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**Radiocommunication objectives and
requirements for Public Protection and
Disaster Relief**

M Series
**Mobile, radiodetermination, amateur
and related satellite services**



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REPORT ITU-R M.2377-1

**Radiocommunication objectives and requirements for
Public Protection and Disaster Relief**

(2015-2017)

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1 Introduction

Public Protection and Disaster Relief (PPDR) radiocommunication systems are vital to the achievement of the maintenance of law and order, response to emergency situations, protection of life and property and response to disaster relief events.

This Report discusses the broad objectives and requirements of PPDR applications, including the increasing use of broadband technologies to meet those objectives and requirements. The expanding scope of PPDR capabilities, ranging from narrowband through wideband and broadband, offers greater utility for emergency response operations around the world, including in developing countries.

The advances in broadband technologies offer the potential of enhanced capability and capacity to facilitate the achievements of both public protection operations and responding to major emergencies and catastrophic disasters. Whilst noting that narrowband and wideband technologies for PPDR services and applications are still widely used in all three ITU Regions.

2 Scope

This Report addresses:

- the categorization of operational, technical and functional objectives and requirements relating to PPDR systems;
- the use of PPDR systems, not only in terms of generic capabilities, but also as they vary according to narrowband, wideband and broadband capabilities;
- the development of mobile broadband PPDR services and applications enabled by the evolution of advanced broadband technologies;
- the efficient and economical use of the radio spectrum; and
- the needs of developing countries;

With the above, this Report is also considered supporting, but not limited to, the preparation of WRC-15 agenda item 1.3, especially in response to the requirements of Resolution **648 (WRC-12)**.

References, terminology, abbreviations and descriptions of PPDR operations can be found in Annexes 1, 2 and 3 of this report. PPDR applications and related examples, and PPDR requirements can be found in Annexes 4 and 5.

Annex 6 contains a study on deployment of broadband and narrowband integrated PPDR network from one country.

Annex 9 provides an example of functional requirements from one country.

Spectrum requirements and examples of spectrum calculations are addressed in Report ITU-R M.2415.

Part 1 – Generic PPDR radiocommunications

This Part describes the objectives and user requirements for PPDR services and applications that can be provided by all types of PPDR implementations (narrowband, wideband and broadband) by summarizing the general PPDR objectives and requirements, as provided by Administrations and the PPDR agencies and organizations. These are further categorized into narrowband, wideband and broadband applications in Annex 4. The requirements are also further detailed in Annex 5.

PPDR communications that support the protection of human life and property are considered mission critical. Regardless of technology or network deployment type, mission critical communications must be secure, reliable and readily available.

3 Objectives and requirements of PPDR systems

This section covers both the objectives and requirements of PPDR radiocommunications systems. The requirements categorized as generic are applicable to narrowband, wideband and broadband systems as specified in Table A5-1 of Annex 5. The additional requirements applicable only to broadband systems are categorized in Table A5-2 of Annex 5. The choice of PPDR applications and features to be provided in any given area is a national or PPDR service provider-specific decision based on local needs and demands. The spectrum aspects of PPDR systems are addressed in § 5 of this Report. In addition, Annex 9 provides an example of specific minimum functional requirements determined by one country.

3.1 Technical and functional objectives

The technical objectives of PPDR systems may be regarded as those that relate to the performance capabilities of PPDR systems, while functional objectives involve how, and for what purposes, those systems may be used. PPDR radiocommunication systems have the following technical and functional objectives:

- a) to support the integration of voice, data, video and image communications as part of a multimedia capability;
- b) to provide additional level(s) of priority, availability and layered security associated with the source, destination and type of information carried over the communication channels used by various PPDR applications and operations (e.g. authentication, air-to-air encryption, end-to-end encryption (subscriber device management and application security));
- c) to provide each PPDR agency and organization with user authentication (e.g. public key cryptography) among PPDR agencies and organizations and for their devices prior to granting access to their applications or network resources;
- d) to support operation in extreme or adverse environments (high mobility, heat, cold, dust, rain, water, noise, shock, vibration, extreme temperature, and extreme electromagnetics, etc.);
- e) to support robust equipment (e.g. hardware, software, operational and maintenance aspects, long battery life, to meet intrinsic safety requirements). Equipment (handheld or transportable) that functions while the user is in motion is also required. Equipment may also require unique accessories, which could include special microphones (e.g. lapel, in-ear) or design features to enable use while wearing gloves;
- f) to accommodate the use of repeaters for covering long distances between terminals and base stations in rural and remote areas and also for intensive on-scene localized areas;

- g) to provide fast¹ call set-up, one-touch broadcasting (PTT to group) and group call features;
- h) to provide for emergency calls, one-touch emergency alert (emphasizing that this function is used in life threatening situations and should receive the highest level of priority), emergency voice PTTs, and emergency data PTTs (e.g. sending images, real-time video) during PPDR events;
- i) to support information pull, push and subscription with prioritization;
- j) to provide for strong multi-national/multi-agency technical interoperability over multi-network and device technologies in a seamless fashion;
- k) to provide Localized Communication Services (LCS), Relayed Device Mode Communications (RDM) , Direct Mode Operation (DMO);
- l) to provide for the ability of PPDR communication systems to interface with other dedicated PPDR and/or commercial systems;
- m) to be scalable in order to suit small and large agencies, without sacrificing the ability to interoperate;
- n) to provide for quick deployment of temporary infrastructure and services as well as recovery from failure;
- o) to support continuous use of basic PPDR services in case of infrastructure collapse or failure, e.g. loss of backhaul link between base station and core network;
- p) to support the need for high level of security without compromising the response time;
- q) to provide audio quality that ensures the listener is able to understand without repetition, identify the speaker, detect stress in a speaker's voice, and hear background sounds without interfering with the primary voice communications.

Requirements g), h) and q) above may be deemed essential for providing mission critical PPDR operations.

3.2 Operational objectives

The operational objectives of PPDR systems may be regarded as related to how the system operates, is used or deployed, interworks with other systems/agencies and shares, roams or offloads capacity. PPDR radiocommunications systems have the following operational objectives:

- a) to provide security, including optional end-to-end encryption and secure terminal/network authentication;
- b) to enable communications management to be fully (or partly) controlled by PPDR agencies and organizations through such functions as: dispatch and incident management, instant/dynamic reconfiguration changes to talk groups, guaranteed access controls(including device and application priority pre-emption calls, groups or general calls), spectrum resource availability for multiple PPDR agencies and organizations, and coordination and rerouting;
- c) to support interoperability and interworking between networks(both nationally and for cross-border operation) and roaming of both mobile and portable units in emergency and disaster relief situations (including interconnectivity with public networks);
- d) to provide group communications through the system/network and/or independent of the network (e.g. such as localized communication services, simplex radio and push-to-talk);

¹ Low Latency – very short call set up times (< 500 ms) and very limited end to end voice/data transmission delay (< 1 s).

- e) to provide customized and reliable coverage, especially for indoor areas such as underground and inaccessible areas;
- f) to allow for the extension of coverage area and/or capacity in rural and remote areas or under severe conditions during emergency and disaster situations;
- g) to provide full service continuity, high reliability and sufficient failure tolerance through measures such as redundancy;
- h) support for isolated sites/stations working in case of backhaul loss, and the possibility to rapidly deploy temporary coverage and capacity, or when there is partial loss of infrastructure;
- i) to provide high quality-of-service, including fast call set-up and dialling, push-to-talk, resilience under extreme load, very high call set-up success rate, etc.;
- j) to support a wide variety of PPDR applications;
- k) to provide for multi-national/multi-agency interoperability at various levels of incident management and chain of command as well as with other, collaborating organizations and/or entities; and
- l) to have user handsets/devices that are easily useable and configurable with little need for technical expertise.

3.3 Operational requirements

Systems supporting PPDR should be able to operate in the various scenarios described in Annex 3. This section defines the operational requirements of PPDR users and lists key attributes as provided in Table 5A-1 of Annex 5.

3.3.1 Priority access requirements

Systems serving PPDR should have the ability to manage high-priority traffic and possibly manage low-priority traffic-load shedding during high-traffic situations. PPDR operations may require either the exclusive use of frequencies or equivalent high-priority access to other systems, or a combination thereof.

In addition, this could also mean giving priority access to certain public safety personnel or agencies when they connect to a given network either permanently or at pre-defined times. This is especially important in any scenario where the network supports a mixture of PPDR communications and ordinary commercial communications. Priority access may entail some sort of immediate pre-emption capability through the network (e.g. LTE priority access). One of the key requirements of the PPDR communications is the need to have dynamic priority management. These requirements may be deemed essential for providing mission critical PPDR operations.

3.3.2 Grade-of-service (GoS) requirements

A suitable grade of service should be considered as a requirement that may be deemed essential for providing mission critical PPDR operations.

3.3.3 Quality-of-service (QoS) requirements

PPDR users may also require reduced response times for accessing the network and information directly at the scene of incident, including fast subscriber/network authentication.

An overview of QoS classification is available in Attachment 1 to Annex 5.

3.3.4 Reliability requirements

PPDR applications should be provided on a stable and resilient working platform. Reliability requirements should include a stable and easy-to-operate management system, offer resilient service delivery and a high level of availability² (commonly achieved using redundancy and backup, fall-back and auto-recovery, and self-organization).

In the event of a network failure or loss of network coverage, localized communication services such as isolated base stations, relayed device mode of operation, Direct Mode Operation (DMO) and Device-to-Device (D2D) communication are required between PPDR users as an immediate solution for re-establishing communications. Localized communication services are needed, either through deliberate user action or as a result of devices leaving the network coverage. Localized communications may also be required at a local incident where the coverage does not extend inside a building. See Table A5-3 for more detail on localized communication services. These requirements may be deemed essential for providing mission critical PPDR operations.

3.3.5 Coverage and Capacity requirements

A PPDR system is typically required to provide extensive geographic coverage³ for "normal" traffic within the relevant jurisdiction and/or area of operation (national, provincial/state or local level). This coverage typically is required 24 hours per day, 365 days per year. To date, systems supporting PPDR agencies and organizations were designed for peak loads, and therefore experienced wide fluctuations in usage (including periods of minimal usage).

Additional resources for systems providing for PPDR (e.g. enhancing either coverage, system capacity or both) may need to be employed during a Public Protection (PP) emergency or Disaster Relief (DR) event through techniques such as reconfiguration of networks with use of transportable base station sites, Direct Mode Operation (DMO), high-power UE and vehicular repeaters, and may be required for coverage of localized areas. Urban PPDR systems are often designed for highly reliable coverage of subscribers outdoors and indoors, using direct propagation through the walls of buildings. Sub-systems may be installed in specific buildings and/or structures like tunnels if coverage from external systems is insufficient. Narrowband PPDR systems have tended to use larger radius cells and higher-power mobile and personal radios compared to devices available in commercial service providers' systems (for service to the general public). Trade-offs of coverage, capacity and spectrum reuse against infrastructure costs will likely be a decision for each administration to consider.

Spectrum planning for narrow-band technologies such as TETRA, P25 and DMR provided sufficient channels within frequency tuning ranges and arrangements for DMO. DMO is also required on broadband systems, such as LTE when used for PPDR. As such, sufficient radio resources should be provided for its operation to cater for both cellular and direct mode communications.

Use of DMO or D2D operation on broadband PPDR when smaller channel bandwidths are used, may place constraints on the number of supported user talks groups limited by the number of sub-carriers available per channel. Broadband PPDR systems typically employ a single wide frequency channel across the whole network.

In order to address co-existence with other co-located D2D user groups and cellular services deployed in the adjacent channels, proper channel size planning should be considered.

² For example: Availability – in time (often) specified as three, or four nines or five nines of availability (e.g. 99.98% or better at all times).

³ For example: Coverage (national) – defined by geography rather than population, e.g. 99% of landmass. Also see 99.5% (outdoor mobile), 65% or better (indoor mobile), 99.9% (air to ground).

3.3.6 Connectivity and compatibility requirements

PPDR networks should allow end-user-to-end-user connectivity or otherwise be compatible with existing networks used for PPDR communications. Compatibility requirements may include diversity of supply, use of open international standards, backward compatibility and a smooth upgrade and evolution path.

The current, on-going evolution of systems and technologies providing PPDR might alleviate most of the compatibility challenges.

3.3.7 Interoperability requirements

Interoperability is an important requirement of PPDR operations. PPDR interoperability is the ability of PPDR personnel from one agency/organization to communicate and share data and multimedia in different management levels by radio with personnel from another agency/organization, on demand (planned and unplanned) and in real time.

This includes the interoperability of equipment internationally and nationally for those agencies that require domestic and international cross-border cooperation with other PPDR agencies and organizations.

Several options are available to facilitate communications interoperability between multiple agencies, networks and devices.

These options may include, but are not necessarily limited to:

- a) the adoption of a common technology and/or standards, such as those listed in Recommendation ITU-R M.2009;
- b) the use of standardized equipment and harmonized frequency bands;
- c) equipment and infrastructure supporting multiple modes (e.g. capability to provide services using different technologies in the same equipment);
- c) utilizing local, on-scene command vehicles/equipment/procedures;
- d) communicating via dispatch centres/patches;
- e) utilizing technologies such as audio switches or software defined radios. Typically multiple agencies use a combination of options; or
- f) interconnection (via standard interface and open system infrastructure) with:
 - narrow-/wide- and broadband PPDR systems;
 - commercial communication networks (fixed and mobile);
 - satellite communications networks; and
 - other information systems.

How these options are used to achieve interoperability depends on how the PPDR agencies and organizations want to communicate with each other and at which level in the organization. Usually, coordination of tactical communications between the on-scene or incident commanders of multiple PPDR agencies and organizations is required.

Regarding the technology element, there are a variety of solutions implemented either through pre-planning activities or by using particular technologies, which could support and facilitate interoperability.

3.3.8 Interoperability via commercial services

The use of commercial services is effective in providing interoperability for PPDR operations on an interim basis, particularly when administrative connectivity between disparate users (PPDR agencies and organizations of different jurisdictions) is necessary. This interoperability solution is also

beneficial in off-loading administrative or non-critical communications when the demand for the tactical system is greatest.

3.3.9 Support and integration of multiple applications

Systems providing for PPDR operations should be able to support and integrate a broad range of applications as identified in Annex 4. These systems should be able to support the simultaneous use of several different applications with a range of bit rates.

In addition, the requirements in Table A5-2 of Annex 5 shows that systems providing for broadband PPDR operations are likely to have to accommodate high data throughput, with demands for several applications running in parallel.

Location based services can enable more efficient allocation of personnel and equipment.

3.3.10 Interface/interconnect systems

Although substantial investment may be required to implement interface/interconnect systems, such functions have frequently proven to be effective in providing interoperability between different communications systems. For example, these systems can simultaneously cross-band two or more different radio systems such as LTE, trunked mobile, and satellite systems; or connect a radio network to a telephone line or a satellite. The ability to interface/interconnect different systems allows the users of different equipment in different bands to utilize the type of equipment that best meets their operational requirements.

3.3.11 SDR (Software-Defined Radio)

Enhanced functions for the user are possible with SDR technology that uses computer software to generate its operating parameters, particularly those involving waveforms and signal processing. This is currently in use by some government agencies. Some companies are also starting to benefit by using SDR technology in their products. SDR systems have the ability to span multiple frequency bands and multiple modes of operation and will have the capability in the future to adjust its operating parameters, or reconfigure themselves in response to changing environmental conditions. An SDR radio will be able to electronically "scan" the spectrum to determine if its current mode of operation will permit it to operate in a compatible fashion with both legacy systems and other SDRs on a particular frequency in a particular mode.

SDR systems could be capable of transmitting voice, video, and data, and have the ability to incorporate cross-banding, which could allow for the ability to communicate, bridge, and route communications across dissimilar systems. Such systems could be remotely controlled and may be compatible with new products and backward-compatible with legacy systems. By building upon a common open architecture, these SDR systems will improve interoperability by providing the ability to share waveform software between radios – even those in different physical domains. Further, SDR technology could facilitate public protection organizations to operate in a harsh electromagnetic environment, to not be readily detected by scanners, and to be protected from interference by a sophisticated criminal element.

Additionally, such systems could replace a number of radios currently operating over a wide range of frequencies and allow interoperation with radios operating in disparate portions of that spectrum.

3.3.12 Multi-band, multi-mode radios

Although the initial investment to purchase these radios is significant, it does provide several advantages:

- no dispatcher intervention is required;

- users can establish more than one simultaneous interoperability talk group or channel simply by having subscriber units switch to the proper frequency or operational mode;
- agencies need not change, reprogram, or add to the radio system infrastructure on any backbone systems;
- outside users can join the interoperability talk group(s) or channel(s) by simply selecting the right switch positions on their subscriber units; and
- no additional wireline leased circuits are needed. Multi-band, multi-mode radios can provide interoperability among subscriber units on the same radio system or on different systems. Equipment specifically designed and currently available that can operate on many frequency bands and in different voice and data modes. This also provides flexibility for users to operate independent systems in support of their missions with the added capability of linking different systems and bands on an as needed basis. Although this solution is not wide-spread due to the lack of software defined radios (SDRs), many public protection agencies use radios that operate in different frequency bands for interoperability.

SDR technology, for example, may permit interoperability without incurring other incompatibilities. The use of SDRs for commercial use, particularly for PPDR has potential advantages for meeting multiple standards, multiple frequencies, and the reduction of mobile and station equipment complexity.

3.3.13 Security-related requirements

Efficient and reliable PPDR communications within a PPDR agency or organization and between various PPDR agencies and organizations, which are capable of secure operation, may be required. Notwithstanding, there may be occasions where administrations or organizations, which need secure communications, bring equipment to meet their own security requirements. Furthermore, it should be noted that many administrations have regulations limiting the use of secure communications for visiting PPDR users.

Table A5-1 of Annex 5 shows that end-to-end, encrypted communications for mobile-to-mobile, dispatch and group call communications are a generic requirement for all PPDR networks.

In addition, Table A5-2 of Annex 5 shows that broadband PPDR networks should provide a secure operational environment. Security requirements should include:

- encryption technology;
- support for domestic encryption algorithms;
- authentication for users, terminals and networks;
- user identification and location, air interface encryption and integrity protection ability;
- end-to-end encryption;
- support for third-party key management centre;
- system authorization management; and
- over-the-air re-keying (OTAR) updating.

In addition to these system-level requirements, suitable operational procedures will generally need to be developed to accomplish required levels of security for information being passed across the network.

Rapid dynamic reconfiguration of the system serving PPDR may be required. This includes robust operation administration and maintenance (OAM) offering status and dynamic reconfiguration. System capability of over-the-air programmability of field units is extremely beneficial.

These requirements may be deemed essential for providing mission critical PPDR operations.

3.3.14 New Capabilities

To meet the PPDR operational objectives outlined in § 3.2 of this Report, some further capabilities may be appropriate. For example, as the global trend continues toward fully IP-based networking, PPDR systems may also benefit from full end-to-end IP-compliance or otherwise be capable of seamless interfacing with fully IP-based networks.

PPDR users may also require communications capabilities with aircraft and marine vessels, control of robotic devices, and vehicular coverage extenders (deployable base stations, or mobile repeaters to extend network coverage and capacity to remote or difficult to reach locations).

3.3.15 Electromagnetic compatibility (EMC) requirements

Systems supporting PPDR should be in compliance with appropriate regulations concerning EMC, which may take into account not only interference but also protection from inadvertent electromagnetic pulse or surge effects. Adherence to national EMC regulations may be required between networks, radiocommunications standards and co-located radio equipment.

3.4 User requirements

User requirements are detailed in Annex 5. The Annex covers both the generic and broadband- only user requirements. The requirements categorized as generic are those that can be met by narrowband, wideband and broadband systems as included in Table A5-1 of Annex 5. The additional requirements that can only be met by broadband systems are categorized in Table A5-2 of Annex 5.

Tables A5-1 and A5-2 also provide the relative importance (high, medium or low) of each PPDR user requirement in the three radio operating environments identified as PP(1) - for Day-to-day operations; PP(2)-for Large emergencies and/or public events; and DR -for Disasters.

3.5 Other requirements

3.5.1 Cost-effectiveness requirements

Cost-effective solutions and applications are extremely important and are enabled by open standards, a competitive marketplace, and economies of scale. Furthermore, cost-effective solutions that are widely implemented can reduce the deployment costs of network infrastructure, as well as lower the cost of user devices and other equipment.

This includes compliance with open international standards, with technology exhibiting backward compatibility and a smooth upgrade path. These requirements, together with a requirement for end-user to end-user connectivity with existing networks used for PPDR communications should lead to a diversity of supply.

PPDR equipment should be available at a reasonable cost, while incorporating the technical and functional aspects sought by countries/organizations. Administrations should consider the cost advantages of procuring interoperable equipment; noting that this requirement should not be so expensive as to preclude implementation within an operational context (see also Table 5A-1).

It should be noted that PP networks may cost more than DR networks due to the more-stringent requirements of PP systems⁴. However, most of these costs are related to network design (power supply, redundant transmission etc.).

⁴ <http://www.erodocdb.dk/Docs/doc98/official/pdf/ECCREP199.PDF>.

3.5.2 Regulatory compliance

Systems supporting PPDR should operate in accordance with provisions of the Radio Regulations and comply with relevant national regulations. In cross-border areas and roaming situations, coordination of frequencies should be arranged between administrations (especially where DMO or D2D use may be required), as appropriate.

3.5.3 Planning requirements

Planning and pre-coordination by PPDR agencies and organizations are essential to providing reliable PPDR communications. This includes ensuring that sufficient equipment and backhaul capacity is available (or can be rapidly called upon) in order to provide communications during unpredictable events and disasters, and ensure that channels/resources, user groups and encryption keys are pre-allocated for seamless deployment. It is beneficial to maintain accurate and detailed information so that PPDR users can access this information at the scene.

Administrations may also find it beneficial to have provisions supporting national, state/provincial and local (e.g. municipal) systems.

4 PPDR applications

As PPDR operations have become more reliant on electronic databases and data processing, access to accurate and detailed information by PPDR operational staff in the field is critical to improving effectiveness in resolving emergency situations. This information is typically held in office-based database systems and includes images, maps, architectural plans of buildings, locations of hazardous materials systems, operational procedures/plans and reference information.

The flow of information back from units in the field to operational control and specialist knowledge centers is equally important. Examples to note are the remote monitoring of patients and remote, real-time video monitoring of civil emergency situations, including the use of remote-controlled robotic devices. More related examples are available in Annex 4. Moreover, in disaster and emergency situations, critical decisions to be made by controlling authorities are often impacted by the quality and timeliness of the information received from the field.

These applications, increasingly, require higher bit-rate data communications than can be provided by narrowband PPDR systems. The availability of advanced applications is expected to be of significant benefit to PPDR operations.

Annex 4 lists the envisioned applications with particular features and specific PPDR examples. The applications are grouped under the narrowband, wideband or broadband headings to indicate which technologies are most suitable to supply the particular application and their features. For each example, the importance weighting (high, medium, low) of that particular application and feature to PPDR is indicated. This importance weighting is indicated for the three radio operating environments that are identified in Annex 3: § 3.2.1 "Day-to-day operations"; § 3.2.2 "Large emergency and/or public events", and; § 3.2.3 "Disasters", represented by PP(1), PP(2) and DR, respectively.

In addition to the applications provided by Narrow band Wideband technologies, broadband technologies are expected to be able to supply all of the applications shown in the Table A4-3 of Annex 4. Broadband applications enable an entirely new level of functionality with additional capacity to support higher-speed data and higher-resolution images. The exact applications and particular features to be provided by the various PPDR agencies and organizations are a matter for national administrations and PPDR agencies and organizations. Furthermore, for each example, the relative importance (high, medium or low) of that particular application and feature to PPDR based on current operational imperatives is indicated in the Table.

The progressive launch of new multimedia applications for PPDR depends on various factors, including: cost, regulatory and the national legislative climate, nature of the PPDR mandates and the needs of the area to be served. The exact applications and particular features to be provided by the various PPDR agencies and organizations are to be decided by individual organizations.

The challenge to be taken on board by the future evolution of applications and services providing for PPDR operation is to keep track with the changing demands and requirements of the PPDR agencies and organizations. The following, amongst others, should be considered:

- implementing advanced solutions enabling existing services to fulfil broader future demands and requirements – e.g. to provide for higher data rates;
- wide availability of such advanced technology with interoperability to reduce cost and network rollout times, and – e.g. by using common standards and common frequency tuning ranges;
- spectrum aspects of existing and future use – e.g. considering the pooling of PPDR usage.

5 Spectrum considerations for PPDR

Resolution **646 (Rev.WRC-15)** encourages administrations to use harmonized frequency ranges for PPDR to the maximum extent possible and to consider the regionally harmonized frequency bands/ranges included in that resolution or parts thereof when undertaking their national planning for PPDR solutions. To further assist administrations, Recommendation ITU-R M.2015 contains the frequency arrangements for PPDR systems in these bands.

It should be noted that the frequency bands/ranges included in Resolution **646** are allocated to a variety of services in accordance with the relevant provisions of the Radio Regulations and that flexibility must be afforded to administrations to determine, at national level, what portions of the spectrum within the bands/ranges in this Resolution can be used by PPDR agencies and organizations in order to meet their particular national requirements.

When considering appropriate frequencies for PPDR systems it should be recognized that the propagation characteristics of lower frequencies allow signals to propagate further than higher frequencies, making lower frequency systems potentially less costly to deploy, e.g. in rural areas. Lower frequencies are also sometimes preferred in urban settings due to their superior building penetration. However, these lower frequencies and the related bands have become saturated over time and to prevent further congestion, some administrations are using more than one frequency band in different parts of the radio spectrum.

5.1 Spectrum-requirement calculations for PPDR

In order to evaluate the amount of required spectrum and to plan efficient use of spectrum assessments are usually made by PPDR agencies and organizations on the operational and tactical requirements of PPDR operations in the different scenarios. For this purpose, different methodologies exist. Spectrum requirements and examples of spectrum calculations are addressed in Report ITU-R M.2415.

5.2 Harmonization of spectrum

Significant amounts of spectrum are already in use in various bands in various countries for narrowband PPDR applications. It should be noted, however, that sufficient spectrum capacity will be required to accommodate future operational needs including narrowband, wideband and broadband applications. Since the first adoption of Resolution **646** in 2003, experience has shown that the advantages of harmonized spectrum include economic benefits, the development of compatible networks and effective services and the promotion of interoperability of equipment

internationally and nationally for those agencies that require national and cross-border cooperation with other PPDR agencies and organizations. Some of the benefits are:

- economies of scale in the manufacturing of equipment;
- readily available off-the-shelf equipment;
- competitive markets for equipment procurement;
- increased spectrum efficiency;
- efficient planning and border coordination of land mobile spectrum due to globally/regionally harmonized frequency arrangements; and
- stability in band planning; that is, evolving to globally/regionally harmonized spectrum arrangements may assist in more efficient planning of land mobile spectrum; and
- increased effective response to disaster relief.

PART 2 – NARROW/WIDEBAND PPDR COMMUNICATIONS

This Part addresses narrowband and wideband PPDR radiocommunications systems only.

In many countries, PPDR agencies and organizations rely on narrowband and/or wideband PPDR radiocommunications systems in carrying out mission-critical tasks.

6 Narrow/wideband PPDR communications

This section addresses areas specific to narrowband/ wideband PPDR communications.

Recommendation ITU-R M.2009 identifies radio interface standards applicable for public protection and disaster relief (PPDR) operations in some parts of the UHF band in accordance with Resolution **646 (Rev.WRC-12)**.

6.1 Narrow/wideband applications

The following three types of narrowband and wideband applications might be provided for different PPDR operations and scenarios:

- a) applications associated with the routine day-to-day and emergency operations for public protection applications as outlined in Tables A4-1 and A4-2;
- b) applications associated with disaster relief operations as outlined in Tables A4-1 and A4-2; and,
- c) applications for PPDR could be further developed to support a variety of user terminals including handheld and vehicle-mounted.

Further information on proposed PPDR operations and scenarios for narrowband and wideband applications can be seen in the relevant Tables of Annex 4.

6.1.1 Narrowband PPDR services and applications

Voice communication plays a dominant role in narrowband PPDR services and applications. The following voice services are typically supported:

- group call with fast call set-up;
- broadcast call; and
- point-to-point call;
- DMO;
- Emergency call.

The following low-speed PPDR data applications may also be supported:

- pre-defined status messages;
- transfer of location information;
- vehicle status;
- short messages; and
- access to databases (very small data volume only).

Internet Protocol-based services and applications are supported with very low transmission speeds due to data speed and throughput limitations of the narrowband bearer service. The services and applications will usually be specially designed to cope with the limited data speed, which is lower by several orders of magnitude than the speed provided by current state-of-the-art IP networks.

6.1.2 Wideband PPDR services and applications

Wideband systems carry data rates of several hundred kbit/s (e.g. in the range of 384-500 kbit/s). With this data speed, many widely used application programs for IP-based services can be used. Wideband services are therefore less limited than narrowband services, while supporting the same voice services.

Examples of PPDR services and applications which may be supported in addition to the narrowband PPDR services and applications mentioned in § 6.2.1 include:

- E-mail;
- access to databases (medium data volume only);
- access to server-based applications, including office applications and applications tailored to the needs of the specific organization; and
- file transfers (e.g. pictures, fingerprints).

The servers providing those services typically reside in the IP networks of the respective PPDR agency or organization, rather than in the public Internet, and the PPDR data bearer service provides access to this separate IP network without involvement of the public Internet. This gives the PPDR agency or organization full control over security and availability. The PPDR network is typically designed for higher reliability, availability and security than the public Internet.

6.2 Solutions to support interoperability for narrowband/ wideband PPDR

As indicated in Part 1, § 3.3.8, there are several elements/components which affect interoperability including, spectrum, technology, network, standards, planning, and available resources. Regarding the technology element, there are a variety of solutions implemented either through pre-planning activities or by using particular narrow- and wideband technologies, which could support and facilitate interoperability as described in the examples below.

6.2.1 Cross-band repeaters

Although less spectrum efficient, the cross-band repeater solution may provide interoperability, especially on a temporary basis. It is a viable solution when agencies, which need to interoperate use different bands and have incompatible systems (either conventional or trunked communications systems, using analogue versus digital modulation and operating in wideband versus narrowband mode). Currently, this solution is a practical approach for radio-radio interconnection because audio and push-to-talk (PTT) logic inputs and outputs are typically available. It requires little or no dispatcher involvement and is typically automated. Once activated, all broadcasts from one channel of one radio system are rebroadcast onto one channel of the second radio system. It also allows each user group involved to use its own subscriber equipment and allows subscriber equipment to have only basic features. The mobile radio implementation of cross-band repeaters is used, especially in mobile command vehicles, by public protection agencies to interconnect mobile users in different frequency bands. Using cross-banding repeaters is a method to solve spectrum and standards incompatibilities with a technology that exists today.

6.2.2 Radio reprogramming

Radio reprogramming to provide channel interoperability occurs between user groups operating in the same frequency band by allowing frequencies to be installed in all incident responders' radio equipment. Therefore, in order for this to be an effective solution, the radios should have this as a built-in capability. Radio reprogramming costs less than other interoperability solutions; it may or may not require additional infrastructure; it does not require coordinating and licensing of additional frequencies; and it can provide interoperability on very short notice.

New techniques such as over the air reprogramming allow for instantaneous reprogramming to first responders in critical situations. This can be extremely useful in providing dynamic changes in a chaotic environment.

6.2.3 Radio exchange

Exchange of radios is a simple means to obtain interoperability. Radio exchange provides interoperability between responders with incompatible systems; it does not require coordinating and licensing of additional frequencies; and it can provide interoperability on very short notice.

PART 3 – BROADBAND PPDR RADIOCOMMUNICATIONS

This Part addresses elements of PPDR requirements, standards and harmonization that are associated with the development of broadband technologies for PPDR applications.

A broadband PPDR system is expected to support various media, such as a flexible combination of multi-media capabilities (simultaneously and in real-time), data and narrowband voice applications.

7 Broadband PPDR requirements and evolution

Broadband PPDR applications, such as multi-media transmission capabilities (e.g. real time access to PPDR agencies and organizations database) require much higher bit-rates than narrowband or wideband PPDR technology can deliver. Despite inherent trade-offs between achievable data rates and coverage range, depending on the technology and the deployed configuration, broadband systems have a greater ability to provide fast, high-data-rate applications to PPDR agencies and organizations in the field.

Broadband PPDR services can be realized through any type of network configuration (commercial, hybrid or dedicated), with the possibility to use available commercial equipment, or equipment based on commercial radio modules or chipsets to reduce the costs for network infrastructure (e.g. base stations) and user devices (e.g. terminals).

The PPDR user community has recognized that a need for broadband PPDR services exists.

7.1 Economies of scale

Economic considerations are a factor in the choice of PPDR solution, network design and/or realization time frame. The mobile broadband market is large, and therefore leveraging the use of commercial equipment supporting a range of harmonized frequency bands is beneficial. With a broadband PPDR system not supported by commercial equipment, PPDR equipment may use different radio modules or chipsets in lower production volumes that may result in longer product cycles and higher development cost ultimately passed onto the end user.

7.2 Wide area coverage

Uplink coverage range is typically less than downlink coverage (for an equivalent data rate) due to handset form factor and regulatory limits on user terminal maximum transmit power due to thermal considerations and associated battery life. A solution is to permit, for vehicular applications, a higher power class, using directional antennas, which can be supported in a larger form factor to improve the coverage, particularly for PPDR services. This new power class/form factor will allow ‘first responders’ to send and receive video and data, thus providing the ability to co-ordinate response and protect lives in these wider geographic coverage scenarios. The key benefit would be to enhance the ability of both commercial and dedicated LTE systems to support wider coverage scenarios for PPDR services with no significant increase in network costs.

7.3 Cell throughput

In the public safety environment, the most demanding load expected is at the scene of a multi- user response incident. These sorts of incidents can occur in any part of the coverage area; therefore, appropriate network design, load management and user priority need to be pre-organized to cope with a rapid increase in cell loading. The ability for additional capacity to be overlaid (either through portable terminals, roaming, etc.) into the coverage area quickly is important to ensure public safety agencies can respond appropriately.

7.4 Broadband PPDR radiocommunication standards

Recommendation ITU-R M.2009 identifies radio interface standards applicable for PPDR operations in some parts of the UHF band in accordance with Resolution **646**. The broadband standards identified in this Recommendation are capable of supporting users at broadband data rates, taking into account the ITU-R definitions of “wireless access” and “broadband wireless access” found in Recommendation ITU-R F.1399. These standards are based on common specifications developed by standards development organizations (SDOs). Using this Recommendation, regulators, manufacturers and PPDR operators and users should be able to determine the most appropriate standards for their needs.

Report ITU-R M.2291 considered how the use of IMT, and LTE in particular, can support current and possible future PPDR applications. The broadband PPDR communication applications are detailed in various ITU-R Resolutions, Recommendations and Reports; this Report has assessed the LTE system capabilities to support these applications. Report ITU-R M.2291 has also considered the benefits that can be realized when common radio interfaces, technical features, and functional capabilities are employed to address communications needs of public safety agencies.

Standards development organizations, such as 3GPP, ATIS and CCSA, are working on standards to support broadband PPDR applications. Information from these SDOs is provided in Annex 7.

7.5 Advantages of globally harmonized IMT technology for BB PPDR

Should harmonized IMT technologies for Broadband PPDR be implemented, it would increase availability and significantly reduce the cost of equipment, increase the potential for interoperability, provide for a wider range of end-to-end solutions, and reduce network infrastructure rollout time.

Some countries are in the process of developing their technical requirements and analyses using example technologies (e.g. LTE).

Furthermore, introduction of these technologies may enable PPDR agencies and organizations to keep up with increasing demands by enabling them to progressively implement more advanced voice, text, video and other intensive data applications and services designed to enhance service delivery.

In this regard, it should be noted that any development or planning for the use of future IMT technologies would require that consideration be given to spectrum aspects for broadband PPDR applications.

7.6 Harmonisation of spectrum and conditions for broadband PPDR

Some administrations are considering implementation of broadband PPDR applications based on IMT technologies and assigning either dedicated spectrum or spectrum shared with commercial networks, or a combination of both dedicated and shared spectrum.

Efforts to harmonize spectrum for broadband PPDR applications are aimed at accommodating the operational needs of broadband PPDR applications, while noting that significant amounts of spectrum bands are already in use in various countries for narrowband PPDR applications.

Harmonization of spectrum for broadband PPDR is largely facilitated if:

- 1) a suitable tuning-range is identified, taking account of relevant performance constraints; and
- 2) a common technology standard is adopted, such as IMT (LTE).

Harmonization should be broad enough to enable nations/regulators the flexibility to choose their preferred PPDR band(s) from within the recommended tuning ranges, in accordance with local needs. The common broadband technology may then offer full roaming and interoperability even where respective PPDR spectrum bands are not precisely aligned across borders.

7.7 Advantages of PPDR using frequency bands harmonized for IMT

Broadband PPDR systems, based on open standards such as 3GPP LTE or LTE-Advanced, may be realized through deployment of dedicated PPDR networks using exclusive spectrum, priority access to commercial networks, or via a hybrid approach using either dedicated spectrum in a partitioned commercial network or a combination of dedicated and commercial networks. When comparing the different alternatives, each approach may be seen as offering both advantages and disadvantages. Eventually the choice of implementation is a national matter.

The identification of spectrum specifically for broadband PPDR use, within bands identified for IMT or in near/ adjacent bands in the Radio Regulations is expected to result in the majority of commercial components (e.g. terminals and chipsets) becoming available for use in PPDR application.

Furthermore, it facilitates roaming arrangements between the broadband PPDR networks and commercial networks.

PART 4 – NEEDS OF DEVELOPING COUNTRIES

8 The needs of developing countries

The ITU has made significant commitments to developing countries in a series of instruments:

- Article 17 of the ITU Constitution that the functions of ITU-T are to be performed “bearing in mind the particular concerns of the developing countries”;
- Resolution 123 (Rev. Busan, 2014) on bridging the standardization gap; and
- Resolution ITU-T 34 (Rev. Dubai, 2012) of the World Telecom Development Conference (WTDC-14) on “The role of telecommunications/information and communication technology in disaster preparedness, early warning, rescue, mitigation, relief and response”.

8.1 Factors to be considered by developing countries

Most developing countries have areas that suffer due to their small size, limited resources, remoteness and susceptibility to natural disasters. The growth and development of these areas has been disadvantaged by high transportation and communication costs, disproportionately expensive public administration and PPDR infrastructure and the absence of opportunities to create economies of scale.

The issue of harmonized spectrum and interoperability has become more important as these countries increasingly deploy PPDR systems to meet the challenge of worsening law and order situation as well as the threat of terror incidents and disasters. In order to provide high-quality services to citizens it is important that PPDR services can be accessed from the widest possible range of equipment at the lowest possible cost. Despite the enormous progress made in bridging the digital divide and, in particular, the standardization gap, there remain significant problems in terms of conformance and interoperability due to lack of commonly harmonized spectrum for PPDR.

In recognition of the rapidly increasing trend of urbanization and associated challenges in developing country contexts, public safety organizations such as police and fire safety agencies have been intensifying efforts at getting requisite PPDR communications infrastructures. For many countries, especially in developing country contexts, the lack of comprehensive and reliable indicators and indices of safety and peace makes it difficult to develop evidence-led and context-appropriate interventions with consequent investment decisions, and to allow for evaluation of progress and effectiveness. High levels of injury and criminal events together with the historical context in many such countries provide a particularly relevant test bed for deployment of advanced narrow band and broadband digital PPDR systems.

8.2 PPDR requirements for developing countries

As with the development of broadband PPDR applications in more-developed countries, developing countries will share some requirements, such as the following:

- Common standards and technologies – PPDR broadband networks based on LTE or LTE-Advanced may need to provide better coverage and availability/throughput performance than provided by typical commercial LTE systems, which generally tend to focus on population density coverage at the expense of rural areas – particularly in the early deployment phase.
- Interoperability – The components that facilitate interoperability include the use of common frequencies, technologies and standards. The adoption of open standards, in addition to facilitating interoperability, will also contribute towards market transparency and increase competition and economies of scale.

In addition to these requirements, there are additional ones that are more unique to developing countries. These are elaborated in the following sub-sections.

8.2.1 Radio spectrum

Harmonized radio spectrum where PPDR radio systems can be deployed is critical for developing countries. Due to the economics of developing countries, the propagation characteristics of frequencies below 1 GHz are particularly desirable for wide area, nationwide deployment of PPDR mobile broadband systems.

8.2.2 Direct mode operation

Considering that critical power shortages, difficult terrain, and disaster situations can occur anywhere, and that the lack of infrastructure in developing countries may increase the impact of such events, it is likely that the base PPDR network may not be available at all times. Therefore the use of Direct Mode Operation (DMO) or Device-to-Device (D2D) communications between the user terminals in a given area is a key PPDR requirement, particularly in developing countries.

8.2.3 Rural coverage

Providing wireless coverage in rural and low population density areas has always proved difficult. These areas tend to be challenging in terms of terrain and size of the area that needs to be covered. The main reason being the cost of building and deploying base station sites.

Even in many developed countries, studies show that only 30-40% of the main roads are served by all the major 3G network operators and that, critically, nearly 10% of major roads have no cellular coverage whatsoever. This coverage issue may be compounded in developing countries. In terms of a traffic incident, this lack of basic road coverage will be a major factor in the ability to support emergency services using LTE in areas of likely road incidents. The situation can be more extreme in developing countries. With the introduction of high power vehicular mobiles it should now be possible to reduce these areas with limited or no coverage.

8.2.4 Deployment

Developing countries may not have the resources to deploy a nationwide broadband network to support broadband PPDR applications. Considering the cost, technology gap and the existing deployment status of developing countries, the long-term coexistence of narrowband, wideband and broadband has to be highlighted. Developing countries may choose to install more broadband, wideband or narrowband network sites and equipment, based on their available budget. An integrated narrowband/wideband/broadband network system using the same core network might be suggested. So, for developing countries there may be a need for flexible deployment approaches.

Annex 6 provides an example of a flexible deployment scheme in China for reference.

Annex 10 provides an example scenario of public protection agencies' implementation of PPDR in India that could also be considered as a reference model for other developing countries to follow.

Annex 1

References

A1.1 ITU-R Resolutions, Recommendations and Reports

- Resolution ITU-R 53 – The use of radiocommunications in disaster response and relief
- Resolution ITU-R 55 – ITU studies of disaster prediction, detection, mitigation and relief
- Resolution ITU-R **646 (Rev.WRC-15)** – Public protection and disaster relief
- Recommendation ITU-R M.1042 – Disaster communications in the amateur and amateur-satellite services
- Recommendation ITU-R M.1073 – Digital cellular land mobile telecommunication systems.
- Recommendation ITU-R M.1390 – Methodology for the calculation of IMT-2000 terrestrial spectrum requirements
- Recommendation ITU-R F.1399 – Vocabulary of terms for wireless access
- Recommendation ITU-R M.1457 – Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications-2000 (IMT-2000)
- Recommendation ITU-R M.1637 – Global cross-border circulation of radiocommunication equipment in emergency and disaster relief situations
- Recommendation ITU-R M.1746 – Harmonized frequency channel plans for the protection of property using data communication
- Recommendation ITU-R M.1768 – Methodology for calculation of spectrum requirements for the terrestrial component of International Mobile Telecommunications
- Recommendation ITU-R M.1801 – Radio interface standards for broadband wireless access systems, including mobile and nomadic applications, in the mobile service operating below 6 GHz
- Recommendation ITU-R M.1826 – Harmonized frequency channel plan for broadband public protection and disaster relief operations at 4 940-4 990 MHz in Regions 2 and 3
- Recommendation ITU-R M.2009 – Radio interface standards for use by public protection and disaster relief operations in some parts of the UHF band in accordance with Resolution **646 (Rev. WRC-12)**
- Recommendation ITU-R M.2012 – Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications Advanced (IMT-Advanced)
- Recommendation ITU-R M.2015 – Frequency arrangements for public protection and disaster relief radiocommunication systems in UHF bands in accordance with Resolution **646 (Rev.WRC-12)**
- Report ITU-R M.2014 – Digital land mobile systems for dispatch traffic
- Report ITU-R M.2085 – Role of the amateur and amateur-satellite services in support of disaster mitigation and relief
- Report ITU-R M.2241 – Compatibility studies in relation to Resolution 224 in the bands 698-806 MHz and 790-862 MHz
- Report ITU-R M.2291 – The use of International Mobile Telecommunications (IMT) for broadband public protection and disaster relief (PPDR) applications

A1.2 Other ITU Resolutions and Recommendations

Resolution 123 (Rev. Busan, 2014) – Bridging the standardization gap between developing and developed countries

Resolution ITU-T 34 (Rev. Dubai, 2012) – Voluntary contributions

Recommendation ITU-T E.800 (09/2008) – Definitions of terms related to quality of service

A1.3 Recommendations and Reports of other organizations

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ETSI TR 102 022-1 V1.1.1 (2012-08) – User Requirement Specification; Mission Critical Broadband Communication Requirements.

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Public Safety Statement of Requirements (PS SoR) for Communications and Interoperability (C&I), Volume 1, v1.2 and Volume 2, v1.0, by the Department of Homeland Security's Office for Interoperability and Compatibility, October 2006.

"FCC Takes Action to Advance Nationwide Broadband Communications for America's First Responders" hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-304244A1.doc.

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Annex 2

Terminology and Abbreviations

A2.1 Terminology used for PPDR

Broadband (BB) PPDR Radiocommunications

Broadband applications enable an entirely new level of functionality, with additional capacity to support higher data speeds and higher image resolution. It should be noted that the demand for multimedia capabilities (several simultaneous wideband and/or broadband applications running in parallel) puts a huge demand for very-high bit rates on a wireless system.

Broadband applications provide voice, high-speed data, high-quality, digital, real-time video and multimedia (indicative data rates are in the range of 1-100 Mbit/s) with channel bandwidths dependent on the use of spectrally efficient technologies.

Examples of possible applications include:

- high-resolution video communications from wireless clip-on cameras to a vehicle-mounted computer, used during traffic stops or responses to other incidents, or for video surveillance of security entry points such as airports with automatic detection based on reference images, hazardous material or other relevant parameters;
- remote monitoring of patients and remote, real-time video views that demand high bit rates. The demand for capacity can easily be envisioned during rescue operations following a major disaster.

Broadband applications are considered capable to cover functionalities provided by narrowband and wideband applications.

Commercial communication network

A network that is built and operated by profit-oriented operators in order to offer public communication services.

Commercial technology standard

A technical standard e.g. GSM, LTE, that is initially or primarily developed as platform for the operation of commercial communication networks.

Cross-border

PPDR agencies and organizations have to assist each other in certain cases, meaning they have to be able to work in foreign countries with the local PPDR agencies and organizations and at the same time with their own agencies and organizations.

Day-to-day operation

Day-to-day operations encompass the routine tasks that PPDR agencies conduct within their jurisdiction. Typically these tasks are conducted inside national borders. Generally most PP spectrum and infrastructure requirements are determined using this scenario with the addition of extra capacity to cover unspecified and sudden emergency events.

Disaster

Disasters are situations caused by either natural or human activity. For example, natural disasters include an earthquake, major tropical storm, a major ice storm, floods, etc. Examples of disasters caused by human activity include large-scale criminal incidents or situations of armed conflict. Generally, both the existing PP communications systems and special on-scene communications equipment brought by DR agencies and organizations are deployed.

Device to Device (D2D)

Device-to-device communication enables direct communication between nearby devices. D2D has several modes of operation depending on mobile devices connectivity to the PPDR network and its core: all connected, some connected and some not, and all disconnected from the network.

Direct Mode Operation (DMO)

A mode of local communication in which two or more end user (UE) devices are able to communicate with each other directly in the event they are disconnected from the network, or when operating outside the coverage of the network or when switched on for security or other purposes.

Grade of Service (GoS)

Definition: A number of network design variables used to provide a measure of adequacy of a group of resources under specified conditions (e.g. GoS variables may be probability of loss, dial tone delay, etc.).

International Mobile Telecommunication Systems (IMT)

IMT specifications and standards are defined in Recommendations ITU-R M.1457 and ITU-R M.2012.

Isolated Base Station (IBS)

A base station that is disconnected from its core can continue to serve devices connected to it. The case may be generalized to an isolated group of base stations which can connect directly with each other but are all disconnected from network core.

Large emergency/public events

Events that PP and potentially DR agencies and organizations respond to in a particular area of their jurisdiction. However, they are still required to perform their routine operations elsewhere within their jurisdiction. The size and nature of the event may require additional PPDR resources from adjacent jurisdictions, cross-border agencies, or international organizations. In most cases there are either plans in place or there is some time to plan and coordinate the requirements.

Localized Communication Services

General term for special communications modes prevalent in PPDR systems in cases where coverage is inadequate or network infrastructure is harmed by the disaster by failures or both.

Topologies included under Localized Communication Services are: Device-to-device (D2D), Isolated Base Station (IBS) Communication and Relayed Device Mode (RDM) Communications.

Long Term Evolution (LTE)

LTE, marketed as 4G LTE, is a standard for wireless communication of high-speed data for mobile phones and data terminals. The LTE specifications are developed by the 3GPP (3rd Generation Partnership Project), while the standards are written regionally such as in ETSI, ATIS, ARIB and other regional Standard Development Organizations.

Mission critical communications

Communications that are used by PPDR agencies and organizations to carry out their activities, in situations where human life, property and other values for the society are at risk, especially when time is a vital factor. Mission critical communications are secure, reliable and readily available and as a consequence responders cannot afford the risk of having failures in their individual and group communications (e.g. voice and data or video transmissions)."

Narrowband (NB) PPDR radiocommunications

To provide PPDR narrowband applications, one established approach is to implement wide area networks, including digital trunked radio networks that provide digital voice and low-speed data applications (e.g. pre-defined status messages, data transmissions of forms and messages, and access to databases). ITU Report ITU-R M.2014 lists a number of systems, with typical channel bandwidths up to 25 kHz, which currently are used to deliver narrowband PPDR applications. Some countries do not mandate specific technology standards, but rather promote the use of spectrum-efficient technologies.

Out-Of-Band Emissions (OOBE)

Emission on a frequency or frequencies immediately outside the necessary bandwidth which results from the modulation process, but excluding spurious emissions.

Public protection and disaster relief (PPDR)

The term Public Protection and Disaster Relief (PPDR) is defined in Resolution **646 (Rev.WRC-15)** as a combination of two key areas of emergency response activity:

- Public protection (PP) radiocommunication: Radiocommunications used by agencies and organizations responsible for dealing with maintenance of law and order, protection of life and property, and emergency situations.
- Disaster relief (DR) radiocommunication: Radiocommunications used by agencies and organizations dealing with a serious disruption in the functioning of society, posing a significant, widespread threat to human life, health, property or the environment, whether caused by accident, nature or human activity, and whether suddenly or as a result of complex, long-term processes.

PPDR dedicated network

A network solely designed to fulfil the specific PPDR requirements: this can be a GoGo model (Government Owned, Government Operated), but also a service delivered by a third party (CoCo: Company Owned, Company Operated). Another model is GoCo (network owned by Government, but operated by a third party).

PPDR interoperability

PPDR interoperability is described in this Report as the ability of PPDR personnel from one PPDR agency and/or organization to communicate by radio with personnel from another PPDR agency and/or organization, on demand (planned and unplanned) and in real time. There are several elements/components which affect interoperability including, spectrum, technology, network, standards, planning, and available resources. Systems from different vendors, or procured for different countries, should be able to interoperate at a predetermined level without any modifications or special arrangements in other PPDR or commercial networks. Interoperability might also be needed in a 'multi-vendor' situation where terminals from different suppliers are working on infrastructures from other suppliers.

PPDR specific standard

A radio communication standard that has been developed specifically for PPDR applications or that is a further development of an already existing (commercial) standard.

Quality of Service (QoS)

The collective effect of service performance which determines the degree of satisfaction of a user of the service.

NOTE 1 – The quality of service is characterized by the combined aspects of service support performance, service operability performance, serviceability performance, service security performance and other factors specific to each service.

NOTE 2 – The term "quality of service" is not used to express a degree of excellence in a comparative sense nor is it used in a quantitative sense for technical evaluations. In these cases a qualifying adjective (modifier) should be used.

NOTE 3 – Recommendation ITU-T E.800 (94). Rec. ITU-R M.1224 – The collective effect of service performances which determine the degree of satisfaction of a user of a service. It is characterized by the combined aspects of performance factors applicable to all services, such as: – service operability performance, – service accessibility performance, – service retainability performance, – service integrity performance, – other factors specific to each service.

Relayed Device Mode (RDM) communications

In RDM communications some of the devices do not have direct connectivity to the network core due to missing or obstructed coverage. In the RDM case some devices become also relays between the disconnected devices and the core, while continuing to perform their usual device tasks.

Roaming

The ability of a user to access wireless telecommunication services in areas other than the one(s) where the user is subscribed.

Wideband (WB) PPDR Radiocommunications

Wideband systems carry raw data rates of several hundred kilobits per second (e.g. in the range of 384-500 kbit/s). In the future, it is anticipated that networks may be required to support higher data rates to accommodate the introduction of a whole new class of applications, including wireless transmission of larger blocks of data, video and Internet Protocol-based connections in mobile PPDR systems.

The use of relatively high data speeds in commercial activities has spurred the development of specialized mobile data applications. Short message and e-mail are seen as a fundamental part of any communications command and control system and may play an integral part of any PPDR capability.

A wideband wireless system may be able to reduce response times for accessing the Internet and other information databases directly from the scene of an incident or emergency. This has initiated the development of a range of secure applications for PPDR agencies and organizations.

Systems for wideband applications to support PPDR are under development in various standards organizations. Many of these developments are referenced in Report ITU-R M.2014 and in Recommendations ITU-R M.1073, ITU-R M.1457, ITU-R M.1801 and ITU-R M.2012.

A2.2 Abbreviations and acronyms

3GPP	Third generation partnership project
ACLR	Adjacent channel leakage ratio
A(V)LS	Automatic (vehicle) location system
AGA	Air-ground-air (communication)
AMR	Adaptive multi rate
ANPR	Automatic number plate recognition
API	Application programming interface
APT	Asia pacific telecommunity
ARIB	Association of Radio Industries and Businesses
ATG	Announcement talk group
ATIS	Alliance for Telecommunications Industry Solutions
ATIS WTSC	ATIS Wireless Technologies and Systems Committee
BB	Broadband
BHCA	Busy hour call attempts
BDA	Bi-directional amplifier
BB-PPDR	Broadband PPDR
BS	Base station
B-TrunC	Broadband trunking communication
BW	Bandwidth
CAD	Computer aided dispatch
CAI	Common air interface
CBC	Cell broadcast centre
CBE	Cell broadcast entity
CCC	Command and control centre
CCSA	China communications standards association
CDF	Cumulative distribution function
CEPT	European Conference of Postal and Telecommunications Administrations

CIF	Common intermediate format
CITEL	Inter-American Telecommunication Commission
CMAS	Commercial mobile alerts service
CMRS	Commercial mobile radio service
CMSP	Commercial mobile service provider
CoW	Cell on wheels
D2D	Device to device (communications)
DL PTM	Downlink point-to-multipoint
DL PTP	Downlink point-to-point
DMO	Direct mode operation
DMR	Digital mobile radio
DR	Disaster relief
CHOGM	Commonwealth Heads of Government Meeting
ECC	Electronic Communication Committee (of CEPT)
e.i.r.p.	Equivalent isotropically radiated power
EMC	Electromagnetic compatibility
EMI	Electromagnetic interference
EMP	Electromagnetic pulse
EMS	Emergency medical services
EPS	Evolved packet system
ERP	Effective radiated power
ESD	Electrostatic discharge
ETSI	European Telecommunications Standards Institute
EUTRAN	Evolved UMTS terrestrial radio access network
FCC	Federal Communications Commission
FDD	Frequency division duplex
FDMA	Frequency division multiple access
FEC	Forward error correction
GIS	Geographical information system
GMPCS-MoU	Global mobile personal communications by Satellite – Memorandum of understanding
GoS	Grade of service
GPS	Global positioning system
GSM	Global system for mobile communications
HD	High definition
HF	High frequency

HPUE	High power UE
IBS	Isolated base station
ID	Identification
IMS	IP multimedia subsystem
IMT	International mobile telecommunications
IP	Internet protocol
LAES	Lawfully authorized electronic surveillance
LCS	Localised communication services
LEWP	Law enforcement working party
LMR	Land mobile radio
LPR	License plate recognition
LTE	Long term evolution
MABAS	Multi-agency box alarm system
MBSFN	Multicast-broadcast single frequency network
MIMO	Multiple input multiple output
MM	Multimedia
MMES	Multimedia emergency services
MMS	Multimedia messaging service
MPSS	Ministry of public safety and security of korea
MS	Mobile station
MSS	Mobile satellite service
MTTR	Mean time to repair
NB	Narrowband
NPSTC	National Public Safety Telecommunications Council
NPSTC BBWG	NPSTC broadband working group
OAM	Operation administration and maintenance
OOBE	Out-of-band emissions
OTAP	Over-the-air-programming
OTAR	Over-the-air Re-keying
P25	Project 25 (P25 or APCO-P25) is a suite of standards for digital radio communications for use by federal, state/province and local public safety agencies in North America
PBS	Public broadcasting service
PDA	Personal digital assistant
PIM	Personal information manager

PP	Public protection
PPDR	Public protection and disaster relief
PS	Public safety
PS SoR	Public safety statement of requirements
PSDN	Public switched data network
PSTN	Public switched telephone network
PSWAC	Public safety wireless advisory committee
PTT	Push to talk
PWS	Public warning system
QAM	Quadrature amplitude modulation
QoS	Quality of Service
QPSK	Quadrature phase shift keying
QVGA	Quarter video graphics array
RAN	Radio access network
RDM	Relayed device mode
RF	Radio frequency
SAG	Spectrum aspects group of UMTS forum
SD	Standard definition
SDO	Standards Development Organization
SDR	Software defined radio
SINR	Signal-to-interference-plus-noise ratio
SMS	Short message service
SNR	Signal-to-noise ratio
SWAT	Special weapons and tactics teams
TCC	Text control centre
TDD	Time division duplex
TD-LTE	Long-term evolution time-division duplex
TDMA	Time division multiple access
TETRA	European terrestrial trunked radio
TG	Talk group
TIA	Telecommunications industry association
TMS	Text message service
TR	Technical report (3gpp)
TRS	Trunk radio system
TS	Technical specification (3GPP)
UAE	United Arab Emirates

UAE TRA	UAE Telecommunications Regulatory Authority
UAS	Unmanned aerial system
UE	User equipment
UHF	Ultra high frequency
UI	User interface
UL	Uplink
UMTS	Universal mobile telecommunications system
USA	United States of America
VHF	Very high frequency
VPN	Virtual private network
WAN	Wide area network
WB	Wideband
WI	Work item
WRC	World radiocommunication conference
WTDC	World telecommunication development conference

Annex 3

PPDR Operations

A3.1 Operating environments

Systems supporting PPDR efforts should be able to operate in a variety of radio operating environments explained in this section.

The purpose of further explaining distinct radio operating environments is to define scenarios that, from the radio perspective, may impose different requirements on the use of PPDR applications and their importance.

The identified PPDR scenarios could serve as the basis for identifying PPDR requirements and may complement the estimate for spectrum.

It is extremely beneficial to have PPDR systems and equipment capable of being deployed and set-up rapidly for large emergencies, public events and disasters (e.g. severe floods, large fires, the Olympics,) are extremely beneficial. It is also important to have the ability to reallocate both uplink and downlink (data) rates in order to manage radiocommunication resources more efficiently.

PPDR scenarios include day-to-day operations, large emergencies or public events and disasters. These can have distinct characteristics and may impose different requirements for PPDR communications, including a variety of cross-border operational activities (e.g. medical emergency, cross-border pursuit, Air-Ground-Air and Direct Mode Operations). The overall safety of PPDR personnel can be significantly improved via more functional, more reliable, and more extensive wireless communications systems.

It is preferable that PPDR radiocommunications equipment support all of these radio operating environments. For any of these environments, information may be required to flow to and from units in the field to the operational control centre and specialist knowledge centres.

Although the type of operator for systems supporting PPDR is usually a regulatory and national matter, systems supporting PPDR may be satisfied by public or private operators, or a combination of the two.

A3.2 Categories of operations

It is useful to identify categories of PPDR communications based on the situations in which they may be deployed. Public protection radiocommunications, for example, are used by responsible agencies and organizations dealing with maintenance of law and order, protection of life, property and emergency situations under the following types of scenarios:

- Day-to-day operations – planned (category “PP1”);
- Large emergency and/or public events – planned and/or unplanned (category “PP2”);
- Disasters – unplanned (category “DR”).

A3.2.1 Day-to-day operations

Day-to-day operations encompass the routine operations that PP agencies and organizations conduct within their jurisdictions. Typically, these operations are within national or, where appropriate, regional borders. Generally, most PP spectrum and infrastructure requirements are determined using this scenario, taking into account the need for extra capacity to cover unspecified emergency events. Day-to-day operations can be either mission-critical or non-mission-critical. For the most part, day-to-day operations are minimal for DR.

A3.2.2 Large emergency and/or public events

Large emergencies and/or public events are those to which PP and potentially DR agencies and organizations respond in a particular area of their jurisdictions. Meanwhile, agencies must still perform standard PP operations elsewhere within their jurisdictions. The size and nature of the event may call for additional PPDR resources from adjacent jurisdictions, cross-border agencies, or international organizations. In most cases, there are either plans in place, or there is some time to plan and coordinate the requirements.

A large fire encompassing 3-4 blocks in a large city (e.g. New York, New Delhi) or a large forest fire are examples of large emergencies under this scenario. Likewise, a large public event (national or international) could include the Commonwealth Heads of Government Meeting (CHOGM), G8 Summit, the Olympic Games, etc.

Generally, additional radiocommunication equipment for large events is brought to the area as required. This equipment may, or may not, be linked to the existing PP network infrastructure. In Tables A4-1 and A4-2, large emergencies or public events are referred to as PP (2).

A3.2.3 Disaster relief

Disasters can be caused by either natural or human activity. For example, natural disasters may include earthquakes, major tropical storms, major ice storms, floods, etc. Examples of disasters caused by human activity include large-scale criminal or terrorist acts, or situations of armed conflict. Generally, both the existing PP communications systems and special on-scene communication equipment, brought by DR agencies and organizations, are employed.

In DR operations, public protection agencies will use an entire variety of communications provided by PP networks to meet their operational requirements. Even in areas where suitable terrestrial services exist, satellite systems will play a significant role in disaster relief operations, because the

existing terrestrial infrastructure may have been damaged or may be unable to cope with the increased traffic loads resulting from the disaster situation. In these situations, satellite services can offer a reliable solution.

The frequency bands used by Mobile Satellite Service (MSS) systems are generally harmonized at a global level. However, the cross border circulation of terminals in disaster situations is a critical issue, as recognized in the Tampere Convention. It is imperative that neighbouring countries that may possess satellite terminals as part of their contingency planning offer the initial essential communications needed, with minimum delay. To this end, advanced bilateral and multilateral agreements are desirable and may be accomplished through, for example the Global Mobile Personal Communications by Satellite Memorandum of Understanding (GMPCS-MoU).

Some PPDR agencies/organizations and amateur radio groups use High Frequency (HF) narrowband systems, allowing the use of data modes of operation as well as voice. Other capabilities, such as digital voice, high-speed data and video have been implemented using either terrestrial or satellite network services.

A3.3 Localized Communication Services

The degree of reliability required for PPDR communications is such that PPDR systems need to continue operating in cases where there is no coverage, where coverage is inadequate or network infrastructure is harmed by the disaster by failures or both and to have the ability to manage capacity.

In such an event localized communication services comprising Isolated Base Stations, Relayed Device Mode operation and Device-to-device operation between PPDR users is required as an immediate solution for maintaining or re-establishing communications. The importance of the provisions of those services is summarized in Table A5-3 of Annex 5.

Methods of achieving a localized service between users are also needed either through deliberate user action or as a result of devices leaving the network coverage.

A3.4 Examples of PPDR network deployment scenarios and technical implementation

When considering these sections, it is important to note that public protection organizations currently use various arrangements of mobile systems or a combination thereof, as described below in Table A3-1².

² Examples of the types of mobile systems can be found in Recommendations ITU-R M.1073, ITU-R M.1457, ITU-R M.1801, ITU-R M.2012 and in Report ITU-R M.2014.

TABLE A3-1

Arrangements of mobile systems used by public protection agencies

Item	Network ownership	Operator	User(s)	Spectrum assignment
A	PP organization	PP agency	PP exclusive	PP
B	PP organization	Commercial	PP exclusive	PP
C	Commercial	Commercial	PP exclusive	PP or commercial
D	Commercial	Commercial	Shared with PP priority	PP or commercial
E	Commercial and PP organization	Commercial and PP organization	Shared with PP (e.g. Virtual Private Network (VPN) or PPDR as a preferential subscriber with suitable assigned priority)	Commercial
f)	Commercial	Commercial	Shared with PP treated as ordinary customer	Commercial

A3.4.1 Dedicated PP systems owned and operated by Government/PP agencies

As shown in Table A3-1 (item a), PP agencies have traditionally relied on their own, purpose-built networks, using dedicated spectrum, to meet their unique operational requirements. Under such an approach, PP organizations have their own infrastructure and control their systems' full capabilities during times of emergencies. PP organizations are able to dynamically change the performance of the service as the situation demands, so that PP decision-makers can make the appropriate decisions based on the best available information. With dynamic control of their systems, PP agencies can determine the level of security, reliability, robustness, and survivability of those systems.

A3.4.2 Dedicated PP systems owned by agencies' but operated by commercial entities

A variation of the dedicated PP system approach (shown as item b in Table A3-1), involves use of PP agency-owned systems that are operated by commercial networks. In some countries, however, PP agencies have expressed concerns with the concept of operational reliance on commercial operators, and with the motivation or willingness of commercial entities to meet the functional and performance requirements specified by the PP sector.

These concerns are focused on:

- assurances with regard to communications security and priority access;
- the level of network "hardening" compared to their traditional networks, including susceptibility to failure, intrusion and sabotage;
- requirements for a range of more ruggedized user devices (e.g. for motorcycles, marine craft, aircraft and handheld applications) that contain chipsets that may differ in robustness from those provided to commercial consumers;
- commercial networks that do not extend into less-populated areas (while noting that investment constraints on PPDR networks often result in such coverage shortcomings); and
- reliance on commercial operators' commitments to maintain mission-critical services, especially during major incidents.

However, where these concerns have been addressed, successful arrangements of mobile systems as described in item b) of Table A3-1 can result.

A3.4.3 Dedicated PPDR systems owned and operated by commercial

Under these service management arrangements, summarized as Item c, the PPDR network is owned and operated by a commercial entity. Reasons for this approach include flexibility for funding the build-out and maintenance of the network.

These networks enjoy the same benefits as the dedicated PP agencies and organizations networks and are used in some countries today. In some cases, such networks are not favoured due to privacy and security concerns.

A3.4.4 PPDR agencies using commercial networks as a special subscriber

As an alternative (or complementary) approach to deployment of a dedicated PPDR network, a further option (Item d) that might be considered by PPDR agencies and organizations is the use of commercial services as a special subscriber group. To satisfy PPDR operational needs, such an arrangement may involve negotiating special commercial terms for such features as:

- priority access privileges, especially relating to emergencies and disaster events;
- extended coverage arrangements that may go beyond areas ordinarily considered viable for commercial services;
- enhanced minimum Grade of Service (GoS), reliability and robustness, in the context of potential equipment failure, power failure and natural disaster scenarios;
- dynamically reconfigurable push-to-talk group-calling functions, in order to facilitate efficient and effective multi-agency co-ordination and response to events; and
- special encryption and authentication/security features, to ensure an appropriate level of network traffic integrity to protect PPDR operational communications.

At a domestic level, this option would provide a degree of natural harmonization of spectrum resources and technology compatibility among PPDR agencies. Depending on the agreements made between agencies and commercial operators, this option also could result in seamless interoperability across agencies and jurisdictions. This would not necessarily translate, however, into international interoperability. In this case, harmonization among administrations would be subject to sovereign decisions by each country and associated agreements to adopt a common spectrum and technology approach.

In some cases, the cost to PPDR agencies and organizations of paying for such generic features as listed above may be less than the cost of deploying a dedicated PPDR network (since a large proportion of the underlying network and its functionality will be almost entirely subsidized by the larger 'base-load' of commercial users). However, this is dependent on a full cost analysis between the commercial and dedicated network options.

For example, many of the additional costs, such as for extended coverage, may provide indirect yet tangible benefits for the broader customer base.

Therefore, PPDR agencies and organizations may not bear the full amount of associated additional capital or operational costs. Consequently, this option may present a significantly lower capital and operational cost burden for national/local governments in comparison to deploying a dedicated network. Relevant savings could instead be directed toward further extending coverage and increasing functionality to a much greater degree than would otherwise be possible under a dedicated network approach. Furthermore, this option could negate the need for dedicated spectrum for PPDR, which could result in license cost savings for PPDR agencies and organizations. With regard to special PPDR requirements for user terminal devices, including issues of robustness, air and marine

certification, and special mounting arrangements, sourcing arrangements may either be via the commercial network operator (who retains User Equipment (UE) authentication responsibility) or directly managed by the relevant PPDR agencies and organizations. In the latter case, there may also be a need for special arrangements to address UE authentication setup procedures.

On the assumption that the priority access, coverage, functionality and security concerns are met, there may yet be lingering concern over the degree of control that PPDR agencies and organizations can exert over their access usage, as well as the functional configuration of network resources.

This network sharing approach could provide the following benefits:

- access to new capabilities when required by both commercial and PPDR users;
- improved access to more radiocommunication resources for other uses;
- provision of better services and applications to consumers by the commercial operators; and
- access to a large ecosystem of terminals, integrated seamlessly in existing and future devices, providing hand-over among the various IMT systems as well as between different frequency bands, while also providing backward compatibility and international roaming.

A3.4.5 Sharing the public operator's infrastructure (e.g. as a Shared RAN)

Under this model (Item e), PPDR agencies and organizations share the common radio access network (RAN) infrastructure with a commercial operator but own and be responsible for operation of their own switching nodes, authentication nodes, gateways, and user management facilities. Such arrangements are specifically aimed at reducing expenditures on duplication of the radio network portions of commercial systems – and for shared use of the scarce radio spectrum resource.

With this option, PPDR agencies and organizations have greater operational management control over their “networks” and users, because they share ownership of the system or, alternatively, enter into a contractual agreement that provides them the necessary level of control over the system in times of crisis. This requires that the system infrastructure be built to accommodate the required functions and features that PPDR agencies and organizations demand in order to execute their various missions.

It is expected that there will still be a need for negotiated commercial arrangements to cover additional requirements including: priority access in times of crisis, extended coverage, network reliability/robustness, and security. This option may provide improved coverage, capacity and the expanded functionality found in modern all-Internet Protocol (IP) public networks.

In this approach, coexistence of established, dedicated PPDR radiocommunication networks alongside commercial mobile broadband networks would need to continue into the foreseeable future. If a VPN-type model is to be adopted, detailed functional and coverage requirements need to be agreed between PPDR agencies and organizations and commercial network operators, and the contractual arrangements and tariff plans need to be negotiated to fit within financial budget constraints. Agreements with regard to response times to service outages, regular maintenance, technology upgrades, capacity expansions, and even arbitration, change of ownership or commercial circumstance terms need to be determined.

Such an integrated approach could reduce capital and operational costs, harness the power of the larger commercial ecosystem and provide seamless multimedia services to PPDR agencies and organizations. There may also be cost savings for PPDR agencies and organizations if no license fees are required for spectrum. It should be noted that systems described in Report ITU-R M.2014 may still be used.

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.” So, the network deployment scenarios described in Items d) and e) may enable PPDR networks to gain access to extra commercial channels or capacity during emergencies that cannot be made available on a permanent basis.

In some countries, network deployment scenarios described Annex 4 are currently used by PP agencies and organizations to supplement their own systems or in some cases to provide all their communications requirements, but not necessarily for all the features and requirements specified in Tables A4-1 and A5-1. It is likely that this trend will continue into the future, particularly with the introduction of advanced wireless technologies, such as IMT.

Some of the applications listed in Annex 4 may depend significantly on commercial systems, while other applications for the same PP agencies and organizations may be totally independent of commercial systems.

Annex 4

PPDR Applications and related examples

The Tables in this Annex consist of PPDR applications and related examples divided into its applicability for narrow-, wide- and broadband.

All applications in the "Narrowband" part are to be considered generic and should be covered by the systems providing for both, wideband and broadband as mentioned in Tables A4-2 and A4-3.

TABLE A4-1
Generic / Narrowband Part

Application	Feature	PPDR Example	Importance ⁽¹⁾			
			PP (1)	PP (2)	DR	
Voice	Person-to-person	Selective calling and addressing	H	H	H	
	One-to-many	Dispatch and group communication	H	H	H	
	Talk-around/direct mode operation	Groups of portable to portable / mobile-mobile in close proximity without infrastructure	H	H	H	
	Push-to-talk	Push-to-talk	H	H	H	
	Instantaneous access to voice path	Push-to-talk and selective priority access	H	H	H	
	Phone interconnect	Telephone call from/to radio subscriber		H	H	M
		Dispatcher terminal		H	H	H
		Multi select		H	H	H
	CAD	Computer aided dispatch	H	H	H	
Security	Voice encryption/scrambling	H	H	M		
Facsimile	Person-to-person	Status, short message	L	L	H	
	Emergency alert	Pressing the emergency button causes alert at the TG or dispatcher	H	H	H	
	Security	Data encryption/scrambling	H	H	H	
	One-to-many (broadcasting)	Initial dispatch alert (e.g. address, incident status)	L	L	H	
Messages	Person-to-person	Status, short message, short e-mail	H	H	H	
	One-to-many (broadcasting)	Initial dispatch alert (e.g. address, incident status)	H	H	H	
Security	Priority/instantaneous access	Man down alarm button	H	H	H	
	Emergency alert	Pressing the emergency button causes alert at the TG or dispatcher	H	H	H	
	Emergency call	Priority voice call caused by pressing the emergency button	H	H	H	
Location Telemetry	Location status	GPS latitude and longitude information	H	M	H	
	Sensory data	Vehicle telemetry/status	H	H	M	
		EKG (electrocardiograph) in field	H	H	M	
	Environmental information including sensory data on air quality, temperature, contamination, radiation levels etc.	M	M	M		
Database interaction (minimal record size)	Forms based records query	Accessing vehicle license records	H	H	M	
		Accessing criminal records/missing person	H	H	M	
		Computer aided dispatch directly to field resources	M	M	L	
	Forms based incident Report	Filing field Report	H	H	H	

⁽¹⁾ The importance of that particular application and feature to PPDR is indicated as high (H), medium (M), or low (L). This importance factor is listed for the three radio operating environments: "Day-to-day operations", "Large emergency and/or public events", and "Disasters", represented by PP (1), PP (2) and DR, respectively.

Systems providing for Wideband PPDR should support also the Narrowband applications as described in Table A4-1.

TABLE A4-2
Additional Wideband Part

Application	Feature	PPDR Example	Importance ⁽¹⁾		
			PP (1)	PP (2)	DR
Messages	E-mail possibly with attachments	Routine e-mail message	M	M	L
Privacy	Security	Data encryption/scrambling	H	H	H
Data Talk-around/direct mode operation	Direct unit to unit communication without additional infrastructure	Direct handset to handset, on-scene localized communications	H	H	H
Database interaction (medium record size)	Forms and records query	Accessing medical records	H	H	M
		Lists of identified person/missing person	H	H	H
		Computer aided dispatch directly to field resources	H	M	L
		Computer aided dispatch directly to field resources	H	M	L
		GIS (geographical information systems)	H	H	H
Text file transfer	Data transfer	Filing report from scene of incident	M	M	M
		Records management system information on offenders	H	M	L
		Downloading legislative information	M	M	L
Image transfer	Download/upload of compressed still images	Biometrics (finger prints, facial recognition)	H	H	M
		ID picture (car number plate recognition)	H	H	M
		Building layout maps	H	H	H
Telemetry	Location status and sensory data	Vehicle status	H	H	H
OTAP	Over the air programming	UE programming through the air	H	H	H
Security	Priority access	Critical care	H	H	H
Video	Download/upload compressed video	Video clips	M	L	L
		Patient monitoring (may require dedicated link)	M	M	M
		Video feed of in-progress incident	H	H	M
Interactive	Location determination	2-way system	H	H	M
		Interactive location data	H	H	H

⁽¹⁾ The importance of that particular application and feature to PPDR is indicated as high (H), medium (M), or low (L). This importance factor is listed for the three radio operating environments: "Day-to-day operations", "Large emergency and/or public events", and "Disasters", represented by PP (1), PP (2) and DR, respectively.

Systems providing for Broadband PPDR should support also the Narrowband/Wideband applications as described in Tables A4-1 and A4-2.

TABLE A4-3

Additional Broadband Part

Application	Feature	PPDR Example	Importance ⁽¹⁾		
			PP (1)	PP (2)	DR
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	H	H	H
Privacy	Security	Data encryption/scrambling	H	H	H
Database access	Intranet/Internet access	Accessing architectural plans of buildings, location of hazardous materials	H	H	H
	Web browsing	Browsing directory of PPDR organization for phone number	M	M	L
Robotics control	Remote control of robotic devices	Bomb retrieval robots, imaging/video robots	H	H	M
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	H	H	H
		Image or video to assist remote medical support	H	H	H
		Surveillance of incident scene by fixed or remote controlled robotic devices	H	H	M
		Assessment of fire/flood scenes from airborne platforms	M	H	M
		Multi-scene video dispatch	L	H	H
		Multicast of Multimedia from a BS to multiple users in a given area (e.g. Pt to MPt/Broadcast)	L	H	H
		video conferencing 1 to 1, 1 to many, etc.	L	H	H
		Encrypted video streaming	M	M	M
Real-time multimedia intelligence	Real time optimization of video or other multimedia content	Optimize the use of allocated bandwidth to support multiple video streams	H	H	H
Imagery	Download/upload High resolution imagery	Downloading Earth exploration-satellite images	L	L	M
		Real-time medical imaging	M	M	M

⁽¹⁾ The importance of that particular application and feature to PPDR is indicated as high (H), medium (M), or low (L). This importance factor is listed for the three radio operating environments: "Day-to-day operations", "Large emergency and/or public events", and "Disasters", represented by PP (1), PP (2) and DR, respectively.

Annex 5

PPDR Requirements

This Annex contains tables of requirements indicating the degree of importance attaching to particular requirements under the three radio operating environments: “Day-to-day operations”, “Large emergency and/or public events”, and “Disasters”. The degree of importance attributed to each requirement may be different between administrations. It is up to the administrations to make a choice regarding the relative importance of these requirements.

Furthermore the Tables divided into generic user requirements supported by NB/WB/BB communications (Table A5-1) and additional requirements supported by broadband communications only (Table A5-2).

Table A5-3 contains the capabilities to be provided in Localized Communication Services Mode.

TABLE A5-1

Table of generic user requirement supported by PPDR narrow-, wide-, and broadband communications

User Requirement	Specifics	Importance ⁽¹⁾		
		PP (1)	PP (2)	DR
<i>1. System</i>				
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	H	H	M
Simultaneous use of multiple applications	Voice and data	H	H	M
	Multicast and unicast services			
	Real time instant messaging			
	Mobile office functions			
	VPN services			
	Telemetry			
	Remote control			
Priority access	Manage high priority and low priority traffic load shedding during high traffic	H	H	H
	Accommodate increased traffic loading during major operations and emergencies	H	H	H
	Exclusive use of frequencies or equivalent high priority access to other systems	H	H	H
Grade Of Service	Suitable grade of service	H	H	H

TABLE A5-1 (continued)

User Requirement	Specifics	Importance ⁽¹⁾		
		PP (1)	PP (2)	DR
Quality of Service	Quality of service	H	H	H
	Reduced response times of accessing network and information directly at the scene of incidence, including fast subscriber/network authentication	H	H	H
Reliability	Stable and resilient working platform	H	H	H
	Stable and easily operated management system	H	H	H
	Resilient service delivery	H	H	H
	High level of availability	H	H	H
	Localized communication services (e.g. isolated base stations, relayed mode operation, direct mode operation (DMO), Device-to-Device (D2D)).	H	H	H
Coverage	PPDR system should provide complete coverage within relevant jurisdiction and/or operation	H	H	M
	Coverage of relevant jurisdiction and/or operation of PPDR organization whether at national, provincial/state or at local level	H	H	M
	Systems designed for peak loads and wide fluctuations in use	H	H	M
	Enhancing system capacity during PP emergency or DR by techniques such as reconfiguration of networks with intensive use of direct mode operation	H	H	H
	Standalone transportable site in order to support local site operation	H	H	H
	Mobile site in standalone mode or wide area mode in order to increase coverage/ to enhance capacity.	H	H	H
	Air-to-ground communication	H	H	H
	Vehicular repeaters (NB and WB) for coverage of localized areas/ transportable site	H	H	H
	Reliable indoor/outdoor coverage including bi-directional amplifier (BDA)	H	H	H
	Coverage of remote areas, underground and inaccessible areas including bi-directional amplifier (BDA)	H	H	H
	Appropriate redundancy to continue operations, when equipment/infrastructure fails – standalone site services	H	H	H

TABLE A5-1 (continued)

User Requirement	Specifics	Importance ⁽¹⁾		
		PP (1)	PP (2)	DR
Capabilities	Rapid dynamic reconfiguration of system	H	H	H
	Control of communications including centralized dispatch, access control, dispatch (talk) group configuration, priority levels and pre-emption.	H	H	H
	Robust OAM offering status and dynamic reconfiguration	H	H	H
	Internet Protocol compatibility (complete system or interface with)	M	M	M
	Robust equipment (hardware, software, operational and maintenance aspects)	H	H	H
	Portable equipment (equipment that can transmit while in motion)	H	H	H
	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)	H	H	H
	Fast call set-up and instant push-to-talk (PTT) group call operation	H	H	H
	Location services	H	H	H
	Communications to aircraft and marine equipment, control of robotic devices	M	H	L
	One touch broadcasting/group call/ATG – announcement to all or some of talk groups and session establishment	H	H	H
	Terminal-to-terminal communications without infrastructure (e.g. direct mode operations/talk-around), vehicular repeaters	H	H	H
	Emergency alert - Pressing the emergency button causes alert at the TG or dispatcher	H	H	H
	Emergency call - Priority voice call caused by pressing the emergency button	H	H	H
	Recording and monitoring of audio and video transmissions for evidential purpose, for safety reasons and lessons learned.	H	H	H
	Multi select TG's - Ability to aggregate several TG's and establish one call for all of them	H	H	H
	Appropriate levels of interconnection to public telecommunication network(s).	H	H	H
	Stable and easy to operate management system	H	H	H
2. Security related requirements	End-to-end encrypted communications for mobile-mobile, dispatch and/or group calls communications (Voice and Data)	H	H	L

TABLE A5-1 (continued)

User Requirement	Specifics	Importance ⁽¹⁾		
		PP (1)	PP (2)	DR
3. Cost related	Open standards	H	H	H
	Cost effective solution and applications	H	H	H
	Competitive marketplace for supply of equipment and terminals	H	H	H
	Reduction in deployment of permanent network infrastructure due to availability and commonality of equipment	H	H	L
4. EMC	PPDR systems operation in accordance with national EMC regulations	H	H	H
5. Operational				
Scenario	Support operation of PPDR communications in any environment	H	H	H
	Implementable by public and/or private operator for PPDR applications	H	H	M
	Rapid deployment of systems and equipment for large emergencies, public events and disasters (e.g. large fires, Olympics, peacekeeping)	H	H	H
	Information to flow to/from units in the field to the operational control center and specialist knowledge centers	H	H	H
	Greater safety of personnel through improved communications	H	H	H
Compatibility	End-user to end-user connectivity	H	H	H
	Compatible with existing networks used for PPDR communications (e.g. trunked radio)	H	H	M
Interoperability	Intra-system: Facilitate the use of common network channels and/or talk groups	H	H	H
	Inter-system: Promote and facilitate the options common between systems	H	H	H
	Coordinate tactical communications between on-scene or incident commanders of the multiple PPDR agencies	H	H	H
6. Spectrum usage and management	Share with other terrestrial mobile users	L	L	M
	Suitable spectrum availability (NB, WB, BB channels)	H	H	H
	Minimize interference to PPDR systems	H	H	H
	Increased efficiency in use of spectrum	M	M	M
	Appropriate channel spacing between mobile and base station frequencies	M	M	M

TABLE A5-1 (*end*)

User Requirement	Specifics	Importance ⁽¹⁾		
		PP (1)	PP (2)	DR
7. Regulatory compliance	Comply with relevant national regulations	H	H	H
	Coordination of frequencies in border areas	H	H	M
	Provide capability of PPDR system to support extended coverage into neighbouring country (subject to agreements)	M	M	M
	Ensure flexibility to use various types of systems in other Services (e.g. HF, satellites, amateur) at the scene of large emergency	M	H	H
	Adherence to principles of the Tampere Convention	L	L	H
8. Planning	Reduce reliance on dependencies (e.g. power supply, batteries, fuel, antennas, etc.)	H	H	H
	As required, have readily available equipment (inventoried or through facilitation of greater quantities of equipment)	H	H	H
	Provision to have national, state/provincial and local (e.g. municipal) systems	H	H	M
	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)	H	H	H
	Maintain accurate and detailed information so that PPDR users can access this information at the scene	M	M	M

⁽¹⁾ The importance of that particular requirement to PPDR is indicated as high (H), medium (M), or low (L). This importance factor is listed for the three radio operating environments: "Day-to-day operations", "Large emergency and/or public events", and "Disasters", represented by PP (1), PP (2) and DR, respectively.

Table A5-2 below consists of additional requirements of PPDR that are supported by broadband communications only.

TABLE A5-2

Table of additional requirements for PPDR broadband communications

Technical Requirement	Specifics	Importance ¹		
		PP (1)	PP (2)	DR
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	H	H	M
	Scene video transmission	H	H	M
Quality of Service (see Attachment 1 below)	support of a prioritized range of services	H	H	H
	Guaranteed throughput	H	H	H
	Rapid session set up			
Coverage	RAN shall utilize maximum frequency reuse efficiency.	H	H	M
	Vehicular repeaters (Broadband) for coverage of localized areas/transportable site	H	H	H
Capabilities	Network system level management capability	M	H	H
	Network to perform basic self-recovery, expediting service restoration and a return to redundant operations.	H	H	H
	Packet data capability	H	H	H
	Rapid deployment capability - infrastructure and terminals	L	H	H
	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.	H	H	H
	A single common air interface (CAI) shall be utilized for the mobile broadband network.	H	H	H
	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.	L	L	L
Support	24-hour and 7 days-a-week (24/7) support for fixed and user equipment	H	H	H
	The network operations centre to operate on a 24x7x365 basis	H	H	H
	24/7 operations including field based support as necessary to maintain the availability of the network. In all cases, 24/7 access to call center support for issue resolution and assistance is also required	H	H	H

TABLE A5-2 (continued)

Technical Requirement	Specifics	Importance ¹		
		PP (1)	PP (2)	DR
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.	H	M	L
	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	H	H	H
	Robust network	H	H	H
	Self-managed network	H	H	H
	Coordinated development of business continuity plans.	H	H	H
	Resilient service delivery	H	H	H
	High availability design e.g. Diversity, redundancy, automated failover protection, backup operational processes.	H	H	H
	Network and operational testing to ensure data/call processing functionality is restored within predetermined and guaranteed time period following an outage	H	H	H
	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).	H	H	H
Availability	Service availability shall not be calculated to allow a prolonged outage even in one service area.	H	H	H
	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)	H	H	H
	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.	H	H	H
	Redundant elements should automatically detect failure and activate to provide service upon failures of primary network components	H	H	H
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.	H	H	L
	Support for domestic encryption arithmetic	H	H	L
	The encryption should support both point-to-point traffic and point-to-multipoint traffic.	H	H	L
	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.	H	H	H
	The network shall provide cryptographic controls to ensure that received transmissions have not been modified in transit.	H	H	L

TABLE A5-2 (continued)

Technical Requirement	Specifics	Importance ¹		
		PP (1)	PP (2)	DR
	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.	H	H	M
	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.	H	H	M
	The device authentication service shall utilize an open standard protocol.	H	H	H
	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.	H	H	H
	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.	H	H	H
	For organizations requiring user authentication, the network must facilitate sequential authentication of multiple users from a single device.	H	H	H
	System authorization management. Each organization shall be granted control over authorization by means of an administrative interface.	H	H	H
	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.	H	H	H
	For organizations requiring user authentication, the network must facilitate sequential authentication of multiple users from a single device	H	H	H
	The network should have dedicated PPDR system core	H	H	H
	3 rd party key management system	L	L	L
	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.	H	H	H
	Over the air key update	L	L	L
	The network shall enforce a configurable time-out, imposing a maximum time that each device may be connected to the network.	H	H	H

TABLE A5-2 (continued)

Technical Requirement	Specifics	Importance ¹		
		PP (1)	PP (2)	DR
	The network shall enforce an inactivity time-out, imposing a maximum time that each device may be connected to the network without transmitting data.	H	H	H
	Each PPDR organization shall be granted control of the network time out and inactivity setting for individual devices assigned to that organization.	H	H	H
	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.	H	H	H
	The network shall be capable of attack monitoring.	H	H	H
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.	H	H	H
	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.	H	H	H
	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.	H	H	H
	Devices may support a means of erasing (via best practice multiple pass overwriting of data storage media) all data stored on the device.	H	H	H
	Devices may support a means of encrypting data stored on the device such that user authentication is required for decryption.	H	H	H
Cost	Scalable system	L	H	M
	Open system architecture	H	H	H
	Implementable by public and/or private operator for PPDR applications	H	H	M
Interoperability	Interoperable/Interconnection with narrowband trunked systems. Interconnection required with: Inter RF subsystem Interface Voice service and Supplementary services Console supplementary Interface Voice service and Supplementary services	M	H	H
	Interoperable/ Interconnection with other broadband systems	H	H	H
	Interoperable/ Interconnection with satellite systems	H	H	H

TABLE A5-2 (*end*)

Technical Requirement	Specifics	Importance ¹		
		PP (1)	PP (2)	DR
	Interconnection with other information systems	H	H	H
	Interfaces that interconnect to other communication systems	H	H	H
	API compatible with standard interfaces	H	H	H
	Appropriate levels of interconnection to public telecommunication network(s) – fixed and mobile	M	M	M
Spectrum usage and management	Dynamic spectrum allocation	H	H	H
	Suitable spectrum availability (Broadband channels for uploads at maximum data rates)	H	H	H
	Reallocation of upstream and downstream rates	H	H	H

⁽²⁾ The importance of that particular requirement to PPDR is indicated as high (H), medium (M), or low (L). This importance factor is listed for the three radio operating environments: "Day-to-day operations", "Large emergency and/or public events", and "Disasters", represented by PP (1), PP (2) and DR, respectively.

Table A5-3 summarizes capabilities to be provided under in Localized communication services modes:

TABLE A5-3

Capabilities provided under Localized Communication Services

Localized Communication Services	Attributes	D2D/ DMO	Isolated Base Station		Relayed Mode	
			Isolated	Connected to Core	Isolated	Connected to Core
Topology						
Voice	Person-to-person	H	H	H	H	H
	One-to-many	H	H	H	H	H
	Push-to-talk	H	H	H	H	H
	Priority	H	H	H	H	H
	Encryption	H	H	H	H	H
	Emergency PTT	H	H	H	H	H
Multimedia (V+V+D)	Person-to-person	H	H	H	H	H
	One-to-many	H	H	H	H	H
	Push-to-MM	H	H	H	H	H
	Priority	H	H	H	H	H
	Encryption	H	H	H	H	H
	Real time video	H	H	H	H	H
Text Message / Instant Message	Person-to-person	H	H	H	H	H
	Emergency alert	H	H	H	H	H
	One-to-many	H	H	H	H	H

TABLE A5-3 (*end*)**Capabilities provided under Localized Communication Services**

Localized Communication Services	Attributes	D2D/ DMO	Isolated Base Station		Relayed Mode	
			Isolated	Connected to Core	Isolated	Connected to Core
Topology						
Multi Media Message / Instant Message	Person-to-person	H	H	H	H	H
	One-to-many	H	H	H	H	H
	SD	H	H	H	H	H
	HD	M	H	H	M	M
	Presence	H	H	H	H	H
Data Base Interaction		N	H	L	H	N
Location	Interactive location data	H	H	H	H	H
File Transfer		H	H	H	H	H
Client Server App.		N	H	L	H	N
Peer to Peer App		H	H	H	H	H
Miscellaneous	Software /Firmware update online	N	M	N	M	N
	GIS maps updates	N	M	N	M	N
	Automatic telemetries	N	M	N	M	N
	Hotspot on disaster or event area	H	H	H	H	H
	Alarming / paging	H	H	H	H	H

H Highly Desired
M Medium Importance
L Low Importance
N Not Needed

Attachment 1 to Annex 5

Classification of QoS

TABLE A5-4

QoS Class of Service	Description/Definition
QoS Class of Service 0	The network shall support a QoS class of service for real-time, jitter-sensitive, high interaction (cellular voice, push-to-talk voice, etc.).
QoS Class of Service 1	The network shall support a QoS class of service for real-time, jitter-sensitive, interactive (cellular voice, push-to-talk voice, etc.).
QoS Class of Service 2	The network shall support a QoS class of service for transaction data, highly interactive (signaling).
QoS Class of Service 3	The network shall support a QoS class of service for transaction data, interactive.
QoS Class of Service 4	The network shall support a QoS class of service for low-loss, real-time video.
QoS Class of Service 5	The network shall support a QoS class of service for low-loss only (short transactions, bulk data).
QoS Class of Service 6	The network shall support a QoS class of service for traditional applications of default IP networks.

Annex 6

Study on deployment of broadband and narrowband integrated PPDR network in China

A6.1 Background

The existing narrowband PPDR network has been deployed in many countries, which can supply mission critical voice and short message services for PPDR agency. It might be uneconomical to abandon the existing narrowband PPDR network completely. Meanwhile, it will be a huge investment to build a new nationwide broadband PPDR network based on LTE technology. Therefore, the broadband and narrowband integrated network deployment solution which is a cost-efficient, operable and quickly applied deployment mode need to be studied.

For example, in China, 12,000 narrowband base stations have been built and well-covered the whole nationwide to provide the PPDR applications for police and fire department. Dedicated broadband PPDR network might require several times or even more of base stations than narrow band network, with the approximate spectrum and technology as IMT. In the short-term, it would be a tremendous load for Chinese administration and PPDR agency to afford the huge investment to achieve the full coverage of broadband PPDR network at once.

The advantages of broadband and narrowband integrated network deployment solution areas following:

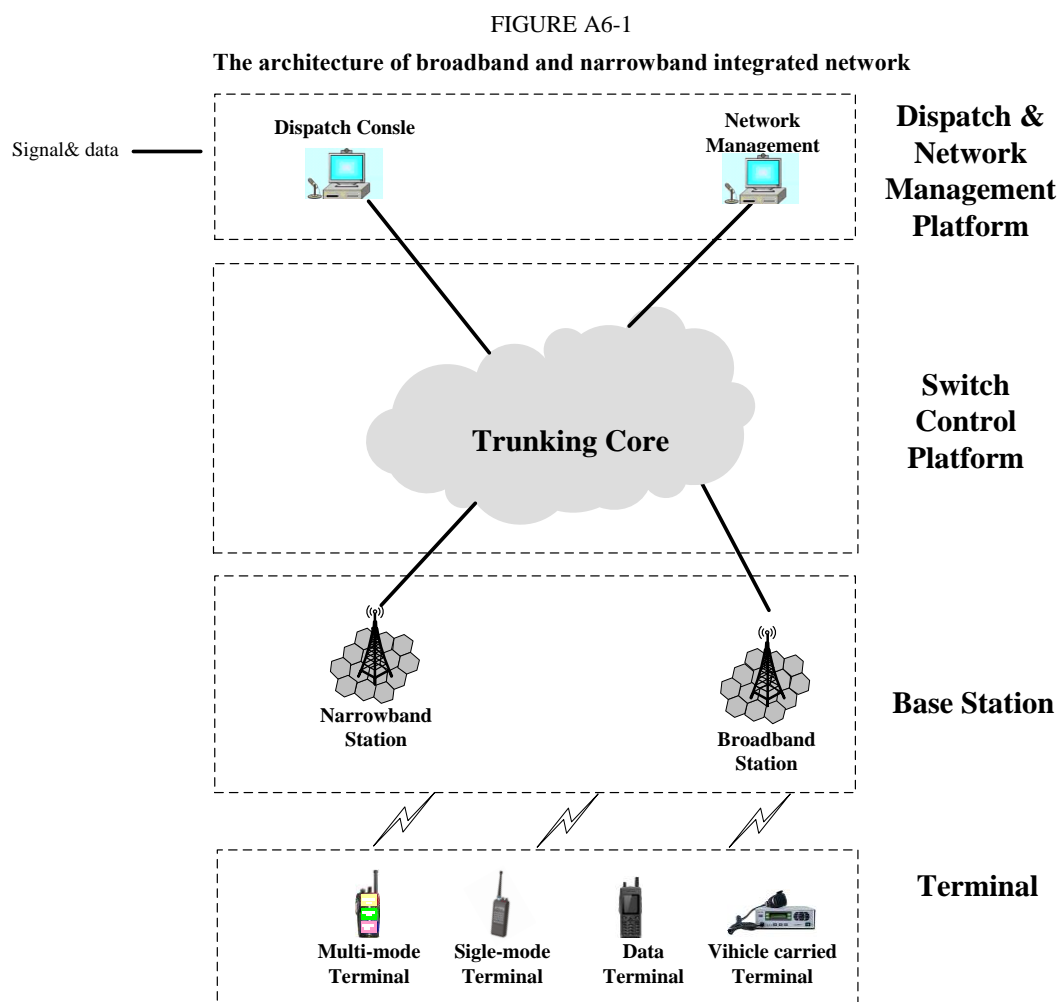
Make full use of existing backbone network and mature technology, protecting the original investment. The existing narrowband system can still meet the needs of PPDR requirements in voice and short message. Its equipment and operational mode are quite mature, which could be transplanted to the emerging broadband system. It can still be used rather than being replaced as a whole. If the integration with broadband system is achieved in the core network, the existing narrowband system resources can be reused to protect the original investment.

Have more flexible and practical investment options. With the hot spots and the key parts of the city being deployed firstly, the administration's budget might be well met by a step-to-step investment, avoiding the large one-off cost.

Obtain by natural robust invulnerability ability. In the case of disaster recovery, the two radio access networks in parallel may back up each other and it may improve the invulnerability of one single system.

A6.2 Deployment Schemes

The unified trunking core network is adopted in the broadband and narrowband integrated network with unified service procedures, interfaces, numbering of user and multi-mode terminals, which supports the broadband and narrowband trunking services (voice, data, image, multimedia services etc.). The overall architecture is shown below as Fig. A6-1.



The network architecture includes four layers: Terminal, base station, Switch control platform, Dispatching and network management platform.

Terminal layer includes various terminals, e.g. Multi-mode terminal, Single-mode terminal, Data terminal, Vehicle-carried terminal, which support the functions of video and voice codec, channel coding, modulation-demodulation, service applications, and human-machine interface.

Base station layer includes broadband and narrowband base stations to process signalling and data of PPDR functions (radio resource management, scheduling, user access control, user authentication, etc.). It allows the access of terminals with different modes and connects to the same trunking core network.

Switch control platform includes the unified trunking core network elements to provide the PPDR service control (service registration, service establishment and management, data routing and transmission, management of user information, etc.) and PPDR service traffic transfer including voice, video, and data. It supports the access of various base stations (e.g. narrowband base station, broadband base station), and interface with other communication systems (e.g. public network, satellite).

Dispatch and network management platform includes dispatch console and network management server. The major functions include dispatching and command, user service record, network management, etc. which provide the interfaces for manual operations.

A6.3 Operational procedure

On the circumstance that narrowband PPDR network had been build and fulfilled PPDR services, the integrated network operational procedure is as following.

Phase 1: some broadband PPDR sites are built and cover the hot spots separately; these distributed sites only offer broadband data services.

Phase 2: the broadband PPDR sites are deployed contiguously and cover all hot spots and large cities, working together with narrowband PPDR sites to offer all kinds of voice, video and data services, which play an important role in PPDR communication. But some rural, mountain and undeveloped areas may only be covered by narrowband.

Phase 3: the broadband sites cover the whole area of the country to offer all kinds of services. However, considering the backup and disaster recovery invulnerability, the narrow communication sites would support the narrow voice and low rate service for a period of time.

Annex 7

Information from international standardization organization on activities with regards to public protection and disaster relief (PPDR)

ATIS would like to draw attention to two ATIS WTSC Issues (i.e. work items) concerning PPDR:

- Issue P0032, Support of Public Safety Requirements in LTE Networks.
- Issue P0039, Public Safety Mission Critical Push to Talk (PTT) Voice Interoperation between Land Mobile Radio (LMR) and Long Term Evolution (LTE) Systems.

Furthermore, ATIS is working on activities related to PPDR as shown below:

Issue #	Title	Output
P0018	Proposed Joint ATIS/TIA Standards on Commercial Mobile Alerts Service (CMAS)	J-STD-100 J-STD-101
P0019	ATIS Standard on Commercial Mobile Alerts Service (CMAS) Specification for GSM/UMTS Using Cell Broadcast Service	ATIS-0700006
P0021	Canadian LAES Location Reporting	ATIS-0700009
P0024	ATIS Implementation Guidelines and Best Practices for GSM/UMTS Cell Broadcast Service	ATIS-0700007
P0026	CMAS via Evolved Packet System (EPS) Public Warning System (PWS)	ATIS-0700010
P0027	Cell Broadcast Entity (CBE) to Cell Broadcast Centre (CBC) Interface Protocol	ATIS-0700008
P0028	Certification and Testing of the CMAS C-Interface	J-STD-102
P0030	Implementation of 3GPP Common IMS Emergency Procedures for IMS Origination and ESInet/Legacy Selective Router Termination	ATIS-0700015
P0031	CMAS C1 Interface between PBS and CMSP Gateway	J-STD-101.a
P0033	Support for Delivery of Spanish Language Commercial Mobile Alerts System (CMAS) Alerts	ATIS-0700012 ATIS-0700013 ATIS-0700014
P0034	Automating Location Acquisition for Non-Operator-Managed Over-the-Top VoIP Emergency Services Calls	<i>Under development</i>
P0037	SMS-to-9-1-1	J-STD-110
P0038	Errata for ATIS and Joint ATIS/TIA Standards on Commercial Mobile Alerts Service (CMAS)	ATIS-0700006.a ATIS-0700010.a J-STD-100.a J-STD-101.a J-STD-101.b J-STD-102.a
P0040	Canadian Commercial Mobile Alerts Service (CMAS)	<i>Under development</i>
P0041	Commercial Mobile Alerts Service (CMAS) International Roaming	<i>Under development</i>
P0042	CMRS and TCC Provider Implementation Guidelines for the Joint ATIS/TIA SMS to 911 Standard (J-STD-110)	J-STD-110.01
P0043	Implementability Fixes for J-STD-110	J-STD-110.a
P0044	Extending ATIS-0700015 to address Multimedia Emergency Services (MMES)	<i>Under development</i>

CCSA has approved 4 Technical Specifications for B-TrunC System, which can support PPDR communications. The Technical Requirement for B-TrunC and Technical Specification for Radio interface have been published by Ministry of Industry and Information Technology of the People's Republic of China.

- 1 YD/T 2689-2014, Technical Requirement for B-TrunC System (Phase 1). The scope of the technical specification is the services, scenario, functions, performance, architecture and interfaces for B-TrunC System. The technical specification is already approved by CCSA and published by Ministry of Industry and Information Technology of the People's Republic of China.

- 2 YD/T 2741-2014, Technical Specification for Uu-T Interface of B-TrunC System (Phase 1). The scope of the technical specification is the physical layer protocol, Medium Access Control protocol, Radio Link Control protocol, Packet Data Convergence Protocol and Radio Resource Control protocol of radio interface for B-TrunC System. The technical specification is already approved by CCSA and published by Ministry of Industry and Information Technology of the People's Republic of China.
- 3 Technical Specification for Interface between UE and Trunking Core Network of B-TrunC System (Phase 1). The scope of the technical specification is the high layer protocol of the interface between UE and Trunking Core Network. The technical specification is already approved by CCSA.
- 4 Technical Specification for Interface between Trunking Core Network and Dispatcher of B-TrunC System (Phase 1). The scope of the technical specification is the application layer protocol of the interface between Trunking Core Network and Dispatcher. The technical specification is already approved by CCSA.

For the detailed specifications, please refer to the link below:

www.ccsa.org.cn/english/show_article.php?categories_id=737fa209-91aa-9568-4f4a-46b7e24c3a99&article_id=cyzx_f8ee005b-8736-e347-4737-5365989a05f6

Annex 8

Using higher power terminals to increase cell coverage in rural areas

High power user equipment (HPUE) can be deployed in rural areas for coverage extension purposes. The studies conducted for 3GPP Release 11 resulted in the development of specifications for a new power class of device (Power Class 1 UE 31 dBm) for ITU-R Region 2 in the 700 MHz Band. Coexistence studies were performed to make sure that when two systems are deployed in the same geographical area and in adjacent spectrum there would be no interference. The results of this analysis can be extended to any other bands where HPUE can be potentially deployed. Intuitively, as long as the absolute OOB of the HPUE is kept the same as the power class 3 UE 23 dBm, the victim receiver does not see any difference in terms of the interference between a HPUE and a power class 3 UE.

In a PPDR network, it is possible that in urban areas, the system is designed for power class 3 UE and in rural areas; the system is designed for HPUE. In this case, the cost can be reduced significantly while still providing necessary area/population coverage. It is calculated that the coverage of an LTE eNodeB could be increased by 300% through the use of HPUE.

This deployment scenario creates a system that has mixed power class UEs. However, this will not cause any problems and is well under the scope of 3GPP EUTRAN specification due to power control. Power control implies for a given service or throughput the network will set the maximum transmit power. So for a similar that service/throughput the network will define the same transmit power irrespective if the device is a higher power (31 dBm) or standard power (23 dBm).

A8.1 Link budget calculations for higher power LTE UE to meet PPDR broadband requirements of developing countries

The estimated increase in coverage using a higher transmit power is shown below assuming the maximum LTE cell radius to support a required 256 kbit/s UL throughput. The required SINR from

this service is chosen from 3GPP TS36.104 specification. The RF environmental assumptions are for a rural forested environment which is mapped to a Hata suburban propagation model used for the cell radius calculation.

Note that we have assumed the vehicular antenna gain to be -1 dBd as indicated in TIA TSB-88.1-C. Typical mobile cable loss is 2 dB and therefore the aggregate gain is $(-1 \text{ dBd} + 2.1-2) = -0.9$ dBi.

So using a HPUE will provide 300% increase in coverage area and will also reduce the number of sites required by roughly 66%. Additionally this would provide the ability to re-use existing high tower rural antenna sites. This analysis on link budget is similar to the other contributions in 3GPP that shows the benefit of a higher UE power class in terms of increase cell radius and higher cell throughput.

TABLE A8-1

Example link budget to show impact of higher UE transmit power (23 dBm vs. 31 dBm)

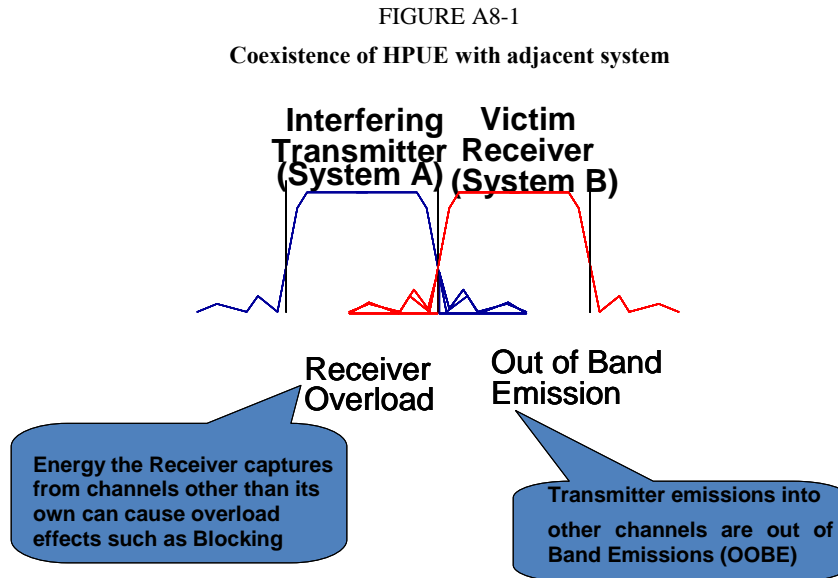
UE Power class	23 dBm	31dBm
UL Transmission configuration	256 kbit/s	256 kbit/s
RB allocation	10	10
Channel model	EVA 70 Hz	EVA 70 Hz
36.104 SINR (dB) @ 30% TPUT	-4.5	-4.5
IoT (dB)	4	4
eNB NF (dB)	3	3
eNB sensitivity (dBm)	-108.9	-108.9
UE Pc max after MPR (dBm)	22	30
Vehicular antenna gain - cable loss (dBi)	-0.9	-0.9
eNB antenna gain (dBi)	15	15
eNB cable loss (dB)	3	3
TMA gain (dB)	3	3
Shadowing margin (dB)	8.1	8.1
Maximum allowed path loss (dB)	137.0	145.0
UL transmission frequency (MHz)	790	790
eNB antenna height (m)	80	80
Vehicle antenna height (m)	1.5	1.5
RF environment	Forrested	Forrested
Maximum cell radius (km)	7.9	13.7

A8.2 Coexistence issues for high power LTE systems

Co-existence of HPUE with adjacent system

When two systems are deployed in the same geographical area and in adjacent spectrum, coexistence issues needs to be studied to make sure both systems are not causing harmful interference to each other. Typical interference mechanisms considered are Transmitter Out-Of-Band emission (OOBE), Receiver Blocking.

- Interfering Transmitter OOB: The OOB sums with the thermal noise floor of the victim receiver. The increase in noise power in the receiver requires an equal increase in desired signal power to maintain equivalent signal-to-noise ratio (SNR) and thus causes a reduction in the sensitivity of the victim receiver. The interference is due to noise that is on-channel to the victim receiver and there is nothing that can be done at the victim receiver to mitigate interference due to OOB.
- Victim Receiver Blocking: The interfering in-band Tx power itself can block reception of the desired signal or degrade sensitivity of the victim handsets or base stations.



To analyse the system impact of the victim system due to adjacent system interference, complex simulations are usually employed. In 3GPP, extensive studies have been conducted for various system coexistence issues, the results were used to derive RF requirements. The simulation methodology is described in 3GPP TR 36.942 (Radio Frequency (RF) system scenarios).

During the B14 LTE HPUE WI study phase, comprehensive simulations have been conducted by the industry to study the interference issue between B14 HPUE and adjacent LTE system's eNBs, both due to OOB and due to Rx blocking. Four companies have run the Monte-Carlo simulations to analyse the interference impact from HPUE to adjacent LTE systems and the results are shown in Fig. below (based on the results reported in 3GPP TR 36.837).

Both the average throughput degradation and cell edge user (5-percentile) throughput degradation were simulated, and results are compared with the impact from a baseline system with 23 dBm UEs. Table below shows the delta ACLR needed for HPUE in order to achieve the similar impact to B13 700 MHz systems from power class 3 (23 dBm) UEs.

It can be seen that due to the deployment difference (HPUE are mainly deployed in rural area with bigger cell radius), an ACLR value increase of up to 6 dB is enough for HPUE to co-exist with adjacent LTE system for different type of network power control algorithms. However, it was eventually decided that the ACLR of HPUE should be 7 dB higher (37 dB) than the power class 3 UE (30 dB). In the meantime, HPUE shall have the same absolute output RF spectrum emission requirement as a power class 3 UE (see 3GPP TS 36.101 subclause 6.6).

FIGURE A8-2

Impact of HPUE to adjacent systems (based on results reported in TR 36.837)

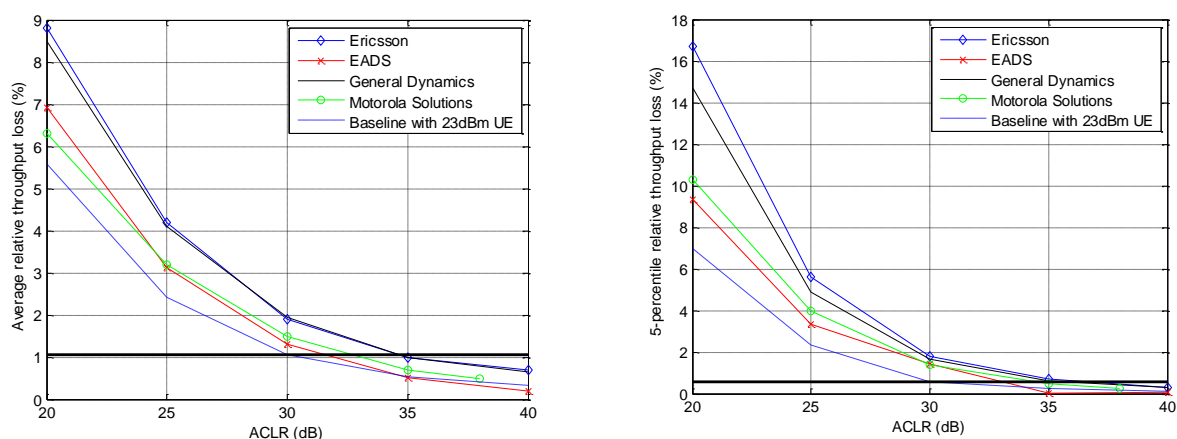


TABLE A8-2

B14 HPUE (+31 dBm) ACLR offset value (dB) to achieve similar interference as the baseline

Power control Parameters	Company	Power control set 1A		Power control set 2A	
		Average throughput	5% CDF	Average throughput	5% CDF
1A/2A	Ericsson/ST-Ericsson	<5	<5	<5	<5
1A/2A	EADS	5	3.6	2	4
1A/2A	General Dynamics Broadband	4.6	5.4	2.9	3.3
1A/2A	Motorola Solutions	4.5	3.5	3	3

(Table 5.4.2.6-2 from 3GPP TR 36.837)

The results of this analysis can be extended to any other bands where HPUE can be potentially deployed. Intuitively, as long as the absolute OOB of the HPUE is kept the same as the power class 3 UE, the victim receiver does not see any difference in terms of the interference between a HPUE and a power class 3 UE. The blocking level at the victim receiver is higher for HPUE; however, it is still well under the tolerance of LTE eNBs.

Co-existence of HPUE in the same system

HPUE is usually deployed in rural areas for coverage extension purpose. In a PPDR network, it is possible that in urban areas, the system is designed for power class 3 UE and in rural areas; the system is designed for HPUE. In this case, the cost can be reduced significantly while still providing necessary area/population coverage.

This deployment scenario creates a system that has mixed power class UEs. However, this will not cause any problems and is well under the scope of 3GPP EUTRAN specification due to power control. Power control implies for a given service or throughput the network will set the maximum transmit power. So for a similar that service/throughput the network will define the same transmit power irrespective if the device is a higher power (31 dBm) or standard power (23 dBm).

In this case higher power > 23 dBm would only be used at the edge of the cell to provide an increase in coverage/throughput.

Additionally, the maximum transmit power of a UE is always under the control of the network in a per cell basis, i.e. the network can signal different maximum allowed transmit power of the UE for each cell irrespective of the Power Class of the device. When a HPUE move from rural into urban area, it will obey the max power rule set by the urban cell. Similarly, if a power class 3 UE move to rural areas, it can switch to power class 1 mode if the network allows. So in this case the network can limit the maximum power of any device in its network on a per cell bases.

Annex 9

37 functional requirements for the nationwide mission critical PPDR wireless communication system

TABLE A9-1

Table of functional requirements for the nationwide mission critical PPDR broadband wireless communication system

Note: 37 functional requirements are generated from five Generic Requirements: Survivability and Resilience (7), Capability to Respond Disaster (10), Security (5), Interoperability (3) and Operational Efficiency (12)

Functional Requirements)	Specifics	Importance ⁽¹⁾		
		PP (1)	PP (2)	DR
1. Survivability and Resilience				
Direct mode Operation	Function for Direct mode operation between mobile terminals/ Repeater and gateway Functions in order to achieve survivability of mobile terminal in any unexpected circumstances	H	H	H
Mobility Support	Function that enables mobile terminal to sustain established bearer path in order to sustain service continuity thus to maintain stable service status in any system coverage area	H	H	H
Capability to respond to burst call attempt	Function that provides capability to respond to burst call attempt in order to support stable system operation thus ultimately to prepare the unexpected highest demand of call situation, i.e. disaster	H	H	H
Standalone mode operation of base station	Function that provides base station with stand-alone operation mode in which base station provides communication bearer path in case of any possible failure in mobile backhaul and switching centre in order to support group communication function in corresponding area	M	M	M

TABLE A9-1 (continued)

Functional Requirements)	Specifics	Importance ⁽¹⁾		
		PP (1)	PP (2)	DR
Duplication/transport media management	Function that provides automatic switch-over of transport network media (Microwave, satellite and other IP networks) for switching centre, base station and access network in case of any failure and stable provision of seamless communication service	M	M	M
Communication service quality	Function that satisfies voice, video and data service provided by domestic professional technical group under the stable provision of seamless communication service	M	M	M
Backup Restoration	Function that provides automatic back-ups and restoration of important data in management system (Group management information, call attempt history and failure logs) in order to support remote situation recognition around mobile terminal e.g. hijacking by system management node (Dispatcher)	M	M	M
2. Capability to respond disaster				
Individual Call	Function that provides one-to-one communication by using of caller ID in order to give a call to a specific person	H	H	H
Group call	Function that provides one-to-many communication. This function provides effective communication capability that enable group based communication in order to provide effective communication service in specific circumstances e.g. mutual cooperation or assessing situation	H	H	H
Area selection	Function that all mobile terminals registered in specific area (single or multiple base stations) shall be selected and called by use of system management interface in order to respond fast in specific regional catastrophe	H	H	H
Dynamic Group Number Assignment	Function that creates new communication group, delete communication group and re-program existing communication group remotely according to situational change	H	H	H
Call Interruption	Function that suspend on-going group call to join the conversation in order to enable high priority intervention call by dispatcher	H	H	H
Emergency call	Function that provides prioritized network access by use of special UI on mobile terminal e.g. pushing emergency button in order to provide immediate communication service without waiting time	H	H	H
Identification of mobile terminal location	Function that provides location of mobile terminal by use of satellite or base station location measurement technology in order to identify the location of mobile terminal in any situation	H	H	H

TABLE A9-1 (continued)

Functional Requirements)	Specifics	Importance ⁽¹⁾		
		PP (1)	PP (2)	DR
Video call	Function that provides one-to-one or one-to-many video call for the rapid situation recognition and response	M	M	M
Ambient Listening	Function that provides remote listening of mobile terminals whose transmitter was turned on by remote system manager (or dispatcher) in order to support remote situation recognition around mobile terminal e.g. hijacking by system management node (or dispatcher)	M	M	M
Multiple group communication reception by single mobile terminal	Function that provides single mobile terminal with reception of multiple group communication in order to support situation monitoring function for multiple group communications	M	M	M
3. Security				
Validation or barring the use of mobile terminal	Function that authenticates or invalidates the use of mobile terminal in order to sustain security in case of stolen/missing terminals)	H	H	H
Encryption	Function that eavesdrops or wiretaps by encrypting the bearer path in order to achieve communication security in case of specific events and talks between major commanders	H	H	H
Authentication	Function that provides valid communication service to authenticated users with registration of mobile terminal/users	H	H	H
Provision of security enforcement interface	Function that provides standardized interface to inter-work with external security equipment in order to conform the security standard of law and institution	H	H	H
Integrated Security Control	Function that provides integrated security control e.g. intrusion detection, prevention against security attack in order to protect from possible hacking attack in order to provide integrated security monitoring system to respond to any security issues	H	H	H
4. Interoperability				
Openness/conformity of standards	Function that provides inter-working interface specification and conform domestic/international standards to achieve interoperability between different vendor's system	M	M	M
Call establishment	Function that provides minimal call establishment and delay time to support interoperability between different vendor's systems	M	M	M
Network interconnectivity	Function that provides interoperability with legacy PPDR network (UHF/VHF/TRS ...) and public network (PSTN, PSDN and Internet) in order to support information sharing	M	M	M

TABLE A9-1 (end)

Functional Requirements)	Specifics	Importance ⁽¹⁾		
		PP (1)	PP (2)	DR
5. Operational efficiency				
Rapid propagation of situation messages	Function that provides message (included data) broadcasting by system management (dispatcher) or mobile terminal for rapid propagation of situation status	H	H	H
Security of communication capacity	Function that provides security of subscriber capacity required for stable PPDR operation of telecommunication network in various situations	H	H	H
Full duplex multi group communication	Function that provides simultaneous calls with different multiple mobile terminals in order to support conference call in any situation	M	M	M
Data service	Function that supports data communication service while in single/multiple calls in order to support seamless communication capability	M	M	M
Recording of voice/video call	Function that provides recording of specific voice/video call in order to secure the evidence in any cases of incident/accident	M	M	M
Caller ID representation	Function that provides caller identification by use of ID appearing on any display unit in order to identify any communication-protocol-related offense case by use of caller ID	M	M	M
Remote network management	Function that provides remote management function to authenticate/register mobile terminal as well as network O&M in order to provide efficient network management function e.g. remote programming of mobile terminal	M	M	M
Network Management system	Function that provides centralized network management systems which give the overall information of network operation in order to provide the management functions e.g. system control, securing of account and security, resolve of obstacle and performance	M	M	M
Reporting function	Function that provides automatic report generation function about subscriber information, traffic statistics and alarm history in order to provide systematic response to any cases	M	M	M
Call capacity enhancement	Function that provides the enhancement communication capacity in the system and base stations when insufficient communication capacity issue arises in specific area in disaster situation	M	M	M
Broadband/Network coverage	Function that provides enhanced throughput speed and nationwide network coverage in order to establish mobile broadband and secure nationwide network coverage	M	M	M
Frequency Multiplexing	Function that provides high communication capacity in a single frequency band in order to support efficient management of limited radio frequency resource	M	M	M

⁽¹⁾ The importance of that particular requirement to PPDR is indicated as high (H), medium (M), or low (L). This importance factor is listed for the three radio operating environments: "Day-to-day operations", "Large emergency and/or public events", and "Disasters", represented by PP (1), PP (2) and DR, respectively.

Annex 10

Requirements and example scenario of PPDR use by agencies in India

It is observed that the day to day requirements of Police Organizations and Security agencies are often overlooked due to use of the peak requirements for disaster relief communication taking precedence over day to day requirements, which in any case is part and parcel of the functions of Police and Public Protection Agencies. In some developing countries, the Telecommunication networks belonging to Police and Public Protection agencies are separate, distinct and dedicated. And, this requirement flows from the day- to- day functions carried out by these agencies which are not only administrative but are highly operational and deals with all sorts of emergencies.

- 1 The day-to-day operations of Public Protection agencies involving maintenance of law and order activities encompass the routine operations that these agencies conduct within their jurisdiction. These operations are within national borders. The Public Protection (PP) telecommunication infrastructure is planned to cover unspecified emergency events also. During large emergencies and/or public events Public Protection and potentially Disaster Relief agencies respond to in a particular area of their jurisdiction; however public protection agencies are still required to perform their routine operations during rescue and relief activities;
- 2 The public protection agencies have installed telecommunication infrastructure within their geographical boundaries to meet their day to day requirements and also to cater for the disaster activities. In an event of any disaster both the existing Public Protection communications systems and special on-scene communications equipment brought by Disaster Relief organizations are employed.
- 3 The disaster management uses different mode of communication during each phase of disaster. The telecommunication used during pre-disaster phase is (and can be) entirely dependent on commercial networks while post disaster phase ad-hoc telecommunication/radio communication is established at disaster site. Moreover the network of PP agencies is to provide security, including end-to-end encryption, and secure terminal/network authentication. Efficient and reliable communications within a Public Protection organization also needs to be secured by use of appropriate encryption techniques to meet their own security requirement.
 Since the public protection telecommunications are wide spread, their communication requirement are secured and reliable communication as compared to disaster relief telecommunication which are concerned with the specific zone of disaster only. Moreover there is no stringent requirement of secure communication for disaster relief activities.
- 4 So, the telecommunication requirement of public protection agencies is paramount and encompass the communication requirement of disaster relief agencies so the requirement of PP and DR must be looked in reference to some commonalities wherein DR can only be a subset of PP radio communications.
- 5 Another issue that needs attention is the suggestion of intermingling of commercial network with the PP Network. It is seen that during the emergency/disaster events which requires immediate response and actions, the Public/Commercial Network get overloaded due to excessive calling by the public during a short span of time. Due to vulnerability of commercial network getting choked at the time of emergency/disaster event it is not possible to rely on this mode of communication by agencies involved in emergency/disaster relief and response.
- 6 On the other hand the initial response for such emergency situations by PP agencies is very critical and any delay in response may lead to greater loss of life and property.

In the event of common networks/ shared network resources between the PP Agencies and the commercial network it is likely that the network of PP agencies get affected/ hampered due to the excessive loading in the commercial network. Therefore, it is recommended that the common/shared network resources with the commercial network by PP agencies are not required.

FIGURE A10.1

Simplified Representation of Practical deployments

