	Support of a prioritized range of services	Supported; Rel. Independent	Supported; Rel. Independent
	Guaranteed throughput	Supported; Rel. Independent	Supported; Rel. Independent
	Rapid session set up	Supported; Rel. Independent	Supported; Rel. Independent

TABLE 3 (CONTINUED)

User requirement	Specifics	Support by 3GPP LTE and Release Number	Support by 3GPP NR and Release Number
Coverage	RAN shall utilize maximum frequency reuse efficiency	Supported; Rel. Independent	Supported; Rel. Independent
	Vehicular repeaters (Broadband) for coverage of localized areas/transportable site	Supported; Rel. Independent	Supported; Rel. Independent
Capabilities	Network system level management capability	Supported; Rel. Independent	Supported; Rel. Independent

User requirement	Specifics	Support by 3GPP LTE and Release Number	Support by 3GPP NR and Release Number
	Network to perform basic self-recovery, expediting service restoration and a return to redundant operations	Supported; Rel. Independent	Supported; Rel. Independent
	Packet data capability	Supported; Rel. Independent	Supported; Rel. Independent
	Rapid deployment capability – Infrastructure and terminals	Supported; Rel. Independent	Supported; Rel. Independent
	The Network shall provide seamless coverage (via handoff/handover mechanisms) and continuous connectivity within the 95th percentile coverage area at stationary and vehicular speeds up to 120 kph	Supported; Rel. Independent	Supported; Rel. Independent
	A single common air interface (CAI) shall be utilized for the mobile broadband network	Supported; Rel. Independent	Supported; Rel. Independent
	Mobile/portable station nominal transmit power shall be 0.25W ERP (24 dBm) and shall not exceed 3 W ERP (34.8 dBm) in rural areas for portable devices	Different UE power classes are specified, including at least one that satisfies the requirement	Different UE power classes are specified, including at least one that satisfies the requirement
Support	24-hour and 7 days-a-week (24/7) support for fixed and user equipment	Supported; Rel. Independent	Supported; Rel. Independent
	The network operations centre to operate on a 24 × 7 × 365 basis	Supported; Rel. Independent	Supported; Rel. Independent
	24/7 operations including field based support as necessary to maintain the availability of the network. In all cases, 24/7 access to call centre support for issue resolution and assistance is also required	Supported; Rel. Independent	Supported; Rel. Independent

TABLE 3 (CONTINUED)

User requirement	Specifics	Support by 3GPP LTE and Release Number	Support by 3GPP NR and Release Number
Reliability and adaptability	Adaptable to extreme natural and electromagnetic environments. No functional network failure during climate events, operational vibration, earthquake, EMI/ESD, and supplied power events	Enabled	Enabled; Rel. Independent

User requirement	Specifics	Support by 3GPP LTE and Release Number	Support by 3GPP NR and Release Number
	Fixed, mobile and terminal equipment adaptable to a wide range of natural environments, with any physical facilities supporting network equipment meeting contemporary standards for electric surge suppression, grounding and EMP Protection	Supported	Supported; Rel. Independent
	Robust network	Enabled	Enabled; Rel. Independent
	Self-managed network	Supported	Supported; Rel. Independent
	Coordinated development of business continuity plans	Supported; Rel. Independent	Supported; Rel. Independent
	Resilient service delivery	Supported; Rel. Independent	Supported; Rel. Independent
	High availability design e.g. Diversity, redundancy, automated failover protection, backup operational processes	Supported; Rel. Independent	Supported; Rel. Independent
	Network and operational testing to ensure data/call processing functionality is restored within predetermined and guaranteed time period following an outage	Supported; Rel. Independent	Supported; Rel. Independent
	The above should result in PPDR broadband networks at least matching the level of robustness displayed by the current public safety land mobile radio (i.e. P-25 or TETRA)	Partially supported; Rel. Independent	Supported; Rel. Independent

TABLE 3 (CONTINUED)

User requirement	Specifics	Support by 3GPP LTE and Release Number	Support by 3GPP NR and Release Number
Availability	Service availability shall not be calculated to allow a prolonged outage even in one service area	Supported; Rel. Independent	Supported; Rel. Independent
	Power backup using battery backup and/or power generation. Redundant backhaul circuits from the RAN to the core and to the base stations. High wind loading for the cell towers (Availability 99.995% at year 10)	Supported; Rel. Independent	Supported; Rel. Independent

User requirement	Specifics	Support by 3GPP LTE and Release Number	Support by 3GPP NR and Release Number
	Highly reliable (99.999%) individual network elements. Ensuring adequate supply and easy access to spares to reduce Mean Time To Repair (MTTR). Operational readiness assured even in a maintenance window	Supported; Rel. Independent	Supported; Rel. Independent
	Redundant elements should automatically detect failure and activate to provide service upon failures of primary network components	Supported; Rel. Independent	Supported; Rel. Independent
Security	End to end encryption. The network shall provide cryptographic controls to ensure that transmissions can only be decoded by the intended recipient. This must include data encryption over all wireless links	Enabled; Rel. Independent	Support expected in Rel.17 or beyond
	Support for domestic encryption arithmetic	Supported; Rel. Independent	Support expected in Rel.17 or beyond
	The encryption should support both point-to-point traffic and point-to-multipoint traffic	Supported; Rel. Independent	Support expected in Rel.17 or beyond
	The network shall support periodic re-keying of devices such that traffic encryption keys may be changed without re-authentication of the device and without interruption of service	Supported; Rel. Independent	Supported; Rel. Independent
	The network shall provide cryptographic controls to ensure that received transmissions have not been modified in transit	Supported; Rel. Independent	Supported; Rel. Independent
	Access to public safety services and applications shall be provided only to those authenticated users and/or devices as specifically authorized by each PPDR organization	Enabled (for any applications and services over IP) Rel. Independent, for MCPTT in R13	Support expected in Rel.17 or beyond

TABLE 3 (CONTINUED)

User requirement	Specifics	Support by 3GPP LTE and Release Number	Support by 3GPP NR and Release Number
	The network shall require each device that attempts to connect to the network to prove its identity prior to granting access to network resources. Each device shall be assigned a unique identifier, and the authentication method must provide strong assurance (e.g. by public key cryptography) of the device's identity in a manner that requires no user interaction	Supported; Rel. Independent	Supported; Rel. Independent
	The device authentication service shall utilize an open standard protocol	Supported; Rel. Independent	Supported; Rel. Independent
	To protect against both malicious devices and malicious network stations, the authentication must be mutual, with the device proving its identity to the network and the network proving its identity to the device	Supported; Rel. Independent	Supported; Rel. Independent
	Each PPDR organization shall be granted the option to require user authentication in addition to device authentication for certain devices assigned to that organization. When user authentication has been selected as a requirement, the network shall require each of the organization's designated devices to prove its user's identity prior to granting access to network resources	Supported in R13	Support expected in Rel.17 or beyond
	For organizations requiring user authentication, the network must facilitate sequential authentication of multiple users from a single device	Supported; Rel. Independent	Support expected in Rel.17 or beyond
	System authorization management. Each organization shall be granted control over authorization by means of an administrative interface	Supported in R13	Support expected in Rel.17 or beyond
		For organizations requiring user authentication, the organization shall be granted via administrative interface (e.g. Web based) the ability to add, remove, and manage user accounts that are permitted to access the network	Supported in R13

TABLE 3 (CONTINUED)

User requirement	Specifics	Support by 3GPP LTE and Release Number	Support by 3GPP NR and Release Number
	For organizations requiring user authentication, the network must facilitate sequential authentication of multiple users from a single device	Supported; Rel. Independent	Support expected in Rel.17 or beyond
	The network should have dedicated PPDR system core	Supported in R13	
	3 rd party key management system	Supported; Rel. Independent	Supported; Rel. Independent
	The network shall maintain a record of all device and user access attempts and all authentication and authorization transactions, including changes to authentication and authorization data stores	Supported; Rel. Independent	Supported; Rel. Independent
	Over the air key update	Supported; Rel. Independent	Supported; Rel. Independent
	The network shall enforce a configurable time-out, imposing a maximum time that each device may be connected to the network	Supported; Rel. Independent	Supported; Rel. Independent
	The network shall enforce an inactivity time-out, imposing a maximum time that each device may be connected to the network without transmitting data	Supported; Rel. Independent	Supported; Rel. Independent
	Each PPDR organization shall be granted control of the network time out and inactivity setting for individual devices assigned to that organization	Supported; Rel. Independent	Supported; Rel. Independent
	Each organization shall also be granted via administrative interface the means to manually and forcibly terminate access, including active sessions, to the network for any of its assigned devices individually	Supported; Rel. Independent for network operators, R13 for PPDR administrators	Support expected in Rel.17 or beyond
The network shall be capable of attack monitoring	Supported; Rel. Independent	Supported; Rel. Independent	
Terminal Requirements for preventing unauthorized use	Devices shall support the network's device authentication protocol. Each device shall be assigned a unique identifier, and the authentication method must provide strong assurance (e.g. by public key cryptography) of the device's identity in a manner that requires no user interaction	Supported; Rel. Independent	Supported; Rel. Independent

TABLE 3 (CONTINUED)

User requirement	Specifics	Support by 3GPP LTE and Release Number	Support by 3GPP NR and Release Number
	To protect against both malicious devices and malicious network stations, the authentication must be mutual, with the device proving its identity to the network and the network proving its identity to the device. The device must not permit connectivity to the PPDR network unless the network is authenticated	Supported; Rel. Independent	Supported; Rel. Independent
	Each PPDR organization shall have the option to require user authentication for device access. When user authentication has been selected as a requirement, the device shall require each user to prove his or her identity prior to granting access to applications or network resources	Supported in R13	Support expected in Rel.17 or beyond
	Devices may support a means of erasing (via best practice multiple pass overwriting of data storage media) all data stored on the device	Supported; Rel. Independent	Supported; Rel. Independent
	Devices may support a means of encrypting data stored on the device such that user authentication is required for decryption	Supported; Rel. Independent	Supported; Rel. Independent
Cost	Scalable system	Supported; Rel. Independent	Supported; Rel. Independent
	Open system architecture	Supported in R13	Support expected in Rel.17 or beyond
	Implementable by public and/or private operator for PPDR applications	Supported in R13	Support expected in Rel.17 or beyond
Interoperability	Interoperable/Interconnection with narrowband trunked systems. Interconnection required with: <ul style="list-style-type: none"> – Inter RF subsystem Interface Voice service and Supplementary services – Console supplementary Interface Voice service and Supplementary services 	Supported in Rel.16	Support expected in Rel.17 or beyond

TABLE 3 (END)

User requirement	Specifics	Support by 3GPP LTE and Release Number	Support by 3GPP NR and Release Number
	Interoperable/Interconnection with other broadband systems	Supported in Rel.16	Support expected in Rel.17 or beyond

User requirement	Specifics	Support by 3GPP LTE and Release Number	Support by 3GPP NR and Release Number
	Interoperable/Interconnection with satellite systems	Not Supported	Not supported Support of service continuity for mobility between terrestrial system and satellite system expected in Rel.17 or beyond
	Interconnection with other information systems	Supported; Rel. Independent	Supported; Rel. Independent
	Interfaces that interconnect to other communication systems	Supported; Rel. Independent	Supported; Rel. Independent
	API compatible with standard interfaces	Enabled; Rel. Independent	Enabled; Rel. Independent
	Appropriate levels of interconnection to public telecommunication network(s) – Fixed and mobile	Supported; Rel. Independent	Supported; Rel. Independent
Spectrum usage and management	Dynamic spectrum allocation	Supported; Rel. Independent	Supported; Rel. Independent
	Suitable spectrum availability (Broadband channels for uploads at maximum data rates)	Supported; Rel. Independent	Supported; Rel. Independent
	Reallocation of upstream and downstream rates	Supported; Rel. Independent	Supported; Rel. Independent

TABLE 4⁷

Capabilities provided under Localized Communication Services

Localized Communication Services: D2D/DMO/ isolated base station/relayed mode		Support by 3GPP and Release number	Support by 3GPP NR and Release number
Topology – Isolated or Connected to Core			
Voice	Person-to-person	Supported in R13	Support expected in Rel.17 or beyond
	One-to-many	Supported in R13	Support expected in Rel.17 or beyond
	Push-to-talk	Supported in R13	Support expected in Rel.17 or beyond

⁷ This Table 4 aligns with Table A5-3 of Report ITU-R M.2377-0, which has the same title. Further, in this Table, all separate columns of Table A5-3 of Report ITU-R M.2377-0 relating to “Localized Communication Services: D2D/DMO, Isolated Base Station and Relayed Mode”, both for “Isolated” and “Connected to the core” topologies have been combined in one column.

TABLE 4⁶ (CONTINUED)

Localized Communication Services: D2D/DMO/Isolated Base Station/Relayed Mode		Support by 3GPP Release Number	Support by 3GPP NR and Release Number
Topology – Isolated or Connected to Core			
	Priority	Supported in R13	Support expected in Rel.17 or beyond
	Encryption	Supported in R13	Support expected in Rel.17 or beyond
	Emergency PTT	Supported in R13	Support expected in Rel.17 or beyond
Multimedia (V+V+D)	Person-to-person	Enabled in R12	Support expected in Rel.17 or beyond
	One-to-many	Enabled in R12	Support expected in Rel.17 or beyond
	Push-to-MM	Enabled in R12	Support expected in Rel.17 or beyond
	Priority	Enabled in R12	Support expected in Rel.17 or beyond
	Encryption	Enabled in R12	Support expected in Rel.17 or beyond
	Real time video	Enabled in R12	Support expected in Rel.17 or beyond
Text Message/ Instant Message	Person-to-person	Enabled in R12	Support expected in Rel.17 or beyond
	Emergency alert	Enabled in R12	Support expected in Rel.17 or beyond
	One-to-many	Enabled in R12	Support expected in Rel.17 or beyond
Multi Media Message/ Instant Message	Person-to-person	Enabled in R12	Support expected in Rel.17 or beyond
	One-to-many	Enabled in R12	Support expected in Rel.17 or beyond
	SD	Enabled in R12	Support expected in Rel.17 or beyond
	HD	Enabled in R12	Support expected in Rel.17 or beyond
	Presence	Enabled in R12	Support expected in Rel.17 or beyond
Data Base Interaction		Enabled in R12	Support expected in Rel.17 or beyond
Location	Interactive location data	Enabled in R9	Support expected in Rel.17 or beyond
File Transfer		Enabled in R12	Support expected in Rel.17 or beyond
Client Server App.		Enabled in R12; Supported in R13	Support expected in Rel.17 or beyond
Peer to Peer App.		Enabled in R12; Supported in R13	Support expected in Rel.17 or beyond

Localized Communication Services: D2D/DMO/Isolated Base Station/Relayed Mode		Support by 3GPP Release Number	Support by 3GPP NR and Release Number
Topology – Isolated or Connected to Core			
Miscellaneous	Software/Firmware update online	Enabled in R12	Support expected in Rel.17 or beyond

TABLE 4⁶ (END)

Localized Communication Services: D2D/DMO/Isolated Base Station/Relayed Mode		Support by 3GPP Release Number	Support by 3GPP NR and Release Number
Topology – Isolated or Connected to Core			
	GIS maps updates	Enabled in R12	Support expected in Rel.17 or beyond
	Automatic telemetries	Enabled in R12	Support expected in Rel.17 or beyond
	Hotspot on disaster or event area	Supported in R13	Support expected in Rel.17 or beyond
	Alarming/Paging	Supported in R13	Support expected in Rel.17 or beyond

Annex 2

Case study – An example of deployment of a dedicated PPDR network owned and operated by a PPDR agency or controlling entity, based on IMT in the United States of America

On February 22, 2012, the United States Congress enacted the Middle Class Tax Relief and Job Creation Act of 2012 (Spectrum Act), containing landmark provisions to create a much-needed nationwide interoperable broadband network that will help police, firefighters, emergency medical service professionals and other public safety officials to safely and effectively perform their mission.

- The spectrum act allocated mobile broadband spectrum in the 700 MHz band for use for a nationwide public safety broadband network based on commercial technologies (i.e. LTE).
- The nationwide entity charged with the deployment and operation of this network is the First Responder Network Authority (FirstNet), an independent entity with the National Telecommunication and Information Administration within the U.S. Department of Commerce.
 - i) Holds the single public safety licence for the nationwide network.
 - ii) Form the FirstNet Board by August 20, 2012.

- FirstNet must ensure “the establishment of a nationwide, interoperable public safety broadband network” and that network must be based on a single national network architecture. See sections 6202 (a) and (b).
- Up to USD 7 billion dollars were allocated to the Public Safety Trust Fund in order to construct this nationwide public safety broadband network.
- Under the Spectrum Act, federal law enforcement (e.g. Customs and Border Patrol, the Drug Enforcement Agency and the FBI), as well as state and local emergency responders will be able to utilize this network.
- In order to ensure that this network is cost-effective, FirstNet is authorized to lease capacity on its network under ‘covered leases’ via a public private partnership with non-public-safety uses, including commercial services, on a secondary basis.

Annex 3

Case study – Broadband wireless communications for public safety in Japan

In Japan, spectrum has been allocated for public safety broadband wireless communication systems in 2011 following conversion of VHF/UHF band analogue TV broadcasting service to digital format. Since this system consists of a portable base station (BS) and multiple mobile stations (MS), it can be operated when and where it is needed. It is capable of providing several Mbit/s transmission data rate within the communication area of several km from the BS. One representative use case is high quality video image transmission from a disaster area to the local emergency headquarters. Technical specifications for the system have been standardized in ARIB STD-T103 based on IEEE Standard 802.16-2009, and elements introduced in ARIB STD-T103 have been incorporated in the new VHF mode of the IEEE P802.16n draft. An overall introduction of the public safety broadband system can be found here: <https://ieeexplore.ieee.org/document/7014917>. The specifications of ARIB STD-T103 are closely related to the specifications of ARIB STD-T105 which is the ARIB transposition of the IMT technology Wireless MAN-Advanced.

Annex 4

Case study – Harmonised conditions and spectrum bands for the implementation of European Broadband PPDR systems (BB-PPDR)

The PPDR community and CEPT, the European Conference of Postal and Telecommunications Administrations, have been working for a number of years to advance the migration towards broadband radio capacity for PPDR services (BB-PPDR).

The PPDR community in Europe wants to be part of the global LTE ecosystem. This, they say, will bring several advantages including a wider choice of terminals and potentially lower equipment prices such as lower costs for chipsets and duplex filters. It could also benefit roaming over commercial networks, whereby end user radio terminal equipment can obtain mobile communication services under the coverage of another radio communication network (the ‘visited network’).

Work on developing the LTE technology to support BB-PPDR specific functionalities has already started in international standardisation organisations (3GPP, ETSI). Support has come from the mobile industry, while PPDR stakeholders have also been involved. However, it is expected to take several years before key features and facilities identified by the PPDR community are fully specified, implemented, tested and integrated into LTE solutions.

European countries are increasingly experiencing the need to give and receive PPDR assistance within areas such as international crime and trafficking, near-border accidents, natural disasters, terror attacks etc.

Different national choices within CEPT will require, within an implementable tuning range, multiple-band BB-PPDR user equipment. Such equipment can be used in either dedicated, commercial or hybrid LTE-based networks.

The required level of interoperability is to be realised on multiple layers through the availability of multiple-band PPDR user equipment, the adoption of common technical standards (i.e. LTE and its evolutions), utilising different PPDR network types, and also by standard conformance and interoperability specifications.

ECC Report 218 proposes the concept of ‘flexible harmonisation’ to enable an efficient implementation of BB-PPDR within CEPT. This includes three major elements:

- a common technical standard (i.e. LTE and its evolutions);
- national flexibility to decide how much spectrum and which specific frequency ranges should be designated for BB-PPDR networks within harmonised tuning range(s), according to national needs;
- national choice of the most suitable implementation model (either dedicated, commercial or hybrid BB-PPDR network solution).

Based on the above, it is not necessary to designate a single frequency band for BB-PPDR.

The ECC Report 218 addresses spectrum options for the implementation of BB-PPDR services in CEPT countries in the 400 MHz and 700 MHz frequency ranges.

Annex 5

Case study – An example scenario of using LTE for PPDR at a chemical factory fire

1 Introduction

This example scenario of use of LTE considers a chemical plant fire and a typical response sequence based on the number of responders, as well as the utility of broadband resources

throughout the duration of the incident. All of the data traffic supporting this response is assumed to be served by a wide area, mobile broadband network.

2 Summary of the incident

In a major suburban industrial township, an explosion occurs at 8:30 p.m. on a Friday evening at a major chemical plant producing insecticides. The fire is spreading fast, a number of people are injured, and still more than 10 persons are trapped in the building (Fig. 1). The factory is situated in an industrial area just outside the city. The buildings on fire are about 100 metres from a gas tank containing the highly toxic methyl isocyanate and the connected production facility for this gas at the plant. The tank is located directly behind the building on fire and the fire is spreading fast towards the tank area (Fig. 2).

FIGURE 1

Picture showing front side of the factory on fire



FIGURE 2

Picture showing the back of the factory and the gas tank



3 The incident timeline

Table 5 provides a summary of the incident and various events and their start times. Deployment of various communications resources is shown in Fig. 3.

TABLE 5

Summary of various events

Event identity number	Time T+ (minutes)	Time	Event description
A1	0	8.30 p.m.	Incident start
A2	15	8.45 p.m.	Fire trucks arrive and secure perimeter, save trapped workers
A3	60	9.30 p.m.	Special chemical fire response team arrives
A4	65	9.35 p.m.	Special chemical fire response team deploys
A5	90	10.00 p.m.	Deploy large unmanned crane; clear connecting area
A6	120	10.30 p.m.	Remote high res. camera deployed
A7	125	10.35 p.m.	Methyl isocyanate gas tank emptying process begins
A8	240	0.30 a.m.	Gas storage tank shut down process starts

A9	245	0.35 a.m.	Gas storage tank shut down
A10	600	6.30 a.m.	Incident ends

Each of these events is summarized in the following paragraphs.

3.1 Event A1

Incident start (Time T = 0)

8.30 p.m. Friday evening an explosion occurs on a major chemical plant producing insecticides on the outskirts of a metro city. The fire is spreading fast, a number of people are injured, and more than 10 persons are trapped in the building.

8.33 p.m. First call received at the fire operations control centre.

8.35 p.m. First call received at police operations room. First responders dispatched.

8.35 p.m. Two fire tenders dispatched from nearest locations.

8.36 p.m. Fire operations control centre receives the alert from the police dispatch centre.

8.37 p.m. Fire operations control centre received calls from public as well as alerts from the control room of the chemical plant (CP).

8.37 p.m. Incident verified and entered into the computer aided dispatch (CAD) system and the location of the incident is displayed on GIS maps. CAD officer made recommendation of responding units based on capabilities, proximity and availability. CAD operator accepted recommendation and pushed the incident to the first responders. Information and details of the incident transmitted to LTE multimedia data terminals in the first responder vehicles and the portable handsets. First responder equipped with LTE devices received multi-media information including video clips, floor plans and HAZMAT info. Dispatcher tracks the movement of the first responders on the GIS maps. Fire operations control centre monitoring live video feed from the incident commander vehicle as it speeds towards the incident site.

8.40 p.m. Video feeds of the CCTV from chemical plant are piped into the fire operations control centre. Due to the severity of the incident, fire operations control centre supervisor escalated the incident and informed the fire operations control centre commander. Being Friday evening, the fire operations control centre commander was away from office, so he was reached on his ruggedized LTE public safety handheld device.

8.40 p.m. Citizens called fire operations control centre with MMS and video messages, sharing photos and videos on various social media such as Facebook, etc.

8.40 p.m. Five additional fire tenders dispatched.

8.40 p.m. Video feeds from chemical plant streaming in the police and fire operations control centre's video wall. Live video images from chemical plant are streaming directly to the Fire Commander's LTE handset.

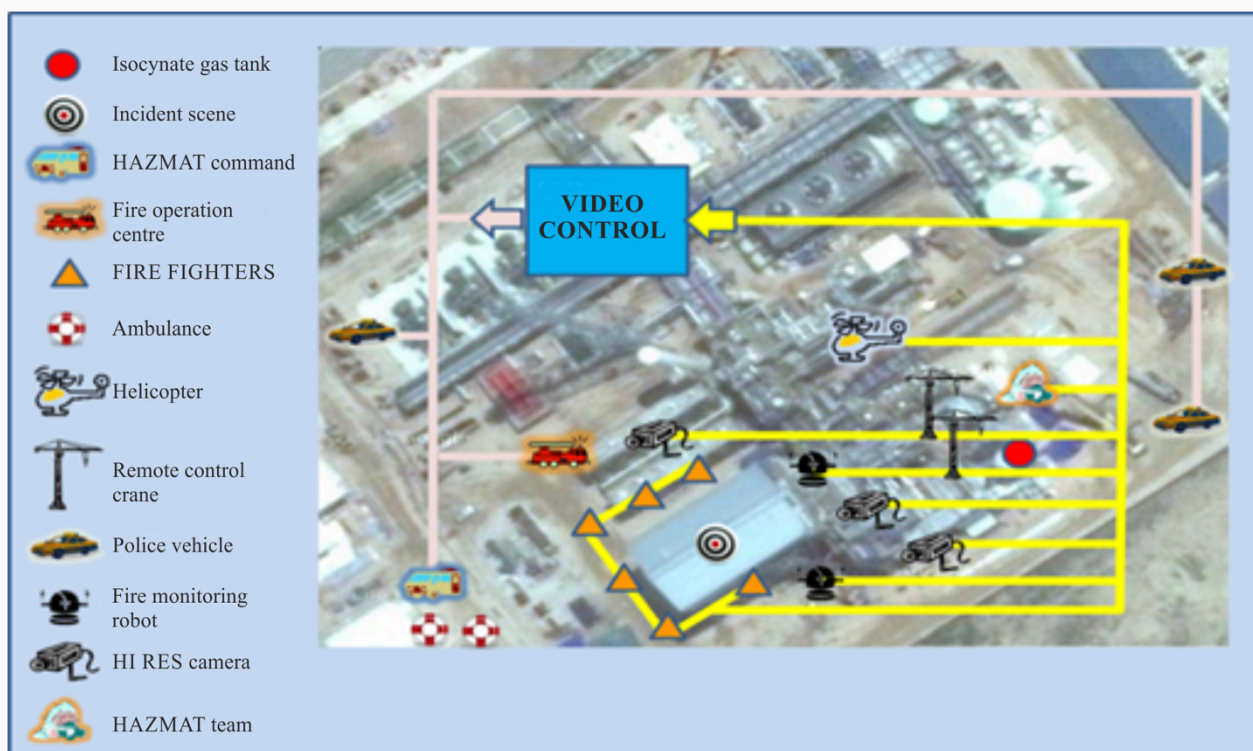
3.2 Event A2

Fire fighters arrive and deployment begins to save trapped workers (Time = T + 15).

8.45 p.m. First fire officer 'Incident Commander' arrives at the incident scene. Fire operations control centre commander, who is still driving towards the scene, calls the incident commander to get a first-hand update on the status from the incident scene ("ground zero"). Fire operations control centre commander also calls the incident commander from his LTE handset. Officers determine that special chemical response units will be required to further proceed with the situation. Upon

awareness of the incident, public safety LTE system resources and capacity have already been dynamically prioritized for the responding officers. Non-essential users on the system are automatically down prioritized, and where necessary the network engages user pre-emption. Necessary safeguards ensure that critical system resources are focused on the emergency and will stay in effect throughout the entire response.

FIGURE 3
Deployment of various resources



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8.46 p.m. Chemical HAZMAT response unit alerted.

9.00 p.m. Police officers establish an outer perimeter and evacuate anyone in harm's way. A police command post is also established. Fire control helicopter arrives on scene and transmits a high-resolution video stream to video control at the network data centre. The video stream from the helicopter is prioritized on the public safety LTE mobile network and multicast from the video control centre at 1.2 Mbit/s to the on-scene responders. Situational updates begin from the command post. The fire team main focus is to evacuate factory workers trapped in the upper level of the building complex in the front area. However, the fire in that area is very strong and applying the high ladder to reach that area directly so far has been unsuccessful.

9.05 p.m. Fire team lands on the upper level and start the victim search and rescue teams successfully enter the room where 10 factory workers are trapped, guided by experts using remote video feeds that have access to the building plans downloaded from the Municipal authority database.

9.15 p.m. The trapped persons rescued from the fire are brought down using ladders and are transferred to the ambulances. Due to severe burns, doctors from a city hospital are getting live videos and are guiding the paramedics for the necessary first aid. Out of trapped persons, two have

severe fire injuries and need to be transferred to the helicopter with remote biometric monitoring and support guidance from remote doctors using LTE handsets.

3.3 Event A3

Special chemical fire response team arrives (Time = T + 60)

9.30 p.m. The Hazmat Chemical response team arrives on scene. A HAZMAT command post is positioned nearby to host the HAZMAT command staff. The growing number of on-scene responders generates an increased number of video streams to choose from. By securely multicasting the video streams and data updates, the additional responders are also able to receive information without further loading the system capacity. Real-time video intelligence optimizes LTE capacity by adjusting video content to available bandwidth and device screen size. The team starts checking nearby buildings to observe and gather intelligence to ensure that no hazardous chemicals are stored near the buildings on fire.

The Hazmat team immediately noticed the gas tank containing Methyl isocyanate at the plant that produces carbonyl, an insecticide. In case the fire reaches near to this tank, the increased temperature inside the tank could cause it to explode and release highly toxic gas. In addition, the heat from the fire could also cause the pressure in the tank to increase and trigger the safety valves, which could result in a large amount of toxic gases being released into the environment. The gas therefore must be safely transferred from the tank into a tanker and taken away. The team calls for a safe HAZMAT tanker which is expected to arrive by 10.30 p.m. The temperature around the tank was already building up due to the heat from the fire. Therefore, the Hazmat commander informs the fire team commander to dispatch pumpers to location in order to cool the tank as much as possible. The expert who has knowledge of the gas and how to transfer it to the tanker safely is away at a marriage party on the other side of the city some 50 kilometres away. The HAZMAT team contacts him on his LTE smartphone, but he cannot reach the site before 11.30 p.m. The HAZMAT team decides to work with him using high resolution Video from High resolution cameras in order to manage the transfer of the gas. The HAZMAT team decides to send a fast dispatcher to the location of the expert with LTE-based devices so that he could guide the team through the process.

3.4 Event A4

Special chemical fire response team deploys (Time = T + 65 minutes)

9.35 p.m. HAZMAT unit starts to deploy the necessary monitoring equipment to transmit data on gas levels directly to their control centre and local commanders. The commanders are ready to evacuate all non-essential, non-protected personnel if gas levels reach hazardous conditions. The HAZMAT team has also immediately deployed high resolution cameras to keep watch on the toxic methyl isocyanate gas storage facility. The Fire commander estimates that unless the fire is controlled, the wind will carry the fire to the storage facility in about one hour. The team monitoring the toxic methyl isocyanate gas storage facility is collectively transmitting to the video control centre with two full resolution video feeds focused on the tank and two low-resolution video feeds for the area between the factory fire and tank. Select video streams from helicopter and fire teams are made available through secure multicast to the appropriate incident responders. Temperatures in the area are becoming increasingly difficult to work and Hazmat commander has decided to pull back the previously deployed fire crews. Therefore, the HAZMAT team decides to deploy two large cranes, each equipped with a video camera and claw to clear the space between the factory and the storage tank to prevent the fire from reaching the tank. Intense heat in the area does not allow humans to work there, even with their fire suits.

3.5 Event A5

Deploy large unmanned crane (Time = T + 90 minutes).

10.00 p.m. HAZMAT team deploys large cranes, each equipped with a camera and a claw to clear away various items clogging the space between the factory and the tank. Video streams from the cranes are transmitted to the command post through the video control centre. Responders are able to receive secure multicast video streams from the helicopter, toxic chemical expert teams and the cranes.

3.6 Event A6

Remote high-resolution camera deployed (Time = T + 120 minutes).

10.30 p.m. HAZMAT team deploys remote high-resolution cameras at 3 500 kbit/s to monitor the gas tank and also share the details of the gas tank with the remote experts. These camera-equipped 'eyeballs' provide additional video streams for situational awareness. Based on consultations with remote experts, the HAZMAT team tactically decides to transfer the gas from the tank to a mobile tanker. For this purpose, they are able to secure a tanker parked in the factory complex for emergency use.

3.7 Event A7

Methyl isocyanate gas tank emptying process begins (Time = T + 125 minutes).

10.35 p.m. The mobile gas tanker vehicle arrives and establishes its position. High resolution cameras guide the HAZMAT experts through voice command using LTE handsets on the key precautions in transferring the highly toxic methyl isocyanate gas to the mobile tanker. The remote expert who has knowledge of the gas and how to transfer it to the tanker safely is connected on his LTE smartphone and uses the high-resolution video feeds to guide the team. The HAZMAT team decides to work with him using high resolution video from high resolution cameras to manage the transfer of the gas.

The time-consuming process of safely transferring the highly toxic methyl isocyanate gas is expected to take about two hours. The fire team has to make sure that during this time the fire will not move to this area and the temperature around the tank is kept low. The support team utilizes incoming video feeds to offer advice, monitor progress and ensure that the primary activity of cooling this area and transferring the gas continues at necessary pace as needed.

3.8 Event A8

Gas tank shut down process starts (Time = T + 240 minutes).

0.30 a.m. As soon as the process of transferring the highly toxic methyl isocyanate gas is completed and the tanker moves away, the expert from the factory needs to shut down the safety valves on the gas producing mechanisms. For this, he needs access to two high resolution cameras to isolate the gas tank from the rest of the factory by intricate valve settings. This is accomplished with the help of two high resolution cameras mounted directly across the various controls connected to the LTE network. This process is extremely complex and dangerous as the residual gas in the tank could be equally dangerous. During this time also the fire team has to make sure that the fire will not move to this area and the temperature around the tank is kept low. The support teams continue to utilize incoming video feeds to offer advice, monitor progress and ensure the primary activity of cooling this area.

3.9 Event A9

Storage tank shutdown (Time = T + 245 minutes).

0.35 a.m. The storage tank has been successfully shut down and the focus now shifts to controlling the fire in the main building. All focus has now shifted to extinguishing the fire.

3.10 Event A10

Incident ends (Time = T + 600 minutes).

6.30 a.m. Finally, the fire has been brought under control after ten hours of extremely hazardous work and the team starts moving various equipment and cameras, etc. and writing necessary reports. All videos of the events are archived and transferred to the main data centre.

Annex 6

Case study: PPDR deployment strategy utilizing partitioning of the service capacity on a national IMT network

This case study describes an arrangement in which an existing national IMT network(s) uses the ability of an LTE system to partition the service capacity (either by the assignment of dedicated spectrum blocks for PPDR and public users or by assignment of dedicated capacity apportionment amongst PPDR and public users) coupled with the ability in certain situations to dynamically adjust the service capacity with prioritization to the PPDR.

An alternative approach to implementation of a dedicated network or a build-own-operate network, utilizes the ability of IMT networks to ‘partition’ designated spectrum blocks for exclusive use by certain user-groups, such as PPDR agencies – while sharing the remaining network coverage, capacity, switching/routing core, backhaul, and radio base-station infrastructure. Using QoS ‘priority’ features available within the IMT technology, and in IP transport layers, a more affordable and effective strategy is available for delivering seamless emergency-grade mobile broadband services over a larger area. The key considerations underlying this strategy include:

- PPDR coverage must be widespread – ideally, PPDR operational coverage should be nationwide for maximum operational effectiveness. While day-to-day public safety events are mostly focused in populated (urban/suburban) areas, natural disasters such as cyclones/tornadoes, tsunamis/floods, volcanic eruptions, earthquakes and forest fires can strike anywhere – often in regional/rural zones. Public networks may already provide national coverage – but further extending and ‘hardening’ an existing public network may be easier, faster and cheaper than building an entirely new ‘dedicated’ network of similar scale. However, the resilience and quality of service may be limited to that provided by the public network unless additional measures are implemented.
- PPDR functionality must be transparently delivered everywhere – irrespective of geographic location, the full PPDR functionality should be readily/seamlessly available to authorized users. Reflecting the urgency of emergency events and disasters, minimal access delays and latency is critical for ensuring effective response by PPDR agencies. This suggests need for an integrated network approach. Reliance on simple roaming to another network is unlikely to satisfy PPDR users in critical situations expecting a fast and seamless experience.
- Mobile broadband networks require significant capital resources to build and operate – the resource requirements of building a near-nationwide IMT network, with high

availability and capacity, can be prohibitive – and the ongoing operations and maintenance costs (along with periodic technology upgrades) can be a significant burden.

- Sharing public network infrastructure will result in greater efficiencies by avoiding the direct need for duplicating core network, backhaul systems, site access/infrastructure, and operational support systems (OSS), as well as leveraging the public network operator’s procurement scale, the incremental capital resource needs of delivering broadband PPDR are considerably reduced. There are significant savings and a better user experience, through more seamless functionality over a homogenous coverage footprint, for PPDR agencies using an integrated network scenario.
- Enhancing public network resiliency (hardening) may be simpler than building an equivalent new network – while some aspects of a public network may need to be further ‘hardened’, the capital needs associated with localized upgrades will always be lower compared to deployment of a dedicated PPDR network. Such upgrades may include: increased site back-up power; backhaul link and node redundancy; additional physical and electronic intrusion detection; and other protective measures. In contrast, some aspects of public network planning offer greater resiliency than traditional PPDR networks: for example, typical public network deployment planning includes overlapping sector-coverage arrangements (coverage ‘depth’) to minimize outage due to loss of a sector – in contrast to the ‘thin’ single-layer coverage typically associated with traditional PPDR network planning. However, geographical coverage objectives of public networks may differ from those of traditional PPDR networks.
- Leveraging public network infrastructure may also facilitate a faster PPDR deployment – since the majority of network infrastructure is already in place, especially in urban and populated areas, PPDR services can be put into active service (over a relatively large coverage area) sooner – even if further network ‘hardening’ and coverage extension work is still proceeding.

This case study also considered several other aspects to be attractive, including: i) The availability of skilled resources for planning, building and operating an IMT broadband wireless network within an existing network operator; ii) technology obsolescence and need for regular upgrades to keep the network fit-for-purpose is the responsibility of existing network operator; and iii) retention and training of specialist technical staff, support vehicles and equipment, shifts to the network operator.

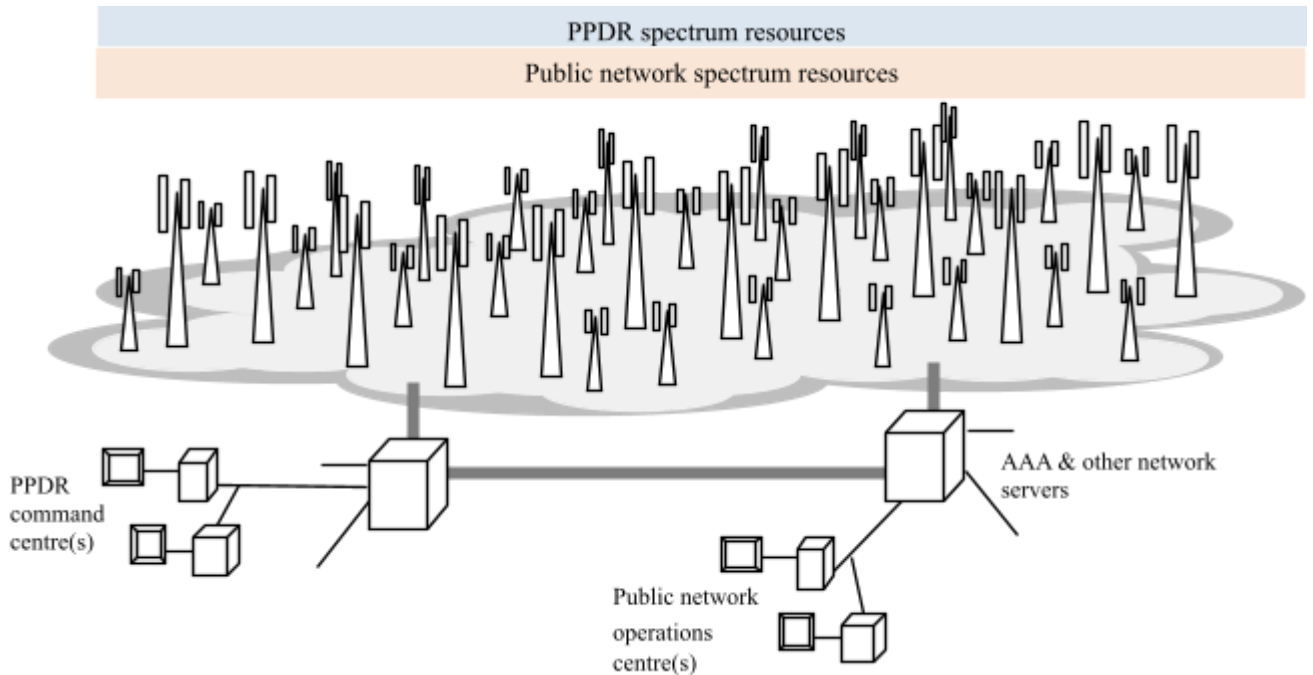
Public networks can efficiently and seamlessly accommodate the needs of mission-critical PPDR users within a nationwide IMT network by implementing a combination of:

- spectrum partitioning, to quarantine spectrum segments to specified users or user-groups;
- enabling differential QoS attributes; and
- enabling dynamic intra- and inter-band ‘carrier aggregation’ of spectrum resources.

This integrated approach to implementing a national broadband PPDR system is illustrated in concept in Fig. 4.

FIGURE 4

Integrated IMT PPDR/public network – based on shared Radio Access Network (RAN), duplicated core, distributed OSS, and configured for partitioned PPDR spectrum and dual HSS/AAA



Delivering an integrated broadband PPDR system

Delivery of emergency-grade mobile broadband services using dedicated PPDR spectrum resources and seamless integration with a public IMT network in this case study is based on a three-stage deployment plan:

- Stage 1 – Deploy the PPDR spectrum as a dedicated resource within a common Radio Access Network (RAN) on existing public network base-station sites, for exclusive use by emergency services.
- Stage 2 – Introduce “priority access” and preferential service levels for PPDR users, to facilitate priority access (‘overflow’) to the public network capacity in times of need (e.g. major event or disaster).
- Stage 3 – In parallel, progressively enhance the resiliency of the public IMT network in accordance with PPDR agency priorities, for more robust operation in times of emergency and disasters.

The concept of ‘partitioned’ spectrum is achieved via two alternative methods: distinct spectrum bands or distinct sub-bands – as illustrated below:

FIGURE 5

Example of cross-band partitioning

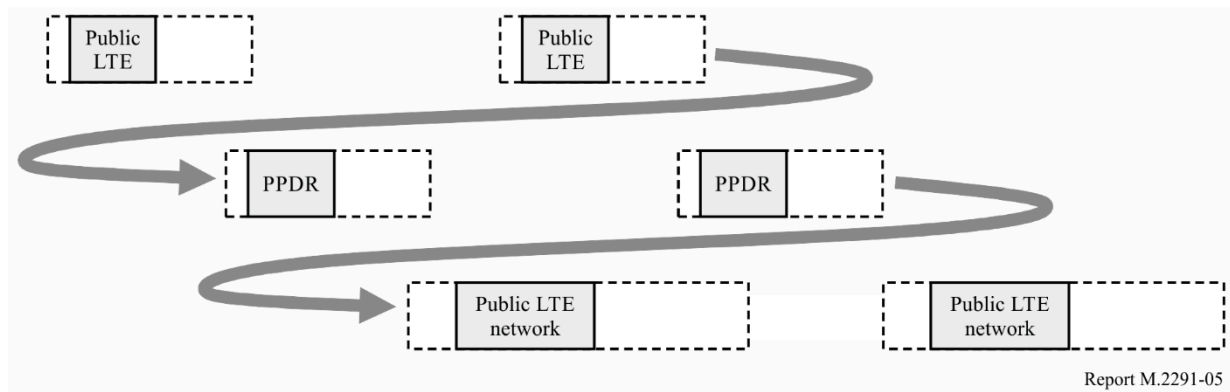


FIGURE 6

Example of sub-band partitioning



Such spectrum partitioning is intended to provide PPDR agencies with sufficient certainty in regard to network coverage and capacity, to support all day-to-day operational requirements and many emergency events and local disasters.

In the case of an integrated host network employing either cross-band or sub-band partitioning, the use of ‘carrier aggregation’ and ‘priority access’ to the public IMT network spectrum enables additional resources to be seamlessly and immediately made available should PPDR traffic needs exceed the dedicated spectrum block threshold capacity. In the event of a major disaster, this effectively provides PPDR agencies with immediate, seamless and transparent access to considerably greater network capacity while avoiding valuable spectrum otherwise largely lying idle/under-utilized, as might be the case for a dedicated PPDR network.

Network capability and resilience

To be fully effective, a host IMT network must provide PPDR users with sufficient coverage reach, availability, and overall resilience. These three key attributes are inextricably associated with the architecture and configuration of the deployed network, and will involve:

- sufficient radio base station sites deployed to not only meet coverage objectives, but also to ensure suitable ‘depth’ of coverage in all priority regions;
- sufficient capacity in base stations to cope with increases in demand that may occur in certain areas during major emergency events;
- sufficient base-station site physical security and back-up power to maintain operations despite adverse natural events and human attack;
- backhaul and core network systems configured for redundancy to mitigate any conceivable single-point-of-failure;

- sufficient security measures and encryption to block unauthorized access or tampering with relevant network servers and routers; and
- 24/7 network status/health monitoring and proactive capacity management to ensure that network issues are immediately addressed before they impact performance or user experience.

All these protective measures are equally important irrespective of the preferred approach to implementing a broadband PPDR network.

Device and terminal considerations

A rich eco-system of access devices and user terminals for public/commercial IMT (LTE) systems is already emerging in the global market. This eco-system includes a wide range of hand-portables, vehicle-mounted devices, and OEM modules.

However, the PPDR sector has traditionally sought ruggedized user terminals, and a variety of special application versions (e.g. for helicopter/aircraft, motorcycle, and covert use). Such requirements will continue – not necessarily for all PPDR users – so vendors of ruggedized devices will continue to play a vital role in this market segment. But, special PPDR user devices have typically involved higher development costs, and a higher sales price, due to their unique design requirements and the relatively small market size. To alleviate such costs, greater harmonization of PPDR spectrum arrangements on a regional (or semi-global) basis is being sought – with harmonization of a key objective of Resolution **646 (Rev.WRC-19)**.

With the wider take-up of mobile broadband services, ‘smart’ phones/devices and tablets will also play a greater role in day-to-day PPDR operations – inevitably encouraging the emergence of new functions, applications, and methods of working.

Case study conclusions

In this case study, it was found that the integrated approach across spectrum and network infrastructure involving use of public IMT (LTE) network resources and systems, even with dedicated PPDR spectrum, offers an alternative method of delivering future mobile broadband services for PPDR agencies. The case study provides a view with regard to these aspects of PPDR deployment:

- early initial PPDR service availability/delivery;
- wide-area prioritized PPDR network access;
- seamless geographic coverage;
- dynamic additional capacity allocation for major events/disasters;
- seamless PPDR user experience across the entire coverage area;
- high levels of resilience;
- potentially lower cost of deployment; and
- opportunity for economies of scale.

The strategy outlined above allows national resources to be efficiently used – and financial investment to be directed toward network ‘hardening’, rather than duplication of existing infrastructure. This strategy also ensures that radio spectrum resources are fully exploited to deliver maximum economic and social benefit to national communities. It may enable a larger PPDR mobile broadband network to be brought into operation, in a relatively short timeframe, and with lower project and financial risk to administrations and PPDR agencies.

Leveraging the existing skills and experience of public IMT network operators may reduce costs, risks and delays associated with bringing advanced LTE mobile broadband technology to assist in enhancing the effectiveness of today's PPDR agencies.
