International Telecommunication Union

ITU-R

Radiocommunication Sector of ITU

Report ITU-R M.2415-0

(11/2017)

Spectrum needs for Public Protection and Disaster Relief (PPDR)

M Series

Mobile, radiodetermination, amateur and related satellite services

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***Note**: This ITU-R Report was approved in English by the Study Group under the procedure detailed in Resolution ITU-R 1.*

Electronic Publication
Geneva, 2018

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REPORT ITU-R M.2415-0

Spectrum needs for Public Protection and Disaster Relief (PPDR)

(2017)

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1 Introduction

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

This Report discusses the estimations of spectrum needs for PPDR. Report ITU-R M.2377 presents 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[1], 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 estimation of the spectrum needs for public protection and disaster relief (PPDR) by providing:

– a method of estimating the amounts of spectrum;

– system scenarios and assumptions;

– validation of the method with respect to existing applications; and

– examples of different national and/or regional spectrum needs for narrowband, wideband and broadband PPDR systems.

References, terminology, abbreviations and descriptions of PPDR operations can be found in Annexes 1, 2 and 3 of Report ITU-R M.2377. PPDR applications and related examples, and PPDR requirements can be found in Annexes 4 and 5 of Report ITU-R M.2377.

Examples of different national and/or regional spectrum needs for narrowband and wideband PPDR systems are addressed in Annex 1 of this Report. Further examples of broadband spectrum needs estimations and scenarios are addressed in Annex 2 (2A to 2F).

3 Spectrum considerations for PPDR

Resolution **646 (Rev.WRC-15)** encourages administrations to use the harmonized frequency 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 ranges.

It should be noted that the frequency ranges included in Resolution **646 (Rev.WRC-15)** 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 ranges in the Resolution can be used by PPDR agencies and organizations in order to meet their particular national requirements.

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[1] Recommendation ITU-R F.1399 defines narrowband wireless access as "Wireless access in which the maximum usable end-user bit rate is up to and including 64 kbit/s."; wideband wireless access as "*Wireless access* in which the maximum usable end-user bit rate is greater than 64 kbit/s and up to, and including, the primary rate."; and, broadband wireless access as "*Wireless access* in which the connection(s) capabilities are higher than the primary rate".

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.

4 Estimation of spectrum needs for PPDR

In regard to PPDR bandwidth needs, various estimates of PPDR traffic levels have been presented to ITU-R.

Wireless PPDR traffic levels are known to vary significantly, depending on localised or broader operational situations – ranging from routine daily activities, local emergency events (e.g. local crime scenes, building fires, industrial incidents, and traffic accidents), wide-area operational events, through to the less frequent major area disasters (e.g. rural forest fires, volcanic eruptions, typhoons, and tsunami). Moreover, PPDR wireless traffic is comprised of a mix of simple narrowband voice communications, messaging and data, through a variety of wideband applications – and will increasingly include broadband applications. As such, PPDR traffic intensity will vary widely on a daily, hourly or minute-by-minute basis, in response to particular operational needs and circumstances.

In ITU-R and regional discussions, many countries have expressed the view that determining minimum PPDR bandwidth remains a national matter – and should take account of differing national policies and priorities, demographics, network investment preferences, PPDR agencies size and structure, operational and procedural differences, and other factors.

In order to evaluate the amount of spectrum needed 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 1 (Narrow/Wideband technologies) and Annex 2 (Broadband technologies) provide examples of estimations of the spectrum needs for PPDR. It should be noted that the examples in Annex 1 were developed during ITU-R study period 2000 to 2003.

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

– Recommendation ITU-R M.1390 is a methodology developed for the calculation of terrestrial spectrum requirement estimates for IMT-2000. This methodology is suitable for evaluating spectrum requirement of systems using single radio access technology and it 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). This methodology considers the application of multiple mobile and fixed communication systems and complex cases of multi-network environments.

– Recommendation ITU-R M.1651 – A method for assessing the required spectrum for broadband nomadic wireless access systems including radio local area networks using the 5 GHz band, which provides the methodology for assessing spectrum requirements for RLANs. Recommendation ITU-R M.1651 was developed and utilized in the WRC-03 study cycle, then again as part of RLAN spectrum requirements under WRC-15 agenda item 1.1.

– Report ITU-R M.2290 – Future spectrum requirements estimate for terrestrial IMT, which utilized user demand forecasts to predict future usage of IMT.

– Recommendation ITU-R SM.1271 – Efficient spectrum utilization using probabilistic methods.

The spectrum estimation methodology employed in some of the estimations shown in Annexes 1 and 2 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).

Recommendation ITU-R M.1390 was the only tool available for calculating IMT spectrum needs when spectrum needs for PPDR were assessed under WRC-03 agenda item 1.3. The Recommendation was published in 1999. It, therefore, reflects the technologies available at that time, e.g. IMT-2000, and other public land mobile systems, which may continue to be deployed. Advances in broadband PPDR technologies since publication are not reflected in the Recommendation. When applying Recommendation ITU-R M.1390 to reflect broadband PPDR technologies, careful consideration should be given to the appropriate values for the parameters, e.g. activity factor, group size, and net system capability. An example of how these parameters can be adapted is provided in Annex 1.

Several other factors should also be considered when addressing the spectrum needs for broadband wireless PPDR systems, such as the sectorization of base stations, traffic prioritization, and the possibility of using any surrounding base stations and/or multiple frequency bands.

5 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 needed 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.

Annex 1

Spectrum needs for narrow-band and wide-band PPDR

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

– a method of estimating the amounts of spectrum;

– system scenarios and assumptions;

– validation of the method with respect to existing applications;

– examples of several administrations projections of their spectrum needs by 2010[2];

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

– conclusions.

The estimation method given in this Annex is provided for assisting in consolidating spectrum needs.

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

Many PPDR entities around the world are currently evaluating the migration from analogue 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 needed for interoperability between various PPDR users and/or additional spectrum may be needed 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 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.

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[2] These spectrum estimations, done during the study cycle 2000-2003, estimated spectrum needs by 2010.

1 Methods of projecting spectrum needs

Description of the methodology

This public protection and disaster relief spectrum need estimation 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.

2 Validity of the methodology

Discussion

Several aspects of the methodology, the assumptions inherent in the model as presented, timing, method of estimation, frequency reuse, possibility of separating the estimation 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 (narrowband (NB), wideband (WB), broadband (BB))?
c) Use of assumptions of PSWAC Report[3] with regard to assessment of traffic for PPDR?
d) Treatment of traffic for PP and DR together?
e) Use of cellular configurations/hotspots in estimating spectrum needs for PPDR?
f) Applicability of the methodologies for the simplex/direct mode operations?

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[3] United States Public Safety Wireless Advisory Committee, Appendix 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.

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 estimations needed for each type of use and technology.

2 Terms of the estimations of spectrum needs 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 estimations of spectrum needs.

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 an estimation 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 radiocommunications.

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 needs 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 need, 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.

4 Extrapolated upper limit

During the ITU-R study period 2000-2003, Korea undertook a parametric analysis of the result of spectrum need estimations 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 needs 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 required to meet the estimated PPDR spectrum needs for WRC-03 agenda item 1.3.

5 Results

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

A summary of results of spectrum estimates for PPDR scenarios presented by some administrations using the proposed 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

6 Discussion of results

The totals listed in the above chart cover all the PPDR applications and both uplink and downlink needs. 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 estimations on whatever scenarios they deemed most appropriate. For example, Korea based its spectrum estimations 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 needs. Other countries may decide to estimate separate PP and DR spectrum needs.

Attachment 1 to Annex 1

Methodology for the estimation of public protection and disaster relief terrestrial spectrum needs

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 estimation methodology, following the format of ITU methodology for the calculation of IMT-2000 spectrum needs, is developed. Because of the differences between commercial wireless users and PPDR wireless users, alternate methodologies are proposed to determine 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.

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.

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 1.1 for a comparison of the proposed PPDR methodology versus the Recommendation ITU-R M.1390 methodology. See Attachment 1.2 for a flowchart of the proposed PPDR methodology.

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 needs 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 user population and penetration rates must be determined. Within the geopolitical boundaries of the study area, PPDR user 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.

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 user 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.

6 D - PPDR user 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 NN 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 XX 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. 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 ten 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 user 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.

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 user 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.

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[4] 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. For PPDR systems that do not use vocoders with discontinuous voice transmission, 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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[4] Public Safety Wireless Communications User Traffic Profiles and Grade-Of-Service Recommendations (13 March 1996) in Appendix D of the Final Report of Spectrum Requirements Subcommittee (SRSC), in Appendix D of the Final Report of the Public Safety Wireless Advisory Committee (11 September 1996).

Example of traffic profiles from PSWAC Report[5]:

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

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

[5] Public Safety Wireless Communications User Traffic Profiles and Grade-Of-Service Recommendations (13 March 1996) in Appendix D of the Final Report of Spectrum Requirements Subcommittee (SRSC), in Appendix D of the Final Report of the Public Safety Wireless Advisory Committee (11 September 1996).

networks may be independent of local networks; police networks may be independent of fire networks).

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[6] levels, less than 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, less than 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 = less than 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).

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.

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6 Public Safety Wireless Communications User Traffic Profiles and Grade-Of-Service Recommendations (13 March 1996) in Appendix D of the Final Report of Spectrum Requirements Subcommittee (SRSC), in Appendix D of the Final Report of the Public Safety Wireless Advisory Committee (September 11, 1996).

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.

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.

Methodology 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 needs. 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.

12 J - Spectrum need estimation

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).

Estimate 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 to Annex 1 for a detailed narrowband voice example using London data from Methodology 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 needs can be estimated. 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 1

Comparison of proposed methodology for the estimation of PPDR spectrum needs 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 analysing 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	**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 = $\pi i R^2$ 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 user population by total area to get PPDR user 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 user population 54 703** Area under consideration. Area within well-defined geographic or political boundaries. Example: City of London = 1 620 km^2 PPDR user population density = PPDR user population/area Example: London = 33.8 PPDR/km^2

<table>
<tr><th>IMT-2000 methodology
(Rec. ITU-R M.1390)</th><th>IMT-2000 methodology</th><th>Proposed PPDR methodology</th></tr>
<tr>
<td>B3 Penetration rate
Percentage of persons subscribing to a service within an environment. Person may subscribe to more than one service</td>
<td>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</td>
<td>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:
<table>
<tr><th>Category</th><th>Population
(NB Voice)</th><th>Penetration</th></tr>
<tr><td>Regular Police</td><td>25 498</td><td>100%</td></tr>
<tr><td>Special Police Functions</td><td>6 010</td><td>10%</td></tr>
<tr><td>Police Civilian Support</td><td>13 987</td><td>10%</td></tr>
<tr><td>Fire Suppression
70%</td><td>7 081</td><td></td></tr>
<tr><td>Part-time Fire
10%</td><td>2 127</td><td></td></tr>
<tr><td>Fire Civilian Support</td><td>0</td><td>0</td></tr>
<tr><td>Emergency Medical Services</td><td>0</td><td>0</td></tr>
<tr><td>EMS Civilian Support</td><td>0</td><td>0</td></tr>
<tr><td>General Government Services</td><td>0</td><td>0</td></tr>
<tr><td>Other PPDR Users</td><td>0</td><td>0</td></tr>
<tr><td colspan="2">TOTAL PPDR user population</td><td>54 703</td></tr>
<tr><td colspan="3">Narrowband Voice
PPDR user population32 667</td></tr>
</table>
PPDR penetration rate for narrowband “service environment” and voice “service”:
= Sum(Pop × Pen)/sum(Pop) = 59.7%</td>
</tr>
</table>

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 3 in Annex 1 § 2 for details.

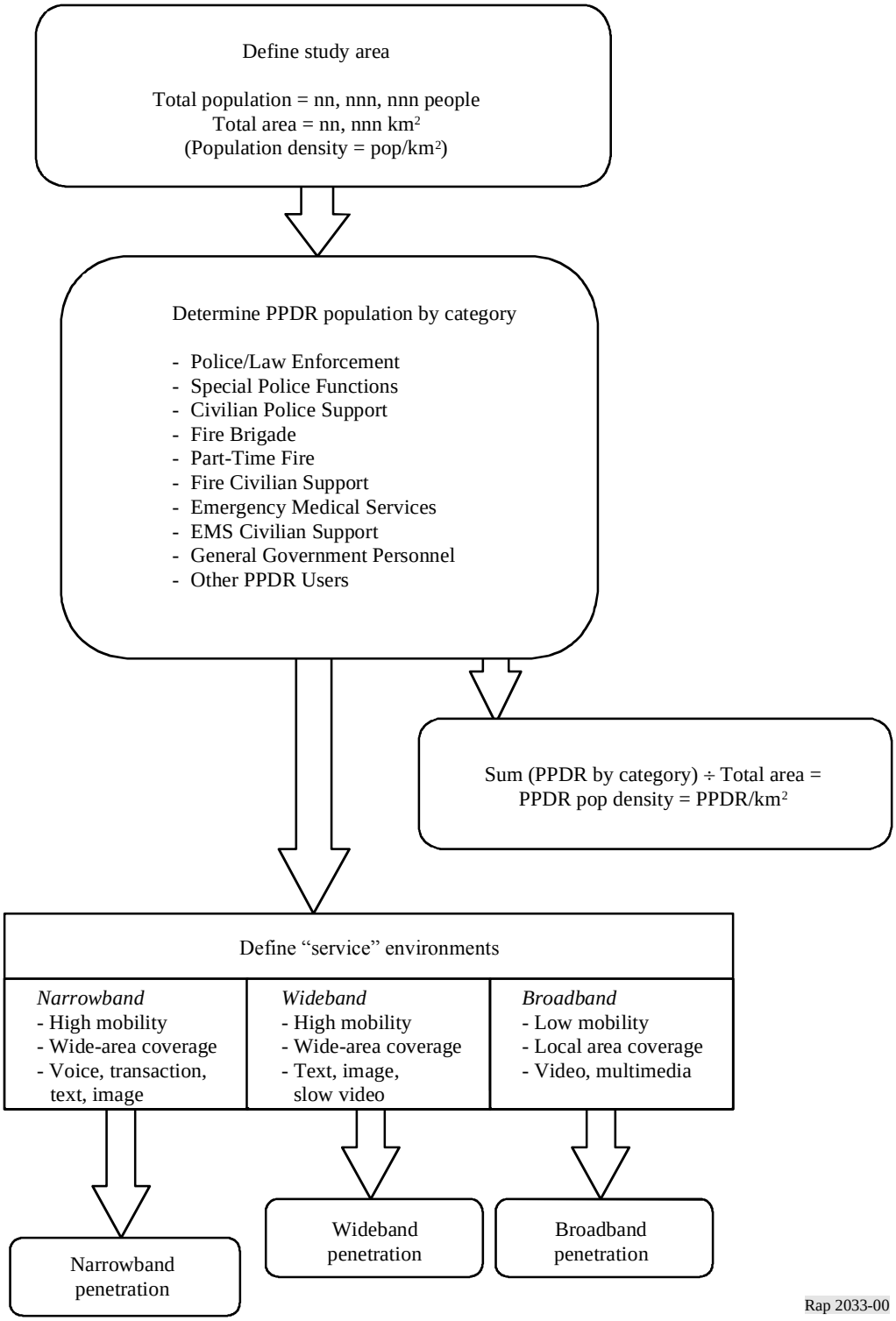
IMT-2000 methodology (Rec. ITU-R M.1390)	IMT-2000 methodology	Proposed PPDR methodology
B8 Quality of service function Offered traffic/cell is multiplied by typical frequency reuse cell grouping size and quality of Service factors (blocking function) to estimate offered traffic/cell at a given quality 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

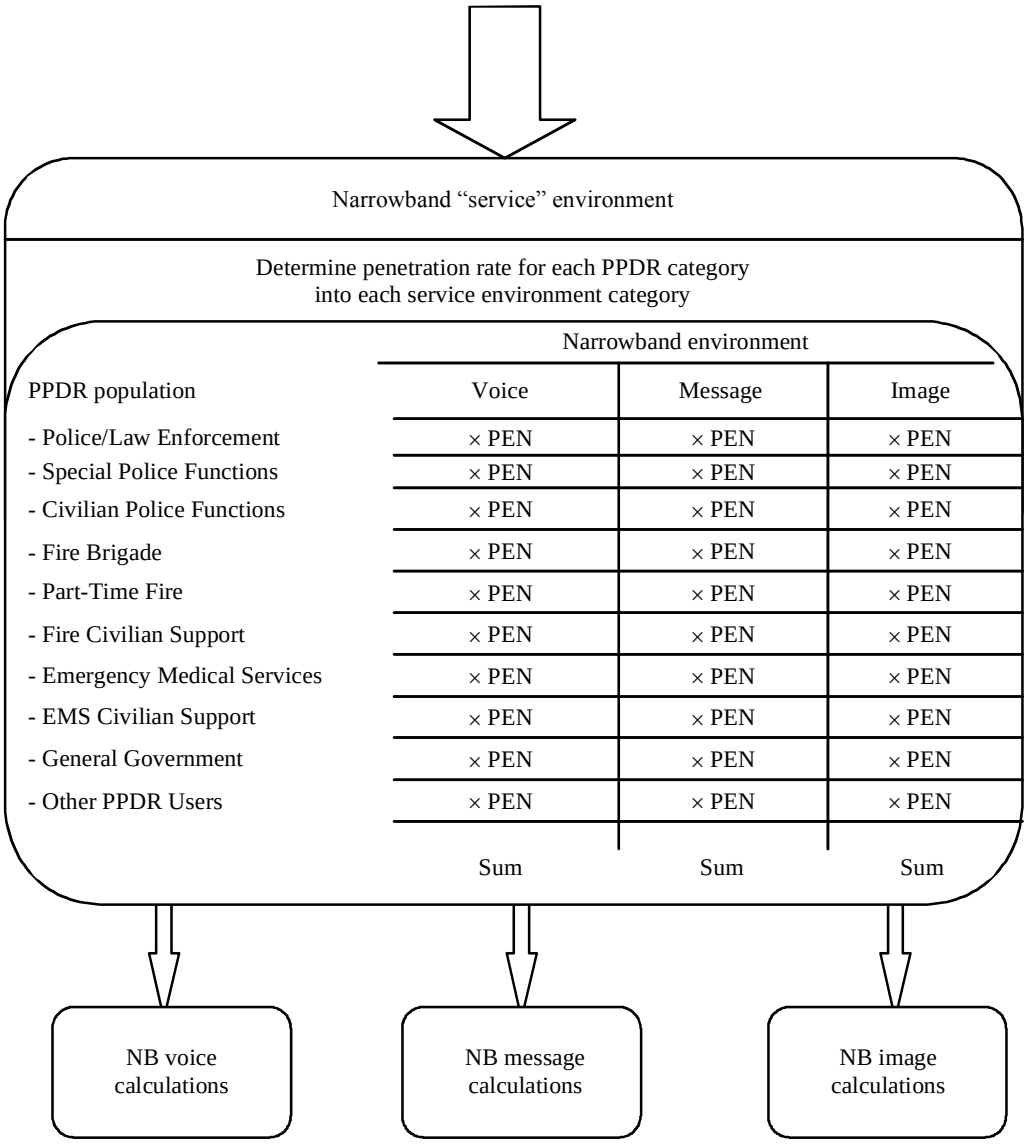
IMT-2000 methodology (Rec. ITU-R M.1390)	IMT-2000 methodology	Proposed PPDR methodology
C Technical and system considerations		
C1 Service channels per cell to carry offered load	**C1** Service channels per cell = Service channels per group/Group size	**C1** Same
C2 Service channel bit rate (kbit/s) 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 1.1 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 1

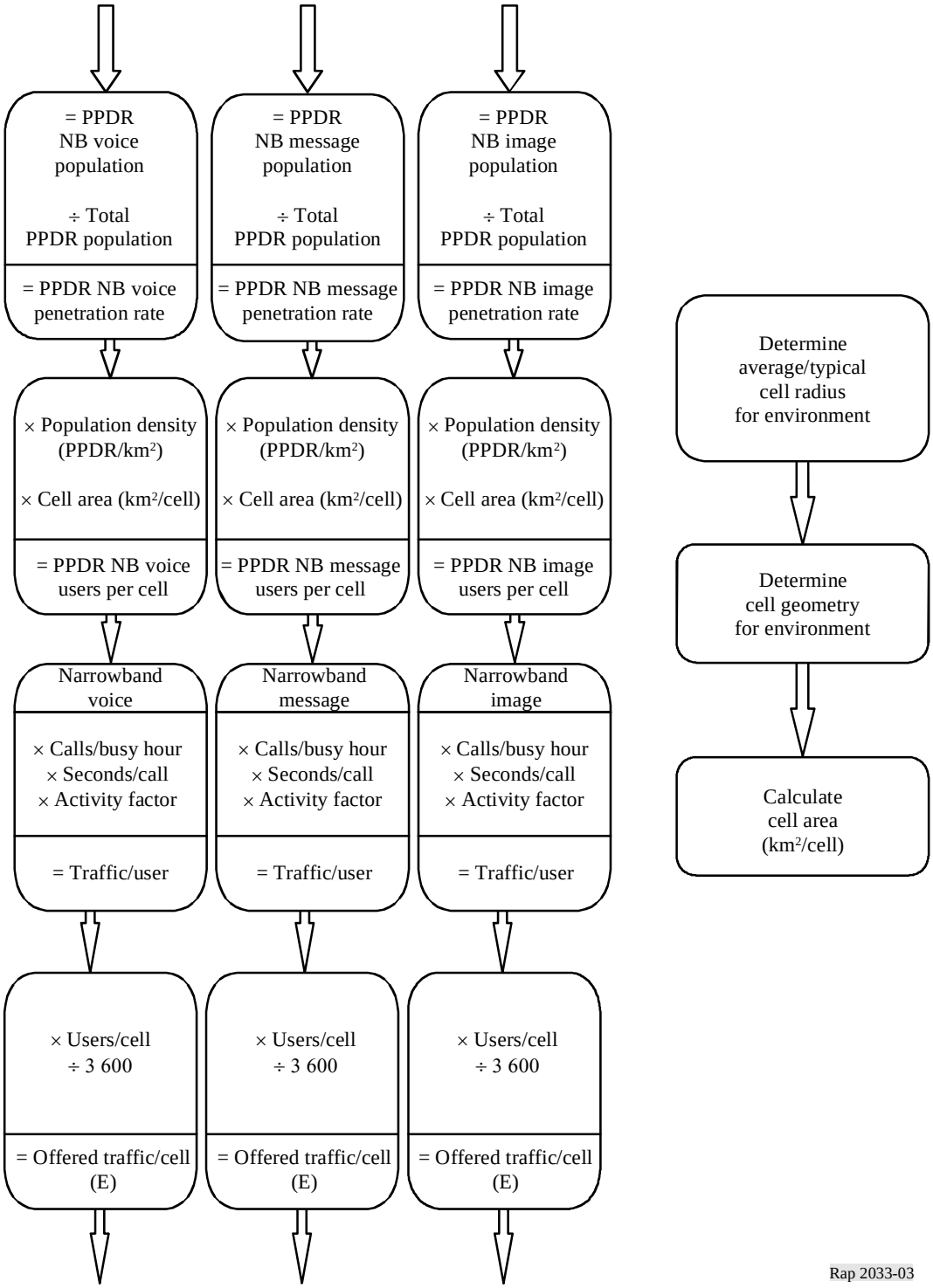
PPDR Spectrum Needs Flowchart

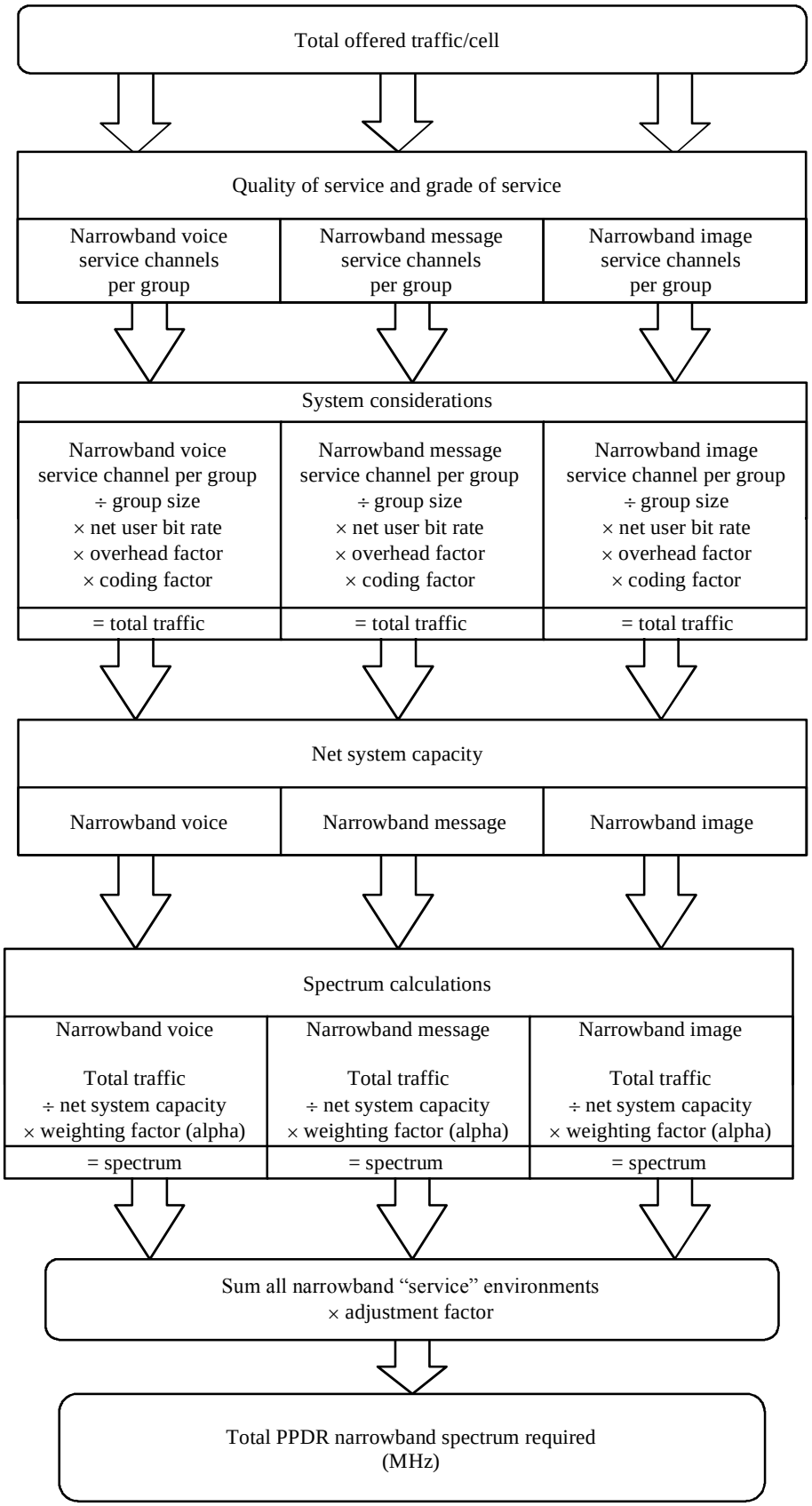


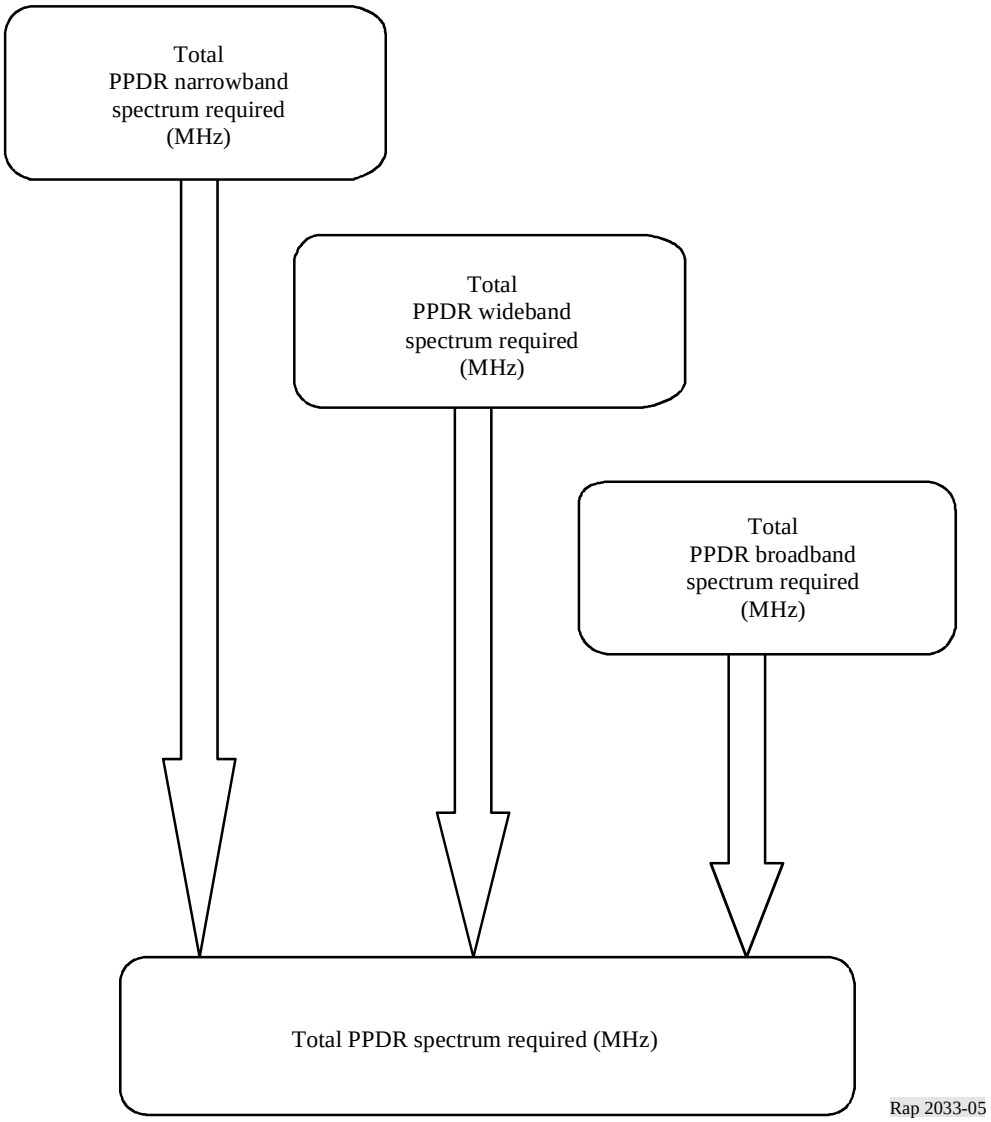


PEN: penetration

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)



Attachment 1.3
to Annex 1

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[8] 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

TDMA: 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.

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.

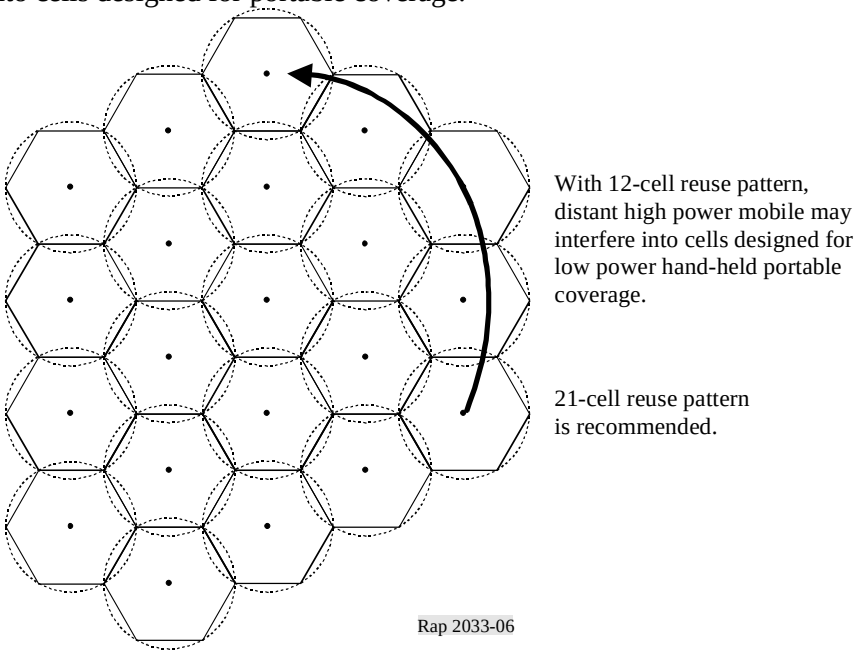
These are not meant to be a direct comparison between the selected technologies. There are numerous other user needs and spectrum allocation factors that affect the functional and operational deployment of a network, the choice of technology, and overall network efficiency. Some of the spectrum factors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

[8] 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.

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 1

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[9]

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[10]

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

9 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.

10 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[11]

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%	

[11] Not included in totals above.

Attachment 1.5
to Annex 1

Example spectrum needs estimation

	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 needs. 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 user 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 user 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[12]	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**

[12] Report from September 1996, see footnote 3 in Annex 1 § 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	Estimated total spectrum need		**PPDR NB voice TOTAL (MHz)**	**17.078 MHz**	

Attachment 1.6
to Annex 1

Example narrowband and wideband spectrum needs estimation 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 need 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[13])	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			

[13] Report from September 1996, see footnote 3 in Annex 1 § 2 for details.

Attachment 2
to Annex 1

PPDR spectrum need estimation based on generic city analysis (demographic population)

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 need based on the size of demographic population, that is, the amount of PPDR spectrum needed 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%).

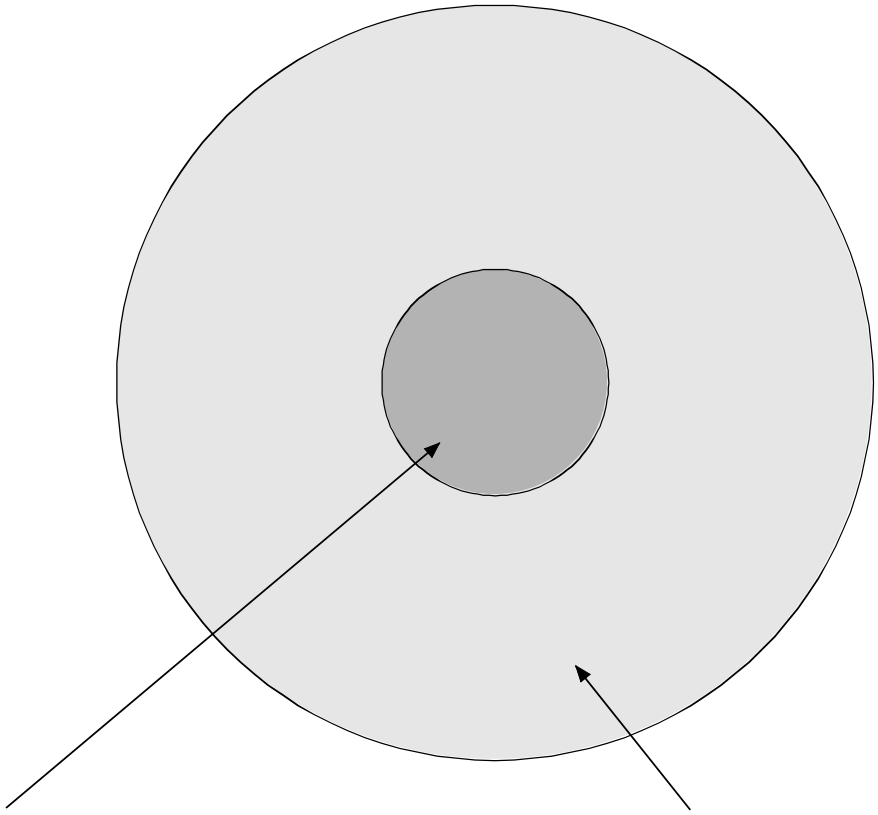
In the generic examples below, and for simplicity, only two densities are used, 180 and 250 police per 100 000 population. Also for simplicity, only two types of cities were analysed: a medium size city (2.5 million population) and a large city (8 million population). This probably underestimates the 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 centre 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 need estimation. Cell size had to be averaged and PPDR user density was lowered. In retrospect, each area should have been treated separately, and the spectrum needs 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)



Urban core
- Assume area in 500 to 1 500 km² range
- Assume population in 2 to 8 million range
- Assume radius of narrowband cells to be in 4 to 5 km range

Adjacent suburban area
- Assume area is ~10 times area of urban core
- Assume population approximately equal to population in urban core
- Assume radius of narrowband cells to be about 3 times radius (10 times area) of cells in urban core

Frequency reuse
- NB: little frequency reuse between urban core and surrounding suburbs due to reuse factor (21)
- WB: smaller radius cells and lower reuse factor (12)
- Allows reuse within the suburban ring and some reuse between urban core and suburban ring

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 estimate spectrum needs

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

3 Spectrum needs

Estimate spectrum needs for:

– Urban day-to-day

– Urban disaster

– Suburban day-to-day

– Suburban disaster

– Spectrum needs 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 needed for NB equals the sum of the urban and suburban spectrum need estimations. 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 needed for WB equals the sum of the urban and half of the suburban spectrum need estimation. 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 needed for NB equals the sum of the urban disaster and the suburban non-disaster spectrum need estimation.

The amount of spectrum needed for WB equals the sum of the urban disaster and half of the suburban non-disaster spectrum need estimation.

c) Suburban disaster operations:

The amount of spectrum needed for NB equals the sum of the urban non-disaster and the suburban disaster spectrum need estimation.

The amount of spectrum needed for WB equals the sum of the urban non-disaster and half of the suburban disaster spectrum need estimation.

Medium metropolitan area

Estimated spectrum needs using a PPDR estimation 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 estimated spectrum need for a medium PPDR user density and the right-hand column shows the estimated spectrum need for a higher PPDR user density.

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

The total spectrum needed is the sum of the urban and suburban estimations. 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 needs. For wideband, the assumption is that some frequencies can be reused, therefore, the total is the sum of the wideband urban need and half of the wideband suburban need.

The bottom half of the chart shows the spectrum need estimated 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 need 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 need increases by about 6%. If a disaster occurs in the urban area, then NB/WB spectrum need increases by about 9%.

Disaster operations for this generic medium size city need 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 need has 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 needs to be in the 50-75 MHz range.

Therefore, for a generic medium size city, the total spectrum need 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 estimated for 180 police officers per 100 000 population

Spectrum Needs – Generic City Estimation		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 Need (MHz)	Busy Hour Users	Spectrum Need (MHz)	Busy Hour Users	Spectrum Need (MHz)	Busy Hour Users	Spectrum Need (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 Need (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 estimated 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 Need (MHz)	Busy Hour Users	Spectrum Need (MHz)	Busy Hour Users	Spectrum Need (MHz)	Busy Hour Users	Spectrum Need (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 Need (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 Need 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 estimated for 250 police officers per 100 000 population

Spectrum Needs – Generic City Estimation			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)	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 Government 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 Need (MHz)	Busy Hour Users	Spectrum Need (MHz)	Busy Hour Users	Spectrum Need (MHz)	Busy Hour Users	Spectrum Need (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 need (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 estimated 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 Need (MHz)	Busy Hour Users	Spectrum Need (MHz)	Busy Hour Users	Spectrum Need (MHz)	Busy Hour Users	Spectrum Need (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 Need (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 Need 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

Estimated spectrum needs using a PPDR estimation spreadsheet.

Large metropolitan area (Urban population ≅ 8.0 million and area ≅ 800 km^2) (Suburban population ≅ 8.0 million and area ≅ 8 000 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	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 estimated spectrum need for a medium PPDR user density and the right-hand column shows the estimated spectrum need for higher PPDR user density.

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

The total spectrum need is the sum of the urban and suburban estimations. 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 needs. For wideband, the assumption is that some frequencies can be reused, therefore, the total is the sum of the wideband urban need and half of the wideband suburban need.

The bottom half of the chart shows the estimated spectrum need 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 need 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 need increases by about 6%. If disaster occurs in the urban area, then the NB/WB spectrum need increases by about 9%.

Disaster operations for this generic large city need 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 need has 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 needs to be in the 50-75 MHz range.

Therefore, for a generic large city, the total spectrum need 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 estimated for 180 police officers per 100 000 population

Spectrum Needs – Generic City Estimation		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	km^2	**10.0**	Ratio Suburban/Urban Area
Area of Surrounding Suburbs	8 000	km^2		Ratio should be near 10.0 (Range of 5 × to 15 × of Urban Area)
Urban Population Density	10 000	People/km^2		
Suburban Population Density	1 000	People/km^2		
"Large" or "Medium" City	LAR	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	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 Government 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 Need (MHz)	Busy Hour Users	Spectrum Need (MHz)	Busy Hour Users	Spectrum Need (MHz)	Busy Hour Users	Spectrum Need (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 Need (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 estimated 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 Need (MHz)	Busy Hour Users	Spectrum Need (MHz)	Busy Hour Users	Spectrum Need (MHz)	Busy Hour Users	Spectrum Need (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 Need (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 Need 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 estimated for 250 police officers per 100 000 population

Spectrum Needs – Generic City Estimation			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	km^2	**10.0**	Ratio Suburban/Urban Area
Area of Surrounding Suburbs	8 000	km^2		Ratio should be near 10.0 (Range of 5 × to 15 × of Urban Area)
Urban Population Density	10 000	People/km^2		
Suburban Population Density	1 000	People/km^2		
"Large" or "Medium" City	LAR	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)	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	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 Need (MHz)	Busy Hour Users	Spectrum Need (MHz)	Busy Hour Users	Spectrum Need (MHz)	Busy Hour Users	Spectrum Need (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 Need (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 estimated 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 Need (MHz)	Busy Hour Users	Spectrum Need (MHz)	Busy Hour Users	Spectrum Need (MHz)	Busy Hour Users	Spectrum Need (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 Need (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 Need 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 user population density analysis

- National average for police officers in the range 180 or 250 police/100 000 population.
- Suburban PPDR user populations based upon police density of 1.25 times the national average.
- Urban PPDR user populations based upon police density of 1.5 times the national average.
- Day-to-day PPDR user 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 user 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 PPDR user 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 PPDR user 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 × 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 2

Annexes on Broadband PPDR Spectrum Needs and Scenarios

Studies performed by several member states and sector members on the needed spectrum for Broadband PPDR are presented in Annex 2. The following table summarizes the studies' results:

Annex	Source	Bandwidth needs (MHz)		Comments
		Uplink	Downlink	
2A	CEPT	10	10	Data only. Based on ECC Report 199 Conclusions
2B	UAE	16.9	12.5	Two incidents data.
2C	Motorola Solutions	> 20	20	Level 3 incident (FDD)
2D	Israel	20	20	
2E	China	30-40		TD-LTE, depends on different scenarios
2F	Korea	10	10	
2G	Telstra			Monte Carlo simulation of throughput
2H	Tunisia	10	10	Based on broadband spectrum requirements. Narrowband spectrum requirements have not been considered in the study as they were already available for PPDR use.

Annex 2A

Methodology for the estimation of broadband PPDR spectrum needs within CEPT[14]

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 estimation of spectrum needs 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 needs.

2A.1 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 need based on assumptions on number of incidents per cell, location of incidents within a cell and spectrum efficiency per incident.

2A.2 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 need based on assumptions on location of users within the cell and spectral efficiency.

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

Annex 2B

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

2B.1 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 needs for broadband services and applications.

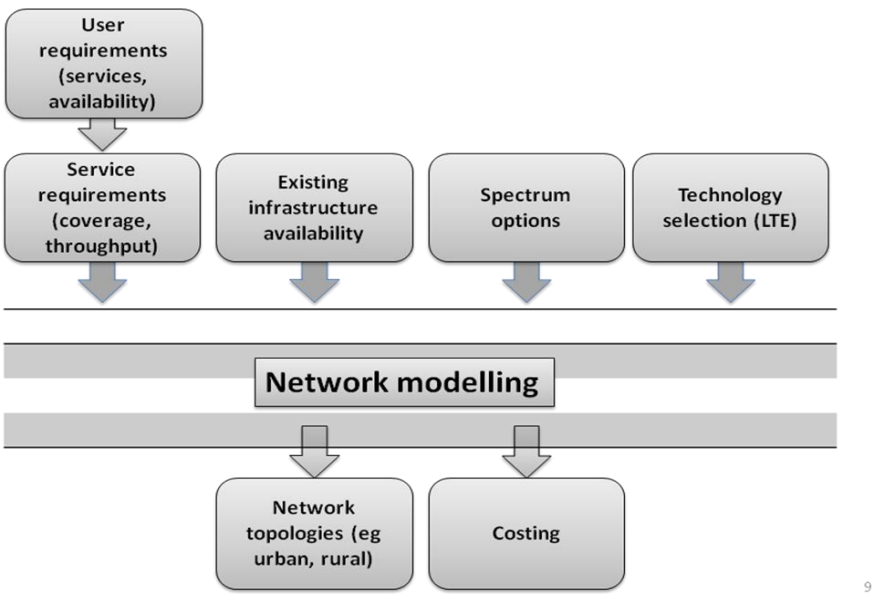
The UAE TRA has met with PPDR industry on several occasions to better understand industry trends and to ensure that what is being proposed for the UAE and the region is consistent with our national interest.

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

2B.2 Methodology

The study is addressing the methodology used to assess and estimate minimum spectrum needs 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 1 GHz to 3.6 GHz.

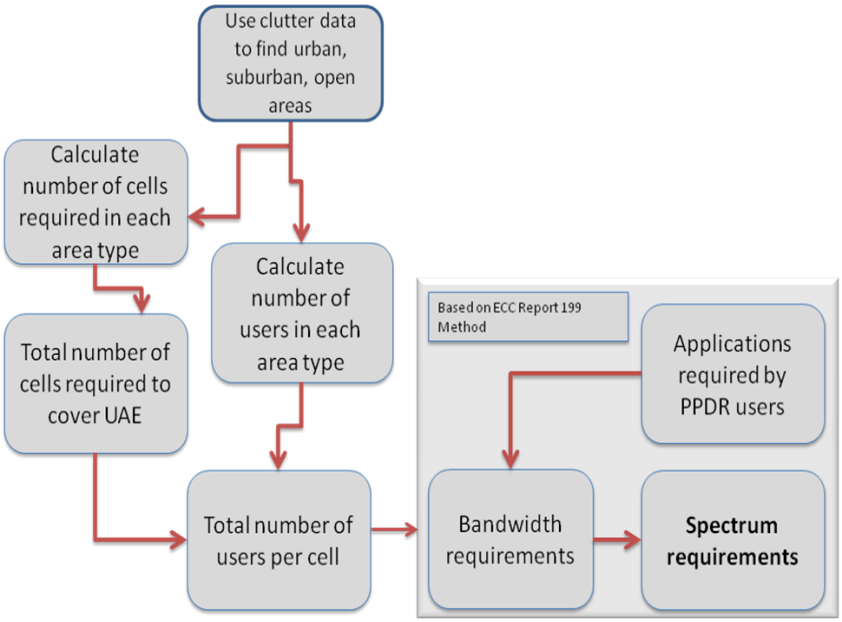
FIGURE 2B-1



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 2B-2



Highlights of PPDR spectrum needs results for UAE

TABLE 2B-1

Clutter data and minimum number of sites needed 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 2B-2

User Equipment		
Parameters	**Value**	**Unit**
Height	1.5	m
Frequency	420/750/2000	MHz
Output Power e.i.r.p.	30	dBm
Antenna Gain	0	dBi
Cable Loss	0	dB
Body Loss	3	dB
Sensitivity	–106.5	dBm

TABLE 2B-3

Base Station		
Parameters	**Value**	**Unit**
Height	40	m
Frequency	420/750/2000	MHz
Output Power e.i.r.p.	43	dBm
Antenna Gain	4.3	dBi
Duplexer Loss	1	dB
Cable Loss	2	dB
Sensitivity	–123.7	dBm

TABLE 2B-4

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

A minimum of 264 sites is expected to be needed 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	74 360
Suburban	15	11 952
Urban	90	11 880
Total		98 192

TABLE 2B-5

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

PPDR 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 PPDR Users per cell in peak time was used to estimate spectrum needs for different scenarios of BB-PPDR use.

2B.3 Summary of the spectrum need estimation – Results

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

– 1 incident needs 6.3 MHz

– 2 incident needs 16.9 MHz

TABLE 2B-6

Spectrum Results

Emergency/Incident conditions							Normal peak busy hour			
Uplink		Downlink					Uplink	Downlink		
		True group call possible		Individual transactions only				Individual only	Group call	
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	3.9	3.7	3.5	MHz

Data throughput requirements:

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

Throughput needs 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 estimation tool has been developed based on the requirements of some Public Safety agencies. This estimation tool is based on a set of PPDR applications which is based on their current operational experience and their vision of future working practices. The estimation tool 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 estimation tool 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 estimation tool, 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 tool allows the study of various effects through simulations of various scenarios, it may be noted that there is significant increase in spectral needs at a cell edge and for large incidents; this 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 need approximately 10+10 MHz of spectrum which is in-line with some other published studies.

Spectrum_Calculator
_v0_8.xlsx

Attachment 1 to this Annex provides some of the PPDR scenarios using this tool to show the throughput and the bandwidth needs 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. Figure 2C-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
to Annex 2C

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. 2C-1 below summarizes the expected public safety equipment and personnel response needed to manage such an incident in a local Chicago (Illinois, USA) suburb.[15]

FIGURE 2C-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**

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

As is clearly evident in Fig. 2C-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.

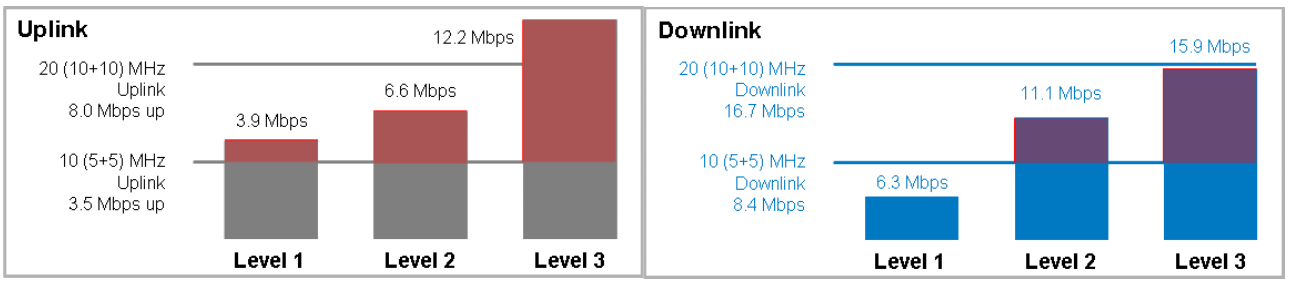
2 **Incident scene database lookups/downloads and information searches**: The classification includes the download of manuals, incident scene images, maps and topography information, building plans, etc. This use case has the unique requirement that, in general, the information is needed quickly as incident 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 centre. Rates of 400 kbit/s (QVGA 320×240 @ 30fps) and 1.2 Mbit/s (1280×960 @ 30fps) are used and the number of each type of video stream is scaled with the size and complexity of the incident.

Figure 2C-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 2C-2

Broadband Wireless Capacity Implications



LTE spectrum need observations

The results shown in Fig. 2C-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 2D

Representative scenario- deploying LTE for PPDR

2D.1 Background

This study is addressing the methodology used to estimate minimum spectrum needs 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.

2D.2 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.

2D.3 Event description

Call received at police operation centre, and the operation centre 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 2D-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

TABLE 2D-1 (*end*)

Scenario time line						
Part number and event description	**Time+**	**Link type**	**Required action Uplink**	**Required action Downlink**	**Used systems**	**No. of users**
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
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 2D-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	2 000	100
High resolution video	Real time video	2 000	2 000
Medium resolution video	Real time video	1 000	1 000
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.

2D.4 Analysis

In order to analyse the needed 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[16].

4 45 m antenna height above ground level.

5 Antenna parameters:

a) 17 dBi antenna gain.

b) 65 degree Horizontal pattern (aperture in the horizontal plane at 3 dB (in degrees).

c) 15 degree Vertical pattern (aperture in the vertical plane at 3 dB (in degrees).

6 3 dB losses (cable losses + connector losses feeder losses).

7 60 dBm e.i.r.p., 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.

[16] 3GPP TS 36.104 version 11.4.0 Release 11 – Table 6.2.1.

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.

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 analyse 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 needed spectrum for event part 12 (the maximum needed spectrum):

1 10 MHz.

2 15 MHz.

3 18 MHz (Not a LTE BW based on spec. has been used just for estimation).

4 18.8 MHz (Not a LTE BW based on spec. has been used just for estimation).

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 spectrum needed 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.

2D.5 Results

The reliability results for each bandwidth are shown in the Tables below:

TABLE 2D-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 2D-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 2D-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 2D-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 2D-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

2D.6 Conclusions of the representative scenario

The reliability results show that the spectrum needed 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 needs 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, 20 MHz X 2 is the spectrum needed for this example.

Attachment 1
to Annex 2D

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 2E

Spectrum need estimations and scenario of LTE based technology for broadband PPDR in China

2E.1 Introduction

The bandwidth needed by broadband PPDR would be tremendously different in different scenarios. This annex aims to research on the PPDR spectrum needs 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 needs for Wuhan city in China are estimated according to the methodology as an example. Additionally a typical PPDR incident scenario in China is also given.

2E.2 Methodology to estimate broadband spectrum needs

TABLE 2E-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 $=\pi i\ R^2$ Hexagonal cells $= 2.6 \cdot R^2$ 3-sector hex $= 2.6/3 \cdot R^2$
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.

TABLE 2E-1 (*cont.*)

IMT-2000 methodology (Recommendation ITU-R M.1390)	Methodology
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 user population by total area to get PPDR user population density. PPDR users are usually separated into well-defined categories by mission. Example: *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 user population 58157** Area under consideration. Area within well-defined geographic or political boundaries. Example: City of Wuhan =1550 km^2 PPDR user population density = PPDR user 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* (NB Voice) — Penetration Regular Police — 25 848 — 100% Special Police Function — 5 169 — 20% Police Civilian Support — 12 924 — 10% Fire Suppression — 7 755 — 0% Emergency Medical service — 1 292 — 50% General Government Service — 130 — 40% Other PPDR users — 5 039 — 40% **Total PPDR user population 58157** **Narrowband Voice** **PPDR user population 36807.9** PPDR penetration rate for narrowband "service environment" and voice "service": = Sum(Pop × Pen)/sum(Pop) =63.2%

TABLE 2E-1 (*cont.*)

IMT-2000 methodology (Recommendation ITU-R M.1390)	Methodology
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 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 Sources: current PPDR data and prediction data s/call 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

TABLE 2E-1 (*end*)

IMT-2000 methodology (Recommendation ITU-R M.1390)	Methodology
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
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 × $Freq_{es}$)

2E.3 Estimation of spectrum needs 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 2E-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 2E-4.

TABLE 2E-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 2E-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 2E-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 centre of politics, economy and culture, which located in the centre of China. It's urban and main suburb cover 1 550 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 2E-5

PPDR user population of Wuhan city in 2020

PPDR category	PPDR user population
Police	25 848
Special police function	5 169
Police civilian support	12 924
Fire	7 755
Emergency medical service	1 292
General government service	130
Other PPDR users	5 039

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

TABLE 2E-6

Spectrum needs of TD-LTE Voice

A	Geographic considerations				
A1	Select operational environment type Each environment type basically forms a column in estimation spread sheet. Do not have to consider all environments, only the most significant contributors to spectrum needs.. 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	25 848	1	
		Special police function	5 169	0.2	
		Police civilian support	12 924	0.1	
		Fire	7 755	0.7	
		Emergency Medical service	1 292	0.5	
		General Government Service	130	0.4	
		Other PPDR users	5 039	0.4	
			36 807.9		
	Area under consideration		1 550	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	

TABLE 2E-6 (*cont.*)

			Population (POP) by PPDR category	Penetration (PEN) rate within PPDR category	
B3	Penetration rate	Police	25 848	0.481	
		Special police function	5 169	0.024	
		Police civilian support	12 924	0.025	
		Fire	7 755	0.106	
		Emergency medical service	1 292	0.011	
		General government service	130	0.001	
		Other PPDR users	5 039	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[17]	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

[17] Report from September 1996, see footnote 3 in Annex 1 § 2 for details.

TABLE 2E-6 (*end*)

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	Estimate total spectrum (MHz)		1.55		

TABLE 2E-7

Spectrum needs of TD-LTE narrow band data

A	Geographic considerations				
A1	Select operational environment type Each environment type basically forms a column in estimation spreadsheet. Do not have to consider all environments, only the most significant contributors to spectrum needs. 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		58 157		
			Population (POP) by PPDR category	Penetration (PEN) rate within PPDR category	
		Police	25 848	0.5	
		Special police function	5 169	0.05	
		Police civilian support	12 924	0.05	

TABLE 2E-7 (*cont.*)

		Fire	7 755	0.35	
		Emergency medical service	1 292	0.2	
		General government service	130	0.2	
		Other PPDR users	5 039	0.21	
			18 162.8		
	Area under consideration		1 550	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	25 848	0.240	
		Special police function	5 169	0.006	
		Police civilian support	12 924	0.012	
		Fire	7 755	0.053	
		Emergency medical service	1 292	0.05	
		General government service	130	0	
		Other PPDR users	5 039	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	

TABLE 2E-7 (*end*)

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 2E-8

Spectrum needs of TD-LTE image

A	Geographic considerations				
A1	Select operational environment type Each environment type basically forms a column in estimation spreadsheet. Do not have to consider all environments, only the most significant contributors to spectrum needs. 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		58 157		

TABLE 2E-8 (*cont.*)

			Population (POP) by PPDR category	Penetration (PEN) rate within PPDR category	
		Police	25 848	0.6	
		Special police function	5 169	0.05	
		Police civilian support	12 924	0.01	
		Fire	7 755	0.3	
		Emergency medical service	1 292	0.2	
		General government service	130	0.2	
		Other PPDR users	5 039	0.24	
			19 908.4		
	Area under consideration		1 550	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	25 848	0.289	
		Special police function	5 169	0.006	
		Police civilian support	12 924	0.002	
		Fire	7 755	0.046	
		Emergency medical service	1 292	0.005	
		General government service	130	0	
		Other PPDR users	5 039	0.023	
			0.40		
B4	The number of cell		265		
	Users/cell		75.19		
B5	Traffic parameters		Uplink	Downlink	

TABLE 2E-8 (*end*)

	Busy hour call attempts (BHCA) (Calls/busy hour) kbit /Image		6.00 8 000.00	6.00 8 000.00	
	Activity factor		1.00	1.00	
B6	Average traffic in call-seconds generated by each user during busy hour		48 000.00	48 000.00	
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 2E-9

Spectrum requirement of TD-LTE video

A	Geographic considerations				
A1	Select operational environment type Each environment type basically forms a column in estimation spreadsheet. Do not have to consider all environments, only the most significant contributors to spectrum needs. 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		

TABLE 2E-9 (*cont.*)

B	Market and traffic considerations				
B1	Telecommunication services offered (kbit/s)				
B2	Total population		58 157 Population (POP) by PPDR category	Penetration (PEN) rate within PPDR category	
		Police	25 848	0.2	
		Special police function	5 169	0.04	
		Police civilian support	12 924	0.02	
		Fire	7 755	0.4	
		Emergency medical service	1 292	0.1	
		General government service	130	0.3	
		Other PPDR users	5 039	0.1	
			9 694.4		
	Area under consideration		1 550	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	25 848	0.096	
		Special police function	5 169	0.005	
		Police civilian support	12 924	0.005	
		Fire	7 755	0.061	
		Emergency medical service	1 292	0.002	
		General government service	130	0.001	
		Other PPDR users	5 039	0.009	
			0.33		
B4	The number of cell		265		
	Users/cell		36.58		

TABLE 2E-9 (*end*)

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) (2 MHz)		2 000.00	2 000.00	
C3	Total Throughput / Mbit/s		10.975	5.487	
C4	Frequency Efficiency		0.430	0.550	
D	Spectrum results				
D 1			25.52	9.98	
D 2	Weighting factor for each environment (α)		1.00	1.00	
D 3	Adjustment factor (β)		1.00	1.00	
D 4	Total Spectrum (MHz)		35.50		

Frequency prediction is summarised in Table 2E-10.

TABLE 2E-10

Example narrowband and wideband spectrum need estimation summaries

PPDR category	Wuhan population	Penetration rates			
		Narrowband voice	Narrowband data	Wideband image	Broadband video
Police	25 848	1	0.5	0.6	0.2
Special police function	5 169	0.2	0.05	0.05	0.04
Police civilian support	12 924	0.1	0.05	0.01	0.02
Fire	7 755	0.7	0.35	0.3	0.4
Emergency medical service	1 292	0.5	0.2	0.2	0.1
General government service	130	0.4	0.2	0.2	0.3
Other PPDR users	5 039	0.4	0.21	0.24	0.1
Total – PPDR users	58 157	36 870	18 162	19 908	9 673
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)	1 550	(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	80 kbit	8 000 kbit	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	80 kbit	8 000 kbit	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 need development of Wuhan city in 2020.

TABLE 2E-11

Total spectrum need 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

2E.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 needs of PPDR agencies in this mission critical scenario are analysed.

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 needed 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 2E-12 lists the bandwidth needs 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 2E-12 only lists the statistics for downlink and uplink bandwidth needed by video.

TABLE 2E-12

Analysis of bandwidth needs 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 fulfil 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.

2E.5 Conclusion

According to the provided methodology and the typical case above, 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 2F

Broadband PPDR spectrum needs in Korea

2F.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[18] and inshore vessel[19]. 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 needs 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 needs 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 needs for the integrated public broadband service are also analysed.

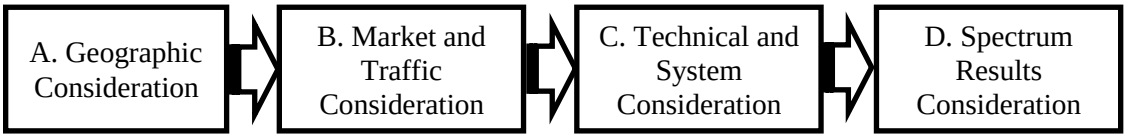
In § A2F.2, spectrum need estimation methodology is explained and traffic parameters of each scenario are presented. Section A2F.4 shows spectrum need estimation results and conclusions are drawn in § A2F.5.

2F.2 Spectrum Need Estimation Methodology

The spectrum need estimation 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 estimate spectrum needs for PPDR is shown in Report ITU-R M.2033. The spectrum need estimation procedure consists of 4 stages as in Fig. 2F-1.

FIGURE 2F-1

Spectrum need estimation 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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[18] 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.

[19] 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 § A2F.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 § A2F.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 needs.

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 2F-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)[20]. 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 needs. Weighting factor and adjustment factor are assumes as 1 in this study.

2F.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.

2F.3.1 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[21].

[20] 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.

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

TABLE 2F-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	2 500	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 2F-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 2F-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 2F-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 2F-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 2F-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				

2F.3.2 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 2F-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

2F.3.3 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 estimate spectrum need 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 needs are determined so as to meet spectrum needs 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 § 2F.3.2 is adopted. For sea area scenario, ship sinking near Busan harbour is considered. In this scenario, PPDR agency officers in harbour area and coast guard vessels in sea are assumed and broadband service for in shore vessel is also provided simultaneously.

2F.4 Spectrum Needs

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

TABLE 2F-9

Uplink spectrum needs 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 2F-10

Downlink spectrum needs 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 needed for uplink and downlink respectively thus 2×10 MHz should be provided for this case.

TABLE 2F-11

Spectrum needs 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 2F-12, it is shown that broadband services in each service area can be supported by using 2×10 MHz spectrum.

TABLE 2F-12

Spectrum needs 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 needs for railway and inshore vessel broadband service is presented in separate report, which will be published in the near future.

2F.5 Conclusion

For individual PPDR agency operation, it is shown that 2×5 MHz spectrum would be sufficient for all scenarios. In case of multiple PPDR agencies operation, 2×10 MHz should be provided. Furthermore, in case of integrated public broadband service, services in each service area can be supported within the range of 2×10 MHz spectrum. Thus, when comparing with individual spectrum use for each public broadband service where total spectrum needed would be 2×20 MHz, it can be shown that spectrum can be saved by 2×10 MHz. Furthermore, considering that PPDR spectrum would be underutilized in day-to-day situation, integration with other public broadband services would be beneficial in terms of efficient spectrum use.

Spectrum needs in above are analysed 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 needs considerable spectrum and it is anticipated that the demand will increase due to the trend of price reduction of high quality video transmission equipment. 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 2G

Estimation of spectrum needs for wireless PPDR systems using Monte Carlo simulation

2G.1 Overview of approach and method used

The aim of this simulation study by Telstra was to determine the achievable throughput in a more realistic context, offered by a typical LTE network in various geographic/deployment scenarios for supporting PPDR operations, taking into account practical network performance.

The particular approach adopted involved three steps: The first step was to implement a realistic simulation model, using specialised software, of a representative 19-cell LTE ‘network’ in accordance with previous models used in other studies by ITU-R on IMT systems (specifically LTE & LTE-Advanced). The simulation then assigned a notional amount of spectrum and placed a number of user-terminals randomly within each sector in that network. The uplink (UL) and downlink (DL) signal-to-noise-and-interference ratio (SINR) and propagation loss was logged for a selected user-terminal. The position of the user-terminal is then randomly moved around within the sector, and the process is repeated as many times as necessary to achieve statistical accuracy. The output of this step is a sufficiently large number of sampled SINR and propagation loss data pairs.

The second step of the analysis was to convert each of the SINR and propagation loss values into a corresponding data throughput using a coverage and capacity dimensioning tool[22]. The output of this step is a cumulative distribution of UL and DL throughput in the sector.

The third step is to compare the achievable throughput to PPDR traffic requirements. These requirements are dependent on the scenario being modelled and would cover day-to-day operational use and emergency situations of increasing severity.

This three step approach has the advantage that it avoids introducing *a priori* averaging assumptions in the estimation of spectrum needs. It models each of the received signal levels taking into account its propagation path loss and converts each signal level and path loss into a throughput for each user-terminal location.

2G.2 Background to the study

The rationale for undertaking these studies is to assist administrations in making policy decisions regarding the provision of wireless broadband PPDR capability – and the opportunity cost versus economic benefit of various deployment options.

Several administrations have already commenced to plan and deploy wireless broadband PPDR. Those efforts have already highlighted the considerable capital cost of building dedicated wireless broadband PPDR networks with high throughput, and the need for careful consideration of the options. Moreover, studies of network build costs in some countries have shown that required capital expenditure, amortised over time, is significantly greater than the cost of alternative deployment/delivery options, such as carrying PPDR traffic as a priority stream on a public mobile broadband network[23]. Public mobile broadband networks may therefore be attractive to some administrations, for economically facilitating broadband capabilities to meet the needs of PPDR agencies. As such, public network operators also need to consider the additional spectrum occupancy associated with supporting PPDR traffic – so these capacity studies are equally relevant to dedicated PPDR and public network based deployment options.

From an overall traffic viewpoint, public LTE networks today serve millions of users using defined spectrum bandwidth assignments, and noting the growing penchant of users for audio-visual applications, PPDR traffic and usage scenarios are unlikely to present insurmountable load or latency issues to public network operators. Thus, as an example of one possible response to a major emergency scenario, a public wireless broadband network could potentially make all of its bandwidth available for priority use by PPDR agency users[24]. In many countries, spectrum assignments to contemporary public LTE networks may already offer considerably greater traffic capacity compared to any prospective dedicated PPDR network. As such, and in addition to cost savings, there may be notable performance advantages for PPDR services delivered over public mobile broadband platforms. However, careful consideration of the implications of PPDR operations and emergency traffic levels are still of interest to public network operators for capacity planning purposes.

2G.3 Initial PPDR Spectrum Estimates

The initial PPDR throughput requirements were reported in a number of past contributions to ITU-R, and documented in this Report (and in previous versions of Report ITU-R M.2377) addressing general PPDR requirements.

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22 Ericsson, Coverage and capacity Dimensioning FDD Recommendation, Release 16A.

23 *Public Safety Mobile Broadband*, Productivity Commission Research Report, December 2015.

24 *Telstra LANES to the rescue*: http://www.telstra.com.au/aboutus/media/media-releases/telstra-lanes-to-the-rescue.xml.

A) Narrowband and Wideband PPDR Spectrum Needs

In particular, Annex 1 of this Report sets out a methodology for determining spectrum needs of narrow and wideband PPDR systems. The methodology adopted an approach developed for IMT-2000 technology[25] and adapted this for narrowband and wideband PPDR systems. It results in a relatively high spectrum need primarily because dedicated channels are assumed (activity factor = 1), and 12 or 21 cell frequency reuse is assumed. However, it has since been recognized that the spectrum needs are significantly reduced when using LTE systems to provide packet-oriented PPDR voice, data and broadband capability[26,27]. For example, if LTE assumptions were substituted in the analysis in Attachment 1.6 to Annex 1, the spectrum needed for London narrowband voice would reduce from 17.1 MHz to well under 1 MHz. Narrowband messaging and imaging requirements will also similarly be significantly reduced when carried on an efficient packet-oriented LTE network.

B) Broadband PPDR Spectrum Needs

In Annex 2 of this Report, several examples were presented for estimating the broadband PPDR spectrum needs. While intended to illustrate the minimum spectrum needs, these examples could also be interpreted as indicating the capacity implications for the case of broadband PPDR functionality being delivered via public mobile broadband networks. Of particular note, the indicative day-to-day and general emergency PPDR traffic estimates are relatively low in comparison to current bit-rates already seen in relation to most public wireless broadband systems in operation today.

In relation to the more extreme spectrum estimates, intended to cater to major disaster events arising relatively infrequently, it is clear that much of the additional spectrum capacity would lie idle over quite large coverage areas for long periods of time – unless it were otherwise made available to alternative usage (such as for public mobile traffic) when not needed for PPDR operations. A further concern is that the top-down methodology underlying these extreme estimates also arbitrarily infers that all possible applications are simultaneously required to be delivered to every PPDR user terminal via a single base-station. In contrast, the bottom-up methodology outlined in this annex adopts a more realistic approach by determining the effective throughput available from a specified channel bandwidth, and compares that to the typical capacity required for various PPDR application streams.

C) Implications for Other deployment Options

As noted above, studies of PPDR spectrum needs can be equally used for determining the ability of public mobile broadband networks to deliver broadband services to PPDR agencies, and the implications for performance.

A further advantage of public mobile broadband networks is that regular improvements in spectral efficiency are routinely implemented by network operators to meet increasing user demand as the technology improves and vendors release hardware and software updates. Such ongoing performance enhancement represents an investment that public network operators can readily justify, but which PPDR agencies may find more difficult due to fiscal appropriation constraints typical of many government agencies.

The analysis in Annex 2 of this Report does not preclude PPDR spectrum needs being met through use of several frequency bands. For example, in 2011 the Australian Communications and Media Authority proposed 10 MHz of dedicated low-band FDD spectrum (below 1 GHz) and supplemented

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[25] Recommendation ITU-R M.1390.

[26] *FirstNet, First responder Network*, http://www.firstnet.gov/network.

[27] *Final contracts for new emergency services network are signed*, https://www.gov.uk/government/news/final-contracts-for-new-emergency-services-network-are-signed.

by 50 MHz of high-band TDD spectrum (4.9 GHz) be made available for PPDR[28]]. More recently, the largest public network operator in Australia (Telstra Corporation) made available its entire nationwide multi-band commercial LTE network for priority access by PPDR users (based on the 700, 1 800, and 2 600 MHz bands)[29].

Additionally, to meet the 'anytime, anywhere' expectations of users, contemporary public networks now typically offer very high outdoor coverage probability – often referred to as 'coverage depth'. Most public mobile broadband networks are specifically designed for 90% indoor coverage probability that, based on typical building attenuation and deployment density values, will result in an outdoor coverage probability significantly exceeding the 95% to 97% design objective for PPDR[30].

2G.4 Wireless Broadband network simulation

A) Defining a model LTE network

As a part of the work of Joint Task Group 4-5-6-7, and which led to identification of additional spectrum to meet the needs of LTE and LTE-Advanced systems, the ITU-R has already reached a consensus regarding the relevant parameters and deployment modelling of LTE networks. Those same modelling methods can also be conveniently used as a starting point for PPDR capacity prediction. Taking account of the technology characteristics and performance capabilities specified by 3GPP, the ITU-R methodology included a 19-cell model network, and several sets of alternative deployment metrics reflecting the differing urban, suburban and rural deployment scenarios.

The 19-cell network and orientation of base stations is illustrated in Figs 2G-2 and 2G-3 in Attachment 1 to this Annex. The associated base-station and user-equipment parameters are further set out in Table 2G-2 of Attachment 1 for the urban, suburban and rural deployment scenarios. For the purposes of the studies in this Annex, the network model was implemented within a widely-recognised software simulation tool: Transfinite's Visualyse™ radio system and interference analysis software tool[31].

B) Generating the Results

The LTE network model was run as a Monte Carlo simulation, comprised of at least 2 000 'snap shots' in each run to ensure sufficient statistical accuracy, and all user terminals were moved randomly in each 'snap shot'.

The path loss between relevant serving base-station and a representative user-terminal, along with its SINR, was recorded in each 'snap shot', to generate a high-resolution distribution of the resulting raw data.

The translation of SNIR and path loss into throughput was done using a spreadsheet implementation of a capacity and network dimensioning tool[32] that has now been well proven by the field performance observations of many LTE network operators around the world.

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[28] Spectrum for public safety radiocommunications: Current ACMA initiatives and decisions, October 2012, http://www.acma.gov.au/~/media/Spectrum%20Licensing%20Policy/Issue%20for%20comment/IFC%20pre%202013/spectrum_for_public_safety%20docx.docx.

[29] Telstra LANES to the rescue: http://www.telstra.com.au/aboutus/media/media-releases/telstra-lanes-to-the-rescue.xml

[30] 9 - G PPDR quality of service functions p.17.

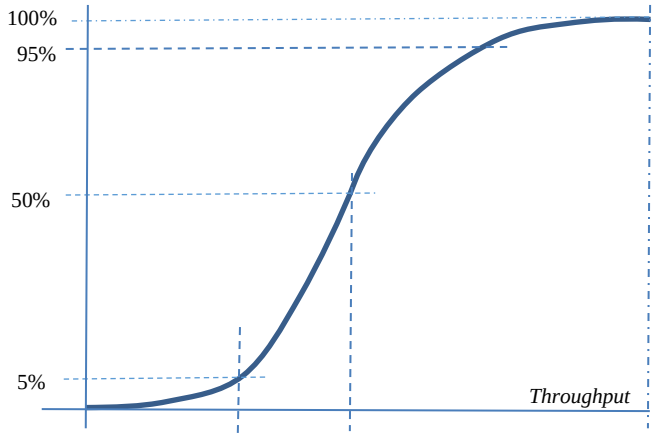
[31] Visualyse Professional V7, http://www.transfinite.com/content/downloadsvisualyse

[32] Ericsson, Coverage and Capacity Dimensioning FDD Recommendation, Release 16A.

The outcome of this Monte Carlo process is a distribution of effective burst throughput-per-user, which provides a realistic indication of the user-experienced bit-rate achieved by such a single-frequency network deployment scenario.

2G.5 Resulting Effective Throughput-per-User

FIGURE 2G-1



The Monte Carlo LTE network model was run numerous times to generate results for all combinations of channel bandwidth (5, 10, 20 MHz) and base-station deployment density (urban, suburban, and rural). For each case, both the uplink and downlink statistics were noted, and the 5-percentile and 50-percentile throughput values and associated effective spectrum efficiency were observed.

The 5-percentile throughput value represents the case of 95% of UEs experiencing a throughput of *better/greater* than the mantissa. The 50-percentile value represents the average throughput-per-user.

An example of the uplink and downlink SNIR and path loss statistics from a sample run of the network simulation is shown in Figs B1 and B2 in Appendix B. The uplink and downlink throughput statistics derived from these is shown in Figs B3 and B4.

The modelling results for throughput and spectrum efficiency are set out in Table 1 below.

TABLE 2G-1

Sector uplink and downlink throughput and spectral efficiency results

Scenario		**Urban**	**Suburban**	**Rural**
Downlink	*Channel (MHz)*			
5^{th} percentile throughput (& spectrum efficiency)	5 10 20	12.3 Mbit/s, 2.4 bps/Hz 20.1 Mbit/s, 2.0 bps/Hz 40.2 Mbit/s, 2.0 bps/Hz	16.2 Mbit/s, 3.2 bps/Hz 32.5 Mbit/s, 3.2 bps/Hz 64.9 Mbit/s, 3.2 bps/Hz	14.4 Mbit/s, 2.8 bps/Hz 28.8 Mbit/s, 2.8 bps/Hz 57.5 Mbit/s, 2.8 bps/Hz

50th percentile throughput (& spectrum efficiency)	5 10 20	15.1 Mbit/s, 3.0 bps/Hz 28.0 Mbit/s, 2.8 bps/Hz 56.0 Mbit/s, 2.8 bps/Hz	18.1 Mbit/s, 3.6 bps/Hz 36.1 Mbit/s, 3.6 bps/Hz 72.2 Mbit/s, 3.6 bps/Hz	17.0 Mbit/s, 3.4 bps/Hz 34.0 Mbit/s, 3.4 bps/Hz 67.9 Mbit/s, 3.4 bps/Hz
Uplink				
5th percentile throughput (& spectrum efficiency)	5 10 20	2.2 Mbit/s, 0.44 bps/Hz 2.4 Mbit/s. 0.24 bps/Hz 1.7 Mbit/s, 0.09 bps/Hz	3.8 Mbit/s, 0.8 bps/Hz 11.1 Mbit/s, 1.1 bps/Hz 15.6 Mbit/s, 0.8 bps/Hz	2.2 Mbit/s, 0.4 bps/Hz 7.2 Mbit/s, 0.7 bps/Hz 8.8 Mbit/s, 0.4 bps/Hz
50th percentile throughput (& spectrum efficiency)	5 10 20	4.9 Mbit/s, 1.0 bps/Hz 6.7 Mbit/s, 0.7 bps/Hz 8.1 Mbit/s, 0.4 bps/Hz	6.9 Mbit/s, 1.4 bps/Hz 17.2 Mbit/s, 1.7 bps/Hz 28.1 Mbit/s, 1.4 bps/Hz	4.8 Mbit/s, 1.0 bps/Hz 13.1 Mbit/s, 1.3 bps/Hz 19.5 Mbit/s, 1.0 bps/Hz

To put the above throughput values in suitable perspective, it is useful to review typical application bit-rates:

– Voice – using Adaptive Multi-Rate Wide Band (AMR-WB) coding in normal mobile environments results in an effective bit rate of about 12.65 kbit/s for *superior audio quality speech and music* (i.e. quality better than a 56 kbit/s Rec. ITU-T G.722 signal) – and can range up to 23.85 kbit/s in adverse background noise environments;

– Audio-visual – for a H.264 composite signal providing HD 720p (1280 × 720) resolution[33] for transfer of vehicle/man-mounted surveillance signals, requires an aggregate bit rate of 2.56 Mbit/s (video 2496 kbit/s + audio 64 kbit/s);

– Data records – variable sizes, depending on application, needing burst-rates ranging from around 0.1-3 Mbits;

– Images/photographs – variable sizes, depending on application, needing burst-rates ranging from around 0.1-3 Mbits.

The resulting effective throughput-per-user reported above therefore suggests that PPDR users can expect satisfactory performance via a 5 MHz FDD channel.

2G.6 Conclusions

The simulation studies outlined in this report illustrate examples of greater spectral efficiencies and correspondingly lower PPDR spectrum needs than have been previously indicated by studies relying on methodologies such as Recommendation ITU-R M.1390 or other bespoke methods – mainly due to under-estimation of actual achievable spectral efficiency factor.

Moreover, these results suggest that carriage of wireless broadband PPDR applications over public mobile broadband networks is generally feasible (even for a 5 MHz channel bandwidth) with better spectrum efficiency than otherwise assumed, and that broadband PPDR traffic can be readily and efficiently accommodated ultimately leading to greater overall public benefit.

[33] For example, see: http://www.lighterra.com/papers/videoencodingh264/.

Attachment 1
to Annex 2G

Model layout and parameters

FIGURE 2G-2

LTE/LTE-Advanced macro network layout

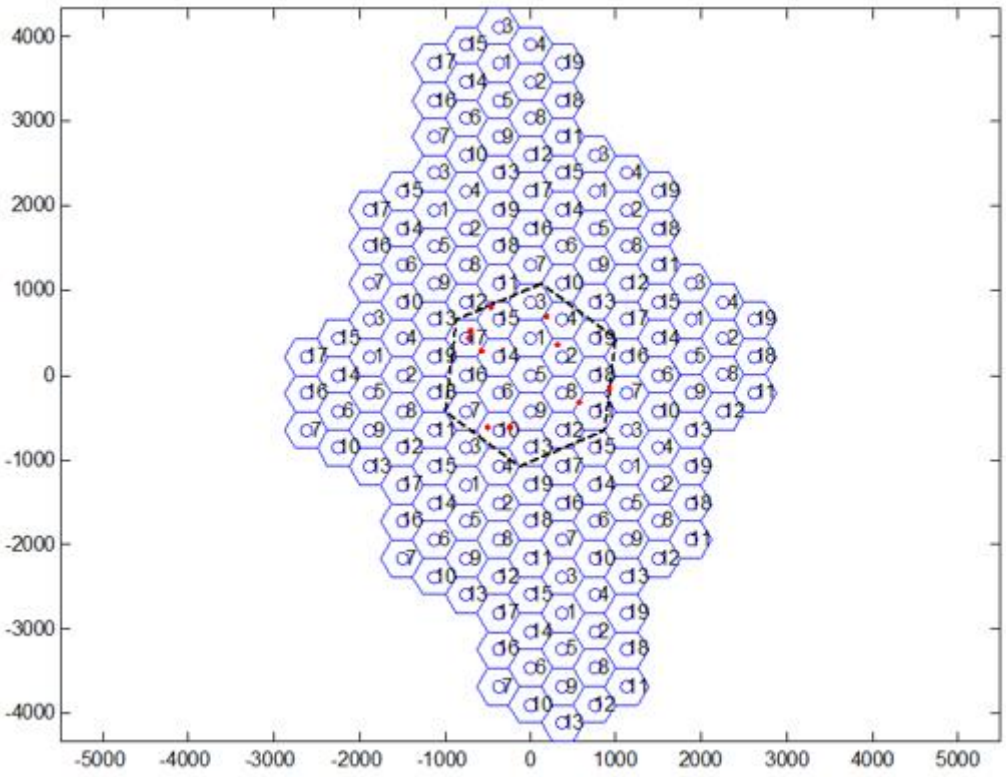
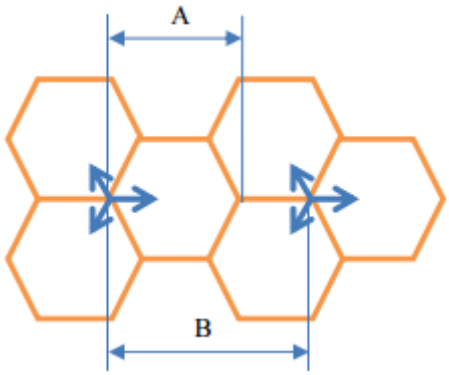


FIGURE 2G-3

Macro-cell layout[34]



[34] Figure 1, Report ITU-R M.2292-0, Characteristics of terrestrial IMT-Advanced systems for frequency sharing/ interference analyses, p. 5.

The parameters used in the modelling are set out in the table below. Typical deployment parameters where indicated were used in the simulation.

Deployment-related parameters for bands below 1 GHz

TABLE 2G-2

Base station deployment parameters for bands below 1 GHz

Base station characteristics / Cell structure	
Cell radius	> 5 km (typical 8 km) for macro rural scenario 0.5-5 km (typical 2 km[1]) for macro urban/suburban scenario
Antenna height	30 m (see Note 1)
Sectorization	3 sectors
Downtilt	3 degrees
Frequency reuse	1
Antenna pattern	Recommendation ITU-R F.1336 (*recommends* 3.1) – $k_a = 0.7$ – $k_p = 0.7$ – $k_h = 0.7$ – $k_v = 0.3$ Horizontal 3 dB beamwidth: 65 degrees Vertical 3 dB beamwidth: Determined from the horizontal beamwidth by equations in Recommendation ITU-R F.1336. Vertical beamwidths of actual antennas may also be used when available.
Antenna polarization	linear / +- 45 degrees
Feeder loss	3 dB
Maximum base station output power	46 dBm in 10 MHz
base station antenna gain	15 dBi
base station EIRP	58 dBm in 10 MHz
Average base station activity factor	50 %
Average base station EIRP/sector taking into account activity factor	55 dBm in 10 MHz

TABLE 2G-3

User terminal characteristics for bands below 1 GHz

User terminal characteristics	
Indoor user terminal usage	50% for macro rural scenario 70% for macro urban/suburban scenario
Average Indoor user terminal penetration loss	15 dB for macro rural scenario 20 dB for macro urban/suburban scenario
User terminal density in active mode to be used in sharing studies	0.17 / 5 MHz/km^2 for macro rural scenario 2.16 / 5 MHz/km^2 for urban/suburban scenario
Maximum user terminal transmitter output power	23 dBm
Average user terminal transmitter output power	2 dBm for macro rural scenario –9 dBm for macro urban/suburban scenario
Antenna gain for user terminals	–3 dBi
Body loss	4 dB

TABLE 2G-4

Additional parameters used in the simulation

Additional base station and user terminal parameters	
Channel bandwidth	5, 10, 20 MHz
Building Penetration Loss	0 dB (outdoor use)
User terminal power control target	Minimum BS receive level -120 dBm
Base-station transmit power (20 MHz channel)	+49 dBm
Base-station transmit power (5 MHz channel)	+43 dBm

Attachment 2
to Annex 2G

Example results

FIGURE 2G-4

CDF of uplink SINR for suburban network model for 10 MHz channel bandwidth

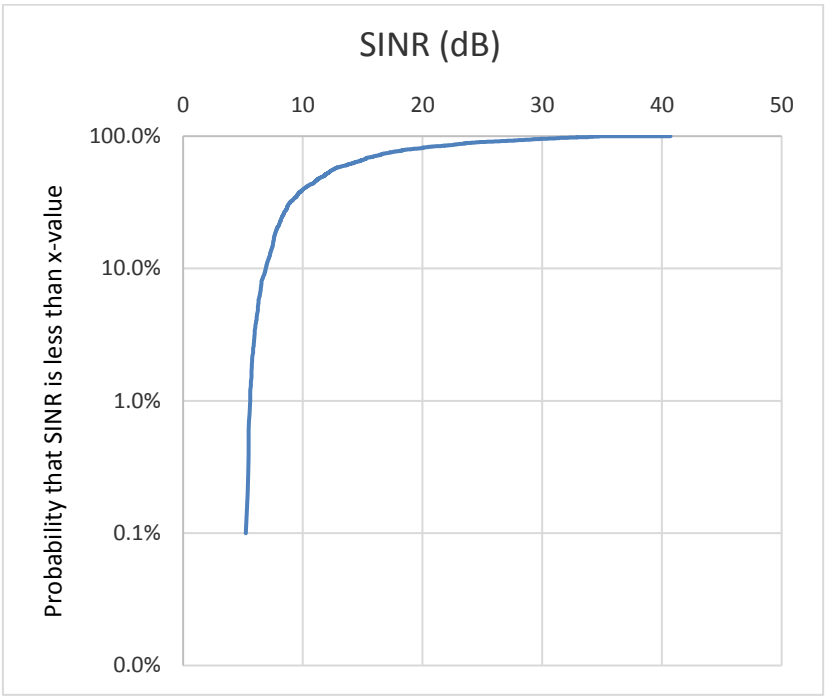


FIGURE 2G-5

CDF of downlink SINR for suburban network model for 10 MHz channel bandwidth

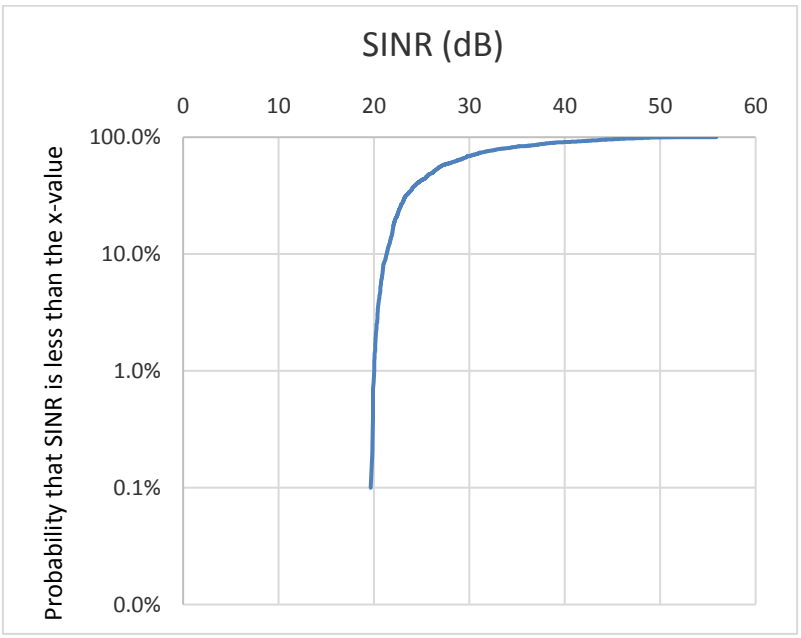


FIGURE 2G-6

CDF of uplink throughput for suburban network model for 10 MHz channel bandwidth

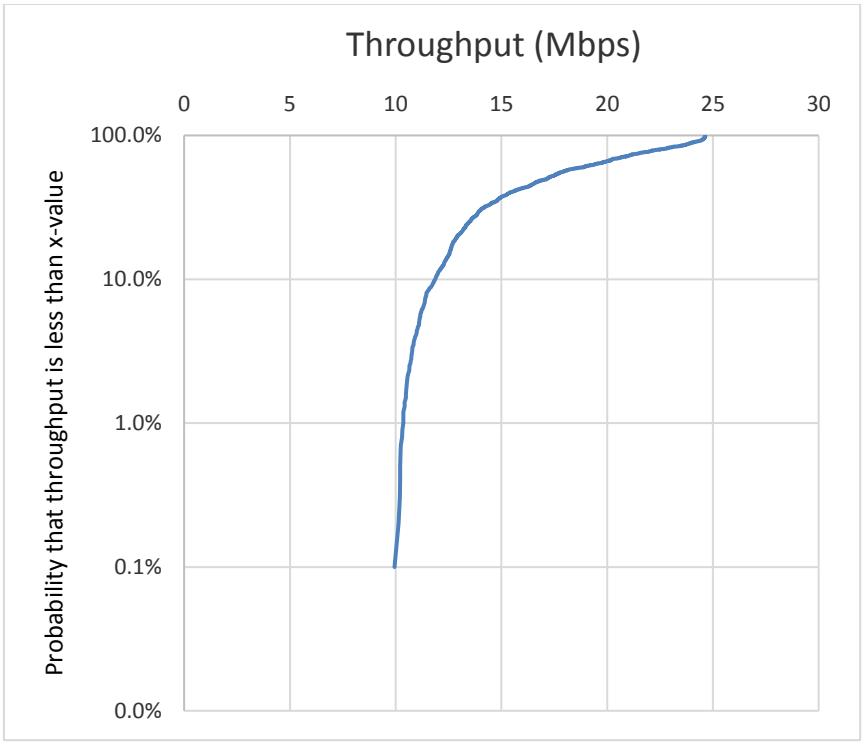
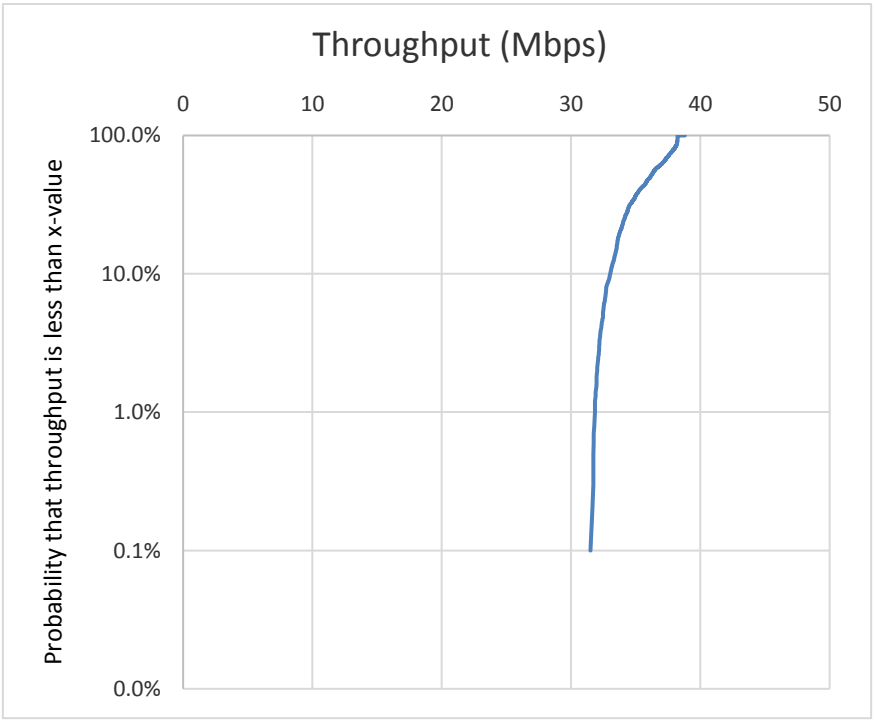


FIGURE 2G-7

CDF of downlink throughput for suburban network model for 10 MHz channel bandwidth



Annex 2H

Spectrum needs for BB PPDR in Tunisia

2H.1 Summary of the spectrum need estimation – Results

After the clearance of the terrestrial broadcasting service from the 700 MHz band in December 2016 in Tunisia following the transition to DTT in lower UHF TV channels (<694 MHz), spectrum requirements for Broadband PPDR have been studied. It was concluded that to support the data rate and applications for smart public safety applications, a block of 20 MHz (10+10 MHz paired) is required. This will be needed for the development of safer and smart communities and for introducing mission critical data and multimedia applications in daily operations of the security agencies and in emergency situations.

The block of spectrum, 723-733 MHz for mobile uplinks paired with 778-788 MHz for base station transmit (downlink), has been identified for the development of a Public Safety broadband network for PPDR.