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Radiocommunication objectives and requirements for Public Protection and Disaster Relief (PPDR)

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REPORT ITU-R M.2377-0

Radiocommunication objectives and requirements for Public Protection and Disaster Relief (PPDR)

(2015)

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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.

Examples of different national and/or regional spectrum requirements for narrowband and wideband PPDR systems are addressed in Annex 6 of this report. Further examples of broadband spectrum calculations and scenarios are addressed in Annex 7 (7A to 7F). Annex 8 contains a study on deployment of broadband and narrowband integrated PPDR network from one country. Annex 11 provides an example of functional requirements from one country.

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 11 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 fast[1] 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;

l) to be scalable in order to suit small and large agencies, without sacrificing the ability to interoperate;

m) to provide for quick deployment of temporary infrastructure and services as well as recovery from failure;

n) 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.

o) to support the need for high level of security without compromising the response time.

p) 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 p) 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 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 availability[2] (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 coverage[3] 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.

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[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 centers/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 center;
– 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.

Table A5-1 and Table 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 systems[4]. 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-12)** encourages administrations 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.

Annex 6 (Narrow/Wideband technologies) and Annex 7 (Broadband technologies) provide examples of estimations of the spectrum requirements for PPDR.

The ITU-R has developed several generic methodologies that may assist administrations in this regard, including:

– Recommendation ITU-R M.1390: contains a methodology for the calculation of terrestrial spectrum requirement estimates for IMT-2000. This methodology could also be used for other public land mobile radio systems.
– Recommendation ITU-R M.1768: describes a methodology for the calculation of terrestrial spectrum requirement estimation for International Mobile Telecommunications (IMT).

The spectrum calculation methodology employed in some of the calculations shown in Annex 6 and 7 follows the format of the generic methodology that was used in Recommendation ITU R M.1390, with the values selected for the PPDR applications taking into account the fact that PPDR utilizes different technologies and applications (including dispatch and direct mode).

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 appliations 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 9.

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. Antalya, 2006)** on bridging the standardization gap; and

– Resolution **34 (Rev. Dubai, 2014)** 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 8 provides an example of a flexible deployment scheme in China for reference.

Annex 12 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

ITU-R Resolutions, Recommendations and Reports

Resolution ITU-R 53 – The use of radiocommunications in disaster response and relief.

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Recommendation ITU-R M.1042 – Disaster communications in the amateur and amateur-satellite services.

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Recommendation ITU-R M.1768 - Methodology for calculation of spectrum requirements for the terrestrial component of International Mobile Telecommunications

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.2012 - Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications Advanced (IMT-Advanced)

Recommendation ITU-R M.1073 - Digital cellular land mobile telecommunication systems

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

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Annex 2

Terminology and Abbreviations

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 ITU-R Resolution **646 (WRC-12)** 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, serveability 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 – ITU-T Recommendation 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 Communications (RDM)

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.

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)
EIRP	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	Telecomunications 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 telecomunication 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 center and specialist knowledge centers.

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 6-1 and 6-2, 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 neighboring 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 A3-1[2].

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 A6-1 (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 A6-1), 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;

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[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.

– 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 A6-1 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 Tables 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 & 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
1. *System*				
Support and integration of multiple applications	Integration of multiple applications (e.g. voice and low/medium speed data) at high speed network to service localized areas with intensive in scene activity	H	H	M
Simultaneous use of multiple applications	Voice & data	H	H	M
	Multicast and unicast services			
	Real time instant messaging			
	Mobile office functions			
	VPN services			
	Telemetry			
	Remote control			
	Location of terminals			
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 are 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 telecommu-nication network(s).	H	H	H
	Stable & 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 & 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 & 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 & 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 & 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

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
	3rd 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
	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

Technical Requirement	Specifics	Importance[1]		
		PP (1)	PP (2)	DR
	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
	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

Technical Requirement	**Specifics**	**Importance[1]**		
		PP (1)	**PP (2)**	**DR**
Spectrum usage & 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

(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 A5-3 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**	
Topology		**Isolated**	**Connected to Core**	**Isolated**	**Connected to Core**	**Isolated**
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

Localized Communication Services	Attributes	D2D/ DMO	Isolated Base Station		Relayed Mode	
Topology		**Isolated**	**Connected to Core**	**Isolated**	**Connected to Core**	**Isolated**
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 of 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

Spectrum requirements for narrow-band and wide-band PPDR

This Annex addresses the estimation of the spectrum requirements for public protection and disaster relief (PPDR), particularly within the context of WRC-03 agenda Item 1.3. The Annex provides:

– a method of calculating amounts of spectrum;

– system scenarios and assumptions;

– validation of the method with respect to existing applications;

– examples of several administrations projections of their requirements by 2010;

– determining the amount of spectrum which should be harmonized in the context of future applications; and,

– conclusions.

The calculation method given in this Annex is provided for assisting in consolidating spectrum requirements.

Note that the contents of Annexes 6 and 7 were agreed to be considered as the basis for the possible future development of a new ITU-R Report or Recommendation on methodologies for estimating PPDR spectrum requirements. Based on the outcome of that effort, the contents of these Annexes might be incorporated into this new Report or Recommendation on PPDR spectrum estimation.

A number of administrations have used the modified methodology in Attachment 1 to this Annex to estimate their national spectrum requirements for PPDR. That methodology, however, is not the only means by which administrations may calculate their national PPDR spectrum needs. Administrations have the discretion to use whatever method, including the modified methodology; they choose to determine their own spectrum requirements for PPDR.

Many PPDR entities around the world are currently evaluating the migration from analog wireless systems to digital for current telecommunication services. The migration to digital will also allow these entities to add some advanced services to these first generation PPDR digital systems. However, there are many more advanced services that PPDR users are likely to demand as they become available to commercial users. While spectrum demand has been estimated and allotted for 2nd and 3rd generation commercial wireless services, similar analysis has not been done for PPDR users.

The greatest demand for public protection and disaster relief telecommunication services is in large cities where different categories of traffic can be found, i.e. that generated by mobile stations (MS), vehicle mounted or portable stations, and personal stations (PS) (hand-held portable radios). The trend is toward designing the PPDR telecommunication network to provide services to personal stations both outdoor and indoor (building penetration).

Maximum demand will be created after a disaster, when many PPDR users converge on the emergency scene utilizing existing telecommunication networks, installing temporary networks, or utilizing vehicle mounted or portable stations. Additional spectrum may be required for interoperability between various PPDR users and/or additional spectrum may be required for installation of temporary disaster relief systems.

Considerations on spectrum demand should take into account the estimated traffic, the available and foreseeable techniques, the propagation characteristics and the time-scale to meet the users' needs to the greatest possible extent. Consideration on frequency matters should take into account that the traffic generated by mobile systems, as well as the number and diversity of services, will continue to grow. Any estimation of the traffic should take into consideration that in the future, non-voice traffic will constitute an increasing portion of the total traffic and that traffic will be generated indoors as well as outdoors by personal and mobile stations.

A6.1 Methods of projecting spectrum requirements

Description of the methodology

This public protection and disaster relief spectrum calculation methodology (Attachment 1 to this Annex) follows the format of the generic methodology that was used for the calculation of IMT-2000 terrestrial spectrum requirements (Recommendation ITU-R M.1390). The use of the methodology can be customized to specific applications by selecting values appropriate to the particular terrestrial mobile application. Another model based on a generic city approach was also used (see Attachment 2 to this Annex)

The values selected for the PPDR applications must take into account the fact that PPDR utilizes different technologies and applications (including dispatch and direct mode).

Required input data $

– the identification of PPDR user categories, e.g. police, fire, ambulance;
– the number of users in each category;
– the estimated number of each user category in use in the busy hour;
– the type of information transmitted, e.g. voice, status message and telemetry;
– the typical area to be covered by the system under study;
– the average cell size of base stations in the area;
– the frequency reuse pattern;
– the grade of service;
– the technology used including RF channel bandwidth.
– the demographic population of the city.

A6.2 Validity of the methodology

Discussion

Several aspects of the methodology, the assumptions inherent in the model as presented, timing, method of calculation, frequency reuse, possibility of separating the calculations for PPDR, urban as opposed to rural situations, and the nature of the operating environments were clarified in the ITU-R study period 2000-2003.

Specifically, the following issues were raised in connection with the methodology:

a) Applicability of IMT-2000 methodology to PPDR?

b) Substituting the geographic areas (e.g. urban, in-building, etc.) in the IMT-2000 methodology by service categories (NB, WB, BB)?

c) Use of assumptions of PSWAC Report[4] with regard to assessment of traffic for PPDR?

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[4] United States Public Safety Wireless Advisory Committee, Attachment D, Spectrum Requirements Subcommittee Report, September 1996. In considering this Annex during the development of this Report it was noted that the PSWAC was chartered to consider total spectrum requirements for the operational needs of public safety entities in the United States through the year 2010; so this Report may not be relevant to requirements in 2015.

d) Treatment of traffic for PP and DR together?

e) Use of cellular configurations/hotspots in estimating spectrum requirements for PPDR?

f) Applicability of the methodologies for the simplex/direct mode operations?

In response, the following points should be noted:

1 While the document is based on the methodology used for IMT-2000, the method is capable of including all technologies from simplex to cellular and beyond. Further work will be required to establish appropriate classifications of service environment categories (e.g. for fire, police, emergency medical services) and model systems for those environments, in order to make the calculations needed for each type of use and technology.

2 Terms of the calculation of spectrum requirements public protection activities could be separated from disaster relief activities, with separate and appropriate parameter values and assumptions being applied for each case. However, it was noted that there are instances where public protection equipment, which is used for routine operations on a day-by-day basis, may also be employed in times of disaster. In these cases, there would need to be some means established to avoid double counting when undertaking calculations of spectrum requirements.

3 In considering the service environments (i.e. narrowband, wideband and broadband), it was noted that those used for IMT-2000 may also have some applicability to PPDR communications.

Validity study

One administration undertook the performance of a study of the validity of the results predicted by this methodology. This was done by inputting the parameters of a working narrowband PPDR system into a calculator spreadsheet and checking that the amount of spectrum it predicted was the same as that actually used by the system. It was concluded that this methodology is valid, provided it is used carefully and correctly. It was also concluded that although not validated by actual measurement, one might extrapolate that model works as well for wideband and broadband as long as the input parameters are carefully considered and applied. Another administration reported on a similar study undertaken in which examples were developed for typical cities, obtaining spectrum estimates that are consistent with other examples previously reported. Using two examples of the application of the methodology – one referred to a middle-sized city and the other to an industrial district – it was concluded that the methodology is appropriate for the evaluation of spectrum needed for PPDR radiocommunication.

A6.3 Critical parameters

In assessing the validity of the methodology several critical parameters were identified which must be selected with care. Studies in estimating spectrum requirements for terrestrial land mobile systems were conducted by some administrations showed that the most influential input parameters are:

– cell radius/frequency reuse;

– number of users.

The results of the studies were shown to be heavily dependent upon cellular architecture parameters. The studies show that changes in cell radius will change the spectrum estimate significantly. While it is true that reducing the size of the cell radius will increase the reuse of the spectrum and thereby reduce the spectrum requirement, the cost of the infrastructure will also significantly increase. Similar considerations apply to other parameters, e.g. using sectored cells decreases the necessary spectrum by a factor of three. For these reasons it is advisable that careful studies of cellular structures are undertaken prior to the final specification of the spectrum to be reserved to PPDR.

In preparing the estimate of spectrum amounts, it will be necessary to get consensus on the input data to put into the generic methodology. Noting the sensitivity of the results to such critical parameters, the input data will need to be selected carefully and will need to reflect a balance between the amount of spectrum sought and the infrastructure cost. Countries that need less spectrum than the full amount identified will have greater freedom in network design, the degree of frequency reuse and infrastructure cost.

A6.4 Extrapolated upper limit

Korea undertook a parametric analysis of the result of spectrum calculations made for Bhopal, Mexico City, and Seoul. The analysis also used data for other cites taken from other contributions to the work of the ITU-R. The parametric analysis provided insight into PPDR spectrum requirements and it showed that considering the worst case/dense user situation a maximum of 200 MHz (Narrowband: 40 MHz, Wideband: 90 MHz, Broadband: 70 MHz) is needed for the PPDR spectrum requirement for WRC-03 Agenda item 1.3.

A6.5 Results

Results of estimates of amount of spectrum required by the year 2010 for PPDR

A summary of results of spectrum estimates for PPDR scenarios presented by some administrations using the proposed spectrum calculator methodology is given below. However the data in the last row was made using various other methods.

Location	Narrowband (MHz)	Wideband (MHz)	Broadband (MHz)	Total (MHz)
Delhi	51.8	3.4	47.6	102.8
Bhopal	24	5.2	32.2	61.4
Seoul	15.1	90.5	69.2	174.8
Mexico City	46.2	39.2	50.2	135.6
Paris	16.6	32.6	–	–
Medium city (Italy high penetration)	21.1	21.6	39.2	81.9
Medium city (Italy medium penetration)	11.6	11.4	39.2	62.2
Industrial district (Italy)	3.0	3.0	39.2	45.2

A6.6 Discussion of results

The totals listed in the above chart cover all the PPDR applications and both uplink and downlink requirements. The results range between 45 MHz and 175 MHz. Such results have to be compared with the national current and forecasted situations taking into account the whole spectrum needed by PPDR users.

There are several reasons for the wide range of spectrum estimates. First, the studies done in obtaining these results showed that the spectrum estimates are very dependent on density and the penetration rate. Second, administrations based their spectrum calculations on whatever scenarios they deemed most appropriate. For example, Korea based its spectrum calculations on the worst case/most dense user requirement. Italy chose to examine the PPDR spectrum needs of a typical medium-size city in Italy. Other administrations used other scenarios.

Many countries do not envisage having physically separate PP and DR networks in their countries and therefore see global/regional harmonization as applying to both PP and DR requirements. Other countries may decide to calculate separate PP and DR spectrum requirements.

Attachment 1 to Annex 6

Methodology for the calculation of public protection and disaster relief terrestrial spectrum requirements

ATT1-1 Introduction

The function of this attachment is to present an initial forecast for spectrum needed by public protection and disaster relief (PPDR) by the year 2010. A spectrum calculator methodology, following the format of ITU methodology for the calculation of IMT-2000 spectrum requirements, is developed. Because of the differences between commercial wireless users and PPDR wireless

users, alternate methodologies are proposed to calculate PPDR user penetration rates and define the PPDR operational environments. Methodologies are also proposed to define PPDR net system capacity and PPDR quality of service.

The analysis is based upon current PPDR wireless technologies and expected trends in demand for advanced applications. From that, an initial forecast can be made for the amount of spectrum needed for specific advanced telecommunication services through the year 2010.

ATT1-2 Advanced services

The advanced services likely to be available to PPDR community by year 2010 are:

– voice dispatch;
– telephone interconnect;
– simple messages;
– transaction processing;
– simple images (facsimile, snapshot);
– remote file access for decision processing;
– Internet/intranet access;
– slow video;
– full motion video;
– multimedia services, like videoconference.

ATT1-3 A Spectrum prediction model

This spectrum prediction model follows the methodology for the prediction of IMT-2000 Spectrum Requirements (Recommendation ITU-R M.1390).

The steps to be used are:

Step 1: Identify the geographical area over which the model will be applied.

Step 2: Identify the population of PPDR personnel.

Step 3: Identify the advanced services used by the PPDR community through year 2010.

Step 4: Quantify technical parameters that apply to each of the advanced services.

Step 5: Forecast the spectral need for each advanced service.

Step 6: Forecast total spectral need for PPDR through year 2010.

See Attachment A for a comparison of the proposed PPDR methodology versus the Recommendation ITU-R M.1390 methodology. See Attachment B for a flowchart of the proposed PPDR methodology.

ATT1-4 B Geographical area

Determine the PPDR user populations within the area of the study.

For this model, we do not need to investigate spectrum demand over an entire country. The area(s) of interest will be one or more of the major metropolitan regions within each country. The population density is highest in these areas. The proportion of PPDR personnel relative to the general population is expected to be highest here, also. Therefore, the demand for spectrum resources should also be highest in the major metropolitan area(s). This is similar to the IMT-2000 methodology where the geography and environments of only the most significant contributors to spectrum requirements are considered.

We need to clearly define the geographic and/or political boundaries of the metropolitan area of study. This may be the political boundary of the city or of the city and surrounding suburban cities and/or counties in the metropolitan area. We need general population data for the metropolitan area. This should be readily available from census data.

Instead of using general population density (population/km^2), the PPDR population and penetration rates must be determined. Within the geopolitical boundaries of the study area, PPDR population must be defined and divided by the area to determine the PPDR user density (PPDR/km^2).

Representative cell area (radius, geometry) needs to be determined for each operational environment within the geographic study area. This is dependent upon the population density, network design, and network technology. PPDR networks tend to utilize higher power devices and larger radius cells than commercial systems.

Follow IMT-2000 methodology A:

Define geographic boundaries and area (km^2) of each environment.

ATT1-5 C Operational environments versus service environments

In the methodology for the calculation of IMT-2000 spectrum requirements, the analysis is conducted on physical operational environments. These environments vary significantly in cell geometry and/or population density. PPDR population density is much lower than the general population density. PPDR networks generally provide wireless services into all physical environments from one, or more, wide-area network(s). This model defines “service environments” which group services by the type of PPDR wireless telecommunication network: narrowband, wideband and broadband. Many services are currently, and will continue to be, delivered by networks using narrowband channels (25 kHz or less). These include dispatch voice, transaction processing, and simple images. More advanced services like internet/intranet access and slow video will require a wideband channel (50 to 250 kHz) to deliver these higher content services. Full motion video and multi-media services will require very wide channels (1 to 10 MHz) to deliver real-time images. These three “service environments” are likely to be deployed as separate overlapping networks utilizing different cell geometries and different network and subscriber technologies.

Also, the services offered within each “service environment” will need to be defined.

Modified version of IMT-2000 methodology A1, A2, A3, A4, B1:

Define “service environment”, i.e. narrowband, wideband, broadband.

Determine direction of calculations for each environment: uplink, downlink, combined.

Determine average/typical cell geometry within each “service” environment.

Calculate representative cell area within each “service” environment.

Define services offered in each “service environment” and net user bit rate for each.

ATT1-6 D PPDR population

Who are PPDR users? These are personnel who respond to day-to-day emergencies and to disasters. They would typically be public protection personnel grouped into mission oriented categories, such as police, fire brigades, emergency medical response. For disasters the scope of responders may increase to include other government personnel or civilians. All these PPDR personnel would be using PPDR telecommunication services during an emergency or disaster. PPDR users may be combined together into categories that have similar wireless communication usage patterns, i.e. the assumption is that all users grouped into “police” category personnel would have similar demands for telecommunication services.

For this model, the categories will only be used to group PPDR users with similar wireless service usage rates. That is, for police, each officer may have a radio, so the wireless penetration rate is 100% for police. For ambulance crews, there may be two people assigned to an ambulance, but only one radio, so the penetration rate is only 50% for ambulance crews. The current penetration rate can easily be determined if the number of mobile and portable stations deployed is known. It is simply the ratio of the number of radios deployed to the number of PPDR users in that category.

We need to determine the PPDR user populations. This can be collected for each PPDR user category; police, law enforcement, fire brigade, emergency medical response, etc. This data may be collected from the specific metropolitan governments or PPDR agencies. This data may be available from several public sources, including annual budgets, census data, and reports published by national or local law enforcements agencies.

The data may be presented in several formats, which must be converted into the total counts from each source for each PPDR category within the area of study.

– Some data may be presented as specific PPDR user counts within a political sub-division; e.g. city A with a population of nnnnn has AA police officers, BB fire fighters, CC ambulance drivers, DD transit police, EE traffic wardens, and FF civilian support personnel.
– Some data may be presented as a percentage relative to the total population; e.g. there are XXX police officers per 100 000 population. This needs to be multiplied by the population within the area of study to calculate the total count for each PPDR category.
– There may be multiple levels of government within the area of study. The PPDR totals for each category need to be combined. Local police, county police, state police, and federal police could be combined into a single “police” category. The assumption is that all these “police” category personnel would have similar demands for telecommunication services.

Example of PPDR categories:

Regular Police	Fire Brigades	Emergency Medical Services
Special Police Functions	Part-time Fire	EMS Civilian Support
Police Civilian Support	Fire Civilian Support	
General Government Personnel	Other PPDR Users	

Growth projections for population and planned increases in PPDR personnel may be used to estimate the future number of PPDR personnel within the area of study in 2010. Analysis over the study area may show that some towns/cities within the area of study do not provide advanced PPDR services today, but plan to deliver those services within the next 10 years. Growth projection may simply be the application of the higher PPDR user population density figures from cities/towns using advanced wireless services today within the area of study to all parts of the study area.

Modified version of IMT-2000 methodology B2:

Determine PPDR population density within study area.

– Calculate for each mission-oriented category of PPDR user or for groups of PPDR users with similar service usage patterns.

ATT1-7 E Penetration rates

Instead of using penetration rates from commercial wireless market analyses, the PPDR penetration rates for current and future wireless telecommunication services must be determined. It is expected that the ITU-R survey on PPDR communications will supply some of this data. One method would be to determine the penetration rate of each telecommunication service within each of the PPDR categories defined above, then convert this to the composite PPDR penetration rate for each telecommunication service within each environment.

Modified version of IMT-2000 methodology B3, B4:

Calculate PPDR population density.

– Calculate for each category of PPDR user.

Determine penetration rate for each service within each environment.

Determine users/cell for each service within each environment.

ATT1-8 F Traffic parameters

The proposed model follows the IMT-2000 methodology. Traffic parameters used in examples below represent average for all PPDR users. However, these traffic parameters could also be calculated for individual PPDR categories and combined to calculate composite traffic/user. Much of this data was determined by PSWAC[5] and that busy hour traffic data will be used in the examples presented below. The "busy hour call attempts" are defined as the ratio between the total number of connected calls/sessions during the busy hour and the total number of PPDR users in the study area during the busy hour. The activity factor is assumed to be 1 for all services, including PPDR speech. Current PPDR systems do not use vocoders with discontinuous voice transmission, so PPDR speech continuously occupies the channel and the PPDR speech activity factor is 1.

Follow IMT-2000 methodology B5, B6, B7:

Determine busy hour call attempts per PPDR user for each service in each environment.

Determine effective call/session duration.

Determine activity factor.

Calculate busy hour traffic per PPDR user.

Calculate offered traffic/cell (E) for each service in each environment.

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[5] Report from September 1996, see Footnote 4 in Annex 6 A6.2 for details

Example of traffic profiles from PSWAC Report[6]:

PSWAC traffic profile summary		Inbound (E)	Outbound (E)	Total (E)	(s)	Ratio of busy hour to average hour	Continuous bit rate (at 4 800 (bit/s)
Voice	Current busy hour	0.0073484	0.0462886	0.0536370	193.1	4.00	85.8
	Current average hour	0.0018371	0.0115722	0.0134093	48.3		21.5
	Future busy hour	0.0077384	0.0463105	0.0540489	194.6	4.03	86.5
	Future average hour	0.0018321	0.0115776	0.0134097	48.3		21.5
Data	Current busy hour	0.0004856	0.0013018	0.0017874	6.4	4.00	2.9
	Current average hour	0.0001214	0.0003254	0.0004468	1.6		0.7
	Future busy hour	0.0030201	0.0057000	0.0087201	31.4	4.00	14.0
	Future average hour	0.0007550	0.0014250	0.0021800	7.8		3.5
Status	Current busy hour	0.0000357	0.0000232	0.0000589	0.2	4.01	0.1
	Current average hour	0.0000089	0.0000058	0.0000147	0.1		0.0
	Future busy hour	0.0001540	0.0002223	0.0003763	1.4	3.96	0.6
	Future average hour	0.00	0.00	0.00	0.34		0.15
Image	Current busy hour	0.0268314	0.0266667	0.0534981	192.6	4.00	85.6
	Current average hour	0.0067078	0.0066670	0.0133748	48.1		21.4

ATT1-9 G PPDR quality of service functions

The IMT-2000 methodology takes the offered traffic/cell data, converts it to the number of traffic channels required to carry that load in a typical cell reuse grouping, and then applies grade of service formulas to determine the number of service channels needed in a typical cell. The same methodology is proposed here, but the factors used for PPDR networks are significantly different.

For PPDR systems the reuse pattern is typically much higher than commercial wireless services. Commercial wireless services are normally designed to use low power devices with power control in an interference limited environment. PPDR systems are typically designed to be “coverage” or “noise” limited. Many PPDR systems use a mixture of high power vehicular devices and low power handheld devices, without power control. Therefore, the separation or reuse distance is much greater for PPDR systems, in the range of 12 to 21.

The technology modularity of PPDR systems is often different than commercial systems. There may be two or more networks covering the same geographic area, in different frequency bands, supporting the PPDR personnel from different levels of government or in different PPDR categories (federal networks may be independent of local networks; police networks may be independent of fire networks).

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6 Report from September 1996, see Footnote 4 in Annex 6 A6.2 for details

The result is networks with fewer channel resources per cell. PPDR networks are normally designed for higher coverage reliabilities, 95 to 97%, because they are trying to cover all operational environments from a fixed network. Commercial networks, with a revenue stream, can continuously adapt their networks to changing user needs. PPDR networks, funded with public monies, normally undergo minimal change in cell locations or service channels per cell over their lifetime of 10-20 years.

For PPDR services, availability of the channel must be very high, even during busy hours, because of the immediate need to transmit critical, sometimes life-saving, information. PPDR networks are designed for lower call blocking levels, <1%, as PPDR personnel need immediate access to the network during emergency situations. While many routine conversations and data transactions can wait several seconds for a response, many PPDR situations are highly tense and require immediate channel availability and response.

Loading varies greatly for different PPDR network topologies and for different PPDR situations. Many police or fire situations may require individual channels to be set aside for on-scene interoperability with very low loading, <10%. Conventional, single channel, mobile relay systems in use today typically operate at 20-25% loading, because unacceptable blockage occurs at higher loading. Large 20 channel trunked systems, which spread the load across all available channels, with a mix of critical and non-critical users, may be able to operate at acceptable levels for critical PPDR operations with busy hour loading of 70-80%.

The net impact causes the Erlang B factor for the average PPDR network to be higher, about 1.5, instead of the 1.1 to 1.2 factors seen with commercial services at 90% coverage and 1% blocking.

Follow IMT-2000 methodology B8:

Unique PPDR requirements:

Blocking = <1%

Modularity = ~ 20 channels per cell per network, results in a high Erlang B factor of about 1.5.

Frequency reuse cell format

= 12 for like power mobile or personal stations

= 21 for mixture of high/low power mobile and personal stations.

Determine number of service channels needed for each service in each “service” environment (NB, WB, BB)

ATT1-10 H Calculate total traffic

The proposed model follows the IMT-2000 methodology. The PPDR net user bit rate should include the raw data rate, the overhead factor and the coding factor. This is dependent upon the technology chosen for each service.

Information is coded to reduce or compress the content which minimizes the amount of data to be transmitted over an RF channel. Voice, which may be coded at a rate of 64 kbit/s or 32 kbit/s for wireline applications, is coded at rates of less than 4 800 bit/s for PPDR dispatch speech applications. The more the information is compressed, the more important each bit becomes, and the more important the error correction function becomes. Error coding rates from 50% to 100% of information content are typical. Higher transmission rates over the harsh multi-path propagation environment of an RF channel require additional synchronization and equalization functions, which use additional capacity. Also, other network access and control functions need to be carried along with the information payload (unit identity, network access functions, encryption).

PPDR systems in operation today use 50-55% of the transmitted bit rate for error correction and overhead.

For example: a technology for speech on narrowband channels may have a speech vocoder output rate of 4.8 kbit/s with a forward error correction (FEC) rate of 2.4 kbit/s and the protocol may be provisioned for another 2.4 kbit/s of overhead signalling and information bits, for a net user bit rate of 9.6 kbit/s.

Follow IMT-2000 methodology C1, C2, C3:

Define net user bit rate, overhead factors, coding factors for each service in each "service" environment.

Convert service channels from B8 back to per cell basis.

Calculate total traffic (Mbit/s) for each service in each "service" environment

ATT1-11 I Net system capacity

The net system capacity is an important measure of the spectrum efficiency of a wireless telecommunications system. The net system capacity calculation produces the maximum system capacity possible within the spectrum band being studied.

The proposed model follows the IMT-2000 methodology. However, the calculation of PPDR net system capacity should be based upon typical PPDR technologies, PPDR frequency bands, and PPDR reuse patterns, rather than the GSM model used in the IMT-2000 methodology.

Attachment C provides an analysis for several PPDR technologies currently in use against some existing PPDR spectrum allocations. These examples show maximum possible system capacity for the purpose of estimating future spectrum requirements. There are numerous other user requirements and spectrum allocation factors, not included here, that affect the functional and operational deployment of a network, the choice of technology, and the resulting network's spectrum efficiency.

Follow IMT-2000 methodology C4, C5:

Pick several PPDR network technologies.

Pick several representative frequency bands.

Follow same calculations format as GSM model.

Calculate typical net system capacities for PPDR land mobile radio technology.

ATT1-12 J Spectrum calculations

The proposed model follows the IMT-2000 methodology.

PPDR networks are very likely to have coincident busy hours. Therefore the alpha factor will be 1.0.

The number of PPDR personnel is likely to grow with general population growth. The demand for PPDR services is likely to increase following trends similar to the demand for commercial wireless telecommunication services.

The beta factor can be set to a number greater than 1.0 here, or the growth factor can be included in the net system capacity calculations.

Follow IMT-2000 methodology D1, D2, D3, D4, D5, D6:

Define alpha factor = 1.

Define beta factor = 1 (include growth under net system capacity, ignore other outside effects for example calculations).

Calculate spectrum need for each service in each “service” environment.

Sum up spectrum needs for each “service” environment (NB, WB, BB).

Sum up total spectrum need.

Examples

See Attachment 1.5 for a detailed narrowband voice example using London data from Attachment D.

Conclusion

It has been demonstrated that the IMT-2000 methodology (Recommendation ITU-R M.1390) may be adapted to calculate the system requirements for public protection and disaster relief communications (or applications). Methods have been provided to determine the PPDR user population and service penetration rates. “Service” environments have been defined over which PPDR spectrum requirements can be calculated. The factors necessary to adapt the IMT-2000 methodology to a PPDR methodology have been identified, including the development of a methodology to define PPDR net system capacity.

ATTACHMENT 1.1 TO ANNEX 6

Comparison of proposed methodology for the calculation of PPDR spectrum requirements to IMT-2000 methodology

IMT-2000 methodology (Recommendation ITU-R M.1390)	**IMT-2000 methodology**	**Proposed PPDR methodology**
A Geography		
A1 Operational Environment Combination of user mobility and user mobility. Usually only analyse most significant contributors.	**A1** Look at three physical environments with different user densities: urban area and in-building, pedestrian, vehicular users	**A1** PPDR user density is much lower and more uniform. PPDR users roam from one environment to another as they respond to emergencies. PPDR systems are usually designed to cover all environments (i.e. wide-area network provides in-building coverage). Instead of analyzing by physical environment, assume that there will likely be multiple overlapping systems each providing different services (narrowband, wideband, and broadband). Each service environment will probably operate in a different frequency band with different network architectures. Analyze three overlapping urban "service environments": narrowband, wideband, broadband.
A2 Direction of calculation	**A2** Usually separate calculations for uplink and downlink due to asymmetry in some services	**A2** Same
A3 Representative cell area and geometry for each environment type	**A3** Average cell radius of radius to vertex for hexagonal cells	**A3** Same
A4 Calculate area of typical cell	**A4** Omni cells = πi R^2 Hexagonal cells = $2.6 \cdot R^2$ 3-sector hex = $2.6/3 \cdot R^2$	**A4** Same

IMT-2000 methodology (Rec. ITU-R M.1390)	IMT-2000 methodology	Proposed PPDR methodology
B Market & traffic		
B1 Services offered	**B1** Net user bit rate (kbit/s) For each service: speech, circuit data, simple messages, medium multimedia, high multimedia, highly interactive multimedia	**B1** Net user bit rate (kbit/s) for each of the three PPDR service environments: narrowband, wideband, broadband
B2 Population density Persons per unit of area within each environment. Population density varies with mobility	**B2** Potential users per km^2 Relative to general population	**B2** Total PPDR user population within the total area under consideration. Divide PPDR population by total area to get PPDR population density. PPDR users are usually separated into well-defined categories by mission. Example: *Category* — *Population* Regular Police — 25 498 Special Police Functions — 6 010 Police Civilian Support — 13 987 Fire Suppression — 7 081 Part-time Fire — 2 127 Fire Civilian Support — 0 Emergency Medical Services — 0 EMS Civilian Support — 0 General Government Services — 0 Other PPDR Users — 0 **Total PPDR population — 54 703** Area under consideration. Area within well-defined geographic or political boundaries. Example: City of London = 1 620 km^2 PPDR population density = PPDR population/area Example: London = 33.8 PPDR/km^2

IMT-2000 methodology (Rec. ITU-R M.1390)	IMT-2000 methodology	Proposed PPDR methodology
B3 Penetration rate Percentage of persons subscribing to a service within an environment. Person may subscribe to more than one service	**B3** Usually shown as table, Rows are services defined in B1, such as speech, circuit data, simple messages, medium multi-media, high multimedia, highly interactive multimedia. Columns are environments, such as in-building, pedestrian, vehicular	**B3** Similar table. Rows are services, such as voice, data, video Columns are "service environments", such as narrowband, wideband, broadband. May collect penetration rate into each "service environment" separately for each PPDR category and then calculate composite PPDR penetration rate. Example: *Category* — *Population* (NB Voice) — *Penetration* Regular Police 25 498 100% Special Police Functions 6 010 10% Police Civilian Support 13 987 10% Fire Suppression 7 081 70% Part-time Fire 2 127 10% Fire Civilian Support 0 0 Emergency Medical Services 0 0 EMS Civilian Support 0 0 General Government Services 0 0 **Other PPDR Users** **0** **0** **TOTAL PPDR Population** **54 703** **Narrowband Voice** **PPDR Population** **32 667** PPDR penetration rate for narrowband "service environment" and voice "service": = Sum(Pop × Pen)/sum(Pop) = 59.7%

IMT-2000 methodology (Rec. ITU-R M.1390)	IMT-2000 methodology	Proposed PPDR methodology
B4 Users/cell Number of people subscribing to service within cell in environment	**B4** Users/cell = Pop density × Pen Rate × Cell area	**B4** Same
B5 Traffic parameters Busy hour call attempts: average number of calls/sessions attempted to/from average user during a busy hour Effective call duration Average call/session duration during busy hour Activity factor Percentage of time that resource is actually used during a call/session. *Example*: bursty packet data may not use channel during entire session. If voice vocoder does not transmit data during voice pauses	**B5** Calls/busy hour s/call 0-100%	**B5** Same Sources: PSWAC Report[7] or data collected from existing PPDR systems Same Same More likely that activity factor is 100% for most PPDR services.
B6 Traffic/user Average traffic generated by each user during busy hour	**B6** Call-seconds/user = Busy hour attempts × Call duration × Activity factor	**B6** Same
B7 Offered traffic/cell Average traffic generated by all users within a cell during the busy hour (3 600 s)	**B7** Erlangs = Traffic/user × User/cell/3 600	**B7** Same

[7] Report from September 1996, see Footnote 4 in Annex 6 A6.2 for details

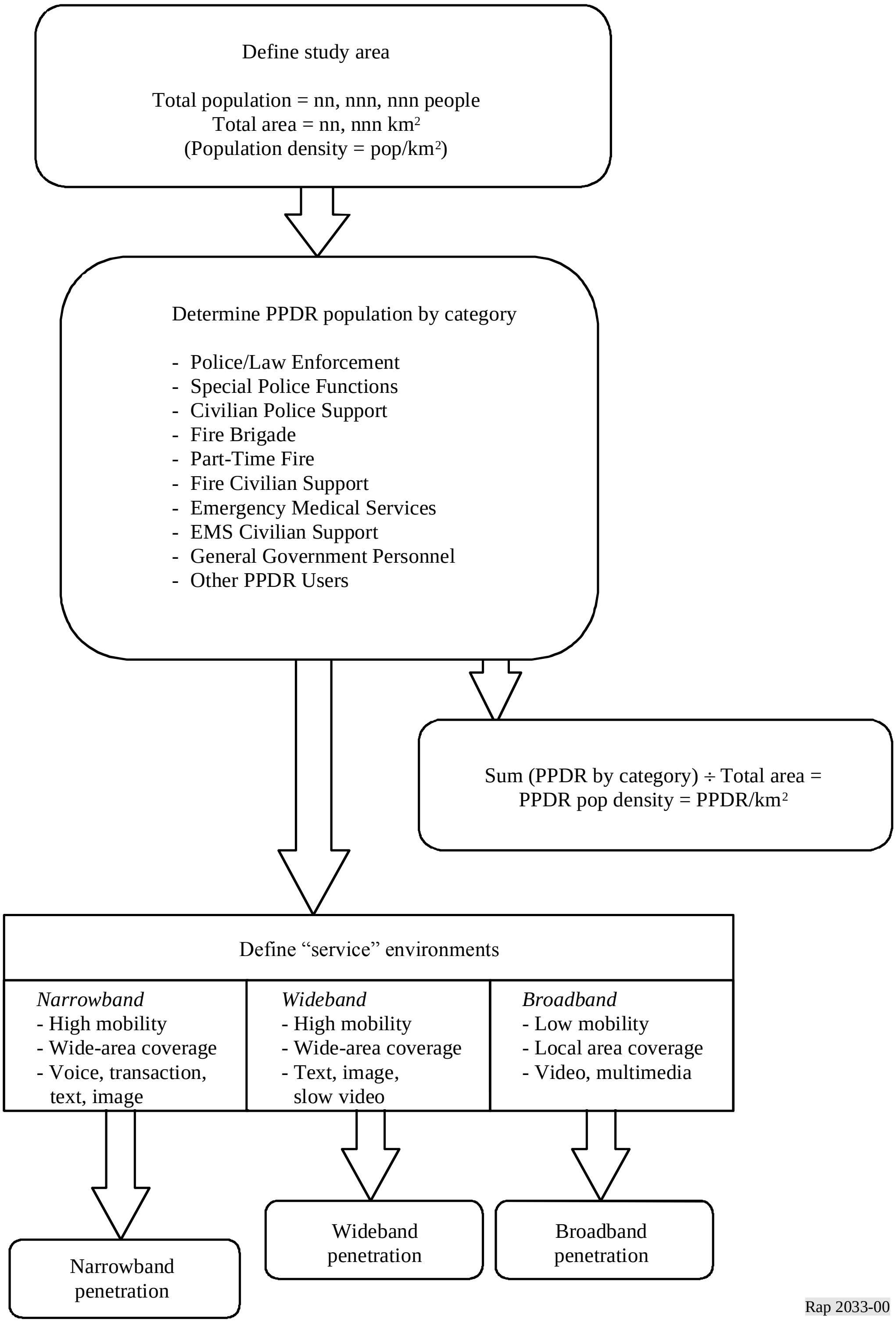
IMT-2000 methodology (Rec. ITU-R M.1390)	IMT-2000 methodology	Proposed PPDR methodology
B8 Quality of service function Offered traffic/cell is multiplied by typical frequency reuse cell grouping size and quality of Service factors (blocking function) to estimate offered traffic/cell at a given quality level		
Group size	Typical cellular reuse = 7	Use 12 for portable only or mobile only systems. Use 21 for mixed portable and mobile systems. In mixed systems, assume that system is designed for portable coverage. Higher power mobiles in distant cells are likely to, so group size is increased from 12 to 21 to provide more separation.
Traffic per group	= Traffic/cell (E) × Group Size	Same
Service channels per group	Apply grade of service formulas Circuit = Erlang B with 1% or 2% blocking Packet = Erlang C with 1% or 2% delayed and delay/holding time ratio = 0.5	Similar Use 1% blocking. Erlang B factor probably close to 1.5. Need to consider extra reliability for PPDR systems, excess capacity for peak emergencies, and number of channels likely to be deployed at each PPDR antenna site. Technology modularity may affect number of channels that can be deployed at a site

IMT-2000 methodology (Rec. ITU-R M.1390)	IMT-2000 methodology	Proposed PPDR methodology
C Technical and system considerations		
C1 Service channels per cell to carry offered load	**C1** Service channels per cell = Service channels per group/Group size	**C1** Same
C2 Service channel bit rate (kbit/s) Equals net user bit rate plus additional increase in loading due to coding and/or overhead signalling, if not already included	**C2** Service channel bit rate = Net user bit rate × Overhead factor × Coding factor If coding and overhead already included in Net user bit rate, then Coding factor = 1 and Overhead factor = 1	**C2** Same Can also sum effects of coding and overhead. If vocoder output = 4.8 kbit/s, FEC = 2.4 kbit/s, and Overhead = 2.4 kbit/s, then Channel bit rate = 9.6 kbit/s
C3 Calculate traffic (Mbit/s) Total traffic transmitted within area under study, including all factors	**C3** Total traffic = Service channels per cell x service channel bit rate	**C3** Same
C4 Net system capability Measure of system capacity for a specific technology. Related to spectral efficiency	**C4** Calculate for GSM system	**C4** Calculate for typical narrowband, wideband and broadband land mobile systems
C5 Calculate for GSM model 200 kHz channel bandwidth, 9 cell reuse, 8 traffic slots per carrier, frequency division duplex (FDD) with 2 × 5.8 MHz, 2 guard channels, 13 kbit/s in each traffic slot, 1.75 overhead/coding factor	**C5** Net system capacity for GSM model = 0.1 Mbit/s/MHz/cell	**C5** See Attachment A for several land mobile examples

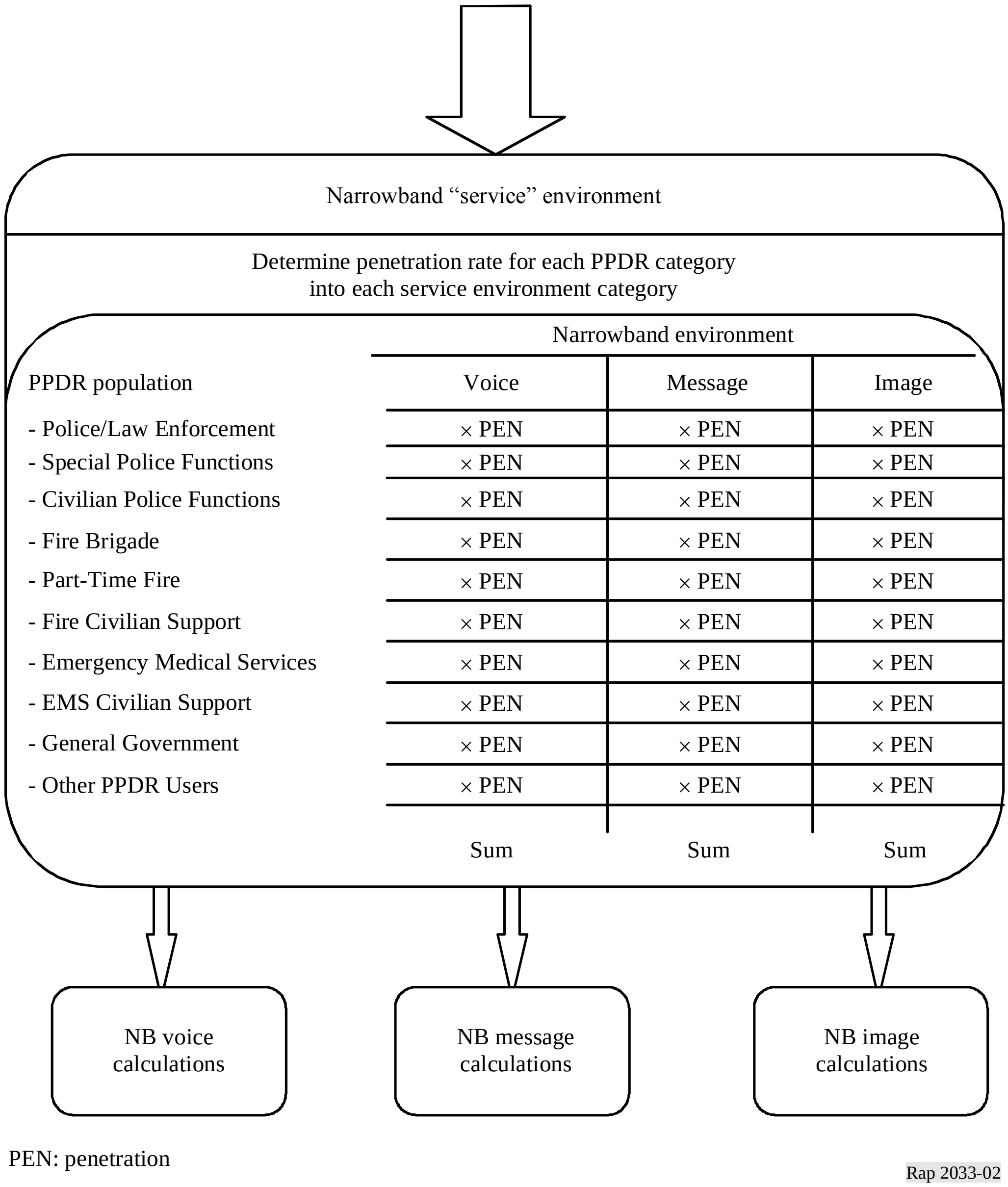
IMT-2000 methodology (Rec. ITU-R M.1390)	IMT-2000 methodology	Proposed PPDR methodology
D Spectrum Results		
D1-D4 Calculate individual components (each cell in service vs environment matrix)	**D1-D4** Freq = Traffic net system capacity for each service in each environment	**D1-D4** Similar, calculate for each cell in service vs. "service environment" matrix
D5 Weighting factor (alpha) for busy hour of each environment relative to busy hour of other environments, may vary from 0 to 1	**D5** if all environments have coincident busy hours, then alpha = 1 $Freq_{es}$ = Freq × alpha requirements in D1-D4	**D5** Same Same
D6 Adjustment factor (beta) for outside effects – multiple operators/networks, guard bands, band sharing, technology modularity	**D6** Freq(total) = beta × sum(alpha × $Freq_{es}$)	**D6** Same

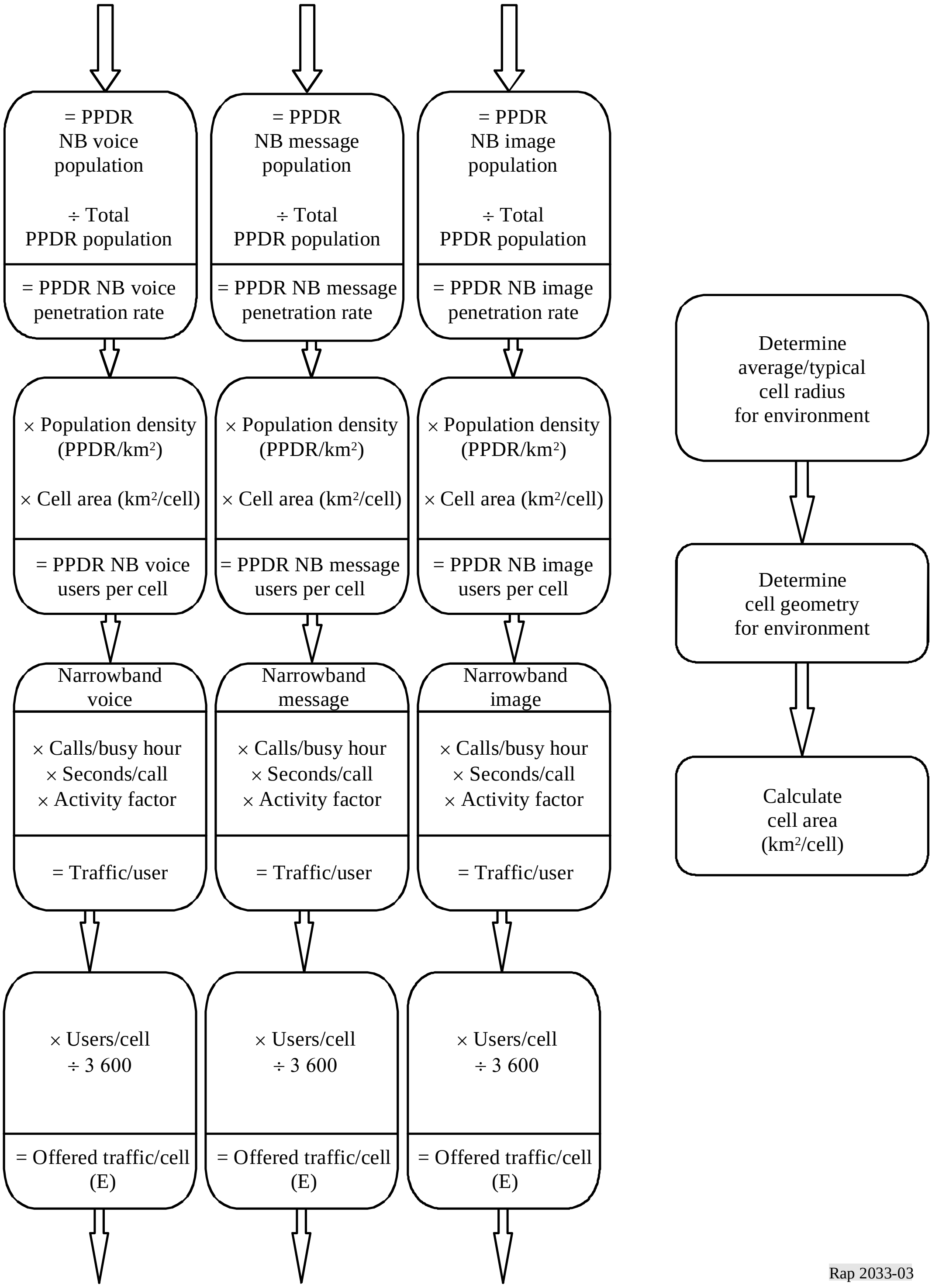
ATTACHMENT 1.2 TO ANNEX 6

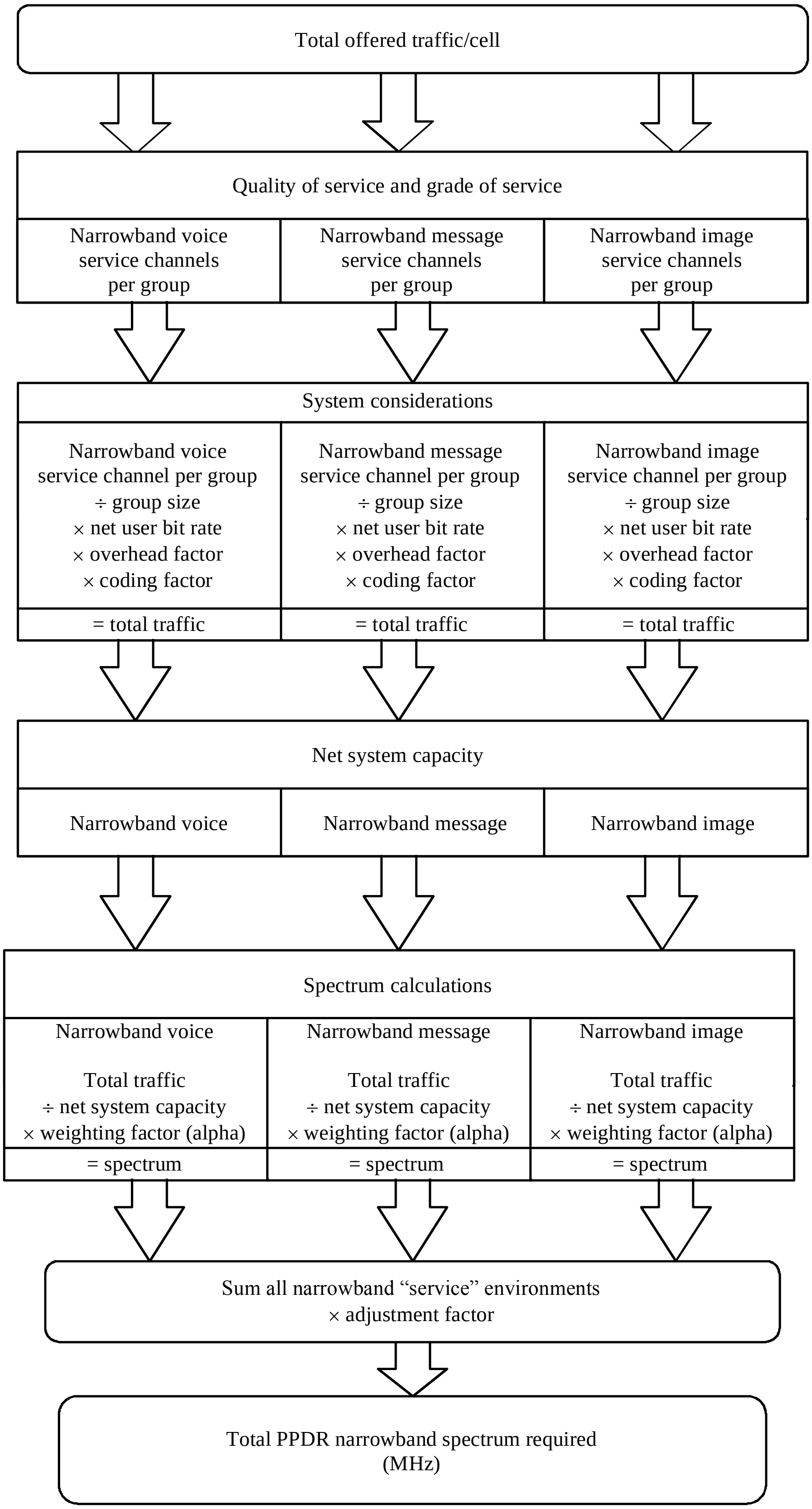
PPDR Spectrum Requirements Flowchart

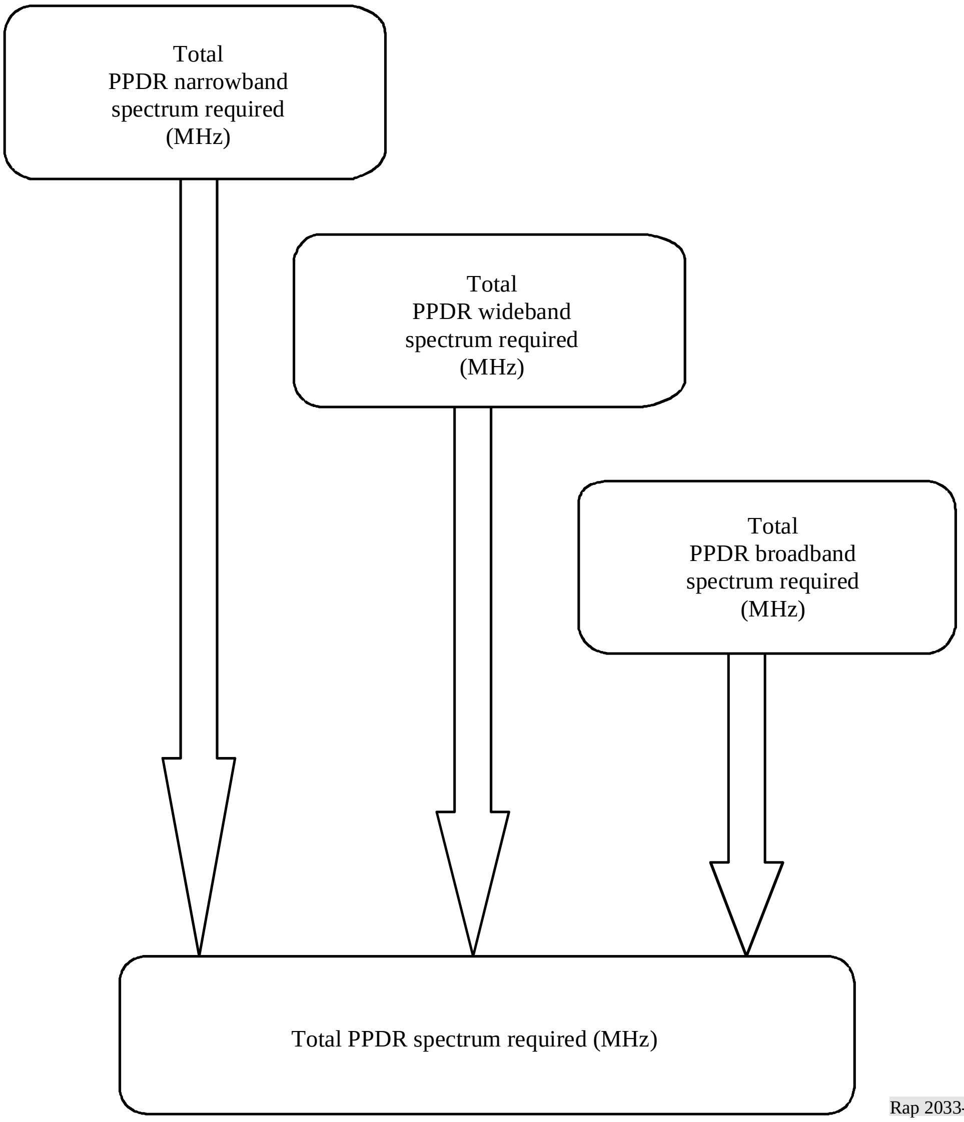


Rap 2033-00


Narrowband "service" environment
Determine penetration rate for each PPDR category
into each service environment category
Narrowband environment
PPDR population
Voice
Message
Image
- Police/Law Enforcement
- Special Police Functions
- Civilian Police Functions
- Fire Brigade
- Part-Time Fire
- Fire Civilian Support
- Emergency Medical Services
- EMS Civilian Support
- General Government
- Other PPDR Users
× PEN
Sum
NB voice
calculations
NB message
calculations
NB image
calculations
PEN: penetration
Rap 2033-02


= PPDR
NB voice
population
÷ Total
PPDR population
= PPDR NB voice
penetration rate
= PPDR
NB message
population
÷ Total
PPDR population
= PPDR NB message
penetration rate
= PPDR
NB image
population
÷ Total
PPDR population
= PPDR NB image
penetration rate
× Population density
(PPDR/km²)
× Cell area (km²/cell)
= PPDR NB voice
users per cell
= PPDR NB message
users per cell
= PPDR NB image
users per cell
Narrowband
voice
Narrowband
message
Narrowband
image
× Calls/busy hour
× Seconds/call
× Activity factor
= Traffic/user
× Users/cell
÷ 3 600
= Offered traffic/cell
(E)
Determine
average/typical
cell radius
for environment
Determine
cell geometry
for environment
Calculate
cell area
(km²/cell)
Rap 2033-03


Total offered traffic/cell
Quality of service and grade of service
Narrowband voice service channels per group
Narrowband message service channels per group
Narrowband image service channels per group
System considerations
Narrowband voice service channel per group ÷ group size × net user bit rate × overhead factor × coding factor
Narrowband message service channel per group ÷ group size × net user bit rate × overhead factor × coding factor
Narrowband image service channel per group ÷ group size × net user bit rate × overhead factor × coding factor
= total traffic
= total traffic
= total traffic
Net system capacity
Narrowband voice
Narrowband message
Narrowband image
Spectrum calculations
Narrowband voice Total traffic ÷ net system capacity × weighting factor (alpha)
Narrowband message Total traffic ÷ net system capacity × weighting factor (alpha)
Narrowband image Total traffic ÷ net system capacity × weighting factor (alpha)
= spectrum
= spectrum
= spectrum
Sum all narrowband “service” environments × adjustment factor
Total PPDR narrowband spectrum required (MHz)


Total
PPDR narrowband
spectrum required
(MHz)
Total
PPDR wideband
spectrum required
(MHz)
Total
PPDR broadband
spectrum required
(MHz)
Total PPDR spectrum required (MHz)

Rap 2033-05

ATTACHMENT 1.3 TO ANNEX 6

System capacity calculation examples

IMT-2000 net system capacity calculation methodology

The spectrum efficiency factor is an important measure of the capacity of a wireless telecommunications system. In order compare spectrum efficiency factors it is necessary to use a common basis to calculate the system capacity (kbit/s/MHz/cell), available to carry traffic. Analysis should take into consideration factors which reduce capacity over the air interface (guard bands, co-channel and adjacent channel interference, channels assigned to other purposes within the band). This calculation should produce the maximum system capacity possible within the spectrum band being studied. Actual systems will be sized for lower traffic levels to achieve the desired grade of service.

Annex 3 of the SAG Report on UMTS/IMT-2000 Spectrum[5] calculates the capacity of a generalized GSM network as:

C4 and C5 Net system capability calculation

GSM and IMT-2000			
Width of band (MHz)	5.8	11.6	MHz total
Width of channel	0.2		MHz
		29.0	FDD channels within band
Reuse group factor	9		
		3.2	Channels per cell
Guard channels	2		(At band edge)
I/O channels	0		
		27.0	**Traffic channels**
Traffic/channel	8		8 TDMA slots per channel
Data/channel	13		kbit/s/slot
Overhead and signalling	1.75		(182 kbit/s per channel total)
		546.0	**kbit/s/cell**
		5.8	MHz bandwidth on outbound or inbound channel
		Total capacity available	
		94.1	kbit/s/cell/MHz on outbound or inbound channel
Speech improvement	1.05	**98.8**	**kbit/s/cell/MHz on inbound or outbound channel with speech improvement**
All improvements	1.1	103.6	kbit/s/cell/MHz on outbound or inbound channel with all improvements

MA: time division multiple access

The GSM net system capacity is usually rounded to 0.10 Mbit/s/MHz/cell for use in IMT-2000 calculations.

5 UMTS Auction Consultative Group, A note on spectrum efficiency factors – UACG(98) 23. (http://www.spectrumauctions.gov.uk/documents/uacg23.html) Reference 1 = SAG Report, Spectrum calculations for terrestrial UMTS, release 1.2, 12 March 1998.

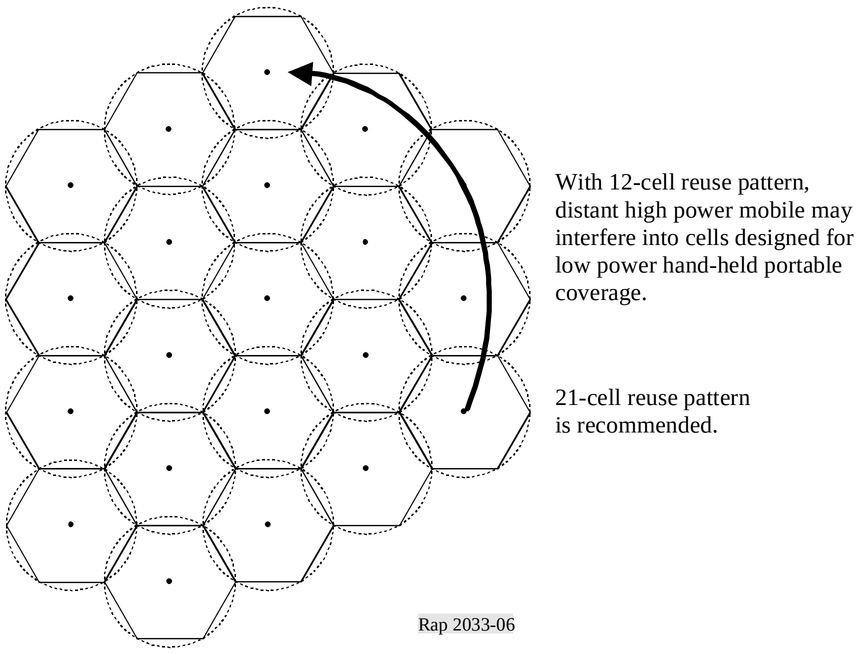
The same methodology is applied below to several example narrowband technologies and several sample spectrum bands. The examples show that the spectrum band structure and frequency reuse factor have a significant effect on the capacity calculation.

These are not meant to be a direct comparison between the selected technologies. There are numerous other user needs and spectrum allocation factors that effect the functional and operational deployment of a network, the choice of technology, and overall network efficiency. Some of the spectrum factors are considered in the alpha and beta factors (Recommendation ITU-R M.1390, D5 and D6).

Net system capability summary			
Spectrum band	**Technology**	**Channels**	**Total capacity available**
Reuse group factor = 12			
European 400 MHz public safety band	**TETRA TDMA**	**4 slots/25 kHz**	**98.0 kbit/s/MHz/cell**
Reuse group factor = 21			
European 400 MHz public safety band	**TETRA TDMA**	**4 slots/25 kHz**	**56.0 kbit/s/MHz/cell**

FDMA: frequency division multiple access.

NOTE – 1 Reuse group factor of 12 is used for systems implementing only low power, handheld, portable devices. Reuse factor of 21 is used for systems implementing both handheld portables and higher power, vehicular mounted, mobile devices. Greater reuse factor is required because of potential for interference from distant mobiles into cells designed for portable coverage.



Example 1: Narrowband technologies for dispatch voice and low rate data.

TETRA TDMA applied to European 400 MHz public safety band.

C4 and C5 Net system capability calculation

TETRA TDMA			**European 400 MHz public safety band**
Width of band (MHz)	3	6.0	MHz total
Width of channel	0.025		
		120.0	FDD channels within band
Reuse group factor	12		(Hand-held portables only)
		10.0	Channels per cell
Guard channels	2		(At band edge)
Interoperability channels	20		(Reserve for direct mode operations)
		98.0	**Traffic channels**
Traffic/channel	4		Slots/channel
Data/channel	7.2		kbit/s/slot
Overhead and signalling	1.25		(36 kbit/s per channel total)
		294.0	**kbit/s/cell**
		3.0	MHz bandwidth on outbound or inbound channel
		Total capacity available	
		98.0	**kbit/s/cell/MHz on outbound or inbound channel**
Speech improvement	1.05	102.9	kbit/s/cell/MHz on outbound or inbound channel with speech improvement
All improvements	1.1	107.8	kbit/s/cell/MHz on outbound or inbound channel with all improvements

TETRA TDMA			**European 400 MHz public safety band**
Width of band (MHz)	3	6.0	MHz total
Width of channel	0.025		
		120.0	FDD channels within band
Reuse group factor	21		(Mixture of portables and mobiles)
		5.7	Channels per cell
Guard channels	2		(At band edge)
Interoperability channels	20		(Reserve for direct mode operations)
		98.0	**Traffic channels**
Traffic/channel	4		Slots/channel
Data/channel	7.2		kbit/s/slot
Overhead and signalling	1.25		(36 kbit/s per channel total)
		168.0	**kbit/s/cell**
		3.0	MHz bandwidth on outbound or inbound channel
		Total capacity available	
		56.0	**kbit/s/cell/MHz on outbound or inbound channel**
Speech improvement	1.05	58.8	kbit/s/cell/MHz on outbound or inbound channel with speech improvement
All improvements	1.1	61.6	kbit/s/cell/MHz on outbound or inbound channel with all improvements

ATTACHMENT 1.4 TO ANNEX 6

Example: Public safety and disaster relief population density data

England and Wales

Population = ~ 52.2 million England = ~ 49.23 million

Wales = ~ 2.95 million

Land Area = ~151 000 km^2 England = ~ 130 360 km^2

Wales = ~ 20 760 km^2

England population density = 346 pop/km^2 = 100 000 pop/289 km^2

London population = 7 285 000 people

London area = 1 620 km^2

London population density = 4 496 pop/ km^2 = 100 000 pop/ 22.24 km^2

Police officer strength[6]

	Total	Density /100 000
Police officers (ordinary duty)	123 841	237.2
Police officers (secondary assignments)	2 255	4.3
Police officers (outside assignments)	702	1.3
Total	126 798	242.9

Full time civilian staff[7]

Full time	48 759	93.4
Part time equivalent (7 897 staff)	4 272	8.2
Total	53 031	101.6

Average densities (ordinary officers)

Average = 237.2 officers per 100 000 population

Urban = 299.7

Non-urban = 201.2

8 largest metro = 352.4

Lowest rural = 176.4

Officer/civilian = 126 798/53 031 = 2.4 officers/civilian staff

[6] Source: Police Service Personnel, England and Wales, as of 31 March 1999, by Julian Prime and Rohith Sen-gupta @ Home Office, Research Development & Statistics Directorate.

[7] Includes National Crime Squad (NCS) & National criminal Intelligence Service (NCIS) civilian staffing.

Police officer distribution by rank

Chief Constable	49	0.04%
Assistant Chief Constable	151	0.12%
Superintendent	1 213	0.98%
Chief Inspector	1 604	1.30%
Inspector	5 936	4.80%
Sergeant	18 738	15.1%
Constable	96 150	77.6%

Other[8]

Special Constables 16 484
Traffic Wardens 3 342 full time equivalents
(3 206 full-time and 242 part-time)

Fire Brigade

Staffing in England and Wales (43 brigades)

Paid	35 417
Retained (part-time or volunteer)	14 600
	50 082

London: assume 126 798/35 417 = 3.58 police/fire
or about 98 fires/100 000 population in London

Fire radio inventory ~24 500 radios

50% penetration of radios into total
70% penetration of full-time fire fighters

London PPDR estimates

PPDR category	PPDR population	PPDR penetration rate for narrowband voice
Police	25 498	100%
Other Police Functions	6 010	10%
Police Civilian Support	13 987	10% (dispatchers, technicians, etc.)
Fire Brigade	7 081	70%
Part-time Fire	2 127	10%
Fire Civilian Support	–	0%
Emergency Medical	–	0%
EMS Civilian Support	–	0%
Services généraux du gouvernement	–	0%
General Government	–	0%
Other PPDR Users	–	0%

[8] Not included in totals above.

Attachment 1.5 to Annex 6

Example calculation

	IMT-2000 methodology (Rec. UIT-R M.1390)		London TETRA Narrowband voice service		
A	Geographic considerations				
A1	Select operational environment type Each environment type basically forms a column in calculation spreadsheet. Do not have to consider all environments, only the most significant contributors to spectrum requirements. Environments may geographically overlap. No user should occupy any two operational environments at one time	Environment = "e" Combination of user density and user mobility: Density: dense urban, urban, suburban, rural; Mobility: in-building, pedestrian, vehicular. Determine which of the possible density/mobility environments co-exist AND create greatest spectrum demand		**Urban pedestrian and mobile**	**Urban pedestrian and mobile**
A2	Select direction of calculation, uplink vs downlink or combined	usually separate calculations for uplink and downlink due to asymmetry in some services		**Uplink**	**Downlink**
A3	Representative cell area and geometry for each operational environment type	Average/typical cell geometry (m): radius for omnidirectional cells; radius of vertex for sectored hexagonal cells		**5**	
A4	Calculate representative cell area	Omni cells: circular = $\pi \cdot R^2$; hexagonal = $2.6 \cdot R^2$; Hex 3-sector = $2.6 \cdot R^2/3$ km^2		**65**	
B	Market and traffic considerations				
B1	Telecommunication services offered	Corresponding net user bit rate (kbit/s)		**7.2 kbit/s = 4.8 kbit/s vocoded voice + 2.4 kbit/s FEC**	

	IMT-2000 methodology (Rec. UIT-R M.1390)		London TETRA Narrowband voice service		
B2	Population density	Total population = sum (POP by category)		**54 703**	**Total PPDR population within area under consideration**
				Population (POP) by PPDR category	Penetration (PEN) rate within PPDR category
					(Narrowband voice)
			Police	25 498	1.00
			Other Police	6 010	0.10
			Police Civilian Support	13 987	0.10
			Fire	7 081	0.70
			Part-time Fire	2 127	0.10
			Fire Civilian Support	0	0.10
			EMS	0	0.50
			EMS Civilian Support	0	0.10
			General Government	0	0.10
			Other PPDR Users	0	0.10
		= SUM (POP × PEN)		**32 667,1**	**PPDR population using NB voice service**
		Area under consideration	308.9 square miles	**1 620**	**km^2**

	IMT-2000 methodology (Rec. UIT-R M.1390)		London TETRA Narrowband voice service		
	Number of persons per unit of area within the environment under consideration. Population density may vary with mobility	Potential user per km^2		**33.8**	**Total POP/km^2**
B3	Penetration rate Percentage of persons subscribing to a service within an environment. Person may subscribe to more than one service, therefore, total penetration rate of all services within environment can exceed 100%		= PEN into PPDR category × PPDR category POP/total PPDR POP	By category (Police = Police PEN × Police POP)	By Category (Police = Police PEN × Police POP)/Total PPDR POP
			Police	25 498.00	0.466
			Other Police	601.00	0.011
			Police Civilian Support	1 398.70	0.026
			Fire	4 956.70	0.091
			Part-time Fire	212.70	0.004
			Fire Civilian Support	0.00	0.000
			EMS	0.00	0.000
			EMS Civilian Support	0.00	0.000
			General Government	0.00	0.000
			Other PPDR Users	0.00	0.000
		= % of total PPDR POP	**Total PPDR penetration**	**59.717**	**% using NB voice**

	IMT-2000 methodology (Rec. UIT-R M.1390)		London TETRA Narrowband voice service		
B4	Users/cell Represents the number of people actually subscribing to the service "s" within a cell in environment "e"	Users/cell = POP density × PEN rate × Cell area Dependent upon population density, cell area, and service penetration rate in each environment		**1 311**	**PPDR NB voice users per cell**
B5	Traffic parameters			**Uplink**	**downlink**
	Busy hour call attempts (BHCA)	Calls/busy hour	From PSWAC[8]	0.0073284 E/busy hour	0.0463105 E/busy hour
	Average number of calls/sessions attempted to/from average user during busy hour		**Per PPDR NB voice user**	**3.535**	**6.283**
	Effective call duration Average call/session duration during busy hours	Seconds/call	**Per PPDR NB voice user**	**7.88069024**	**26.53474455**
	Activity factor Percentage of time that resource is actually used during a conversation/session. Packet data may be bursty and resource is only used a small percentage of time that session is active. If voice is only transmitted when user speaks it does not tie up resource during pauses in speech or when listening	Dispatch voice – each conversation ties up both sides of duplex channel	**Per PPDR NB voice user**	**1**	**1**
B6	Traffic/user Average traffic in call-seconds generated by each user during busy hour	Call-seconds per user = Busy hour attempts × Call duration × Activity	**PPDR NB voice traffic/user**	**27.9**	**166.7**

[8] Report from September 1996, see Footnote 4 in Annex 6 A6.2 for details

	IMT-2000 methodology (Rec. UIT-R M.1390)		London TETRA Narrowband voice service		
B7	Offered traffic/cell Average traffic generated by all users within a cell during the busy hour (3 600 s)	Erlangs = Traffic/user × User/cell/3 600	**PPDR NB voice traffic cell**	**10.14**	**60.70**
B8	Establish quality of service (QOS) function parameters			**Uplink**	**Downlink**
	Group size Number of cells in a group. Because cellular system deployment and technologies provide some measure of traffic "sharing" between adjacent cells, traffic versus QoS is considered within a grouping of cells	12 (portable only) or 21 (portable + mobile) Typical cellular grouping is 1 cell surrounded by 6 adjacent cells for a group size of 7. Traffic/cell is multiplied by group size and quality of service (or blocking function) is applied to grouping. Answer is divided by group size to restore to valuation per cell		**21**	**21**
	Traffic per group	= Traffic/cell (E) × Group size	**PPDR NB voice traffic group**	**213.00**	**1 274.70**
	Service channels per group Determine number of channels required to support traffic from each service, round to next higher whole number	= apply grade of service formulas across group Circuit = Erlang B with 1% blocking. Used Erlang = 1.5, assuming that dispatch voice in broken into multiple systems with no more than 20 channels per site		**1.50**	**1.50**
			PPDR NB voice service channels per group	**319.50**	**1 912.05**

	IMT-2000 methodology (Rec. UIT-R M.1390)		London TETRA Narrowband voice service		
C	Technical and system considerations			**Uplink**	**Downlink**
C1	Service channels per cell needed to carry offered load Actual number of "channels" that must be provisioned within each cell to carry intended traffic	= Service channels per group/Group size	**PPDR NB voice service channels per cell**	**15.21**	**91.05**
C2	Service channel bit rate (kbit/s) Service channel bit rate equals net user bit rate, plus any additional increases in bit rate due to coding factors and/or overhead signalling	= Net user bit rate × Overhead factor × Coding factor This is where coding and overhead factors are included. For coding factor = 1, and overhead factor = 1, = B1 × 1 × 1 = Net user bit rate	9.6 kbit/s includes coding and overhead **PPDR NB voice service channel bit rate**	**9**	**9**
C3	Calculate traffic (Mbit/s) Total traffic to be transmitted within the area of study – includes all factors; user traffic (call duration, busy hour call attempts, activity factor, net channel bit rate) environment, service type, direction of transmission (up/down link), cell geometry, quality of service, traffic efficiency (calculated across a group of cells), and service channel bit rate (including coding and overhead factors)	= Service channels/Cell × Service channel bit rate	**PPDR NB voice traffic (Mbit/s)**	**0.137**	**0.819**
C4	Net system capability Measure of system capacity for a specific technology. Related to spectral efficiency. Requires complex calculation or simulation to determine net system capability for a specific technology deployed in a specific network configuration	Trade-offs between net system capability and QoS. May include the following factors; spectral efficiency of technology, E_b/N_0 requirements, C/I requirements, frequency re-use plan, coding/signalling factors of radio transmission technology, environment, deployment model			

	IMT-2000 methodology (Rec. UIT-R M.1390)		London TETRA Narrowband voice service		
C5	Calculate for GSM model	Calculation for TETRA TDMA using 25 kHz bandwidth channels, 21 cell re-use (mobile + portable), 4 traffic slots per carrier, ignoring signalling channels, 400 MHz bandplan, FDD with 2 × 3 MHz (120 RF channels - 20 DMO channels –2 guard channels at edge of band), data rate of 7.2 kbits/s on each traffic slot, a factor of 1.25 for overhead and coding. Net system capacity for TETRA TDMA = 56.0 kbit/s/MHz/cell	**TETRA**	**0.056**	**0.056**
D	Spectrum results			**Uplink**	**Downlink**
D1-D4	Calculate individual components	Freq = Traffic/Net system capability	**PPDR NB voice (MHz)**	**2.445**	**14.633**
D5	Weighting factor for each environment (alpha) Weighting of each environment relative to other environments - alpha may vary from 0 to 1, correct for non-simultaneous busy hours, correct for geographic offsets	= Freq × alpha If all environments have coincident busy hours and all three environments are co-located,, then alpha = 1	**Alpha = 1**	**1**	**1**
			PPDR NB voice (MHz)	**2.445**	**14.633**
D6	Adjustment factor (beta)	Freq(total) = beta × sum (alpha × Freq)			
	Adjustment of all environments to outside effects - multiple operators/users (decreased trunking or spectral efficiency), guardbands, sharing with other services within band, technology modularity, etc.	For dispatch voice model, assuming one system and fact that guardbands were included in C5, then beta = 1. Multiple systems, such as one for Police and one for Fire/EMS may decrease efficiency and beta would be > 1	**Beta = 1**	**1**	
D7	Calculate total spectrum		**PPDR NB voice TOTAL (MHz)**	**17.078 MHz**	

Attachment 1.6 to Annex 6

Example narrowband and wideband calculation summaries

London narrowband voice, message, and image

Narrowband PPDR category	London users	Penetration rates		
		NB voice	NB message	NB image
Police	25 498	1.00	0.5	0.25
Other Police	6 010	0.10	0.05	0.025
Police Civilian Support	13 987	0.10	0.05	0.025
Fire	7 081	0.70	0.35	0.175
Part-time Fire	2 127	0.10	0.05	0.025
Fire Civilian Support	0	0.10	0.05	0.025
EMS	0	0.50	0.25	0.125
EMS Civilian Support	0	0.10	0.05	0.025
General Government	0	0.10	0.05	0.025
Other PPDR Users	0	0.10	0.05	0.025
Total – PPDR Users	**54 703**	32 667	16 334	8 167
Spectrum by 'service environment' (MHz)		17.1	1.4	4.2
Narrowband spectrum 22.7 MHz				

Other parameters:				
Environment	Urban pedestrian and mobile			
Cell radius (km)	5			
Study area (km^2)	1 620			
Cell area (km^2)	65	(calculated)		
Cells per study area	25	(calculated)		
Net user bit rate	9 kbit/s (7.2 kbit/s per slot + 1.8 kbit/s channel overhead)			
	= 4.8 kbit/s speech, data, or image per slot			
	+ 2.4 kbit/s FEC per slot			
	+ 1.8 kbit/s channel overhead and signalling			
		NB voice	NB data	NB image
		Uplink	Uplink	Uplink

Erlangs per busy hour	(From PSWAC[9])	0.0077384	0.0030201	0.0268314
Busy hour call attempts		3.54	5.18	3.00
Effective call duration		7.88	2.10	32.20
Activity factor		1	1	1
		Downlink	Downlink	Downlink
Erlangs per busy hour	(From PSWAC)	0.0463105	0.0057000	0.0266667
Busy hour call attempts		6.28	5.18	3.00
Effective call duration		26.53	3.96	32.00
Activity factor		1	1	1
Group size	21			
Grade of service factor	1.50			
Net system capacity	0.0560	kbit/s/MHz/cellule		
Alpha factor	1			
Beta factor	1			

[9] Report from September 1996, see Footnote 4 in Annex 6 A6.2 for details

Attachment 2 to Annex 6

PPDR spectrum calculation based on generic city analysis (demographic population)

ATT2-1 Generic City Approach

Instead of looking at specific cities, the following analysis examines several medium sized cities in several countries. This analysis is based upon the average density of police officers relative to the general demographic population and the ratio of police to other public protection providers. From this analysis, a generic example of the relationship between the different PPDR user categories and demographic population density has been developed. This approach shows the optimum PPDR spectrum requirement based on the size of demographic population, that is, the amount of PPDR spectrum requirement based on the idealistic amount of PPDR users in a city based on demographic population size.

The police and PPDR densities were examined from national statistics and city budgets for Australia, and England. Statistics for police show a national average density in the 180 police per 100 000 population to 250 police per 100 000 population. The density in urban areas varies from about 25% above the national average for medium density cities to >100% above the national average for dense urban cities. The density in suburban areas varies from about 25% above the national average for suburbs of medium density cities to 50% above the national average for suburbs of dense urban cities.

Fire and EMS/Rescue levels were harder to determine because they are often combined together. Information was used for cities where they were separate, and ratios of the various PP and DR categories were determined relative to the police population density. For example, ratios for fire fighters were in the range of 3.5 to 4 police officers per fire fighter (25 to 30%). Where Rescue/Emergency Medical/Ambulance could be separated out, ratios for Rescue/EMS were in the range of 3.5 to 4 fire fighters per Rescue/EMS (25 to 30%).

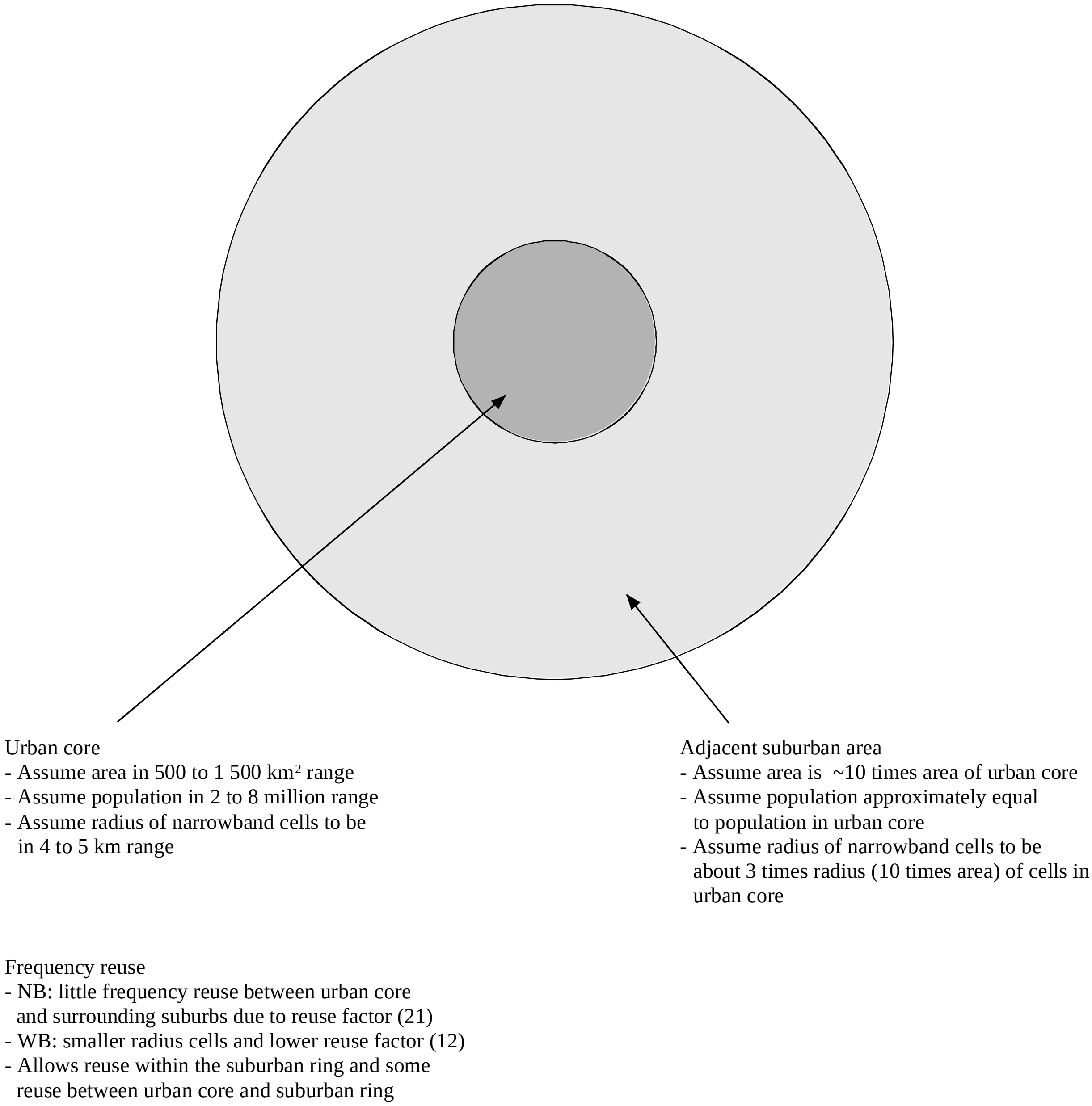
In the generic examples below, and for simplicity, only two densities are used, 180 and 250 police per 100 000 population. Also for simplicity, only two types of cities were analysed: a medium size city (2.5 million population) and a large city (8 million population). This probably underestimates the PPDR density in large urban areas where there are many examples of police densities in the range of 400-500 police per 100 000 population.

The “doughnut” effect was also examined, where frequencies used in the urban center cannot be reused in the suburbs immediately adjacent to the urban area. In ITU-R contributions from the 2000-2003 study period, many of the cities included both the urban and suburban areas together in a single spectrum requirement calculation. Cell size had to be averaged and PPDR user density was lowered. In retrospect, each area should have been treated separately, and the spectrum requirements added together.

Numerous urban areas were examined. Most had a central urban core with a dense population. There was also a suburban ring around the urban core that contained about the same amount of population, but was about 5 to 20 times the area of the urban core. The examples below use a ratio of 10:1 for suburban to urban area. Assuming 4 to 5 km radius cell sizes for the urban core, typical cell sizes in the suburbs should be about 10 times larger in area or ~3 times larger in radius.

FIGURE 1

Metropolitan Area
(Urban core and adjacent suburbs)



ATT2-2 PPDR categories

Three classes of users were defined, which is basically re-grouping the PPDR categories by penetration rates:

Primary users (usage with 30% penetration rate) = PP users normally operating within the geographic area on a day-to-day basis = local police, fire fighters, and emergency medical/rescue

Secondary users (usage with 10% penetration rate) = other police (state, district, province, federal, national, special operations, investigators), part-time or volunteer police/fire, general government workers, civil protection agencies, military/army, utility workers, disaster relief workers

Support users (usage with <10% penetration rate) = civilian support

Penetration rate and PPDR category data used to calculate spectrum requirements

Narrowband and wideband CATEGORY name and number of USER's		Services summary	NB voice	NB message	NB status	WB data	WB video
User category	**Users**		**Penetration rate summary**				
Primary – Local Police	5 625		0.300	0.300	0.300	0.250	0.125
Secondary – Law Enforcement/ Investigators	563		0.100	0.100	0.100	0.010	0.010
Secondary – Police Functions	0		0.100	0.100	0.100	0.010	0.010
Police Civilian Support	1 125		0.100	0.000	0.000	0.010	0.010
Primary – Fire Fighters	1 631		0.300	0.300	0.300	0.250	0.125
Fire Civilian Support	326		0.100	0.000	0.000	0.010	0.010
Primary – Rescue/Emergency Medical	489		0.300	0.300	0.300	0.250	0.125
Rescue/EMS Civilian Support	98		0.100	0.000	0.000	0.010	0.010
Secondary – General Government and Civil Agencies	563		0.100	0.100	0.100	0.010	0.010
Secondary – Volunteers and other PPDR Users	281		0.100	0.100	0.100	0.010	0.010
Total Users	10 701						

Primary users are the users that local public protection system would be designed to handle. A local system would be designed to handle "average busy hour" traffic plus a loading factor to be able to handle peak loads with a reasonable grade of service.

Part of the assumption is that many secondary users may have their own communications system and loading added to local public protection system is for coordination between the secondary users and the primary users.

Disaster scenario

Disaster occurs and personnel from surrounding areas, national government, and international agencies come to support the local agencies. There is immediate need for emergency workers to handle fires and to rescue injured people. Later arrivals are investigators and personnel to clean up the damage.

For disaster response – the following assumptions were made:

– *Civilian support* (<10% penetration rate): No increase in the number of civilian support workers for police/fire/EMS/rescue. The usage remains within the original system design parameters (30% penetration rate, 1.5 GoS peaking factor).

– *Police*: No increase in the number of local police. The usage remains within the original system design parameters (30% penetration rate, 1.5 GoS peaking factor).

– *Other Police*: Increase in personnel providing police functions equal to 30% of local police population, but at a lower secondary level (10% penetration rate). These are personnel who come from outside the area to supplement local police.

– *Investigators and Law Enforcement*: The population doubles as additional investigators move into the disaster area.

– *Fire and EMS/Rescue*: A 30% increase in the number of users. Users from surrounding areas immediately move into the disaster area and operate on the local system or set up additional communication systems. The need for communications is very great. Operate at primary level (30% penetration rate).

– *Secondary level users* (10% penetration rate): Double the number of general government users, volunteers, civil agency users, utility users, etc. who need to communicate with primary users or need to use the local network for communications.

Where is the disaster?

Look at three disaster scenarios:

1 No disaster = normal day-to-day operations

2 Disaster only in urban area

3 Disaster only in suburban area

ATT2-3 Spectrum requirements

Calculate spectrum requirements for:

– Urban day-to-day

– Urban disaster

– Suburban day-to-day

– Suburban disaster

– Spectrum requirements for the three disaster scenarios:

(Instead of worst case analysis)

Urban and suburban systems designed to handle "average busy hour" traffic loading plus a 1.5 GoS factor to handle emergency loading by the normal PPDR users. Disaster operations assumes that additional, outside PPDR personnel are added to the system.

a) *Normal day-to-day operations*:

The amount of spectrum required for NB equals the sum of the urban and suburban spectrum calculations. The assumption is that spectrum used in the urban area cannot be reused in the adjacent suburban area, due to large cell size and large reuse factor.

The amount of spectrum required for WB equals the sum of the urban and half of the suburban spectrum calculation. The assumption is that spectrum used in the urban area can be reused in the adjacent suburban area, due to the smaller cell size and smaller reuse factor. Also, because the urban area sits in middle of the suburban area, there is some additional separation, which would allow additional frequency reuse between suburban sites.

b) *Urban disaster operations*:

The amount of spectrum required for NB equals the sum of the urban disaster and the suburban non-disaster spectrum calculation.

The amount of spectrum required for WB equals the sum of the urban disaster and half of the suburban non-disaster spectrum calculation.

c) *Suburban disaster operations*:

The amount of spectrum required for NB equals the sum of the urban non-disaster and the suburban disaster spectrum calculation.

The amount of spectrum required for WB equals the sum of the urban non-disaster and half of the suburban disaster spectrum calculation.

Medium metropolitan area

Calculated spectrum requirements using a PPDR calculator spreadsheet.

Medium metropolitan area (Urban population ≅ 2.5 million and area ≅ 600 km^2) (Suburban population ≅ 2.5 million and area ≅ 6 000 km^2)					
Medium PPDR density (180 Police per 100 000 population)			**High PPDR density** (250 police per 100 000 population)		
Urban			**Urban**		
NB day-to-day	15.5	MHz	NB day-to-day	21.5	MHz
WB day-to-day	16.2	MHz	WB day-to-day	22.6	MHz
Disaster NB	18.4	MHz	Disaster NB	25.6	MHz
Disaster WB	17.8	MHz	Disaster WB	24.7	MHz
Suburban			**Suburban**		
NB day-to-day	12.9	MHz	NB day-to-day	17.9	MHz
WB day-to-day	13.5	MHz	WB day-to-day	18.8	MHz
Disaster NB	15.4	MHz	Disaster NB	21.4	MHz
Disaster WB	14.8	MHz	Disaster WB	20.6	MHz
Normal day-to-day			**Normal day-to-day**		
NB (urban + suburban)	28.40	MHz	NB	39.40	MHz
WB (urban + 1/2 suburban)	22.95	MHz	WB	32.00	MHz
	51.35	MHz		71.40	MHz
Suburban disaster			**Suburban disaster**		
NB	30.90	MHz	NB	42.90	MHz
WB	23.60	MHz	WB	32.90	MHz
	54.50	MHz		75.80	MHz
Urban disaster			**Urban disaster**		
NB	31.30	MHz	NB	43.50	MHz
WB	24.55	MHz	WB	34.10	MHz
	55.85	MHz		77.60	MHz

The left-hand column shows the spectrum calculated for a medium PPDR user density and the right-hand column shows the spectrum calculated for a higher PPDR user density.

The top-half of the chart shows individual NB and WB spectrum calculations for normal "day-to-day" operations and for a disaster within the local area.

The total spectrum requirement is the sum of the urban and suburban calculations. For narrowband the assumption is that frequencies are not reused between the two areas, so the total is the sum of the NB urban and the NB suburban requirements. For wideband, the assumption is that some frequencies can be reused, therefore, the total is the sum of the wideband urban requirement and half of the wideband suburban requirement.

The bottom half of the chart shows the spectrum calculated for a disaster in either the urban area or the suburban area, where there is a significant increase in the number of users (up to 30% for primary users).

Normal day-to-day operations for this generic medium size city require from 51 MHz to 71 MHz depending on whether it is located in a country with a medium PPDR density or a high PPDR density.

If a disaster scenario described above occurs in the suburban area, then the NB/WB spectrum requirement increases by about 6%. If a disaster occurs in the urban area, then NB/WB spectrum requirement increases by about 9%.

Disaster operations for this generic medium size city require from 55 MHz to 78 MHz depending on where the disaster occurs and whether it is located in a country with a medium PPDR density or a high PPDR density.

The broadband spectrum requirement needs to be added. Since broadband will cover very small radius “hot spots”, the broadband frequencies can be reused throughout the urban and suburban area. ITU-R contributions from the 2000-2003 study period have shown broadband spectrum requirements to be in the 50-75 MHz range.

Therefore, for a generic medium size city, the total spectrum requirement is in the range of 105 to 153 MHz to handle the type of disaster scenario described above.

The following two tables show the breakout of PPDR users and narrowband and wideband services in a medium-sized metropolitan area. Medium metropolitan area calculated for 180 police officers per 100 000 population

Spectrum Requirements – Generic City Calculator			Re-Formatted	July 2002
Metropolitan Study Area	Medium Metropolitan Area			Input Data
Population of Urban Area	2 500 000	People	**1.0**	Ratio Suburban/Urban Population
Population of Surrounding Suburban Area	2 500 000	People		Ratio should be near 1.0 (Range of 0.5 × to 1.5 × of Urban Population)
Area of Urban Center	600	km^2	**10.0**	Ratio Suburban/Urban Area
Area of Surrounding Suburbs	6 000	km^2		Ratio should be near 10.0 (Range of 5 × to 15 × of Urban Area)
Urban Population Density	4 167	People/km^2		
Suburban Population Density	417	People/km^2		
"Large" or "Medium" City	MED	If Urban Population Density > 5 000 people/km^2, then this is a large city, OR if Urban population > 3 000 000 people, then this is a large city, otherwise this is a medium city		
Police User Density (national average)	180.0	Police per 100 000 population		

CATEGORY name and number of USERS User Category	Urban Day-to-Day	Urban Disaster	Suburban Day-to-Day	Suburban Disaster
	Population	Population	Population	Population
Primary – Local Police	6 750	6 750	5 625	5 625
Secondary – Law Enforcement/Investigators	675	1 350	563	1 125
Secondary – Police Functions	0	2 025	0	1 688
Police Civilian Support	1 350	1 350	1 125	1 125
Primary – Fire Fighters	1 958	2 545	1 631	2 121
Fire Civilian Support	392	392	326	326
Primary – Rescue/ Emergency Medical	587	763	489	636
Rescue/EMS Civilian Support	117	117	98	98
Secondary – General Government and Civil Agencies	675	1 350	563	1 125
Secondary – Volunteers and Other PPDR Users	338	675	281	563
Total	12 841	17 317	10 701	14 431

Narrowband	Urban Day-to-Day		Urban Disaster		Suburban Day-to-Day		Suburban Disaster	
	Busy Hour Users	Spectrum Required (MHz)	Busy Hour Users	Spectrum Required (MHz)	Busy Hour Users	Spectrum Required (MHz)	Busy Hour Users	Spectrum Required (MHz)
NB Voice Service	3 143	13.8	3 743	16.4	2 619	11.5	3 119	13.7
NB Message Service	2 957	1.6	3 557	1.9	2 464	1.3	2 965	1.6
NB Status Service	2 957	0.1	3 557	0.1	2 464	0.1	2 965	0.1
Total Narrowband Spectrum Required (MHz)		**15.5**		**18.4**		**12.9**		**15.4**

Normal NB Day-to-Day	28.4 MHz	15.5	<	<	<	12.9		
NB Urban Disaster Scenario	31.3 MHz	<	<	18.4	<	12.9		
NB Suburban Disaster Scenario	30.9 MHz	15.5	<	<	<	<	<	15.4
Larger of the two NB Disaster Scenarios	31.3 MHz							

Medium metropolitan area calculated for 180 police officers per 100 000 population (*end*)

Wideband	Urban Day-to-Day		Urban Disaster		Suburban Day-to-Day		Suburban Disaster	
	Busy Hour Users	Spectrum Required (MHz)	Busy Hour Users	Spectrum Required (MHz)	Busy Hour Users	Spectrum Required (MHz)	Busy Hour Users	Spectrum Required (MHz)
WB Data Service	2 359	15.7	2 587	17.2	1 966	13.1	2 156	14.3
WB Video Service	1 197	0.5	1 330	0.6	998	0.4	1 108	0.5
Total Wideband Spectrum Required (MHz)		**16.2**		**17.8**		**13.5**		**14.8**
						× 1/2		**× 1/2**
Normal WB Day-to-Day	23.0 MHz	16.2	<	<	<	6.8		
Urban WB Disaster Scenario	24.6 MHz	<	<	17.8	<	6.8		
Suburban WB Disaster Scenario	23.6 MHz	16.2	<	<	<	<	<	7.4
Larger of the two WB Disaster Scenarios	24.6 MHz							
Spectrum Requirement Totals	NB		WB		Sum			
Normal Day-to-Day	28.4	+	23.0	=	51.4	MHz		
Suburban Disaster Scenario	30.9	+	23.6	=	54.5	MHz		
Urban Disaster Scenario	31.3	+	24.6	=	55.9	MHz		

Medium metropolitan area calculated for 250 police officers per 100 000 population

Spectrum Requirements – Generic City Calculator			Re-Formatted	July 2002
Metropolitan Study Area	Medium Metropolitan Area			Input Data
Population of Urban Area	2 500 000	People	**1.0**	Ratio Suburban/Urban Population
Population of Surrounding Suburban Area	2 500 000	People		Ratio should be near 1.0 (Range of 0.5 × to 1.5 × of Urban Population)
Area of Urban Center	600	km²	**10.0**	Ratio Suburban/Urban Area
Area of Surrounding Suburbs	6 000	km²		Ratio should be near 10.0 (Range of 5 × to 15 × of Urban Area)
Urban Population Density	4 167	People/km²		
Suburban Population Density	417	People/km²		
"Large" or "Medium" City	MED	If Urban Population Density > 5 000 people/km², then this is a large city, OR if Urban population > 3 000 000 people, then this is a large city, otherwise this is a medium city		
Police User Density (national average)	250.0	Police per 100 000 population		

CATEGORY name and number of USERS User Category	Urban Day-to-Day	Urban Disaster	Suburban Day-to-Day	Suburban Disaster
	Population	Population	Population	Population
Primary – Local Police	9 375	9 375	7 813	7 813
Secondary – Law Enforcement/Investigators	938	1 875	781	1 563
Secondary – Police Functions	0	2 813	0	2 344
Police Civilian Support	1 875	1 875	1 563	1 563
Primary – Fire Fighters	2 719	3 534	2 266	2 945
Fire Civilian Support	544	544	453	453
Primary – Rescue/ Emergency Medical	816	1 060	680	884
Rescue/EMS Civilian Support	163	163	136	136
Secondary – General Govern-ment and Civil Agencies	938	1 875	781	1 563
Secondary – Volunteers and Other PPDR Users	469	938	391	781
Total	17 835	24 052	14 863	20 043

Narrowband	Urban Day-to-Day		Urban Disaster		Suburban Day-to-Day		Suburban Disaster	
	Busy Hour Users	Spectrum Required (MHz)	Busy Hour Users	Spectrum Required (MHz)	Busy Hour Users	Spectrum Required (MHz)	Busy Hour Users	Spectrum Required (MHz)
NB Voice Service	4 365	19.2	5 199	22.8	3 638	16.0	4 333	19.1
NB Message Service	4 107	2.2	4 941	2.7	3 423	1.9	4 117	2.2
NB Status Service	4 107	0.1	4 941	0.1	3 423	0.1	4 117	0.1
Total Narrowband Spectrum Required (MHz)		**21.5**		**25.6**		**17.9**		**21.4**

Normal NB Day-to-Day	39.4 MHz	21.5	<	<	<	17.9		
NB Urban Disaster Scenario	43.5 MHz	<	<	25.6	<	17.9		
NB Suburban Disaster Scenario	42.8 MHz	21.5	<	<	<	<	<	21.4
Larger of the two NB disaster Scenarios	43.5 MHz							

Medium metropolitan area calculated for 250 police officers per 100 000 population (*end*)

Wideband	Urban Day-to-Day		Urban Disaster		Suburban Day-to-Day		Suburban Disaster	
	Busy Hour Users	Spectrum Required (MHz)	Busy Hour Users	Spectrum Required (MHz)	Busy Hour Users	Spectrum Required (MHz)	Busy Hour Users	Spectrum Required (MHz)
WB Data Service	3 277	21.8	3 593	23.9	2 731	18.2	2 994	19.9
WB Video Service	1 663	0.7	1 847	0.8	1 386	0.6	1 539	0.7
Total Wideband Spectrum Required (MHz)		**22.5**		**24.7**		**18.8**		**20.6**
						× 1/2		**× 1/2**
Normal WB Day-to-Day	31.9 MHz	22.5	<	<	<	9.4		
Urban WB Disaster Scenario	34.1 MHz	<	<	24.7	<	9.4		
Suburban WB Disaster Scenario	32.8 MHz	22.5	<	<	<	<	<	10.3
Larger of the two WB Disaster Scenarios	34.1 MHz							
Spectrum Requirement Totals	NB		WB		Sum			
Normal Day-to-Day	39.4	+	31.9	=	71.3	MHz		
Suburban Disaster Scenario	42.8	+	32.8	=	75.7	MHz		
Urban Disaster Scenario	43.5	+	34.1	=	77.6	MHz		

Large metropolitan area

Calculated spectrum requirements using a PPDR calculator spreadsheet.

Large metropolitan area (Urban population ≅ 8.0 million and area ≅ 800 km²) (Suburban population ≅ 8.0 million and area ≅ 8 000 km²)						
Medium PPDR density (180 Police per 100 000 population)				**High PPDR density** (250 police per 100 000 population)		
Urban				**Urban**		
NB day-to-day	23.7	MHz		NB day-to-day	33.0	MHz
WB day-to-day	24.9	MHz		WB day-to-day	34.6	MHz
Disaster NB	28.3	MHz		Disaster NB	39.3	MHz
Disaster WB	27.4	MHz		Disaster WB	38.0	MHz
Suburban				**Suburban**		
NB day-to-day	19.8	MHz		NB day-to-day	27.4	MHz
WB day-to-day	20.7	MHz		WB day-to-day	28.7	MHz
Disaster NB	23.6	MHz		Disaster NB	32.7	MHz
Disaster WB	22.7	MHz		Disaster WB	31.5	MHz
Normal day-to-day				**Normal day-to-day**		
NB (urban + suburban)	43.50	MHz		NB	60.40	MHz
WB (urban + 1/2 suburban)	35.25	MHz		WB	48.95	MHz
	78.75	MHz			109.35	MHz
Suburban disaster				**Suburban disaster**		
NB	47.30	MHz		NB	65.70	MHz
WB	36.25	MHz		WB	50.35	MHz
	83.55	MHz			116.05	MHz
Urban disaster				**Urban disaster**		
NB	48.10	MHz		NB	66.70	MHz
WB	37.75	MHz		WB	52.35	MHz
	85.85	MHz			119.05	MHz

The left-hand column shows the spectrum calculated for a medium PPDR user density and the right-hand column shows the spectrum calculated for higher PPDR user density.

The top-half of the chart shows individual NB and WB spectrum calculations for normal “day-to-day” operations and for a disaster within the local area.

The total spectrum requirement is the sum of the urban and suburban calculations. For narrowband the assumption is that frequencies are not reused between the two areas, so the total is the sum of the NB urban and the NB suburban requirements. For wideband, the assumption is that some frequencies can be reused, therefore, the total is the sum of the wideband urban requirement and half of the wideband suburban requirement.

The bottom half of the chart shows the spectrum calculated for a disaster in either the urban area or the suburban area, where there is a significant increase in the number of users (up to 30% for primary users).

Normal day-to-day operations for this generic large city requires from 79 MHz to 109 MHz depending on whether it is located in a country with a medium PPDR density or a high PPDR density.

If a disaster scenario described above occurs in the suburban area, then the NB/WB spectrum requirement increases by about 6%. If disaster occurs in the urban area, then the NB/WB spectrum requirement increases by about 9%.

Disaster operations for this generic large city require from 84 MHz to 119 MHz depending on where the disaster occurs and whether it is located in a country with a medium PPDR density or a high PPDR density.

The broadband spectrum requirement needs to be added. Since broadband will cover very small radius "hot spots", the broadband frequencies can be reused throughout the urban and suburban area. ITU-R contributions from the 2000-2003 study period have shown broadband spectrum requirements to be in the 50-75 MHz range.

Therefore, for a generic large city, the total spectrum requirement is in the range of 134 to 194 MHz to handle the type of disaster scenario described above.

The following two tables show the breakout of PPDR users and narrowband and wideband service in a large-sized metropolitan area.

Large metropolitan area calculated for 180 police officers per 100 000 population

Spectrum Requirements – Generic City Calculator		Re-Formatted	July 2002	
Metropolitan Study Area	Large Metropolitan Area		Input Data	
Population of Urban Area	8 000 000	People	**1.0**	Ratio Suburban/Urban Population
Population of Surrounding Suburban Area	8 000 000	People		Ratio should be near 1.0 (Range of 0.5 × to 1.5 × of Urban Population)
Area of Urban Center	800	km²	**10.0**	Ratio Suburban/Urban Area
Area of Surrounding Suburbs	8 000	km²		Ratio should be near 10.0 (Range of 5 × to 15 × of Urban Area)
Urban Population Density	10 000	People/km²		
Suburban Population Density	1 000	People/km²		
"Large" or "Medium" City	LAR	If Urban Population Density > 5 000 people/km², then this is a large city, OR if Urban population > 3 000 000 people, then this is a large city, otherwise this is a medium city		
Police User Density (national average)	180.0	Police per 100 000 population		

CATEGORY name and number of USERS User Category	Urban Day-to-Day	Urban Disaster	Suburban Day-to-Day	Suburban Disaster
	Population	Population	Population	Population
Primary – Local Police	21 600	21 600	18 000	18 000
Secondary – Law Enforcement/Investigators	2 160	4 320	1 800	3 600
Secondary – Police Functions	0	6 480	0	5 400
Police Civilian Support	4 320	4 320	3 600	3 600
Primary – Fire Fighters	6 264	8 143	5 220	6 786
Fire Civilian Support	1 253	1 253	1 044	1 044
Primary – Rescue/ Emergency Medical	1 879	2 443	1 566	2 036
Rescue/EMS Civilian Support	376	376	313	313
Secondary – General Govern-ment and Civil Agencies	2 160	4 320	1 800	3 600
Secondary – Volunteers and Other PPDR Users	1 080	2 160	900	1 800
Total	41 092	55 415	34 243	46 179

Narrowband	Urban Day-to-Day		Urban Disaster		Suburban Day-to-Day		Suburban Disaster	
	Busy Hour Users	Spectrum Required (MHz)	Busy Hour Users	Spectrum Required (MHz)	Busy Hour Users	Spectrum Required (MHz)	Busy Hour Users	Spectrum Required (MHz)
NB Voice Service	10 058	21.2	11 979	25.2	8 382	17.6	9 982	21.0
NB Message Service	9 463	2.5	11 384	3.0	7 886	2.0	9 487	2.5
NB Status Service	9 463	0.1	11 384	0.1	7 886	0.1	9 487	0.1
Total Narrowband Spectrum Required (MHz)		**23.7**		**28.3**		**19.8**		**23.6**

Normal NB Day-to-Day	43.5 MHz	23.7	<	<	<	19.8		
NB Urban Disaster Scenario	48.1 MHz	<	<	28.3	<	19.8		
NB Suburban Disaster Scenario	47.3 MHz	23.7	<	<	<	<	<	23.6
Larger of the two NB disaster scenarios	48.1 MHz							

Large metropolitan area calculated for 180 police officers per 100 000 population (*end*)

Wideband	Urban Day-to-Day		Urban Disaster		Suburban Day-to-Day		Suburban Disaster	
	Busy Hour Users	Spectrum Required (MHz)	Busy Hour Users	Spectrum Required (MHz)	Busy Hour Users	Spectrum Required (MHz)	Busy Hour Users	Spectrum Required (MHz)
WB Data Service	7 549	24.1	8 279	26.4	6 291	20.0	6 899	22.0
WB Video Service	3 831	0.8	4 256	0.9	3 193	0.7	3 546	0.8
Total Wideband Spectrum Required (MHz)		**24.9**		**27.4**		**20.7**		**22.7**
						× 1/2		**× 1/2**
Normal WB Day-to-Day	35.3 MHz	24.9	<	<	<	10.3		
Urban WB Disaster Scenario	37.7 MHz	<	<	27.4	<	10.3		
Suburban WB Disaster Scenario	36.3 MHz	24.9	<	<	<	<	<	11.4
Larger of the two WB disaster Scenarios	37.7 MHz							
Spectrum Requirement Totals	NB		WB		Sum			
Normal Day-to-Day	43.5	+	35.3	=	78.8	MHz		
Suburban Disaster Scenario	47.3	+	36.3	=	83.6	MHz		
Urban Disaster Scenario	48.1	+	37.7	=	85.8	MHz		

Large metropolitan area calculated for 250 police officers per 100 000 population

Spectrum Requirements – Generic City Calculator		Re-Formatted		July 2002
Metropolitan Study Area	Large Metropolitan Area			Input Data
Population of Urban Area	8 000 000	People	**1.0**	Ratio Suburban/Urban Population
Population of Surrounding Suburban Area	8 000 000	People		Ratio should be near 1.0 (Range of 0.5 × to 1.5 × of Urban Population
Area of Urban Center	800	km²	**10.0**	Ratio Suburban/Urban Area
Area of Surrounding Suburbs	8 000	km²		Ratio should be near 10.0 (Range of 5 × to 15 × of Urban Area)
Urban Population Density	10 000	People/km²		
Suburban Population Density	1 000	People/km²		
"Large" or "Medium" City	LAR	If Urban Population Density > 5 000 people/km², then this is a large city, OR if Urban population > 3 000 000 people, then this is a large city, otherwise this is a medium city		
Police User Density (national average)	250.0	police per 100 000 population		

CATEGORY name and number of USERS User Category	Urban Day-to-Day Population	Urban Disaster Population	Suburban Day-to-Day Population	Suburban Disaster Population
Primary – Local Police	30 000	30 000	25 000	25 000
Secondary – Law Enforcement/Investigators	3 000	6 000	2 500	5 000
Secondary – Police Functions	0	9 000	0	7 500
Police Civilian Support	6 000	6 000	5 000	5 000
Primary – Fire Fighters	8 700	11 310	7 250	9 425
Fire Civilian Support	1 740	1 740	1 450	1 450
Primary – Rescue/ Emergency Medical	2 610	3 393	2 175	2 828
Rescue/EMS Civilian Support	522	522	435	435
Secondary – General Government and Civil Agencies	3 000	6 000	2 500	5 000
Secondary – Volunteers and Other PPDR Users	1 500	3 000	1 250	2 500
Total	57 072	76 965	47 560	64 138

Narrowband	Urban Day-to-Day		Urban Disaster		Suburban Day-to-Day		Suburban Disaster	
	Busy Hour Users	Spectrum Required (MHz)	Busy Hour Users	Spectrum Required (MHz)	Busy Hour Users	Spectrum Required (MHz)	Busy Hour Users	Spectrum Required (MHz)
NB Voice Service	13 969	29.4	16 637	35.1	11 641	24.5	13 864	29.2
NB Message Service	13 143	3.4	15 811	4.1	10 953	2.8	13 176	3.4
NB Status Service	13 143	0.1	15 811	0.2	10 953	0.1	13 176	0.1
Total Narrowband Spectrum Required (MHz)		**33.0**		**39.3**		**27.4**		**32.7**

Normal NB Day-to-Day	60.4 MHz	33.0	<	<	<	27.4		
NB Urban Disaster Scenario	66.8 MHz	<	<	39.3	<	27.4		
NB Suburban Disaster Scenario	65.7 MHz	33.0	<	<	<	<	<	32.7
Larger of the two NB Disaster Scenarios	66.8 MHz							

Large metropolitan area calculated for 250 police officers per 100 000 population (*end*)

Wideband	Urban Day-to-Day		Urban Disaster		Suburban Day-to-Day		Suburban Disaster	
	Busy Hour Users	Spectrum Required (MHz)	Busy Hour Users	Spectrum Required (MHz)	Busy Hour Users	Spectrum Required (MHz)	Busy Hour Users	Spectrum Required (MHz)
WB Data Service	10 485	33.5	11 498	36.7	8 738	27.8	9 582	30.5
WB Video Service	5 321	1.1	5 910	1.3	4 434	0.9	4 925	1.0
Total Wideband Spectrum Required (MHz)		**34.6**		**38.0**		**28.7**		**31.5**
						× 1/2		**× 1/2**
Normal WB Day-to-Day	49.0 MHz	34.6	<	<	<	14.4		
Urban WB Disaster Scenario	52.4 MHz	<	<	38.0	<	14.4		
Suburban WB Disaster Scenario	50.4 MHz	34.6	<	<	<	<	<	15.8
Larger of the two WB Disaster Scenarios	52.4 MHz							
Spectrum Requirement Totals	NB		WB		Sum			
Normal Day-to-Day	60.4	+	49.0	=	109.4	MHz		
Suburban Disaster Scenario	65.7	+	50.4	=	116.1	MHz		
Urban Disaster Scenario	66.8	+	52.4	=	119.1	MHz		

PPDR population density analysis

- National average for police officers in the range 180 or 250 police/100 000 population.
- Suburban PPDR populations based upon police density of 1.25 times the national average.
- Urban PPDR populations based upon police density of 1.5 times the national average.
- Day-to-day PPDR population estimates:
  - Local police – population based on national average
  - Law enforcement/investigators – 10% of police density
  - Secondary police (coming from outside) – none
  - Police civilian support – 20% of police density
  - Fire fighters – 29% of police density (~3.5 police per fire)
  - Fire civilian support – 20% of fire fighter density
  - Rescue/EMS – 30% of fire fighter density (~11.7 police per EMS)
  - EMS civilian support – 20% of rescue/EMS density
  - General Government – 10% of police density
  - Other PPDR users and volunteers – 5% of police density
- Changes in PPDR populations during a disaster:
  - Local police – population remains the same
  - Law enforcement/investigators – population doubles
  - Secondary police (coming from outside)
  - Additional population about 30% of local police
  - Police civilian support – population remains the same
  - Fire fighters (coming from outside) – 30% increase in fire population
  - Fire civilian support – population remains the same
  - Rescue/EMS (coming from outside) – 30% increase in fire population

– EMS civilian support – population remains the same
– General government – population doubles
– Other PPDR users and volunteers – population doubles

Summary of formulas used to calculate population density (A)

PPDR user category	PPDR density	Suburban normal	Changes for disaster	Suburban disaster
Primary – Local Police	For suburban areas use 1.25 times national average police density	D(sub) = Police density × 1.25 × population/ 100 000	Remains the same	D(sub)
Secondary – Law Enforcement/Investigators	10% of police density	0.10 × D(sub)	Doubles	2.0 × (0.10 × D(sub))
Secondary – Police Functions	0	0.0 × D(sub)	30% of police density	0.3 × D(sub)
Police Civilian Support	20% of police density	0.2 × D(sub)	Remains the same	0.2 × D(sub)
Primary – Fire Fighters	29% of police density	0.29 × D(sub)	29% increase	1.3 × 0.29 × D(sub)
Fire Civilian Support	20% of fire density	0.2 × (0.29 × D(sub))	Remains the same	0.2 × 0.29 × D(sub)
Primary – Rescue/Emergency Medical	30% of fire density	0.3 × (0.29 × D(sub))	30% increase	1.3 × 0.29 × 0.5 × D(sub)
Rescue/EMS Civilian Support	20% of EMS density	0.2 × (0.3 × (0.29 × D(sub)	Remains the same	0.2 × 0.3 × 0.29 × D(sub)
Secondary – General Government and Civil Agencies	10% of police density	0.10 × D(sub)	Doubles	2.0 × 0.10 × D(sub)
Secondary – Volunteers and Other PPDR	5% of police density	0.05 × D(sub)	Doubles	2.0 × 0.05 × D(sub)

Summary of formulas used to calculate population density (B)

PPDR user category	PPDR density	Urban normal	Changes for disaster	Urban disaster
Primary – Local Police	For urban areas use 1.5 times national average police density	D(urb) = Police density × 1.50 × population/ 100 000	Remains the same	D(urb)
Secondary – Law Enforcement/Investigators	10% of police density	0.10 D(urb)	Doubles	2.0 × (0.10 × D(urb))
Secondary – Police Functions	0	0.0 × D(urb)	30% of police density	0.3 × D(urb)
Police Civilian Support	20% of police density	0.2 × D(urb)	Remains the same	0.2 × D(urb)
Primary – Fire Fighters	29% of police density	0.29 × D(urb)	29% increase	1.3 × 0.29 × D(urb)
Fire Civilian Support	20% of fire density	0.2 × (0.29 × D(urb))	Remains the same	0.2 × 0.29 × D(urb)
Primary – Rescue/Emergency Medical	30% of fire density	0.3 × (0.29 × D(urb))	30% increase	1.3 × 0.29 × 0.5 × D(urb)
Rescue/EMS Civilian Support	20% of EMS density	0.2 × (0.3 × (0.29 × D(urb)	Remains the same	0.2 × 0.3 × 0.29 × D(urb)
Secondary – General Government and Civil Agencies	10% of police density	0.10 × D(urb)	Doubles	2.0 × 0.10 × D(urb)
Secondary – Volunteers and Other PPDR	5% of police density	0.05 × D(urb)	Doubles	2.0 × 0.05 × D(urb)

Example parameters

Narrowband – medium city – suburban – medium PPDR density
Population = 2 500 000 people
Area = 6 000 km^2
Police Density Suburban = U(sub) = 1.25 × 180 x 2 500 000/100 000 = 5 625 police
Cell radius = 14.4 km
Cell antenna pattern = Omni
Reuse factor = 21
GoS factor = 1.5
Width of frequency band = 24 MHz
Channel bandwidth = 12.5 kHz
% of band not used for traffic = 10%

Narrowband – medium city – urban – medium PPDR density
Population = 2 500 000 people
Area = 600 km^2
Police density suburban = U(urb) = 1.5 × 180 × 2 500 000/100 000 = 6 750 police
Cell radius = 5.0 km
Cell antenna pattern = Hex
Reuse factor = 21
GoS factor = 1.5
Width of frequency band = 24 MHz
Channel bandwidth = 12.5 kHz
% of band not used for traffic = 10%

Wideband – medium city – suburban – medium PPDR density
Population = 2 500 000 people
Area = 6 000 km^2
Police density suburban = U(sub) = 1.25 × 180 × 2 500 000/100 000 = 5 625 police
Cell radius = 9.2 km
Cell antenna pattern = Omni
Reuse factor = 12
GoS factor = 1.5
Width of frequency band = 24 MHz
Channel bandwidth = 150 kHz
% of band not used for traffic = 10%

Wideband – medium city – urban – medium PPDR density
Population = 2 500 000 people
Area = 600 km^2
Police density suburban = U(urb) = 1.5 × 180 × 2 500 000/100 000 = 6 750 police
Cell radius = 3.2 km
Cell antenna pattern = Hex
Reuse factor = 12
GoS factor = 1.5
Width of frequency band = 24 MHz
Channel bandwidth = 150 kHz
% of band not used for traffic = 10%

Narrowband – large city – suburban – medium PPDR density
Population = 8 000 000 people
Area = 8 000 km^2
Police density suburban = U(sub) = 1.25 × 180 × 8 000 000/100 000 = 18 000 Police
Cell radius = 11.5 km
Cell antenna pattern = Omni
Reuse factor = 21
GoS factor = 1.5
Width of frequency band = 24 MHz
Channel bandwidth = 12.5 kHz
% of band not used for traffic = 10%

Narrowband – large city – urban – medium PPDR density
Population = 8 000 000 people
Area = 800 km^2
Police density suburban = U(urb) = 1.5 × 180 × 8 000 000/100 000 = 21 600 Police
Cell radius = 4.0 km
Cell antenna pattern = Hex
Reuse factor = 21
GoS factor = 1.5
Width of frequency band = 24 MHz
Channel bandwidth = 12.5 kHz
% of band not used for traffic = 10%

Wideband – large city – suburban – medium PPDR density
Population = 8 000 000 people
Area = 8 000 km^2
Police density suburban = U(sub) = 1.25 × 180 × 8 000 000/100 000 = 18 000 Police
Cell radius = 7.35 km
Cell antenna pattern = Omni
Reuse factor = 12
GoS factor = 1.5
Width of frequency band = 24 MHz
Channel bandwidth = 150 kHz
% of band not used for traffic = 10%

Wideband – large city – urban – medium PPDR density
Population = 8 000 000 people
Area = 800 km^2
Police density suburban = U(urb) = 1.5 × 180 × 2 500 000/100 000 = 21 600 Police
Cell radius = 2.56 km
Cell antenna pattern = Hex
Reuse factor = 12
GoS factor = 1.5
Width of frequency band = 24 MHz
Channel bandwidth = 150 kHz
% of band not used for traffic = 10%

Annex 7

Annexes on Broadband PPDR Spectrum Calculations and Scenarios

Note that the contents of Annexes 6 and 7 were agreed to be considered as the basis for the possible future development of a new ITU-R Report or Recommendation on methodologies for estimating PPDR spectrum requirements. Based on the outcome of that effort, the contents of these Annexes might be incorporated into this new Report or Recommendation on PPDR spectrum estimation.

Studies performed by several member states and sector members on the required spectrum for BB-PPDR are presented in Annex 7. The following table summarizes the studies' results:

Annex	**Source**	**Bandwidth requirements (MHz)**		**Comments**
		Uplink	**Downlink**	
7A	CEPT	10	10	Data only. Based on ECC Report 199 Conclusions
7B	UAE	16,9	12,5	Two incidents data.
7C	Motorola Solutions	> 20	20	Level 3 incident (FDD)
7D	Israel	20	20	
7E	China	30-40		TD-LTE, depends on different scenarios
7F	Korea	10	10	

Annex 7A

Methodology for the calculation of broadband PPDR spectrum requirements within CEPT[10]

The frequency ranges used for estimating the necessary spectrum bandwidth are the 400 MHz and 700 MHz ranges. It is assumed that a wide area network would be deployed below 1 GHz in order to reduce the number of necessary cell sites.

A brief description of the methodology used for calculation of spectrum requirements is presented below.

This methodology can be considered as an incident based approach where traffic is summed over several separate incidents and background traffic is then added in order to define the total spectrum requirements.

Methodology for PP1

The methodology used for PP1 scenarios consists of the following 5 steps:

Step 1: Definition of the incidents (scenarios).

Step 2: Estimate the total traffic requirement per incident including background traffic.

Step 3: Calculate the link budgets and cell size.

Step 4: Estimate the number of incidents that should be taken into account simultaneously per cell.

Step 5: Estimate the total spectrum requirement based on assumptions on number of incidents per cell, location of incidents within a cell and spectrum efficiency per incident.

Methodology for PP2

The methodology used for PP2 scenarios consists of the following 3 steps:

Step 1: Definition of the PP2 scenarios.

Step 2: Estimate of the PP2 scenarios traffic.

Step 3: Estimate the total spectrum requirement based on assumptions on location of users within the cell and spectral efficiency.

[10] See ECC Report 199 for more details on methodology used in CEPT.

Annex 7B

Spectrum requirements for BB PPDR Based on LTE in the United Arab Emirates

Background

After the WRC-12 Resolution 648, the UAE TRA initiated and hosted a national dialog through the creation of a National PPDR Committee with representatives from all public safety and disaster relief agencies.

The Committee held regular meetings to create a better understanding of the evolution of technologies, technical and spectrum requirements for broadband services and applications.

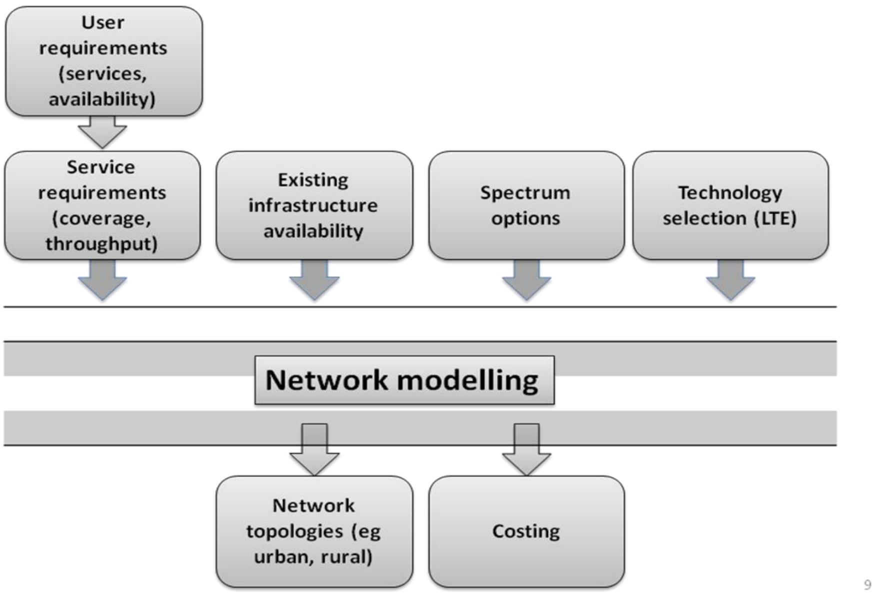
The UAE TRA has met with PPDR industry on several occasions to better understand industry trends and to ensure that what is being proposed for the UAE and the region is consistent with our national interest.

In addition, the TRA has commissioned a specialized consulting company to study, model and calculate the spectrum requirements for BB PPDR in the UAE.

Methodology

The study is addressing the methodology used to assess and calculate minimum spectrum requirements were derived from the works that were done by CEPT under FM49 particularly Report 199 and FM49 LEWP Matrix. The flowchart below explains the basic methodology that was followed. Input was sought from all members of the National PPDR Committee. Number of PPDR users, user requirements for services, applications, coverage, and availability were inputted. Additional data based on technology adopted (LTE/LTE-Advanced), number of existing towers and sites used for the TETRA LMR, and spectrum options from UHF sub 1GHz to 3.6 GHz.

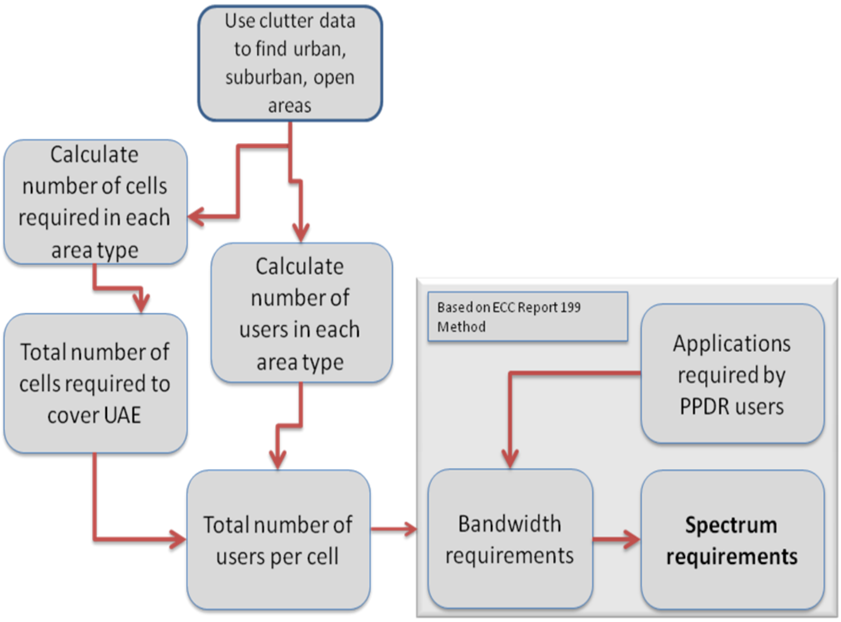
FIGURE 7B-1



In order to model the number of PPDR users per cell site, a study was based on propagation model assumptions for LTE, a list of frequency bands to be considered, clutter data for UAE, and link budget parameters and certain distribution factor for PPDR users.

The total number of users was calculated based on input collected from PPDR representatives to the Committee with additional growth margin. The number used in the model for UAE was based on **98192 PPDR users.**

FIGURE 7B-2



Highlights of PPDR spectrum requirements results for UAE

TABLE 7B-1

Clutter Data and Minimum number of Sites required against Frequency Band calculation sheet

	ID	Clutter Class	Pixels	km²	relative Area	per Calculatio	# of Sites @		
							450 MHz	750 MHz	2 GHz
	1	Sea Water	2.2E+07	54711	-	-	-	-	-
Open	2	Inland Water	9570	24	0.03%		1	1	1
	3	Marsh / Swamp	0	0	0.00%		0	0	0
	4	Sealed Surface	2427	6	0.01%		1	1	1
	5	Open in Urban	24421	61	0.07%		1	1	1
	6	Open	3.2E+07	80646	96.29%		104	161	324
	7	Agriculture	736386	1841	2.20%		3	4	8
	8	Forest	17431	44	0.05%	82622	1	1	1
				82622	98.65%		111	169	336
Suburban	9	Village	76198	190	0.23%		7	12	38
	10	Suburban	190830	477	0.57%		17	30	95
	11	Industrial	131024	328	0.39%		12	21	65
	12	Low Urban	266	1	0.00%	996	1	1	1
				996	1.19%		37	64	199
Urban	13	Urban	42868	107	0.13%		12	24	112
	14	Dense Urban	2690	7	0.01%		1	2	8
	15	Dense Urban High	5270	13	0.02%		2	3	14
	16	Block Buildings	1936	5	0.01%	131.91	1	2	6
				132	0.16%		16	31	140
		TOTAL	3E+07	83749	100.00%	83749	164	264	675

Assumption on antenna height and other parameters were reasonability assumed based on the following data:

TABLE 7B-2

User Equipment		
Parameters	**Value**	**Unit**
Height	1.5	m
Frequency	420/750/2000	MHz
Output Power EIRP	30	dBm
Antenna Gain	0	dBi
Cable Loss	0	dB
Body Loss	3	dB
Sensitivity	-106.5	dBm

TABLE 7B-3

Base Station		
Parameters	**Value**	**Unit**
Height	40	m
Frequency	420/750/2000	MHz
Output Power EIRP	43	dBm
Antenna Gain	4.3	dBi
Duplexer Loss	1	dB
Cable Loss	2	dB
Sensitivity	-123.7	dBm

TABLE 7B-4

Coverage probability used was based on 95% availability location and time.

A minimum of 264 sites is expected to be required to achieve the coverage requirements for UAE in the 750 MHz band which is close to what the PPDR number of available sites is (< 300 site).

	Users per sq. km	Total Users
Open	0.9	74360
Suburban	15	11952
Urban	90	11880
Total		98192

TABLE 7B-5

The average number of users per cell in peak time was calculated based on assumed distribution by geographic zone and based on number of sites required per clutter zone as follows:

Users per cell

	450 MHz	**750 MHz**	2 GHz
Open	670	440	221
Suburban	323	187	60
Urban	743	383	85
Avg.	**599**	**372**	**145**

The number of 372 Users per cell in peak time was used to calculate spectrum requirements for different scenarios of BB-PPDR use.

Summary of the spectrum requirements calculation – Results

– Normal peak busy hours (day-to-day operations) requires 3.9 MHz

– 1 incident requires 6.3 MHz

– 2 incident requires 16.9 MHz

TABLE 7B-6

Spectrum Results

Emergency/Incident conditions						
Uplink		Downlink				
		True group call possible		Individual transactions only		
1 incident	2 incidents	1 incident	2 incidents	1 incident	2 incidents	
6.3	16.9	6.0	8.8	6.6	12.5	MHz

Normal peak busy hour			
Uplink	Downlink		
	Individual only	Group call	
3.9	3.7	3.5	MHz

Data throughput requirements:

Emergency/Incident conditions						
Uplink		Downlink				
		True group call possible		Individual transactions only		
1 incident	2 incidents	1 incident	2 incidents	1 incident	2 incidents	
5504	8568	5969	6850	7118	8475	kbps

Normal peak busy hour			
Uplink	Downlink		
	Individual only	Group call	
3134	5483	5199	kbps

Of which, the background load in incidents is:

Uplink	Downlink		
	Group call	Individual	
2440	5088	5760	kbps

Therefore, incident load is

Uplink		Downlink			
		Group call		Individual call	
1 incident	2 incidents	1 incident	2 incidents	1 incident	2 incidents
3064	6127	881	1763	1357	2715

Annex 7C

Throughput requirements of broadband PPDR scenarios

Mobile Broad Band technology aiming at wide area coverage constitute an evolution from Narrow Band technology currently applied for mission critical PPDR voice communications in all ITU-R Regions.

A Mobile Broad Band application for the PPDR such as transmission of high resolution images and video requires much higher basic bit-rates than current PPDR technology can deliver.

It should be noted that the new demands for several simultaneous multimedia capabilities (several simultaneous applications running in parallel) over a mobile system presents a huge demand on throughput and high speed data capabilities while the system at the same time shall provide very high peak data rates.

Such demand is particularly challenging when deployed in a localized areas with intensive scene-of-incident requirements where PPDR responders are operating under often very difficult conditions.

For example a 700 MHz LTE PPDR base station deployed to support Broad Band applications in urban environments could typically be tailored to servicing a localized area in the order of 1 km^2 or even less offering access to voice, high-speed data, high quality digital real time video and multimedia services, at indicative continuous data rates in the downlink direction in the range of 1-10 - 100-150 Mbit/s per sector, with a total capacity of 300-450 Mbit/s over the area of 1 km^2, with channel bandwidths determined by the particular deployment of the system. Examples of possible applications include:

– high-resolution video communications from portable terminals such as during traffic stops;
– 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 view of the single patient demanding the order of up to 1 Mbit/s. The demand for capacity can easily be envisioned during the rescue operation following a major disaster. This may equate to a net hot spot capacity of over 100 Mbit/s close to a broadband PPDR base station.

Mobile Broad Band systems may have inherent noise and interference trade-offs with data rates and associated coverage. Depending on the technology and the deployed configuration, a single broadband network base station may have different coverage areas in the range of a few hundred metres up to hundred kilometres, offering a wide range in spectrum reuse capability.

Collectively, the high peak data rates, extended coverage and data speeds plus localized coverage area open up numerous new possibilities for BB PPDR applications including tailored area networks as described.

A spectrum throughput and bandwidth calculator has been developed based on the requirements of some Public Safety agencies. This calculator is based on a set of PPDR applications which is based on their current operational experience and their vision of future working practices. The Calculator allows the user to model up to two incident scenes of small, medium, large or very large emergencies. The first incident scene is assumed to take place near the cell edge, and the second incident scene is assumed to be uniformly distributed somewhere in the cell (at a median location/area).

The calculator utilizes a blended spectral efficiency model (with a total of 9 spectral efficiency values dependent on the deployment scenario), where background data traffic is modelled with average spectral efficiencies, and the incident scenes are modelled with different spectral efficiencies depending on their location (based on simulations, which are ongoing).

In this calculator, the user may change any boxes highlighted in blue to study different effects (e.g. incident scene size, placement, system deployment topology, bldg. coverage, actual application usage for each incident size/type). While the calculator allows the study of various effects through simulations of various scenarios, it may be noted that there is significant increase in spectral requirements at a cell edge and for large incidents; this requirement becomes overwhelming, likely resulting in the need to offload PS traffic to commercial networks, or deploy an incident scene microcell (CoW). One can also see from the spreadsheet that a medium sized incident near the cell edge and a large incident at a median location require approximately 10+10 MHz of spectrum which is in-line with some other published studies.

Spectrum_Calculator
_v0_8.xlsx

Attachment 1 of this Annex provides some of the PPDR scenarios using this calculator to show the throughput and the bandwidth requirements of these Broadband PPDR scenarios. These scenarios include level 1 being a Tanker Spill, Level 2, a Clandestine (Drug) Lab, and Level 3, a Petrochemical Refinery incident. The Fig. 7C-1 below summarizes the expected public safety equipment and personnel response needed to manage such an incident in a local Chicago (Illinois, USA) suburb.

Attachment 1 of Annex 7C

Given the unique mission critical requirements of public safety, it is essential that first responders have unilateral control over sufficient broadband capacity to serve current and future needs. To this end, Motorola Solutions developed a model to evaluate public safety's broadband wireless requirements by drawing upon existing policies and recent incident feedback. For purposes of this research, Level 1 through Level 3 Hazardous Materials Incidents were considered: Level 1 being a Tanker Spill, Level 2, a Clandestine (Drug) Lab, and Level 3, a Petrochemical Refinery incident. The Fig. 7C-1 below summarizes the expected public safety equipment and personnel response needed to manage such an incident in a local Chicago (Illinois, USA) suburb.[11]

FIGURE 7C-1

Typical Response Scope for Level 1-3 Hazardous Materials Incidents

	Level 1 Gas Tanker Spill			Level 2 Clandestine Lab			Level 3 Refinery Explosion		
	Individuals	Vehicles	Command Vehicle	Individuals	Vehicles	Command Vehicle	Individuals	Vehicles	Command Vehicle
Incident Command	3	3	0	4	4	0	5	5	0
Command Asst.	0	0	0	4	0	0	5	0	0
Fire Engines	8	2	0	16	4	0	24	6	0
Fire Trucks	15	3	0	15	3	0	20	4	0
Fire Squads	5	1	0	10	2	0	15	3	0
EMS - Responders	4	2	0	6	3	0	10	5	0
EMS - Life Safety	10	5	0	18	9	0	18	9	0
Haz Mat Tech Teams	8	2	0	8	2	0	16	4	0
Mobile Command	0	0	0	4	0	4	4	0	4
Police Blue Team	5	5	0	15	15	0	25	25	0
State Police	2	2	0	2	2	0	2	2	0
State EPA	2	2	0	2	2	0	2	2	0
Federal	0	0	0	6	2	0	0	0	0
Total	**62**	**29**	**0**	**110**	**48**	**4**	**146**	**65**	**4**

As is clearly evident in Figure 7C-1, even the lowest level incident, Level 1, will elicit considerable response from a variety of public safety agencies that will all arrive on the scene needing broadband services.

The incident scene broadband demands are classified as follows based on usage:

1 **Individual (Person/Vehicle) CAD overhead functions**: The classification includes incident data, GPS information, biosensors and other status, messaging, and queries. Each station individually consumes relatively low down/uplink bandwidth but in aggregate usage can be significant across many users.

[11] Specifically Posen, Illinois was used and their MABAS (Multi-Agency Box Alarm System) "Box Card" was evaluated with interpretation from Posen PS employees.

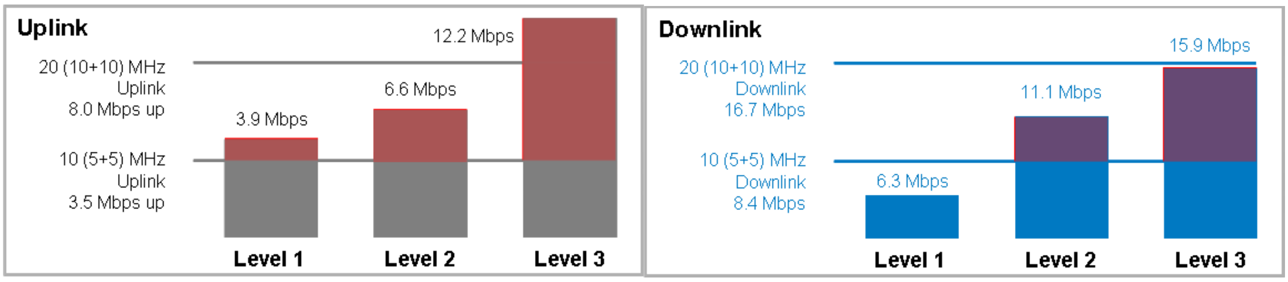
2 **Incident scene database lookups/downloads and information searches**: The classification includes the download of manuals, incident scene images, maps and topography information, building plans, etc. This use case has the unique requirement that, in general, the information is needed quickly as incident commanders initially assess the scene and develop a strategy. The model assumes that all expected initial data is downloaded and available with the first 10 minutes of the incident. The demands are scaled with the incident size and complexity.

3 **Video**: This classification of usage is comprised of personal video cameras for workers operating in the hot-zone, incident scene (car) video positioned around the perimeter, and cameras deployed within the scene. The video is uplinked via the network and a subset of the streams (switchable on command) is down-linked to the on-scene command center. Rates of 400kbit/s (QVGA 320x240 @ 30fps) and 1.2 Mbit/s (1280x960 @ 30fps) are used and the number of each type of video stream is scaled with the size and complexity of the incident.

Figure 7C-2 below summarizes the results of the analysis where the bandwidth demands for both uplink and downlink are compared with the expected *average* capacity of a single LTE serving sector (*cell edge* performance, especially on the uplink, would be considerably less and obviously under optimistic conditions peak data rates can be much higher). A "background" load of 20% is added to the total demand assuming this would be a minimum "base load" for other non-incident related, nominal activities across the sector coverage area.

FIGURE 7C-2

Broadband Wireless Capacity Implications



LTE spectrum requirement observations

The results shown in Fig. 7C-2 clearly show that 10 MHz (5+5) of capacity is insufficient to service the uplink demands for even a Level 1 incident. On the other hand, although 10+10 is still deficient for the ideal Level 3 workload, it services the Level 1 and Level 2 incident demands and comes much closer to providing reasonable capability for the Level 3 case.

Annex 7D

Representative scenario- deploying LTE for PPDR

Background

This study is addressing the methodology used to calculate minimum spectrum requirements for PPDR agencies in Israel.

Use of IMT-LTE for Broadband PPDR system refers to 15 time line events and a typical response sequence based on the number of responders, as well as the broadband resources throughout the incident. The data traffic supporting this response is assumed to be served by a wide area, mobile broadband network. The PPDR agencies also use Project-25 system for voice only. Project-25 system had not been analyzed during this event.

Incident scenario

The scenario includes an accident in which a chemical material truck crashes in the city; the truck hits several cars and the truck tank is damaged. The chemical material starts to leak, and the PPDR agencies start to evacuate the area. Two cars are on fire, the fire is spreading fast, people are injured and some are trapped inside the cars, a nearby building must be evacuated as soon as possible.

The following table shows the time line scenario step by step.

The table includes:

1. Event description.
2. Time line from 0 to 6 hours.
3. Link type: Project 25 system for Voice and LTE for data.
4. Required actions uplink.
5. Required actions downlink.
6. Total number of users that arrive each time line.

The following PPDR agencies take part during the event:

1. Police.
2. Ambulances.
3. Fire brigade.
4. Hazardous materials response team.
5. City control forces.

Event description

Call received at police operation center, and the operation center dispatch immediately broadcasts to all forces to go there as soon as possible. 12 police cars confirm that they on the way to scene. The operation centre dispatch sends location information to vehicles’ computers and the police cars also request more information about the area and more GIS information. The dispatch sends them the GIS information and high resolution video of the event from a security camera close to the truck. After 7 min, the police cars arrive at the scene and send real time low resolution video from the area. The policemen are getting real time high resolution video from a high resolution security camera via the LTE system on a nearby building in which people are trapped because of the fire. They are also getting GIS information and building information. After 12 min, additional police vehicles with 2 chief officers arrive at the scene.

They also send real time low resolution video from the area and they receive real time high resolution video from a police helicopter via the LTE system. After 13 minutes, a city control vehicle with two officers arrives at the scene. They send real time low resolution video from the area to the city control room and they receive real time high resolution video from a city traffic control camera via the LTE system. After 14 minutes, four ambulances arrive. They request GIS information and send real time high resolution video to their Command Centre. They are receiving real time high resolution video from a security camera via the LTE system about the injuries and getting medical information and GIS information. After 15 minutes the fire-brigade arrives, requests GIS information, sends real time medium resolution video from the vehicle's camera, receives real time medium resolution video from the scene and gets GIS information and building scheme. After 16 minutes, hazardous materials response team arrive and request GIS information, send high resolution pictures in order to verify the chemical liquid with the help of their experts, receive real time medium resolution video from the scene and get GIS information. After 20 minutes, Front Command and Control deployed in the scene area are connecting to the police database. They operate voice conference calls and video conferences; receive real time low resolution video from the helicopter and real time high resolution video from forces inside the building. At this point the Front Command and Control are fully connected to the police database and can use any police information such as cars and people information, real time video, and pictures that can be shared with anyone that needs the information. The information is now fully displayed in the main command and control room of the police and other forces. Commanders can share the information and get full control of the event.

TABLE 7D-1

Incident scenario time line

Scenario time line							
Part number and event description		**Time+**	**Link type**	**Required action Uplink**	**Required action Downlink**	**Used systems**	**No of users**
1.	Accident occurs	0					
2.	Call received at police Operation Centre	1 minute					
3.	Operation Centre dispatch sent	2minutes	Voice		Call to the closest police vehicles and send location information to vehicles' computer	Project 25	12
4.	Police vehicles on the way to scene	3 minutes	Voice+ Data	Request for information from Vehicle's computer+GIS information	Getting GIS information and each policeman (total of 12) getting real time high resolution video of the event from security camera close to the truck	Project 25 & LTE	12
5.	Policemen arrive at scene	7 minutes	Voice+ Data	Sending real time low resolution video from the area	Getting real time high resolution video from security camera close to the truck and getting GIS information	Project 25 & LTE	12
6.	Additional police vehicle with 2 chief officers arrives	12 minutes	Voice+ Data	Sending real time low resolution video from the area	Getting real time high resolution video from police helicopter	Project 25 & LTE	2
7.	City control vehicle with 2 officers arrives at scene	13 minutes	Voice+ Data	Sending real time low resolution video from the area	Getting real time high resolution video from traffic control camera	Project 25 & LTE	2

Scenario time line							
Part number and event description		Time+	Link type	Required action Uplink	Required action Downlink	Used systems	No of users
8.	Four ambulances arrival	14 minutes	Voice+ Data	Request for GIS information and sending real time high resolution video to command center	Getting real time high resolution video from security camera about the injuries and getting GIS information	Project 25 & LTE	12
9.	Fire forces arrival	15 minutes	Voice+ Data	Request for GIS information and sending real time medium resolution video from vehicle camera	Getting real time medium resolution video from scene and get GIS information	Project 25 & LTE	3
10.	Hazardous materials response team arrival	16 minutes	Voice+ Data	Request for GIS information and sending high resolution pictures	Getting real time medium resolution video from scene and getting GIS information	Project 25 & LTE	1
11.	Front Command and Control deployment	20 minutes	Voice+ Data	Connecting to police database and video conference	Video conference , getting real time low resolution video from helicopter and real time high resolution video from scene	Project 25 & LTE	4
12.	All forces arrived and operational	20 minutes	Voice+ Data	Total of 36 users who operate 36 applications simultaneously	Total of 36 users who operate 72 applications simultaneously	Project 25 & LTE	
13.	The ambulances leave the area on the way to hospital	40 minutes	Voice+ Data			Project 25 & LTE	
14.	The forces succeeded to isolate the truck and to close the leak	100 minutes	Voice+ Data			Project 25 & LTE	
15.	Chemical material removing to replacement tanks	125 minutes	Voice+ Data				
16.	Replacements tanks are removed from area	200 minutes	Voice+ Data				
17.	The area is clean and checked	250 minutes	Voice+ Data				
18.	End of the event	360 minutes	Voice+ Data				

The following table summarizes the data rate (kbit/s) for each application during the event:

TABLE 7D-2

Application data rate

Application	Description	Downlink (kbit/s)	UL (kbit/s)
Voice	Voice call	N/A (Project 25)	N/A (Project 25)
Request for Information from Vehicle computer	Information from the command center	N/A	N/A (Project 25)
GIS Information	Map of the area of the event	2000	100
High resolution video	Real time video	2000	2000
Medium resolution video	Real time video	1000	1000
Low resolution video	Real time video	500	500
Video conference	Video conference application	384	384
High resolution picture	Image	300	300

The event occurs within 1.6 km radius area. The area has been closed by the police, and one 45 m antenna mast LTE site gives service to this area.

Analysis

In order to analyze the required spectrum 'Monte Carlo' simulation has been used. The urban clutter loss has been defined to 10 dB. The LTE data (see Report ITU-R M.2241 Table 2.2.1-1 for most of the site and equipment parameters):

1. 3 sector site.
2. Dual-transmitter and dual-receiver configuration per sector (MIMO).
3. 40 W on each diversity antenna[12].
4. 45 m antenna height above ground level.
5. Antenna parameters:
   a. 17 dBi antenna gain.
   a. 65 deg Horizontal pattern (aperture in the horizontal plane at 3 dB (in deg.).
   b. 15 deg Vertical pattern (aperture in the vertical plane at 3 dB (in deg.).
6. 3 dB losses (cable losses + connector losses feeder losses).
7. 60 dBm eirp, including cable losses.
8. 2 degree down tilt.
9. Modulation parameters: QPSK, 16-QAM and 64 QAM.
10. Duplex mode – FDD.
11. Duty cycle(downlink applications activity factor): 0.5.

The LTE UE data (see Report ITU-R M.2241 Table 2.2.1-1 for most of the parameters):

1. 1.5 m antenna height above ground level.
2. Omni antenna.

[12] 3GPP TS 36.104 version 11.4.0 Release 11 – Table 6.2.1.

3. 0 dBi antenna gain.
4. Maximum Transmitter e.i.r.p. (dBm): 21 to 23.
5. Average Transmitter e.i.r.p. (dBm): -9.
6. Modulation parameters: QPSK , 16-QAM and 64 QAM.
7. Duplex mode – FDD.
8. Duty cycle (uplink applications activity factor): 0.5.

The analysis has been run to analyze part 12 (all the forces arrived to the area). A total of 36 users get information from a few LTE applications (Table 2). Six bandwidths have been checked to get the required spectrum for event part 12 (the maximum required spectrum):

1. 10 MHz.
2. 15 MHz.
3. 18 MHz (Not a LTE BW based on spec. Has been used just for calculation).
4. 18.8 MHz (Not a LTE BW based on spec. Has been used just for calculation).
5. 20 MHz.

The results from each simulation are:

Reliability. The reliability in % that the system will be able to give the required data rate and for the required spectrum for all users during the event. The goal is to achieve 95% reliability for the whole area and 90% reliability for a particular application. The reliability results are for each application and composite reliability.

Results

The reliability tables results for each bandwidth are shown below:

TABLE 7D-3

10 MHz reliability results (%)

Time line	**Whole area**	**GIS Information**	**High resolution video**	**Medium resolution video**	**Low resolution video**	**Video conference**	**High resolution image**
Downlink	47.7	36.6	35.8	58.1	76.19	81.9	N/A
Uplink	97.5	N/A	78.9	97.9	98.6	98.8	98.9

TABLE 7D-4

15 MHz reliability results (%)

Time line	**Whole area**	**GIS Information**	**High resolution video**	**Medium resolution video**	**Low resolution video**	**Video conference**	**High resolution image**
Downlink	72.9	66.4	65.8	79.1	94	98.3	N/A
Uplink	98.5	N/A	96.2	98.2	98.8	98.9	98.9

TABLE 7D-5

18 MHz reliability results (%)

Time line	Whole area	GIS Information	High resolution video	Medium resolution video	Low resolution video	Video conference	High resolution image
Downlink	94.3	88.5	86.8	93.7	98.9	99	N/A
Uplink	98.6	N/A	96.5	98.2	98.8	98.9	98.9

TABLE 7D-6

18.8 MHz reliability results (%)

Time line	Whole area	GIS Information	High resolution video	Medium resolution video	Low resolution video	Video conference	High resolution image
Downlink	97	94.3	93.6	96.2	99	99	N/A
Uplink	98.7	N/A	96.6	98.3	98.8	98.9	98.9

TABLE 7D-7

20 MHz reliability results (%)

Time line	Whole area	GIS Information	High resolution video	Medium resolution video	Low resolution video	Video conference	High resolution image
Downlink	98.7	98	97.7	98.4	99	99	N/A
Uplink	98.6	N/A	96.8	98.3	98.9	98.9	98.9

Conclusions of the representative scenario

The reliability results show that the required spectrum for this event is 18.8 MHz for the downlink and 15 MHz for the uplink. The heavy loaded application is the high resolution video at the downlink and uplink paths. The limitation path is the Downlink, since more capacity is required; but if additional users would be using additional high resolution video than the uplink path could be the limitation of the spectrum. The growing demand for broadband mobile LTE PPDR requires a dedicated RF spectrum. Since the present IMT FDD channel arrangements provide equal RF for downlink and uplink, and 18.8 MHz is not part of the LTE specification, 20MHz X 2 is the required spectrum for this example.

Attachment 1 of Annex 7D

Example for wireless applications needed for broadband PPDR system

Wireless Applications
Video
real time video from helicopter
real time video from UAS
real time video from other cameras
video transmission from scene
Data
First responders information database connectivity
First responders tactical systems connectivity
First responders cars computers connectivity
First responders citizens information database connectivity
First responders GIS information database connectivity
First responders LPR information database connectivity
First responders vehicle information database connectivity
First responders technical information database connectivity
First responders internal mail connectivity
First responders internal application connectivity
TMS/SMS and MMS capability
Location and GIS
Sending location information
Maps and GIS information
First responders tactical GIS system connectivity
Communications
VOICE call
Conference call
PTT call to P25
PTT group call
Emergency call
Talk around between to handsets capability
video call
Broadband communications
Voice over IP connectivity
Mobile base station connectivity
front command and control connectivity

Annex 7E

Spectrum Calculations and Scenario of LTE based technology for broadband PPDR in China

1 Introduction

The bandwidth needed by broadband PPDR would be tremendously different in different scenarios. This annex aims to research on the PPDR spectrum requirements of some typical scenarios in China. In the methodology part, 1.4 GHz band and TDD duplex mode are introduced into assumptions. Then the spectrum requirements for Wuhan city in China are calculated according to the methodology as an example. Additionally a typical PPDR incident scenario in China is also given.

2 Methodology to calculate broadband spectrum requirements

TABLE 7E-1

Methodology

IMT-2000 methodology (Recommendation ITU-R M.1390)	Methodology
A Geography	
A1 Operational Environment Combination of user mobility and user mobility. Usually only analyze most significant contributors.	**A1** PPDR user density is much lower and more uniform. PPDR users roam from one environment to another as they respond to emergencies. PPDR systems are usually designed to cover all environments (i.e. wide area network provides in-building coverage). Instead of analyzing by physical environment, assume that there will likely be multiple overlapping systems each providing different services (narrowband, wideband, and broadband). Each service environment will probably operate in a different frequency band with different network architectures. Analyse three overlapping urban "service environments": narrowband, wideband, broadband.
A2 Direction of calculation	**A2** Usually separate calculations for uplink and downlink due to asymmetry in some services
A3 Representative cell area and geometry for each environment type	**A3**Average cell radius of radius to vertex for hexagonal cells
A4 Calculate area of typical cell	**A4** Omni cells =πi R^2 Hexagonal cells = 2.6 · R^2 3-sector hex = 2.6/3 · R^2
B Market & traffic	
B1 Services offered	**B1** Net user bit rate (kbit/s) for each of the four PPDR service environments: narrowband voice, narrowband data, wideband image, broadband video.
B2 Population density Persons per unit of area within each environment. Population density varies with mobility	**B2** Total PPDR user population within the total area under consideration. Divide PPDR population by total area to get PPDR population density. PPDR users are usually separated into well-defined categories by mission. Example:

IMT-2000 methodology (Recommendation ITU-R M.1390)	Methodology
	Category / Population Regular Police 25848 Special Police Functions 5169 Police Civilian Support 12924 Fire Suppression 7755 General Government Service 130 Other PPDR users 5039 **Total PPDR population 58157** Area under consideration. Area within well-defined geographic or political boundaries. Example: City of Wuhan =1550 km^2 PPDR population density = PPDR population/area Example: Wuhan = 37.5 PPDR/km^2
B3 Penetration rate Percentage of persons subscribing to a service within an environment. Person may subscribe to more than one service	**B3** Similar table. Rows are services, such as voice, data and video. Columns are "service environments", such as narrowband, wideband, and broadband. May collect penetration rate into each "service environment" separately for each PPDR category and then calculate composite PPDR penetration rate. Example: *Category* / *Population* / Penetration (NB Voice) Regular Police 25848 100% Special Police Function 5169 20% Police Civilian Support 12924 10% Fire Suppression 7755 0% Emergency Medical service 1292 50% General Government Service 130 40% Other PPDR users 5039 40% **Total PPDR Population 58157** **Narrowband Voice** **PPDR Population 36807.9** PPDR penetration rate for narrowband "service environment" and voice "service": = Sum(Pop × Pen)/sum(Pop) =63.2%
B4 Users/cell Number of people subscribing to service within cell in environment	**B4** Users/cell = Pop density × Pen Rate × Cell area
B5 Traffic parameters Busy hour call attempts: average number of calls/sessions attempted to/from average user during a busy hour Effective call duration	**B5** Calls/busy hour Sources: current PPDR data and prediction data s/call

IMT-2000 methodology (Recommendation ITU-R M.1390)	Methodology
Average call/session duration during busy hour Activity factor Percentage of time that resource is actually used during a call/session. Example: bursty packet data may not use channel during entire session. If voice vocoder does not transmit data during voice pauses	0-100%
B6 Traffic/user Average traffic generated by each user during busy hour	**B6** Call-seconds/user = Busy hour attempts × Call duration × Activity factor
B7 Offered traffic/cell Average traffic generated by all users within a cell during the busy hour (3 600 s)	**B7** Erlangs = Traffic/user × User/cell/3 600
B8 Quality of service function Offered traffic/cell is multiplied by typical frequency reuse cell grouping size and quality of Service factors (blocking function) to estimate offered traffic/cell at a given quality level	One carrier is applied in TD-LTE system. Group size is 1.
Group size Traffic per group Service channels per group	 =Traffic/cell (E) Use 1% blocking. Erlang B factor probably close to 1.5. Need to consider extra reliability for PPDR systems, excess capacity for peak emergencies, and number of channels likely to be deployed at each PPDR antenna site. Technology modularity may affect number of channels that can be deployed at a site
C Technical and system considerations	
C1 Service channels per cell to carry offered load	**C1** Service channels per cell = Service channels per group/Group size
C2 Service channel bit rate (kbit/s) Equals net user bit rate plus additional increase in loading due to coding and/or overhead signalling, if not already included	**C2** Service channel bit rate = Net userbit rate × Overhead factor × Coding factor If vocoder output = 4.8 kbit/s, FEC = 2.4 kbit/s, and Overhead = 2.4 kbit/s, then Channel bit rate = 9.6 kbit/s
C3 Calculate traffic (Mbit/s) Total traffic transmitted within area under study, including all factors	**C3** Total traffic = Service channels per cell × service channel bit rate
C4 Net system capability Measure of system capacity for a specific technology. Related to spectral efficiency	**C4** Calculate for typical narrowband voice, narrowband data, wideband image and broadband video, spectrum efficiency based on simulation results.
D Spectrum results	
D1-D4 Calculate individual components (each cell in service vs environment matrix	**D1-D4** Calculate for each cell in service vs. "service environment" matrix

IMT-2000 methodology (Recommendation ITU-R M.1390)	Methodology
D5 Weighting factor (alpha) for busy hour of each environment relative to busy hour of other environments, may vary from 0 to 1	**D5** If all environments have coincident busy hours, then alpha = 1 $Freq_{es}$= Freq × alpha requirements in D1-D4
D6 Adjustment factor (beta) for outside effects – multiple operators/networks, guard bands, band sharing, technology modularity	**D6** Freq(total) = beta × sum(alpha × $Freq_{es}$)

3 Calculation of spectrum requirements for Wuhan city in China

According to above modified method, the frequency band based on TD-LTE system is predicted, considering voice (including point-to-point downlink and uplink and point-to-multipoint downlink and uplink), narrow band data, image and video.

Since packet data is carried in TD-LTE system and the quality of voice service focuses on time delay, corresponding spectrum efficiency is a little bit low, shown in Table 7E-2. The spectrum efficiency of Point-to-point uplink and downlink is 0.2 Mbit/s/cell/MHz. In order to guarantee the quality of cell edge, corresponding spectrum efficiency of point-to-multipoint downlink is a little bit lower, that is 0.1 Mbit/s/cell/MHz.

To narrow band data and image, it needs to be differentiated between the average spectrum efficiency and edge spectrum efficiency. According to simulation results, average spectrum efficiency uplink is 1.2 Mbit/s/cell/MHz, however, the edge of spectrum efficiency uplink is only 0.1 Mbit/s/cell/MHz. Average spectrum efficiency downlink is 1.6 Mbit/s/cell/MHz, however, the edge of spectrum efficiency downlink is only 0.1 Mbit/s/cell/MHz. Average spectrum efficiency is applied to uplink and downlink in this report.

To wide band video service, spectrum efficiency is calculated by factoring average spectrum efficiency and edge spectrum efficiency, shown in Table 7E-4.

TABLE 7E-2

Spectrum efficiency of TD-LTE voice

Parameters of voice	Value	Unit
Band（MHz)	20	
Frequency Reuse factor	1	
Point-to-point uplink spectrum efficiency	0.2	Mbit/s/cell/MHz
Point-to-point downlink spectrum efficiency	0.2	Mbit/s/cell/MHz
Point-to-multipoint downlink spectrum efficiency	0.1	Mbit/s/cell/MHz

TABLE 7E-3

Spectrum efficiency of TD-LTE narrow band data and image

Parameters of voice	Value	Unit
Band（MHz)	20	
Frequency Reuse factor	1	
Uplink average spectrum efficiency	1.2	Mbit/s/cell/MHz
Uplink edge spectrum efficiency	0.1	Mbit/s/cell/MHz
Downlink average spectrum efficiency	1.6	Mbit/s/cell/MHz
Downlink edge spectrum efficiency	0.1	Mbit/s/cell/MHz

TABLE 7E-4

Spectrum efficiency of TD-LTE video

Parameters of voice	Value	Unit
Band（MHz)	20	
Frequency Reuse factor	1	
Spectrum efficiency adjustment factor/ Edge proportion	0.7	
Uplink spectrum efficiency	0.437	Mbit/s/cell/MHz
Downlink spectrum efficiency	0.536	Mbit/s/cell/MHz

Wuhan city is capital of Hubei province and center of politics, economy and culture, which located in the centre of China. It's urban and main suburb cover 1550 km^2. It is predicted that population of 2020 will be about 20 million.

The PPDR is categorized as 4 classes that are police, other police, police civilian support, and fire. The respective probable number is shown as following.

TABLE 7E-5

PPDR population of Wuhan city in 2020

PPDR category	PPDR population
Police	25848
Special police function	5169
Police civilian support	12924
Fire	7755
Emergency medical service	1292
General government service	130
Other PPDR users	5039

Service model of voice and data are from Report ITU-R M.2033.

TABLE 7E-6

Spectrum requirement of TD-LTE Voice

A	Geographic considerations				
A1	Select operational environment type Each environment type basically forms a column in calculation spread sheet. Do not have to consider all environments, only the most significant contributors to spectrum requirements. Environments may geographically overlap. No user should occupy any two operational environments at one time		Urban pedestrian and mobile	Urban pedestrian and mobile	
A2	Select direction of calculation, uplink vs. downlink or combined		Uplink	Downlink	
A3	Representative cell area and geometry for each operational environment type, (radius of vertex for sectored hexagonal cells km)		1.5		
A4	Calculate representative cell area hexagonal = 2.6 • r*r		5.85		
B	Market and traffic considerations				
B1	Telecommunication services offered(kbit/s)				
B2	Total population		58157		
			Population (POP) by PPDR category	Penetration (PEN) rate within PPDR category	
		Police	25848	1	
		Special police function	5169	0.2	
		Police civilian support	12924	0.1	
		Fire	7755	0.7	
		Emergency Medical service	1292	0.5	
		General Government Service	130	0.4	
		Other PPDR users	5039	0.4	
			36807.9		
	Area under consideration		1550	km^2	
	Number of persons per unit of area within the environment under consideration. Population density may vary with mobility Potential user per km^2		37.5	POP/km^2	

			Population (POP) by PPDR category	Penetration (PEN) rate within PPDR category	
B3	Penetration rate	Police	25848	0.481	
		Special police function	5169	0.024	
		Police civilian support	12924	0.025	
		Fire	7755	0.106	
		Emergency medical service	1292	0.011	
		General government service	130	0.001	
		Other PPDR users	5039	0.034	
			0.34	using voice	
B4	The number of cell		265		
	Users/cell		139.58		
B5	Traffic parameters		Uplink	Downlink	
				Point-to-Point	Point-to-Multipoint
	Busy hour call attempts (BHCA) (Calls/busy hour)	From PSWAC[13]	0.0073284E/ busy hour	0.0463105E/ busy hour	
				0.007718417	0.038592083
	Average number of calls/sessions attempted to/from average user during busy hour		3.54	1.05	5.24
	Average call/session duration during busy hours Seconds/call		7.88	26.53	26.53
	Activity factor		1.00	1.00	1.00
B6	Average traffic in call-seconds generated by each user during busy hour		27.86	27.79	138.93
B7	Average traffic generated by all users within a cell during the busy hour (3 600 s) Erlangs		1.08	1.08	5.39
B8	Establish quality of service (QOS) function parameters		1.5	1.5	1.5
	frequency reuse factor		1	1	1
	Traffic per cell		1.08	1.08	5.39
	Total Traffic per cell		1.62	1.62	8.08

[13] Report from September 1996, see Footnote 4 in Annex 6 A6.2 for details

C	Technical and system considerations				
C1	Total Traffic per cell		1.62	1.62	8.08
C2	Bitrate（kbit/s)(12.2k AMR, about 16k)		16.00	16.00	16.00
C3	Calculate traffic（Mbit/s)		0.026	0.026	0.129
C4	Frequency Efficiency		0.200	0.200	0.1
D	Spectrum results				
D1			0.13	0.13	1.29
D2	Weighting factor for each environment（α）		1.00	1.00	1
D3	Adjustment factor（β）		1.00	1.00	1
D4	Calculate total spectrum(MHz)		1.55		

TABLE 7E-7

Spectrum requirement of TD-LTE narrow band data

A	Geographic considerations				
A1	Select operational environment type Each environment type basically forms a column in calculation spreadsheet. Do not have to consider all environments, only the most significant contributors to spectrum requirements. Environments may geographically overlap. No user should occupy any two operational environments at one time		Urban pedestrian and mobile	Urban pedestrian and mobile	
A2	Select direction of calculation, uplink vs downlink or combined		Uplink	Downlink	
A3	Representative cell area and geometry for each operational environment type,(radius of vertex for sectored hexagonal cells km）		1.5		
A4	Calculate representative cell area hexagonal = 2.6 • r*r		5.85		
B	Market and traffic considerations				
B1	Telecommunication services offered(kbit/s)				
B2	Total population		58157		
			Population (POP) by PPDR category	Penetration (PEN) rate within PPDR category	
		Police	25848	0.5	
		Special police function	5169	0.05	

		Police civilian support	12924	0.05	
		Fire	7755	0.35	
		Emergency medical service	1292	0.2	
		General government service	130	0.2	
		Other PPDR users	5039	0.21	
			18162.8		
	Area under consideration		1550	km^2	
	Number of persons per unit of area within the environment under consideration. Population density may vary with mobility Potential user per km^2		37.5		
			Population (POP) by PPDR category	Penetration (PEN) rate within PPDR category	
B3	Penetration rate	Police	25848	0.240	
		Special police function	5169	0.006	
		Police civilian support	12924	0.012	
		Fire	7755	0.053	
		Emergency medical service	1292	0.05	
		General government service	130	0	
		Other PPDR users	5039	0.02	
			0.39		
B4	The number of cell		265		
	Users/cell		68.46		
B5	Traffic parameters		Uplink	Downlink	
	Busy hour call attempts (BHCA) (Calls/busy hour)		30.00	30.00	
	kbit/date		80.00	80.00	
	Activity factor		1.00	1.00	

B6	Average traffic in call-seconds generated by each user during busy hour		2400.00	2400.00	
B7	Average traffic generated by all users within a cell during the busy hour (3 600 s) Erlangs Throughput(kbit/s)		0.67	0.67	
B8	Establish quality of service (QOS) function parameters		1.5	1.5	
	Frequency reuse factor		1	1	
	Traffic/user in a cell Throughput/ kbit/s		1.00	1.00	
C	Technical and system considerations				
C1	Total Throughput / Mbit/s		0.07	0.07	
C2	Frequency Efficiency		1.200	1.600	
D	Spectrum results				
D1			0.06	0.04	
D2	Weighting factor for each environment （α）		1.00	1.00	
D3	Adjustment factor（β）		1.00	1.00	
D4	Total Spectrum(MHz)		0.10		

TABLE 7E-8

Spectrum requirement of TD-LTE image

A	Geographic considerations				
A1	Select operational environment type Each environment type basically forms a column in calculation spreadsheet. Do not have to consider all environments, only the most significant contributors to spectrum requirements. Environments may geographically overlap. No user should occupy any two operational environments at one time		Urban pedestrian and mobile	Urban pedestrian and mobile	
A2	Select direction of calculation, uplink vs downlink or combined		Uplink	Downlink	
A3	Representative cell area and geometry for each operational environment type, (radius of vertex for sectored hexagonal cells km）		1.3		
A4	Calculate representative cell area hexagonal = 2.6 • r*r		5.85		
B	Market and traffic considerations				
B1	Telecommunication services offered(kbit/s)				
B2	Total population		58157		

			Population (POP) by PPDR category	Penetration (PEN) rate within PPDR category	
		Police	25848	0.6	
		Special police function	5169	0.05	
		Police civilian support	12924	0.01	
		Fire	7755	0.3	
		Emergency medical service	1292	0.2	
		General government service	130	0.2	
		Other PPDR users	5039	0.24	
			19908.4		
	Area under consideration		1550	km^2	
	Number of persons per unit of area within the environment under consideration. Population density may vary with mobility Potential user per km^2		37.5		
			Population (POP) by PPDR category	Penetration (PEN) rate within PPDR category	
B3	Penetration rate	Police	25848	0.289	
		Special police function	5169	0.006	
		Police civilian support	12924	0.002	
		Fire	7755	0.046	
		Emergency medical service	1292	0.005	
		General government service	130	0	
		Other PPDR users	5039	0.023	
			0.40		
B4	The number of cell		265		
	Users/cell		75.19		
B5	Traffic parameters		Uplink	Downlink	

	Busy hour call attempts (BHCA) (Calls/busy hour) kbit /Image		6.00 8000.00	6.00 8000.00	
	Activity factor		1.00	1.00	
B6	Average traffic in call-seconds generated by each user during busy hour		48000.00	48000.00	
B7	Average traffic generated by all users within a cell during the busy hour (3 600 s) Erlangs Throughput(kbit/s)		13.33	13.33	
B8	Establish quality of service (QOS) function parameters		1.5	1.5	
	Frequency Reuse factor		1	1	
	Traffic/user in a cell Throughput/ kbit/s		20.00	20.00	

C	Technical and system considerations				
C1	Total Throughput / Mbit/s		1.50	1.50	
C2	Frequency Efficiency		1.200	1.600	

D	Spectrum results				
D1			1.25	0.94	
D2	Weighting factor for each environment (α)		1.00	1.00	
D3	Adjustment factor（β）		1.00	1.00	
D4	Total Spectrum(MHz)		2.19		

TABLE 7E-9

Spectrum requirement of TD-LTE video

A	Geographic considerations				
A1	Select operational environment type Each environment type basically forms a column in calculation spreadsheet. Do not have to consider all environments, only the most significant contributors to spectrum requirements. Environments may geographically overlap. No user should occupy any two operational environments at one time		Urban pedestrian and mobile	Urban pedestrian and mobile	
A2	Select direction of calculation, uplink vs downlink or combined		Uplink	Downlink	
A3	Representative cell area and geometry for each operational environment type,（radius of vertex for sectored hexagonal cells km）		1.5		
A4	Calculate representative cell area hexagonal = 2.6 • r*r		5.85		

B	Market and traffic considerations				
B1	Telecommunication services offered(kbit/s)				

B2	Total population		58157 Population (POP) by PPDR category	Penetration (PEN) rate within PPDR category	
		Police	25848	0.2	
		Special police function	5169	0.04	
		Police civilian support	12924	0.02	
		Fire	7755	0.4	
		Emergency medical service	1292	0.1	
		General government service	130	0.3	
		Other PPDR users	5039	0.1	
			9694.4		
	Area under consideration		1550	km^2	
	Number of persons per unit of area within the environment under consideration. Population density may vary with mobility Potential user per km^2		37.5		
			Population (POP) by PPDR category	Penetration (PEN) rate within PPDR category	
B3	Penetration rate	Police	25848	0.096	
		Special police function	5169	0.005	
		Police civilian support	12924	0.005	
		Fire	7755	0.061	
		Emergency medical service	1292	0.002	
		General government service	130	0.001	
		Other PPDR users	5039	0.009	
			0.33		
B4	The number of cell		265		
	Users/cell		36.58		

B5	Traffic parameters Busy hour call attempts (BHCA) (Calls/busy hour)		Uplink 6.00	Downlink 3.00	
	Average traffic in call-seconds generated by each user during busy hour		60.00	60.00	
	Activity factor		1.00	1.00	
B6	Average traffic generated by all users within a cell during the busy hour (3 600 s) Erlangs Throughput(kbit/s)		360.00	180.00	
B7	Average traffic generated by all users within a cell during the busy hour (3 600 s) Erlangs Throughput(kbit/s)		3.66	1.83	
B8	Establish quality of service (QOS) function parameters		1.5	1.5	
	Frequency Reuse factor		1	1	
	Traffic of all users in a cell Throughput/ kbit/s		3.66	1.83	
	Total traffic in a cell Throughput/ kbit/s		5.49	2.74	

C	Technical and system considerations				
C1	Total Traffic per cell		5.49	2.74	
C2	Bitrate（kbit/s)(2MHz)		2000.00	2000.00	
C3	Total Throughput / Mbit/s		10.975	5.487	
C4	Frequency Efficiency		0.430	0.550	

D	Spectrum results				
D1			25.52	9.98	
D2	Weighting factor for each environment (α)		1.00	1.00	
D3	Adjustment factor（β）		1.00	1.00	
D4	Total Spectrum(MHz)		35.50		

Frequency prediction is summarised in Table 7E-10.

TABLE 7E-10

Example narrowband and wideband calculation summaries

PPDR category	**Wuhan population**	**Penetration rates**			
		Narrowband voice	**Narrowband data**	**Wideband image**	**broadband video**
Police	25848	1	0.5	0.6	0.2
Special police function	5169	0.2	0.05	0.05	0.04
Police civilian support	12924	0.1	0.05	0.01	0.02
Fire	7755	0.7	0.35	0.3	0.4
Emergency medical service	1292	0.5	0.2	0.2	0.1
General government service	130	0.4	0.2	0.2	0.3
Other PPDR users	5039	0.4	0.21	0.24	0.1
Total – PPDR users	58157	36870	18162	19908	9673
Spectrum (MHz)		1.55	0.1	2.19	35.50
Spectrum in total (MHz)	39.34				
Other parameters:					
Environment	Urban pedestrian and mobile				
Cell radius (km)	1.5				
Study area (km^2)	1550	(Calculated)			
Cell area (km^2)	5.85	(Calculated)			
		NB Voice	NB data	WB image	BB Video
		Uplink	Uplink	Uplink	Uplink
Erlangs per busy hour		0.007328			0.1
Busy hour call attempts		3.54	30	6	6
Effective call duration		7.88s	80kbit	8000kbit	60s
Activity factor		1	1	1	1
	NB Voice		NB data	WB image	BB Video
	DL PTP	DL PTM	Downlink	Downlink	Downlink
Erlangs per busy hour	0.00771	0.03859			0.05
Busy hour call attempts	1.05	5.24	30	6	3
Effective call duration	26.53s	26.53s	80kbit	8000kbit	60s
Activity factor	1	1	1	1	1
Group size	1				
Grade of service factor	1.5				
α factor	1				
β factor	1				

Considering narrow band voice, narrow band data, wide band image and broad band video, total 39.34 MHz is maybe minimum PPDR spectrum according to requirement development of Wuhan city in 2020.

TABLE 7E-11

Total spectrum requirement of TD-LTE

Voice/MHz	Narrow data/MHz	Image/MHz	Video/MHz	Total spectrum /MHz
1.55	0.1	2.19	35.5	39.34

4 Scenario of LTE based technology for PPDR broadband

This is a study of a typical PPDR incident, a bank robbery, which happened in China. Wireless bandwidth requirements of PPDR agencies in this mission critical scenario are analyzed.

Process to handle the incident:

a) 110 command centre receives emergency call and dispatches nearby police officers to the scene.

b) The dispatched police officers contact the command centre and ask for the aid of SWAT Police officers in accordance with the situation and set up a command centre on the scene.

c) Firefighters and medical team arrive on the scene.

d) Police helicopter arrives on the scene. The helicopter transmits panoramic high definition images to the on-scene command centre and the on-scene command centre transmits the images through wireless network to remote command centre. The remote command centre transmits large amount of data concerning the incident and the scene to the on-scene command centre, which in turn broadcasts the data to each emergency team.

e) The SWAT Police officers arrive on the scene. They deploy surveillance equipment to conduct covert surveillance and collect information. Critical information is transmitted to the on-scene command centre in a manner of high definition images while general information is transmitted through two channels standard definition images. The on-scene command centre broadcasts the video images to whichever emergency team that needs the video.

f) The SWAT Police officers deploy remote-controlled reconnaissance robots and transmit indoor video in two manners, high definition and standard definition.

g) Negotiation experts arrive on the scene. To make sure the experts can see and hear every detail of the scene; assistants for the negotiation monitor the negotiation by making full use of videos collected through all equipment.

h) SWAT Police officers make the strategy for strike and ten of them prepare to start the strike. Two head-mounted cameras of standard definition are carried with them.

i) The operation is finished.

Throughout the whole process, the peak spectrum demand happens when the SWAT Police team strike. Only when bandwidth requirement during this period is met, the emergency can be properly handled.

Tests have proved that for video of standard definition, at a distance of about 15 m, CIF 352×288p, 25fps, only gender, figure, and motions can be identified, whereas D1 704×576p, 25 fps, face, details of figure, and license plate numbers can be identified; for videos of high definition, at a distance of over 30 m, 720P 1280×720p, only gender, figure, and motions can be identified, whereas 1080P, face, details of figure, and plate numbers can be identified.

Table 7E-12 lists the bandwidth requirements of different personnel and equipment during the strike. Compared to the bandwidth for video transmission, the bandwidth for uploading and downloading voice and data can be ignored. Thus, table 7E-12 only lists the statistics for downlink and uplink bandwidth required by video.

TABLE 7E-12

Analysis of bandwidth requirements during the strike

Emergency Team	Personnel and Equipment	Service(s)	Source Coding Rate	Uplink Bandwidth	Downlink Bandwidth
Command Centre	15	compressed video broadcast			7 MHz
Ordinary Police Officers	20	identity authentication and query			
Medical Team	5	1 channel D1 video upload and download	1 Mbit/s	2 MHz	2 MHz
Fire Fighters	5	1 channel D1 video upload and download	1 Mbit/s	2 MHz	2 MHz
Negotiation Experts	3	high definition video download			4 MHz
Strike Team	10	2 channels CIF video upload and download	0.5 Mbit/s	2 MHz	4 MHz
Police Helicopter	1	1 channel 1080P video upload and download	3 Mbit/s	5 MHz	1 MHz
Reconnaissance Robot	10	1 channel 720P, 1 channel CIF video upload	3.5 Mbit/s	6 MHz	

The above analysis shows that to fulfill the task, uplink needs at least 17 MHz bandwidth and broadcast downlink at least 7 MHz (frequency spectrum utilization about 50%). Consider the routine work; extra 10% background spectrum width is needed. The total spectrum width is about 27 MHz. It is asserted that the more complex the incident case, the more spectrum is needed.

5 Conclusion

According to the provided methodology and the typical case above, it shows that allocating about 30 MHz bandwidth for PPDR agencies may be appropriate to fulfil the requirements of general PPDR scenarios. It would require more spectrum bandwidth (e.g. 40 MHz) if Disaster Relief scenarios are fully considered.

Annex 7F

Broadband PPDR spectrum requirements in Korea

A1.1 Introduction

The Government of Korea recently decided to use Public Safety LTE technologies with 2×10 MHz frequency in the 700 MHz band (718-728 MHz for uplink and 773-783 MHz for downlink) according to APT 700 MHz Band Plan) to build nationwide Public Protection and Disaster Relief (PPDR) Broadband network for sharing among Korean PPDR agencies. According to this decision, the Ministry of Public Safety and Security of Korea (MPSS; http://www.mpss.go.kr/main/main.html) has led the related project to build PPDR Broadband network since 2014. This broadband network is considered to be not only used for PPDR agencies (police, fire brigade, etc.) but also carry out public broadband services for express railway[14] and inshore vessel[15]. The PPDR network is supposed to be built as a nationwide dedicated network basically but the use of commercial network to cover area where PPDR network coverage does not reach is also being considered.

The spectrum requirements have been studied and they are based on traffic scenarios of PPDR agencies (e.g. police, fire brigade, coast guard) in PP1 (day-to-day operation), PP2 (large emergency and public event), DR (disaster) scenarios respectively. Spectrum requirements when multiple PPDR agencies jointly carry out operation are considered. Korea government is considering integrated public broadband services for PPDR, railway, and inshore vessels in a single nationwide LTE network. Thus, spectrum requirements for the integrated public broadband service are also analysed.

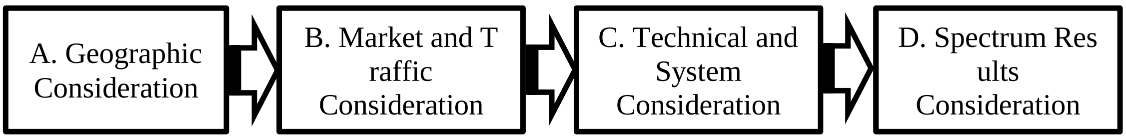
In § A7.2, spectrum requirement calculation methodology is explained and traffic parameters of each scenario are presented. section 4 shows spectrum requirement calculation results and conclusions are drawn in § A7.5.

A1.2 Spectrum Requirements Calculation Methodology

The spectrum requirement calculation methodology adopted in this study is based on Recommendation ITU-R M.1390 which is used for the calculation of IMT-2000 terrestrial spectrum requirements and its use to calculate spectrum requirements for PPDR is shown in Report ITU-R M.2033. The spectrum requirement calculation procedure consists of 4 stages as in Fig. 7F-1.

FIGURE 7F-1

Spectrum requirements calculation procedure in Rec. ITU-R M.1390



In this study, the Recommendation ITU-R M.1390 methodology is considered but modified to reflect PPDR service characteristics as explained below.

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[14] Ministry of Land, Infrastructure and Transport of Korea has been planning a railway broadband service known as Intelligent Railway Integrated System (IRIS) which provides train safety applications including train control and monitoring.

[15] Ministry of Oceans and Fisheries of Korea has been planning to provide ship safety broadband services primarily to inshore small vessels which are not equipped with Global Maritime Distress and Safety System (GMDSS).

A) Geographic Considerations

In this stage, environment type, cell area and geometry etc. are considered. Environment types are usually selected most significant contributors. In this study, dense urban and urban are considered as density and in-building and pedestrian are considered as mobility. Circular cell geometry and at least 1 km cell diameter is assumed. In general, cell diameter is used to calculate the number of user in a cell, but in this study cell diameter is irrelevant to the number of user since it is assumed that most of users are concentrated on one cell. When operation being carried out over wide area (e.g. police PP2 scenario in § 3.1), we assume cell diameter is 1 km.

B) Market and Traffic Considerations

In this stage, the number of user per cell is calculated from service type, population density and penetration rate. Traffic parameters (busy hour call attempt, average call duration, activity factor) for each service (e.g. voice, data, and video) are also considered and traffic per cell in Erlang unit is calculated from the traffic parameters. To calculate required channels from traffic per cell, QoS parameters (e.g. call blocking probability for circuit switched network, packet delay for packet switched network) is also considered. In this study, traffic parameters are collected from major PPDR agencies (police, fire brigade, coast guard) as given in § 3. Stages B and C to calculate traffic in kbit/s unit are integrated as explained in stage C.

C) Technical and System Considerations

The number of channel required for each application is obtained from traffic per cell and QoS parameters through Erlang B or C formula. The obtained number of channel for each application is multiplied by required bit rate of the corresponding applications. Finally, spectral efficiency parameter is considered to transform traffic into spectrum requirements.

In above stages B and C, traffic in Erlang unit are calculated into the required number of channel and transformed into traffic in kbit/s. In this study, for simplicity of calculation, traffic in kbit/s is calculated directly as follows referring to ECC Report 199.

For real time application, traffic [kbit/s] = number of user × call (transaction) attempt per hour × required bit rate [kbit/s] × call (transaction) duration per hour [min] / 60. For non-real time application [kbit/s] = 8 × number of user × call (transaction) attempt per hour × data [Byte] / (3 600 × 1 000).

The result of traffic in kbit/s obtained from this calculation method may be smaller than the result from M.1390 which takes into account QoS parameters. However, it is anticipated that the difference would not be significant because HD quality video transmission services which account for the most of spectrum is assumed to be ensued for their channel.

As a radio interface technology, LTE Release 8 is assumed and its spectral efficiency is given as follows.

TABLE 7F-1

Spectral Efficiencies Assumption

Spectral Efficiency (bit/s/Hz)	Uplink (1×2 MIMO)	Downlink (2×2 MIMO)
Average	0.735	1.69
Cell edge	0.024	0.05

The values of spectral efficiency differ depending on location of mobile station in a cell or transmission modes (e.g. Multicast-broadcast single frequency network (MBSFN)) for a specific application (e.g. group call)[16]. In this study, average spectral efficiency is assumed for simplicity. We also assume a cell is spitted into 3 sectors and due to the cell split total cell capacity is increased by 2.5 times considering inter-sector interference.

D) Spectrum Results Considerations

Traffic in kbit/s for each application is divided by spectral efficiency to obtain spectrum requirements. Weighting factor and adjustment factor are assumes as 1 in this study.

A1.3 Traffic Parameters

Traffic parameters for broadband PPDR network in PP1 (day-to-day operation), PP2 (large emergency and public event), DR (disaster) scenarios are considered. Applications are categorized into voice, data, and video though there are some differences for each agency.

Individual PPDR Agency Operation

Traffic parameters for major individual PPDR agencies of police, fire brigade and coast guard are considered. Each parameter of each scenario is assumed as an average value. Traffic parameter values for PP2 and DR scenarios are presented as below to save pages.

A) Police

In PP1 scenario, commitment of 500 police officers in a cell for daily works such as traffic enforcement, 112 call incident responses, and special facility security are assumed.

In PP2 scenario, it is assumed that a special event occurs over diameter 4-5 km in Seoul metropolitan area and 20-30 thousand police officers are committed to the guard operation. In general, base stations are built densely in metropolitan area to avoid traffic overload in a cell. Thus, it can be assumed that cell diameter is reduced to 1 km and about 2,500 police officers are crowded within a cell[17].

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[16] The effect on spectrum requirement due to communication at cell edge area and the use of different transmission mode is discussed in other literatures such as ECC Report 199.

[17] In LTE system, cell diameter for 700 MHz band is in the range of 2-3 km.

TABLE 7F-2

Traffic parameters of police in PP2 scenario

Traffic	Application	Call attempt per hour	Uplink				Downlink			
			Number of user (or group)	Bit Rate (kbit/s)	Call duration per hour (min)	Activity factor	Number of user (or group)	Bit Rate (kbit/s)	Call duration per hour (min)	Activity factor
Voice	Individual Call	0.5	2500	45.3	0.5	0.5	2500	45.3	0.5	0.5
	Group Call	1	250	45.3	60	0.05	250	45.3	60	0.05
Data	Message	10	250	1	0.02	1	250	1	0.02	1
	Mobile inquiry	20	250	64	0.02	1	250	64	0.02	1
	112 mobile	5	25	64	0.02	1	25	64	0.02	1
	Navigation	10	25	64	0.02	1	25	64	0.02	1
	GPS	30	25	64	0.02	1	25	64	0.02	0.1
	ANPR	500	5	1	0.02	1	5	1	0.02	1
Video	Video Transmission	1	3	2,000	60	1	3	2,000	60	1
	Video Call	1	3	512	2	0.5	3	512	2	0.5
	Image Transmission	4	150	512	0.02	1	150	512	0.02	1

In DR scenario, a special event in Seoul metropolitan area as PP2 scenario along with a disaster is assumed.

TABLE 7F-3

Traffic parameters of police in DR scenario

Traffic	Application	Call attempt per hour	Uplink				Downlink			
			Number of user (or group)	Bit Rate (kbit/s)	Call duration per hour (min)	Activity factor	Number of user (or group)	Bit Rate (kbit/s)	Call duration per hour (min)	Activity factor
Voice	Individual Call	0.05	3,000	45.3	0.5	0.5	3,000	45.3	0.5	0.5
	Group Call	1	300	45.3	60	0.05	300	45.3	60	0.05
Data	Message	10	300	1	0.02	1	300	1	0.02	1
	Mobile inquiry	30	300	64	0.02	1	300	64	0.02	1
	112 mobile	10	30	64	0.02	1	20	64	0.02	1
	Navigation	10	30	64	0.02	1	30	64	0.02	1
	GPS	30	30	64	0.02	1	30	64	0.02	0.1
	ANPR	500	5	1	0.02	1	5	1	0.02	1
Video	Video Transmission	1	3	2,000	60	1	3	2,000	60	1
	Video Call	2	30	512	3	0.5	30	512	3	0.5
	Image Transmission	5	30	512	0.02	1	30	512	0.02	1

B) Fire Brigade

In PP1 scenario, commitment of 1 fire station of average 86 fire fighters is assumed.

In PP2 scenario, it is assumed that regional fire department of 171 fire fighters carry out emergency operation in a cell.

TABLE 7F-4

Traffic parameters of fire brigade in PP2 scenario

Traffic	Application	Call attempt per hour	Uplink				Downlink			
			Number of user (or group)	Bit Rate (kbit/s)	Call duration per hour (min)	Activity factor	Number of user (or group)	Bit Rate (kbit/s)	Call duration per hour (min)	Activity factor
Voice	Individual Call	0.2	171	45.3	0.39	0.5	171	45.3	0.39	0.5
	Group Call	1	19	45.3	60.00	0.075	19	45.3	60.00	0.075
Data	SMS	1.5	19	1	0.02	1	19	1	0.02	1
	MMS	1.5	19	520	0.02	1	19	520	0.02	1
	Internet Access	2	22	384	0.21	1	22	384	1.05	1
	Sensor	360	18	76	0.02	1	22	76	0.02	1
	GPS	360	34	76	0.02	1	22	76	0.02	1
Video	Image(SD)	0.2	171	512	0.03	1	171	512	0.03	1
	Video(HD)	1	1	2,000	60	1	1	2,000	60	1
	Individual Call	0.2	171	512	0.39	0.5	171	512	0.39	0.5
	Group Call	1	9.5	512	60	0.075	9.5	512	60	0.075

In DR scenario, multiple regional fire departments of 685 fire fighters come together to carry out emergency operation in a cell.

TABLE 7F-5

Traffic parameters of fire brigade in DR scenario

Traffic	Application	Call attempt per hour	Uplink				Downlink			
			Number of user (or group)	Bit Rate (kbit/s)	Call duration per hour (min)	Activity factor	Number of user (or group)	Bit Rate (kbit/s)	Call duration per hour (min)	Activity factor
Voice	Individual Call	0.2	685	45.3	0.39	0.5	685	45.3	0.39	0.5
	Group Call	1	76	45.3	60.00	0.075	76	45.3	60.00	0.075
Data	SMS	3	76	1	0.02	1	76	1	0.02	1
	MMS	3	76	520	0.02	1	76	520	0.02	1
	Internet Access	2	30	512	0.39	1	30	512	1.95	1
	Sensor	360	70	76	0.02	1	30	76	0.02	1
	GPS	360	137	76	0.02	1	30	76	0.02	1
Video	Image(SD)	0.2	685	512	0.03	1	685	512	0.03	1
	Video(HD)	1	2	2,000	60	1	2	2,000	60	1
	Individual Call	0.2	685	512	0.39	0.5	685	512	0.39	0.5
	Group Call	1	38	512	60.00	0.075	38	512	60.00	0.075

C) Coast Guard

In PP1 scenario, 1 coast guard vessels are committed to respond vessel failure or to transport emergency patient of island area.

In PP2 scenario, 10 coast guard vessels are committed to carry out searching operation, to respond to marine oil spill, ship fire and flood.

TABLE 7F-6

Traffic parameters of coast guard in PP2 scenario

Traffic	Application	Call attempt per hour	Uplink				Downlink			
			Number of user (or group)	Bit Rate (kbit/s)	Call duration per hour (min)	Activity factor	Number of user (or group)	Bit Rate (kbit/s)	Call duration per hour (min)	Activity factor
Voice	Individual Call	0.5	300	45.3	0.5	0.5	300	45.3	0.5	0.5
	Group Call	1	10	45.3	60	0.05	10	45.3	60	0.05
Data	Message	2	10	520	0.02	1	10	520	0.02	1
	Paging	1	300	1	0.02	1	300	1	0.02	1
	Location data	120	300	56	0.01	1				
Video	Video(HD)	2	10	512	0.2	0.5	10	512	0.2	0.5
	Group Call	1	2	2,000	60	1				

In DR scenario, 50 coast guard vessels are committed to carry out searching operation or to respond to large scale marine oil spill, ship fire and sinking accident.

TABLE 7F-7

Traffic parameters of coast guard in DR scenario

Traffic	Application	Call attempt per hour	Uplink				Downlink			
			Number of user (or group)	Bit Rate (kbit/s)	Call duration per hour (min)	Activity factor	Number of user (or group)	Bit Rate (kbit/s)	Call duration per hour (min)	Activity factor
Voice	Individual Call	0.5	1,500	45.3	0.5	0.5	1,500	45.3	0.5	0.5
	Group Call	1	50	45.3	60	0.05	50	45.3	60	0.05
Data	Message	3	50	520	0.02	1	50	520	0.02	1
	Paging	1	1,500	1	0.02	1	1,500	1	0.02	1
	Location data	120	1,500	56	0.01	1	1,500	56		
Video	Video(HD)	2	50	512	0.3	0.5	50	512	0.3	0.5
	Group Call	1	3	2,000	60	1				

Multiple PPDR Agencies Operation

In case of large emergency, there would be a case that multiple PPDR agencies carry out joint operation to respond emergency. In this study, a gym collapse incident occurred at Gyeongju, Korea in Feb. 2014 is considered. Total number of committed responder is 1,448 which consist of 788 fire fighters, 500 police officers, 80 local government officials and 80 soldiers.

TABLE 7F-8

Traffic parameters of multiple agencies operation scenario

Traffic	Application	Call attempt per hour	Uplink				Downlink			
			Number of user (or group)	Bit Rate (kbit/s)	Call duration per hour (min)	Activity factor	Number of user (or group)	Bit Rate (kbit/s)	Call duration per hour (min)	Activity factor
Voice	Individual Call	0.1	1,448	45.3	0.39	0.5	1,448	45.3	0.39	0.5
	Group Call	1	145	45.3	60	0.075	145	45.3	60	0.075
Data	SMS	3	145	1	0.02	1	145	1	0.02	1
	MMS	3	145	520	0.02	1	145	520	0.02	1
	Internet Access	2	30	512	1	1	30	512	20	1
	Sensor	360	70	76	0.02	1	70	76	0.02	0.1
	GPS	360	145	76	0.02	1	145	76	0.02	0.1
Video	Image(SD)	1	64	512	0.02	1	64	512	0.02	1
	Video(HD)	1	3	2,000	60	1	3	2,000	60	1
	Video(SD)	1	3	1,000	60	1	3	1,000	60	1
	Individual Call	0.2	788	512	0.39	0.5	788	512	0.39	0.5
	Group Call	1	39	512	60	0.075	39	512	60	0.075

PPDR operation with other public broadband services

Traffic scenario of integrated public broadband service where not only PPDR but also other public broadband services (e.g. for railway or inshore vessels) is provided. To calculate spectrum requirement of integrated service, traffic scenarios can be considered separated by geographical service area of land and sea. For land area, PPDR and railway broadband services, for sea area, PPDR and inshore vessel broadband services are used simultaneously. Spectrum requirement are determined so as to meet spectrum requirements of all service areas.

In this study, an incident near Seoul station is assumed for land area scenario and traffic parameters of multiple PPDR agencies as given in § 3.2 is adopted. For sea area scenario, ship sinking near Busan harbor is considered. In this scenario, PPDR agency officers in harbor area and coast guard vessels in sea are assumed and broadband service for in shore vessel is also provided simultaneously.

A.1.4 Spectrum Requirements

Tables 7F-9 and 7F-10 show that for individual PPDR agency operation 2×5 MHz would be sufficient for PP1, PP2, DR scenarios.

TABLE 7F-9

Uplink spectrum requirements for individual PPDR agency operation (MHz)

Agency	**Police**			**Fire Brigade**			**Coast Guard**		
Scenario	PP1	PP2	DR	PP1	PP2	DR	PP1	PP2	DR
Voice	0.087	0.437	0.524	0.038	0.211	0.152	0.003	0.028	0.139
Data	0.036	0.060	0.102	0.250	0.322	0.983	0.035	0.165	0.843
Video	0.007	3.326	3.695	1.323	1.460	4.206	1.089	2.186	3.335
Total	0.131	3.822	4.321	1.611	1.992	5.340	1.127	2.379	4.316

TABLE 7F-10

Downlink spectrum requirements for individual PPDR agency operation (MHz)

Agency	**Police**			**Fire Brigade**			**Coast Guard**		
Scenario	PP1	PP2	DR	PP1	PP2	DR	PP1	PP2	DR
Voice	0.038	0.190	0.228	0.016	0.092	0.066	0.001	0.012	0.060
Data	0.015	0.023	0.003	0.150	0.548	0.352	0.000	0.001	0.011
Video	0.008	1.446	1.607	0.575	0.635	1.829	0.000	0.004	0.030
Total	0.061	1.660	1.838	0.742	1.274	2.247	0.001	0.017	0.102

In case of multiple PPDR agencies operation, 7.4 MHz and 5.2 MHz are required for uplink and downlink respectively thus 2x10 MHz should be provided for this case.

TABLE 7F-11

Spectrum requirements for multiple PPDR agencies operation (MHz)

Services	Voice	Data	Video	Total
Uplink	0.28	1.202	5.869	7.351
Downlink	0.122	2.477	2.552	5.151

When PPDR service is integrated with other public broadband service, spectrum should be provided to cover all areas (both land and sea). From Table 7F-12, it is shown that broadband services in each service area can be supported by using 2x10 MHz spectrum.

TABLE 7F-12

Spectrum requirements for PPDR operation with other public broadband services (MHz)

Service Area	Service	Uplink	Downlink
Land Area	PPDR	7.35	5.15
	Railway Broadband*	2.05	1.85
	Sub Total	9.4	7
Sea Area	Coast Guard	4.32	0.1
	Inshore Vessel Broadband*	4.89	4.21
	PPDR	0.35	0.62
	Sub Total	9.56	4.93

* Analysis of spectrum requirements for railway and inshore vessel broadband service is presented in separate report, which will be published in the near future.

A1.5 Conclusion

For individual PPDR agency operation, it is shown that 2x5 MHz spectrum would be sufficient for all scenarios. In case of multiple PPDR agencies operation, 2x10 MHz should be provided. Furthermore, in case of integrated public broadband service, services in each service area can be supported within the range of 2x10 MHz spectrum. Thus, when comparing with individual spectrum use for each public broadband service where total required spectrum would be 2x20 MHz, it can be shown that spectrum can be saved by 2x10 MHz. Furthermore, considering that PPDR spectrum would be under utilized in day-to-day situation, integration with other public broadband services would be beneficial in terms of efficient spectrum use.

Spectrum requirement in above are analyzed based on specific traffic scenarios and average spectral efficiency thus spectrum deficiency may occur in severe disaster situations. Specifically, HD quality video transmission identified in demand among Korean PPDR agencies requires considerable spectrum and it is anticipated that the demand will increase due to the trend of price reduction of high quality video transmission equipments. Also, spectrum needs may be increased when an incident scene is located near cell edge where spectral efficiency is significantly low. In this case, spectrum usage can be limited to a certain level referred to as spectrum cap in ECC Report 199 but users may be subject to service quality degradation.

To respond to spectrum deficiency, PPDR agencies should take countermeasures to secure additional communication capacity. For example, a mobile cell site can be installed near cell edge to secure additional cell capacity and ad-hoc point-to-point or point-to-multi point networks using frequency such as 5 GHz band recommended as broadband PPDR frequency band in APT/AWF/REC-01(Rev.1) also can be built to offload heavy traffic due to a hot spot area. Roaming to a commercial network also can be considered when there is service provision agreement between PPDR agencies and commercial wireless broadband service provider.

Annex 8

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

A2.1 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.

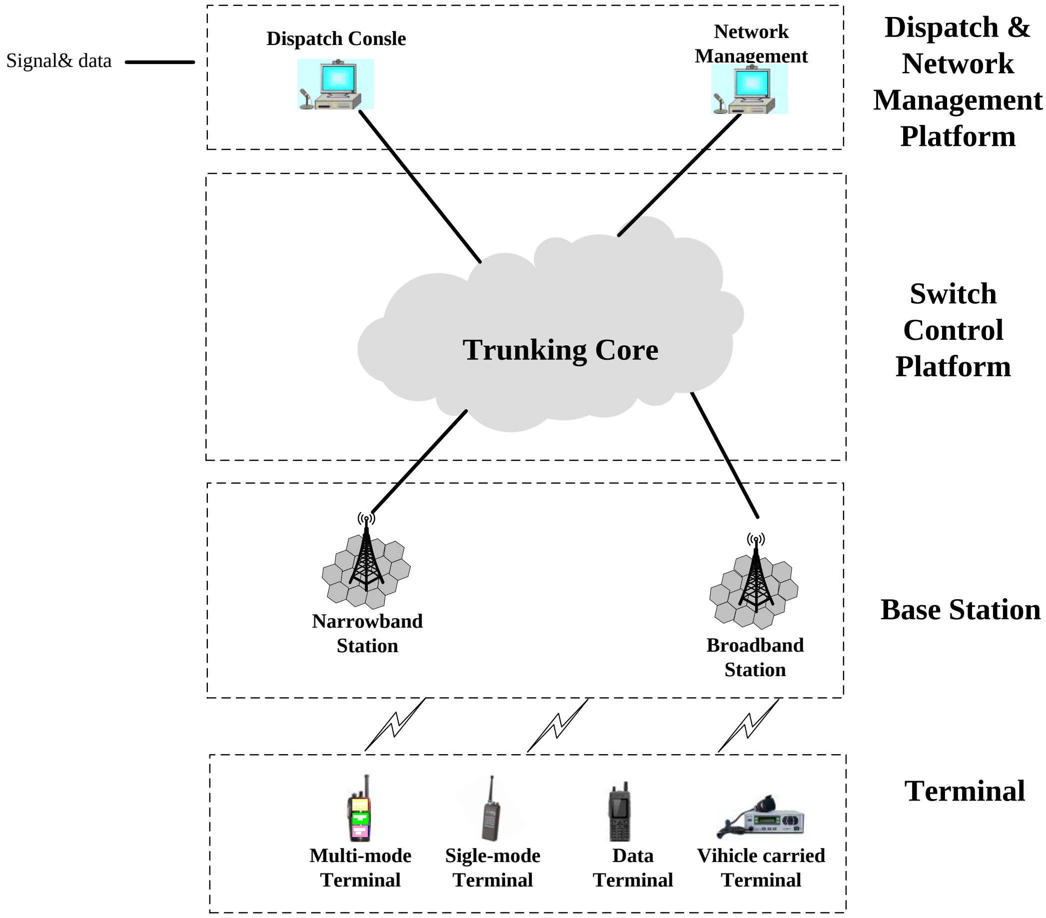
Obtain by natural robust invulnerability ability. In the case of disaster recovery, the two radio access networks in parallel may back up each other and it may improve the invulnerability of one single system.

A2.2 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. A8-1.

FIGURE A8-1

The architecture of broadband and narrowband integrated network



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

A2.3 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 9

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	*Under development*
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)	*Under development*
P0041	Commercial Mobile Alerts Service (CMAS) International Roaming	*Under development*
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)	*Under development*

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:

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

Annex 10

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 OOBE 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).

A10.1 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 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 A10-1

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

UE Ppowerclass	23 dBm	31 dBm
UL Tranmsisson configuration	256kbps	256kbps
RB allocation	10	10
Channel Model	EVA 70Hz	EVA 70Hz
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
Max Allowed Path Loss (dB)	137.0	145.0
UL tranmisson Frequency (MHz)	790	790
eNB Ant. Height (m)	80	80
Vehicle Ant. Height (m)	1.5	1.5
RF Environment	Forrested	Forrested
Maximum Cell Radius (km)	7.9	13.7

A10.2 Coexistence issues for high power LTE systems

Co-existence of HPUE with adjacent system

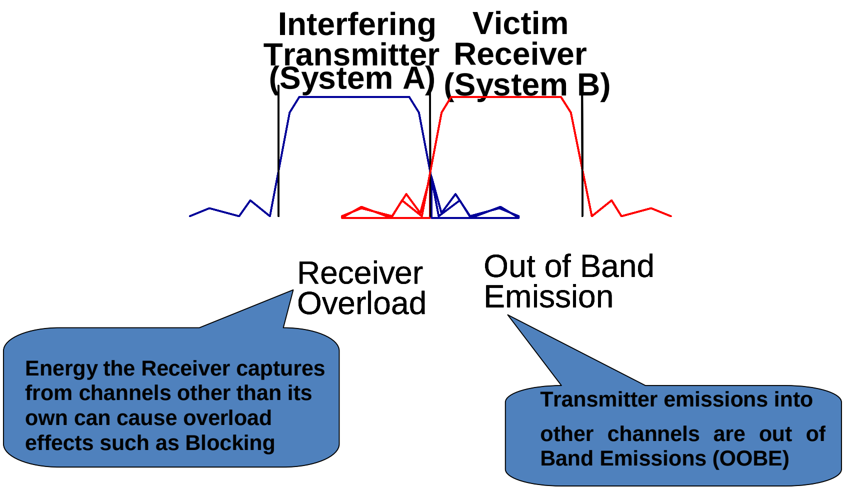
When two systems are deployed in the same geographical area and in adjacent spectrum, coexistence issues needs to be studied to make sure both systems are not causing harmful interference to each other. Typical interference mechanisms considered are Transmitter Out-Of-Band emission (OOBE), Receiver Blocking.

– Interfering Transmitter OOBE: The OOBE 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 OOBE.

– 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.

FIGURE A10-1

Coexistence of HPUE with adjacent system



To analyze 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 OOBE and due to Rx blocking. Four companies have run the Monte-Carlo simulations to analyze the interference impact from HPUE to adjacent LTE systems and the results are shown in Fig. below (based on the results reported in 3GPP TR36.837).

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 sub clause 6.6).

FIGURE A10-2

Impact of HPUE to adjacent systems (based on results reported in TR36.837)

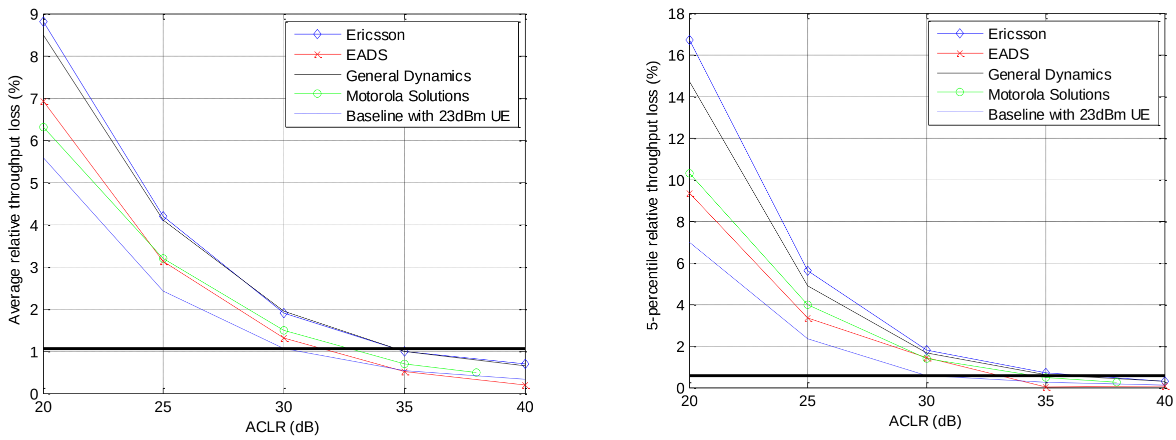


TABLE A10-2

B14 HPUE (+31dBm) 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 OOBE 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 11

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

TABLE A11-1

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

**** Note: 37 functional requirements are generated from 5 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 center in order to support group communication function in corresponding area	M	M	M
Duplication/transport media management	Function that provides automatic switch-over of transport network media (Microwave, satellite and other IP networks) for switching center, 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		H	H	H

Functional Requirements)	**Specifics**	**Importance[1]**		
		PP-1	**PP-2**	**DR**
	Function that provides one-to-one communication by using of caller ID in order to give a call to a specific person			
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
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

Functional Requirements)	Specifics	Importance[1]		
		PP-1	PP-2	DR
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
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	M	M	M

Functional Requirements)	**Specifics**	**Importance[1]**		
		PP-1	**PP-2**	**DR**
	provide the management functions e.g. system control, securing of account and security, resolve of obstacle and performance			
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 12

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.

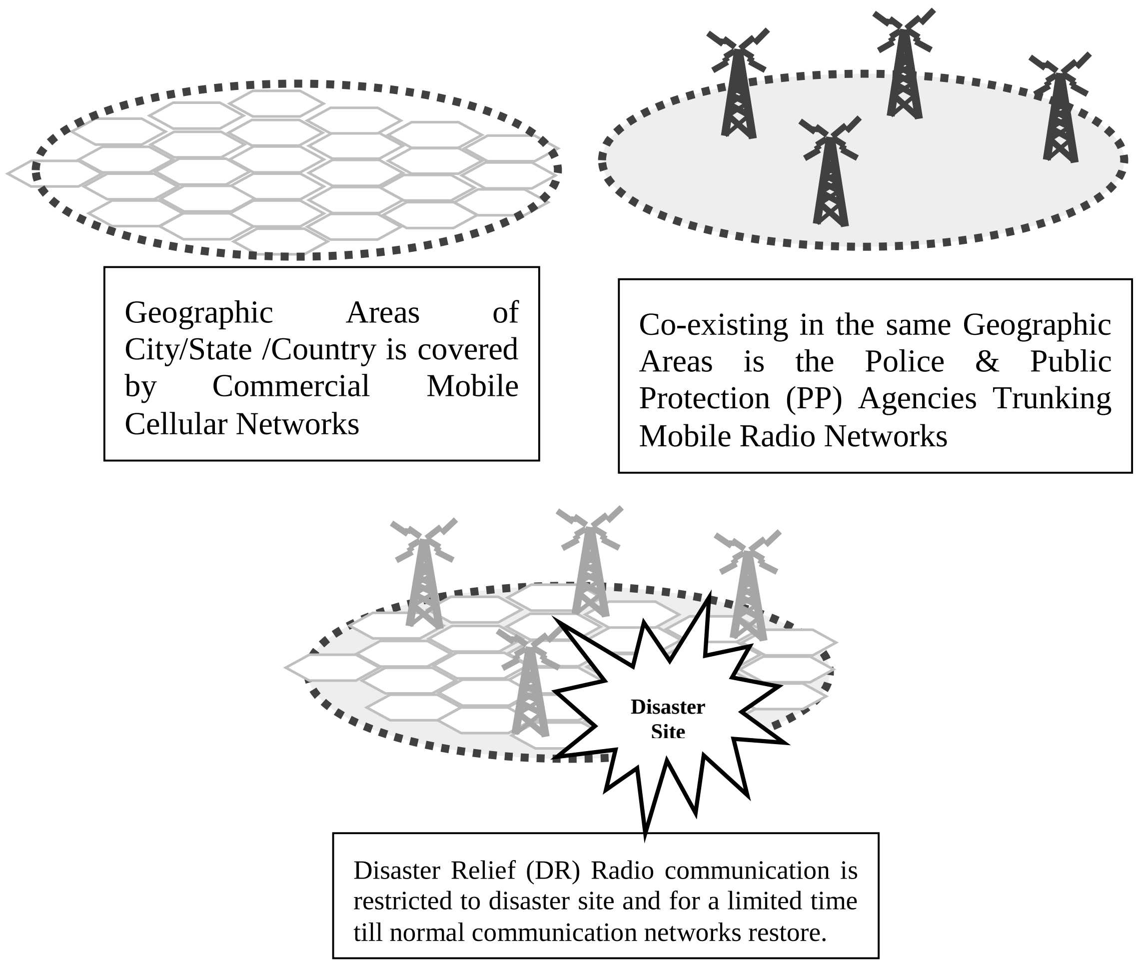
4 So, the telecommunication requirement of public protection agencies is paramount and encompass the communication requirement of disaster relief agencies so the requirement of PP and DR must be looked in reference to some commonalities wherein DR can only be a subset of PP radio communications.

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 A12.1

Simplified Representation of Practical deployments



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