Report ITU-R M.2415-1

(09/2023)

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

Spectrum aspects of Public Protection and Disaster Relief (PPDR)

Foreword

The role of the Radiocommunication Sector is to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including satellite services, and carry out studies without limit of frequency range on the basis of which Recommendations are adopted.

The regulatory and policy functions of the Radiocommunication Sector are performed by World and Regional Radiocommunication Conferences and Radiocommunication Assemblies supported by Study Groups.

# Policy on Intellectual Property Right (IPR)

ITU-R policy on IPR is described in the Common Patent Policy for ITU-T/ITU-R/ISO/IEC referenced in Resolution ITU‑R 1. Forms to be used for the submission of patent statements and licensing declarations by patent holders are available from <http://www.itu.int/ITU-R/go/patents/en> where the Guidelines for Implementation of the Common Patent Policy for ITU‑T/ITU‑R/ISO/IEC and the ITU-R patent information database can also be found.

|  |  |
| --- | --- |
| Series of ITU-R Reports  (Also available online at <https://www.itu.int/publ/R-REP/en>) | |
| **Series** | Title |
| **BO** | Satellite delivery |
| **BR** | Recording for production, archival and play-out; film for television |
| **BS** | Broadcasting service (sound) |
| **BT** | Broadcasting service (television) |
| **F** | Fixed service |
| **M** | **Mobile, radiodetermination, amateur and related satellite services** |
| **P** | Radiowave propagation |
| **RA** | Radio astronomy |
| **RS** | Remote sensing systems |
| **S** | Fixed-satellite service |
| **SA** | Space applications and meteorology |
| **SF** | Frequency sharing and coordination between fixed-satellite and fixed service systems |
| **SM** | Spectrum management |
| **TF** | Time signals and frequency standards emissions |

|  |
| --- |
|  |

|  |
| --- |
| ***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, 2023

© ITU 2023

All rights reserved. No part of this publication may be reproduced, by any means whatsoever, without written permission of ITU.

REPORT ITU-R M.2415-1

Spectrum aspects of Public Protection and Disaster Relief (PPDR)

(2017-2023)

TABLE OF CONTENTS

*Page*

[1 Introduction 4](#_Toc149740831)

[2 Scope 4](#_Toc149740832)

[3 Spectrum considerations for PPDR 4](#_Toc149740833)

[4 Estimation of spectrum for PPDR 5](#_Toc149740834)

[5 Harmonization of spectrum 6](#_Toc149740835)

[Annex 1 Spectrum for narrow-band and wide-band PPDR 7](#_Toc149740836)

[1 Methods of projecting spectrum aspects 8](#_Toc149740837)

[2 Validity of the methodology 8](#_Toc149740838)

[3 Critical parameters 9](#_Toc149740839)

[4 Extrapolated upper limit 10](#_Toc149740840)

[5 Results 10](#_Toc149740841)

[6 Discussion of results 10](#_Toc149740842)

[Attachment 1 to Annex 1 – Methodology for the estimation of public protection and disaster relief terrestrial spectrum aspects 11](#_Toc149740843)

[1 Introduction 11](#_Toc149740844)

[2 Advanced services 11](#_Toc149740845)

[3 A – Spectrum prediction model 11](#_Toc149740846)

[4 B – Geographical area 12](#_Toc149740847)

[5 C – Operational environments versus service environments 12](#_Toc149740848)

[6 D – PPDR user population 13](#_Toc149740849)

[7 E – Penetration rates 14](#_Toc149740850)

[8 F – Traffic parameters 14](#_Toc149740851)

[9 G – PPDR quality of service functions 15](#_Toc149740852)

[10 H – Calculate total traffic 16](#_Toc149740853)

[11 I – Net system capacity 17](#_Toc149740854)

[12 J – Spectrum estimation 17](#_Toc149740855)

[Attachment 1.1 to Annex 1 – Comparison of proposed methodology for the estimation of PPDR spectrum to IMT-2000 methodology 19](#_Toc149740856)

[Attachment 1.2 to Annex 1 – PPDR spectrum aspects flowchart 26](#_Toc149740857)

[Attachment 1.3 to Annex 1 – System capacity calculation examples 30](#_Toc149740858)

[Attachment 1.4 to Annex 1 – Example: Public safety and disaster relief population density data 34](#_Toc149740859)

[Attachment 1.5 to Annex 1 – Example spectrum estimation 36](#_Toc149740860)

[Attachment 1.6 to Annex 1 – Example narrowband and wideband spectrum estimation summaries 43](#_Toc149740861)

[Attachment 2 to Annex 1 – PPDR spectrum estimation based on generic city analysis (demographic population) 44](#_Toc149740862)

[1 Generic city approach 44](#_Toc149740863)

[2 PPDR categories 45](#_Toc149740864)

[3 Spectrum aspects 47](#_Toc149740865)

[Annex 2 – Annexes on Broadband PPDR Spectrum Aspects and Scenarios 63](#_Toc149740866)

[2A.1 Methodology for PP1 64](#_Toc149740867)

[2A.2 Methodology for PP2 64](#_Toc149740868)

[2A.3 Spectrum aspects for broadband PPDR Based on LTE in France 64](#_Toc149740869)

[Annex 2B – Spectrum for BB PPDR Based on LTE in the United Arab Emirates 65](#_Toc149740870)

[2B.1 Background 65](#_Toc149740871)

[2B.2 Methodology 66](#_Toc149740872)

[2B.3 Summary of the spectrum estimation – Results 69](#_Toc149740873)

[Annex 2C – Throughput needs of broadband PPDR scenarios 70](#_Toc149740874)

[Attachment 1 to Annex 2C 71](#_Toc149740875)

[Annex 2D – Representative scenario- deploying LTE for PPDR 73](#_Toc149740876)

[2D.1 Background 73](#_Toc149740877)

[2D.2 Incident scenario 73](#_Toc149740878)

[2D.3 Event description 74](#_Toc149740879)

[2D.4 Analysis 77](#_Toc149740880)

[2D.5 Results 78](#_Toc149740881)

[2D.6 Conclusions of the representative scenario 79](#_Toc149740882)

[Attachment 1 to Annex 2D – Example for wireless applications needed for broadband PPDR system 79](#_Toc149740883)

[Annex 2E – Spectrum estimations and scenario of LTE based technology for broadband PPDR in China 80](#_Toc149740884)

[2E.1 Introduction 80](#_Toc149740885)

[2E.2 Methodology to estimate broadband spectrum 81](#_Toc149740886)

[2E.3 Estimation of spectrum for Wuhan city in China 84](#_Toc149740887)

[2E.4 Scenario of LTE based technology for PPDR broadband 98](#_Toc149740888)

[2E.5 Conclusion 99](#_Toc149740889)

[Annex 2F – Broadband PPDR spectrum in Korea 100](#_Toc149740890)

[2F.1 Introduction 100](#_Toc149740891)

[2F.2 Spectrum estimation methodology 100](#_Toc149740892)

[2F.3 Traffic parameters 102](#_Toc149740893)

2F.3.1 Individual PPDR agency operation 102

[2F.3.2 Multiple PPDR Agencies Operation 106](#_Toc149740894)

[2F.3.3 PPDR operation with other public broadband services 107](#_Toc149740895)

[2F.4 Spectrum aspects 107](#_Toc149740896)

[2F.5 Conclusion 109](#_Toc149740897)

[Annex 2G – Estimation of spectrum for wireless PPDR systems using Monte Carlo simulation 109](#_Toc149740898)

[2G.1 Overview of approach and method used 109](#_Toc149740899)

[2G.2 Background to the study 110](#_Toc149740900)

[2G.3 Initial PPDR spectrum estimates 110](#_Toc149740901)

[2G.4 Wireless Broadband network simulation 112](#_Toc149740902)

[2G.5 Resulting effective throughput-per-user 113](#_Toc149740903)

[2G.6 Conclusions 114](#_Toc149740904)

[Attachment 1 to Annex 2G – Model layout and parameters 115](#_Toc149740905)

[Attachment 2 to Annex 2G – Example results 118](#_Toc149740906)

[Annex 2H Spectrum for BB PPDR in Tunisia 120](#_Toc149740907)

[2H.1 Summary of the spectrum estimation – Results 120](#_Toc149740908)

# 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 aspects for PPDR. Report [ITU-R M.2377](https://www.itu.int/pub/R-REP-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]](#footnote-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 aspects 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 aspects for narrowband, wideband and broadband PPDR systems.

References, terminology, abbreviations and descriptions of PPDR operations can be found in Annexes 1, 2 and 3 to Report [ITU-R M.2377](https://www.itu.int/pub/R-REP-M.2377). PPDR applications and related examples, and PPDR requirements can be found in Annexes 4 and 5 to Report [ITU-R M.2377](https://www.itu.int/pub/R-REP-M.2377).

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

# 3 Spectrum considerations for PPDR

Resolution **646 (Rev.WRC-19)** 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](https://www.itu.int/rec/R-REC-M.2015/en) 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.

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 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 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 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](https://www.itu.int/rec/R-REC-M.1390/en) 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](https://www.itu.int/rec/R-REC-M.1768/en) 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](https://www.itu.int/rec/R-REC-M.1651/en) ‒ 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](https://www.itu.int/rec/R-REC-M.1651/en) 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](https://www.itu.int/pub/R-REP-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](https://www.itu.int/rec/R-REC-SM.1271/en) ‒ 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](https://www.itu.int/rec/R-REC-M.1390/en), 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](https://www.itu.int/rec/R-REC-M.1390/en) was the only tool available for calculating IMT spectrum 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](https://www.itu.int/rec/R-REC-M.1390/en) 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 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 for narrow-band and wide-band PPDR

This Annex addresses the estimation of the spectrum 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 by 2010[[2]](#footnote-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 aspects.

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

# 1 Methods of projecting spectrum aspects

Description of the methodology

This public protection and disaster relief spectrum 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](https://www.itu.int/rec/R-REC-M.1390/en)). 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]](#footnote-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 for PPDR?

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

In response, the following points should be noted:

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

2 Terms of the estimations of spectrum for 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.

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 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 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 used, 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 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 aspects 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 to be used 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 to be used 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 aspects 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 aspects.

Attachment 1   
to Annex 1  
  
Methodology for the estimation of public protection and disaster  
relief terrestrial spectrum aspects

# 1 Introduction

The function of this Attachment is to present an initial forecast for spectrum to be used 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, 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 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](https://www.itu.int/rec/R-REC-M.1390/en)).

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](https://www.itu.int/rec/R-REC-M.1390/en) 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 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/km2), 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/km2).

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 (km2) 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.

There is a 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]](#footnote-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.

Example of traffic profiles from PSWAC Report[[5]](#footnote-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 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 to 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]](#footnote-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. 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 aspects. 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 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 for each service in each “service” environment.

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

Sum up total spectrum.

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](https://www.itu.int/rec/R-REC-M.1390/en)) 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 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 to IMT-2000 methodology

|  |  |  |
| --- | --- | --- |
| IMT-2000 methodology  (Rec. [ITU-R M.1390](https://www.itu.int/rec/R-REC-M.1390/en)) | 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  i *R*2  Hexagonal cells  2.6 · *R*2  3-sector hex  2.6/3 · *R*2 | **A4** Same |

|  |  |  |
| --- | --- | --- |
| IMT-2000 methodology  (Rec. [ITU-R M.1390](https://www.itu.int/rec/R-REC-M.1390/en)) | IMT-2000 methodology | Proposed PPDR methodology |
| **B** Market and 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 km2  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 km2  PPDR user population density  PPDR user population/area  Example: London  33.8 PPDR/km2 |

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

|  |  |  |
| --- | --- | --- |
| IMT-2000 methodology (Rec. [ITU-R M.1390](https://www.itu.int/rec/R-REC-M.1390/en)) | 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]](#footnote-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 |
| IMT-2000 methodology (Rec. [ITU-R M.1390](https://www.itu.int/rec/R-REC-M.1390/en)) | 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  Traffic per group | Typical cellular reuse  7   Traffic/cell (E)  Group Size | 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.  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](https://www.itu.int/rec/R-REC-M.1390/en)) | 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](https://www.itu.int/rec/R-REC-M.1390/en)) | 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  Freqes  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  Freqes) | **D6** Same |

Attachment 1.2   
to Annex 1  
  
PPDR spectrum aspects flowchart











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]](#footnote-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](https://www.itu.int/rec/R-REC-M.1390/en), D5 and D6).

|  |  |  |  |
| --- | --- | --- | --- |
| Net system capability summary | | | |
| Spectrum band | Technology | Channels | Total capacity available |
| Reuse group factor = 12 | | | |
| European 400 MHz public safety band | TETRA TDMA | 4 slots/25 kHz | 98.0 kbit/s/MHz/cell |
| Reuse group factor = 21 | | | |
| European 400 MHz public safety band | TETRA TDMA | 4 slots/25 kHz | 56.0 kbit/s/MHz/cell |
| FDMA: Frequency division multiple access.  NOTE – 1 Reuse group factor of 12 is used for systems implementing only low power, handheld, portable devices. Reuse factor of 21 is used for systems implementing both handheld portables and higher power, vehicular mounted, mobile devices. Greater reuse factor is required because of potential for interference from distant mobiles into cells designed for portable coverage. | | | |



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

TETRA TDMA applied to European 400 MHz public safety band.

C4 and C5 Net system capability calculation

|  |  |  |  |
| --- | --- | --- | --- |
| TETRA TDMA | | | **European 400 MHz public safety band** |
| Width of band (MHz) | 3 | 6.0 | MHz total |
| Width of channel | 0.025 |  |  |
|  |  | 120.0 | FDD channels within band |
| Reuse group factor | 12 |  | (Hand-held portables only) |
|  |  | 10.0 | Channels per cell |
| Guard channels | 2 |  | (At band edge) |
| Interoperability channels | 20 |  | (Reserve for direct mode operations) |
|  |  | **98.0** | **Traffic channels** |
|  |  |  |  |
| Traffic/channel | 4 |  | Slots/channel |
| Data/channel | 7.2 |  | kbit/s/slot |
| Overhead and signalling | 1.25 |  | (36 kbit/s per channel total) |
|  |  | **294.0** | **kbit/s/cell** |
|  |  | 3.0 | MHz bandwidth on outbound or inbound channel |
|  |  |  |  |
|  |  | **Total capacity available** | |
|  |  | **98.0** | **kbit/s/cell/MHz on outbound or inbound channel** |
| Speech improvement | 1.05 | 102.9 | kbit/s/cell/MHz on outbound or inbound channel with speech improvement |
| All improvements | 1.1 | 107.8 | kbit/s/cell/MHz on outbound or inbound channel with all improvements |
|  | | | |
| TETRA TDMA | | | **European 400 MHz public safety band** |
| Width of band (MHz) | 3 | 6.0 | MHz total |
| Width of channel | 0.025 |  |  |
|  |  | 120.0 | FDD channels within band |
| Reuse group factor | 21 |  | (Mixture of portables and mobiles) |
|  |  | 5.7 | Channels per cell |
| Guard channels | 2 |  | (At band edge) |
| Interoperability channels | 20 |  | (Reserve for direct mode operations) |
|  |  | **98.0** | **Traffic channels** |
|  |  |  |  |
| Traffic/channel | 4 |  | Slots/channel |
| Data/channel | 7.2 |  | kbit/s/slot |
| Overhead and signalling | 1.25 |  | (36 kbit/s per channel total) |
|  |  | **168.0** | **kbit/s/cell** |
|  |  | 3.0 | MHz bandwidth on outbound or inbound channel |
|  |  |  |  |
|  |  | **Total capacity available** | |
|  |  | **56.0** | **kbit/s/cell/MHz on outbound or inbound channel** |
| Speech improvement | 1.05 | 58.8 | kbit/s/cell/MHz on outbound or inbound channel with speech improvement |
| All improvements | 1.1 | 61.6 | kbit/s/cell/MHz on outbound or inbound channel with all improvements |

Attachment 1.4   
to Annex 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 km2 England  ~ 130 360 km2

Wales  ~ 20 760 km2

England population density  346 pop/km2  100 000 pop/289 km2

London population  7 285 000 people

London area  1 620 km2

London population density  4 496 pop/ km2  100 000 pop/ 22.24 km2

Police officer strength[[9]](#footnote-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]](#footnote-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

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]](#footnote-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 PPDR PPDR penetration rate

category population 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%

Attachment 1.5   
to Annex 1  
  
Example spectrum 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. 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 = π · *R*2; hexagonal = 2.6 · *R*2; Hex 3‑sector = 2.6 · *R*2/3 km2 |  | 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** |
|  |  | = SUM (POP  PEN) |  | Population (POP) by PPDR category | Penetration (PEN) rate within PPDR category |
|  |  | Police  Other Police  Police Civilian Support  Fire  Part-time Fire  Fire Civilian Support  EMS  EMS Civilian Support  General Government  Other PPDR Users | 25 498  6 010  13 987  7 081  2 127  0  0  0  0  0 | (Narrowband voice)  1.00  0.10  0.10  0.70  0.10  0.10  0.50  0.10  0.10  0.10 |
|  | **32 667,1** | **PPDR user population using NB voice service** |
|  |  | **Area under consideration** | 308.9 square miles | **1 620** | **km2** |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | 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 km2 |  | **33.8** | **Total POP/km2** |
| **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% | = % of total PPDR POP | = 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  Other Police  Police Civilian Support  Fire  Part-time Fire  Fire Civilian Support  EMS  EMS Civilian Support  General Government Other PPDR Users | 25 498.00  601.00  1 398.70  4 956.70  212.70  0.00  0.00  0.00  0.00  0.00 | 0.466  0.011  0.026  0.091  0.004  0.000  0.000  0.000  0.000  0.000 |
| **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]](#footnote-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** |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | 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, *Eb*/*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 |  | **PPDR NB voice TOTAL (MHz)** | **17.078 MHz** | |

Attachment 1.6  
to Annex 1  
  
Example narrowband and wideband spectrum 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 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 (km2) | 1 620 |  |  |  |  |
| Cell area (km2) | 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]](#footnote-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 |  |  |  |  |

Attachment 2   
to Annex 1  
  
PPDR spectrum 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 aspects based on the size of demographic population, that is, the amount of PPDR spectrum 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.

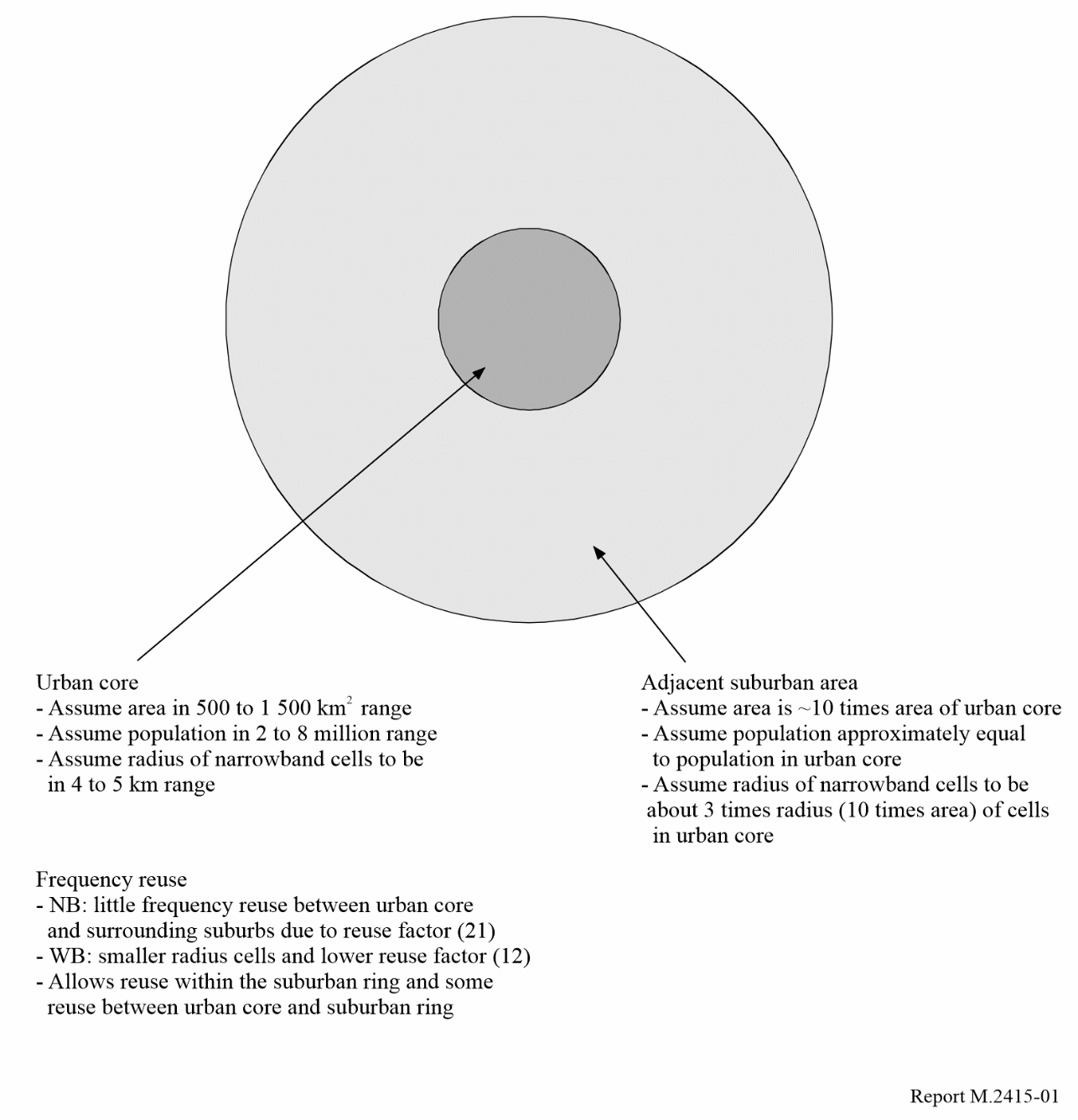
The “doughnut” effect was also examined, where frequencies used in the urban centre cannot be reused in the suburbs immediately adjacent to the urban area. In ITU-R contributions from the 2000‑2003 study period, many of the cities included both the urban and suburban areas together in a single spectrum 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 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)



# 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

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Narrowband and wideband CATEGORY name and number of USERs | | 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 aspects

Estimate spectrum for:

– Urban day-to-day

– Urban disaster

– Suburban day-to-day

– Suburban disaster

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

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

c) Suburban disaster operations:

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

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

Medium metropolitan area

Estimated spectrum using a PPDR estimation spreadsheet.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Medium metropolitan area** (Urban population ≅ 2.5 million and area ≅ 600 km2) (Suburban population ≅ 2.5 million and area ≅ 6 000 km2) | | | | | | |
| **Medium PPDR density** (180 Police per 100 000 population) | | |  | **High PPDR density** (250 police per 100 000 population) | | |
| **Urban** |  |  |  | **Urban** |  |  |
| NB day-to-day WB day-to-day | 15.5 16.2 | MHz MHz |  | NB day-to-day WB day-to-day | 21.5 22.6 | MHz MHz |
|  |  |  |  |  |  |  |
| Disaster NB Disaster WB | 18.4 17.8 | MHz MHz |  | Disaster NB Disaster WB | 25.6 24.7 | MHz MHz |
| **Suburban** |  |  |  | **Suburban** |  |  |
| NB day-to-day WB day-to-day | 12.9 13.5 | MHz MHz |  | NB day-to-day WB day-to-day | 17.9 18.8 | MHz MHz |
|  |  |  |  |  |  |  |
| Disaster NB Disaster WB | 15.4 14.8 | MHz MHz |  | Disaster NB Disaster WB | 21.4 20.6 | MHz MHz |
| **Normal day-to-day** |  |  |  | **Normal day-to-day** |  |  |
| NB (urban  suburban) WB (urban  1/2 suburban) | 28.40 22.95 | MHz MHz |  | NB WB | 39.40 32.00 | MHz MHz |
|  | 51.35 | MHz |  |  | 71.40 | MHz |
| **Suburban disaster** |  |  |  | **Suburban disaster** |  |  |
| NB WB | 30.90 23.60 | MHz MHz |  | NB WB | 42.90 32.90 | MHz MHz |
|  | 54.50 | MHz |  |  | 75.80 | MHz |
| **Urban disaster** |  |  |  | **Urban disaster** |  |  |
| NB WB | 31.30 24.55 | MHz MHz |  | NB WB | 43.50 34.10 | MHz MHz |
|  | 55.85 | MHz |  |  | 77.60 | MHz |

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

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

The total spectrum 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 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 used increases by about 6%. If a disaster occurs in the urban area, then NB/WB spectrum used 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 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 to be in the 50‑75 MHz range.

Therefore, for a generic medium size city, the total spectrum 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– 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 | | | km2 | | | **10.0** | | Ratio Suburban/Urban Area | | | | | | | |
| Area of Surrounding Suburbs | | 6 000 | | | km2 | | | Ratio should be near 10.0 (Range of 5  to 15  of Urban Area) | | | | | | | |
|  | | | | | | | | | | | | | | | | | |
| Urban Population Density | | 4 167 | | | People/km2 | |  | | | | | | | | | | |
| Suburban Population Density | | 417 | | | People/km2 | |
|  | |  |  | | | | | |  | | | | | | | | |
| “Large” or “Medium” City | | MED | | | If Urban Population Density > 5 000 people/km2, then this is a large city, OR if Urban population > 3 000 000 people, then this is a large city, otherwise this is a medium city | | | | | | | | | | | | |
|  | |  | | |
| Police User Density (national average) | | 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 (MHz) | | Busy Hour Users | | | Spectrum (MHz) | | Busy Hour Users | | Spectrum (MHz) | | Busy Hour Users | Spectrum (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 (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 (MHz) | Busy Hour Users | Spectrum (MHz) | Busy Hour Users | Spectrum (MHz) | Busy Hour Users | Spectrum (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 (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 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– 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 | | | | km2 | | **10.0** | | Ratio Suburban/Urban Area | | | | | | | | |
| Area of Surrounding Suburbs | | | 6 000 | | | | km2 | | Ratio should be near 10.0 (Range of 5  to 15  of Urban Area) | | | | | | | | |
|  | | | | | | | | | | | | | | | | | | | |
| Urban Population Density | | | 4 167 | | | | People/km2 | | |  | | | | | | | | | |
| Suburban Population Density | | | 417 | | | | People/km2 | | |
|  | |  | | | |  | | | |  | | | | | | | | | |
| “Large” or “Medium” City | | | MED | | | | If Urban Population Density > 5 000 people/km2, then this is a large city, OR if Urban population > 3 000 000 people, then this is a large city, otherwise this is a medium city | | | | | | | | | | | | |
|  | |  | | | | |
| Police User Density (national average) | | 250.0 | | | | | Police per 100 000 population | | | | | | | | | | | | |
|  | |  | | | |  | | | |  | | | | | | | | | |
| Category name and number of users User category | Urban Day-to-Day | | | | | | | Urban Disaster | | | | | Suburban Day-to-Day | | | | Suburban Disaster | | |
| Population | | | | | | | Population | | | | | Population | | | | Population | | |
| Primary – Local Police | 9 375 | | | | | | | 9 375 | | | | | 7 813 | | | | 7 813 | | |
| Secondary – Law Enforcement/Investigators | 938 | | | | | | | 1 875 | | | | | 781 | | | | 1 563 | | |
| Secondary – Police Functions | 0 | | | | | | | 2 813 | | | | | 0 | | | | 2 344 | | |
| Police Civilian Support | 1 875 | | | | | | | 1 875 | | | | | 1 563 | | | | 1 563 | | |
| Primary – Fire Fighters | 2 719 | | | | | | | 3 534 | | | | | 2 266 | | | | 2 945 | | |
| Fire Civilian Support | 544 | | | | | | | 544 | | | | | 453 | | | | 453 | | |
| Primary – Rescue/ Emergency Medical | 816 | | | | | | | 1 060 | | | | | 680 | | | | 884 | | |
| Rescue/EMS Civilian Support | 163 | | | | | | | 163 | | | | | 136 | | | | 136 | | |
| Secondary – General 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 (MHz) | | | Busy Hour Users | | | Spectrum (MHz) | | Busy Hour Users | | Spectrum (MHz) | | Busy Hour Users | | Spectrum  (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 (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 (MHz) | Busy Hour Users | Spectrum (MHz) | Busy Hour Users | Spectrum (MHz) | Busy Hour Users | Spectrum (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 (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 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 using a PPDR estimation spreadsheet.

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

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

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

The total spectrum 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 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 used increases by about 6%. If disaster occurs in the urban area, then the NB/WB spectrum used 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 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 to be in the 50‑75 MHz range.

Therefore, for a generic large city, the total spectrum 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– 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 | | | | km2 | | **10.0** | | Ratio Suburban/Urban Area | | | | | | | | | |
| Area of Surrounding Suburbs | | | 8 000 | | | | km2 | | Ratio should be near 10.0 (Range of 5  to 15  of Urban Area) | | | | | | | | | |
|  | | | | | | | | | | | | | | | | | | | | |
| Urban Population Density | | | 10 000 | | | | People/km2 | | |  | | | | | | | | | | |
| Suburban Population Density | | | 1 000 | | | | People/km2 | | |
|  | |  | | | |  | | | |  | | | | | | | | | | |
| “Large” or “Medium” City | | | LAR | | | | If Urban Population Density > 5 000 people/km2, then this is a large city, OR if Urban population > 3 000 000 people, then this is a large city, otherwise this is a medium city | | | | | | | | | | | | | |
|  | |  | | | | |
| Police User Density (national average) | | 180.0 | | | | | Police per 100 000 population | | | | | | | | | | | | | |
|  | |  | | | |  | | | |  | | | | | | | | | | |
| CATEGORY name and number of USERS User Category | Urban Day-to-Day | | | | | | | Urban Disaster | | | | | | Suburban Day-to-Day | | | | Suburban Disaster | | |
| Population | | | | | | | Population | | | | | | Population | | | | Population | | |
| Primary – Local Police | 21 600 | | | | | | | 21 600 | | | | | | 18 000 | | | | 18 000 | | |
| Secondary – Law Enforcement/Investigators | 2 160 | | | | | | | 4 320 | | | | | | 1 800 | | | | 3 600 | | |
| Secondary – Police Functions | 0 | | | | | | | 6 480 | | | | | | 0 | | | | 5 400 | | |
| Police Civilian Support | 4 320 | | | | | | | 4 320 | | | | | | 3 600 | | | | 3 600 | | |
| Primary – Fire Fighters | 6 264 | | | | | | | 8 143 | | | | | | 5 220 | | | | 6 786 | | |
| Fire Civilian Support | 1 253 | | | | | | | 1 253 | | | | | | 1 044 | | | | 1 044 | | |
| Primary – Rescue/ Emergency Medical | 1 879 | | | | | | | 2 443 | | | | | | 1 566 | | | | 2 036 | | |
| Rescue/EMS Civilian Support | 376 | | | | | | | 376 | | | | | | 313 | | | | 313 | | |
| Secondary – General 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 (MHz) | | | Busy Hour Users | | | | Spectrum (MHz) | | Busy Hour Users | | Spectrum (MHz) | | Busy Hour Users | | Spectrum (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 (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 (MHz) | Busy Hour Users | Spectrum (MHz) | Busy Hour Users | Spectrum (MHz) | Busy Hour Users | Spectrum (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 (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 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– 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 | | | | km2 | | **10.0** | | Ratio Suburban/Urban Area | | | | | | | | |
| Area of Surrounding Suburbs | | | 8 000 | | | | km2 | | Ratio should be near 10.0 (Range of 5  to 15  of Urban Area) | | | | | | | | |
|  | | | | | | | | | | | | | | | | | | | |
| Urban Population Density | | | 10 000 | | | | People/km2 | | |  | | | | | | | | | |
| Suburban Population Density | | | 1 000 | | | | People/km2 | | |
|  | |  | | | |  | | | |  | | | | | | | | | |
| “Large” or “Medium” City | | | LAR | | | | If Urban Population Density > 5 000 people/km2, then this is a large city, OR if Urban population > 3 000 000 people, then this is a large city, otherwise this is a medium city | | | | | | | | | | | | |
|  | |  | | | | |
| Police User Density (national average) | | 250.0 | | | | | police per 100 000 population | | | | | | | | | | | | |
|  | |  | | | |  | | | |  | | | | | | | | | |
| CATEGORY name and number of USERS User Category | Urban Day-to-Day | | | | | | | 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 (MHz) | | | Busy Hour Users | | | Spectrum (MHz) | | Busy Hour Users | | Spectrum (MHz) | | Busy Hour Users | | Spectrum (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 (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 (MHz) | Busy Hour Users | Spectrum (MHz) | Busy Hour Users | Spectrum (MHz) | Busy Hour Users | Spectrum (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 (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 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 range180 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 km2

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 km2

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 km2

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 km2

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 km2

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 km2

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 km2

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 km2

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 Aspects 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 within CEPT[[14]](#footnote-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 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.

## 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 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 based on assumptions on location of users within the cell and spectral efficiency.

## 2A.3 Spectrum aspects for broadband PPDR Based on LTE in France

Introduction

In France, as the full 2 × 30 MHz (703-733 MHz paired with 758-788 MHz) have been granted for commercial MFCN networks, the following sub-bands are dedicated for BB-PPDR for voice services as well as data communications, in accordance to ECC Decision 16(02):

– 2 × 3 MHz: 733-736 MHz (UL) paired with 788-791 MHz (DL).

– 2 × 5 MHz: 698-703 MHz (UL) paired with 753-758 MHz (DL).

The use of 2 × 3 MHz for voice traffic

With the block of 2 × 3 MHz (733-736 MHz (UL) paired with 788-791 MHz (DL), it was observed that the number of users under coverage was 120 within an area of 1 km2, where UE BB-PPDR were located at a reasonable distance and in direct line of sight of the base station.

In the event of propagation and/or interference issues impacting the radio link quality, the low signal-to-noise-and-interference ratio (SINR) could reduce the spectral efficiency of the BB-PPDR network and limit the number of users down to 80.

With the additional spectrum of 2 × 5 MHz, these values could be at most double (~150 up to 200 terminals).

Therefore, the dedicated spectrum of 2 × 3 MHz and 2 × 5 MHz could allow a communication capacity for 230 up to 320 terminals.

Spectrum for broadband PPDR in France

ECC Report 199 concluded that a minimum of 2 × 10 MHz spectrum was required for broadband PPDR data services and around 2 × 3.2 MHz for voice traffic.

In France, critical situations (such as terrorist attacks) in a heavily populated area has involved the intervention of at least 500 people including security forces, firefighters, paramedics, etc.

Consequently, in order to simultaneously enable voice services and data communications between 400 and 600 users, a block contiguous of 2 × 15 MHz would be needed considering the high density of population per km² in urban areas.

Annex 2B  
  
Spectrum 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 aspects for broadband services and applications.

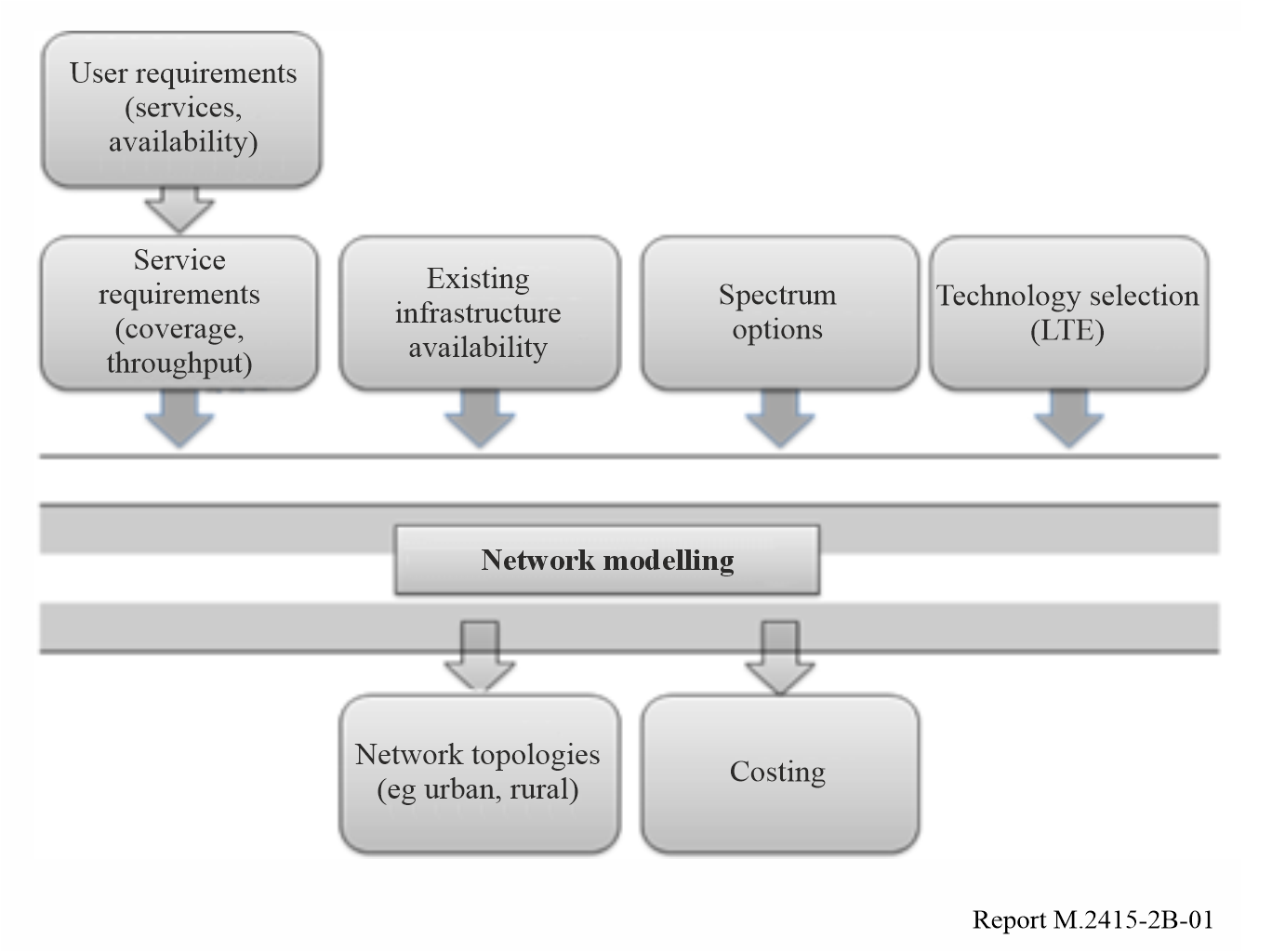
The UAE TRA has met with PPDR industry on several occasions to better understand industry trends and to ensure that what is being proposed for the UAE and the region is consistent with our national interest.

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

## 2B.2 Methodology

The study is addressing the methodology used to assess and estimate minimum spectrum 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.

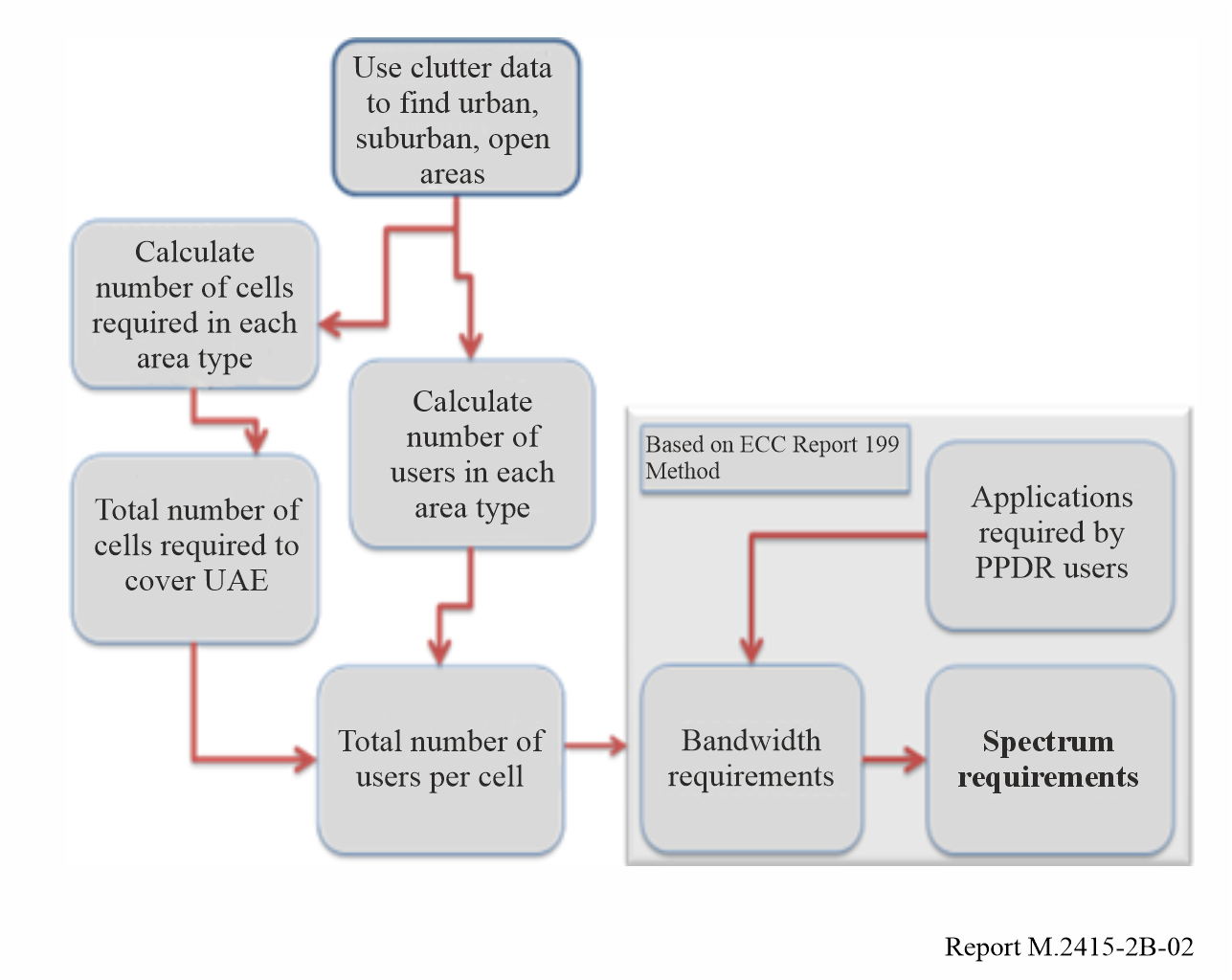
Figure 2b-1



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 results for UAE

TABLE 2B-1

Clutter data and minimum number of sites needed against  
frequency band calculation sheet

A table with numbers and a number of objects

Description automatically generated with medium confidence

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 |
| Height (m) | 40 |
| Frequency (MHz) | 420/750/2 000 |
| Output power e.i.r.p. (dBm) | 43 |
| Antenna gain (dBi) | 4.3 |
| Duplexer loss (dB) | 1 |
| Cable loss (dB) | 2 |
| Sensitivity (dBm) | –123.7 |

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 km2 | Total users |
| Open | 0.9 | 74 360 |
| Suburban | 15 | 11 952 |
| Urban | 90 | 11 880 |
| Total |  | 98 192 |

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:

TABLE 2B-5

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 for different scenarios of BB-PPDR use.

## 2B.3 Summary of the spectrum 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

A screenshot of a graph

Description automatically generated

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 km2 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 km2, 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.



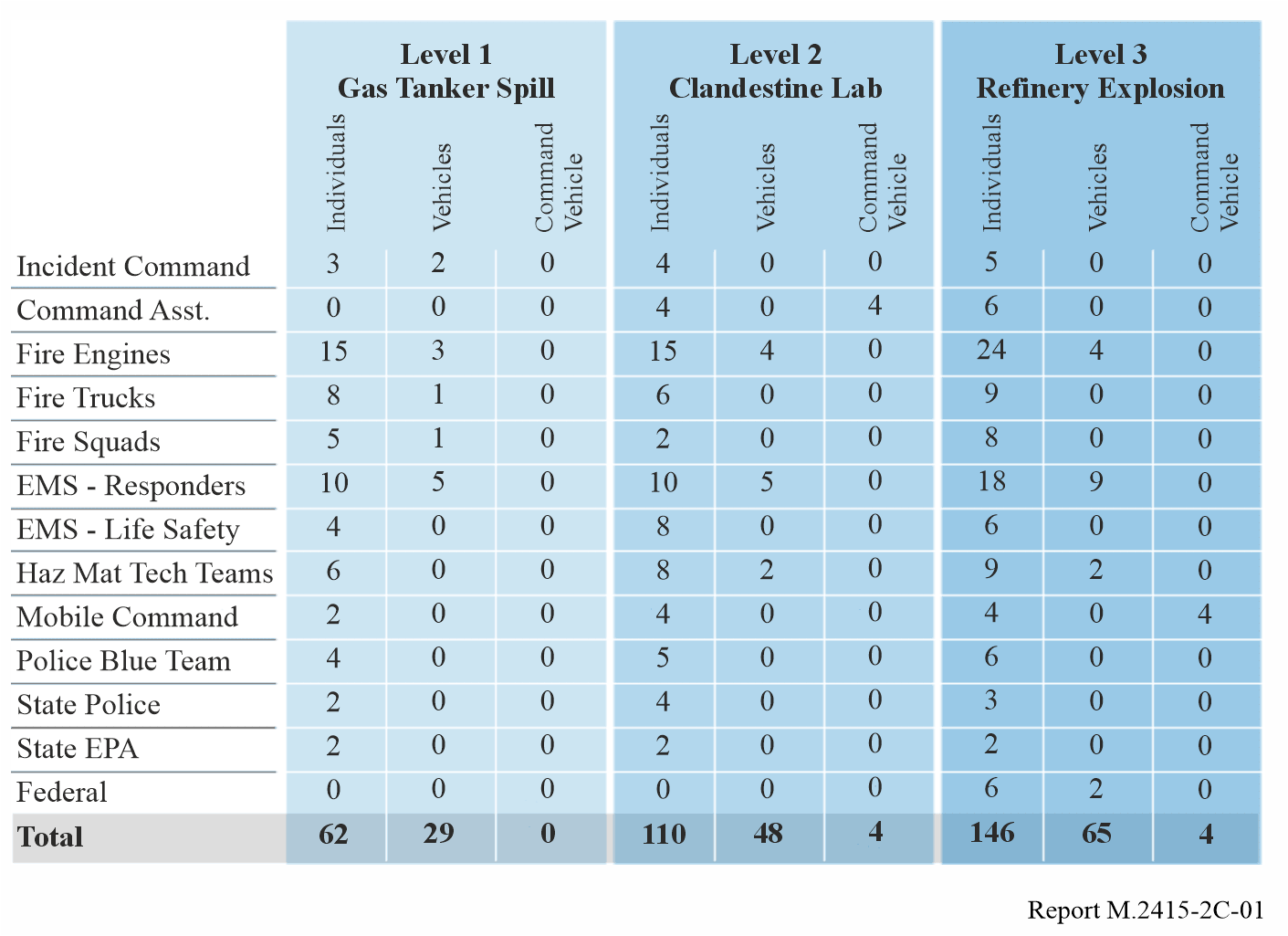
Attachment 1 to this Annex provides some of the PPDR scenarios using this tool to show the throughput and the bandwidth needs of these Broadband PPDR scenarios. These scenarios include level 1 being a Tanker Spill, Level 2, a Clandestine (Drug) Lab, and Level 3, a Petrochemical Refinery incident. Figure 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]](#footnote-15)

Figure 2C-1

Typical response scope for level 1-3 hazardous materials incidents



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.

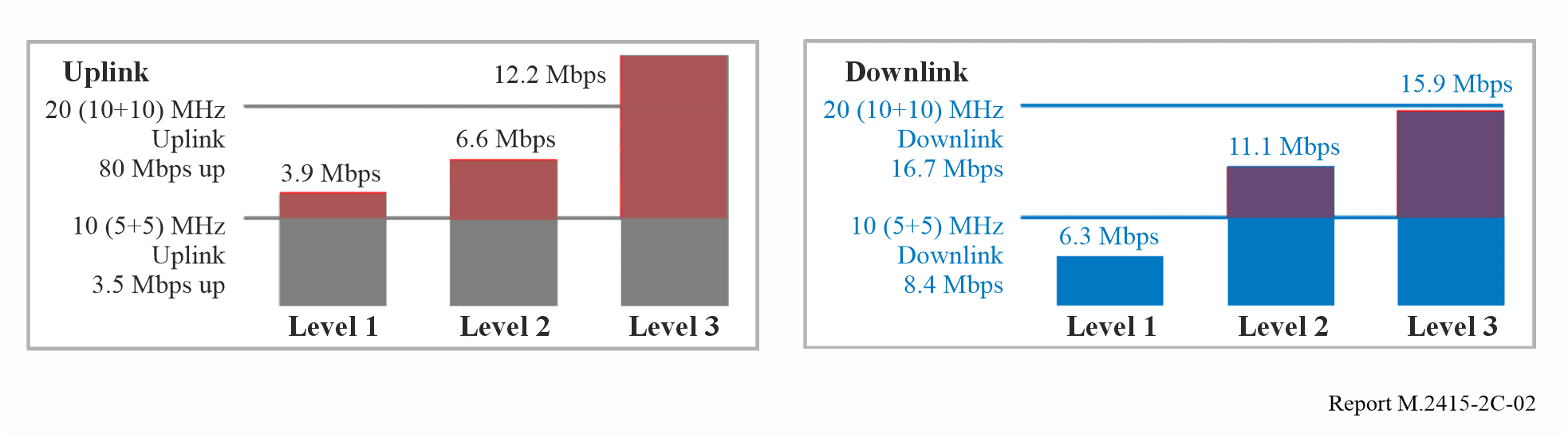
**2 Incident scene database lookups/downloads and information searches**: The classification includes the download of manuals, incident scene images, maps and topography information, building plans, etc. This use case has the unique requirement that, in general, the information is needed quickly as incident 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 at 30fps) and 1.2 Mbit/s (1280×960 at 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 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 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 | | | | | | |
| --- | --- | --- | --- | --- | --- | --- |
| No. of users | Used systems | Required action downlink | Required action uplink | Link type | Time+ | Part number and event description |
|  |  |  |  |  | 0 | 1 Accident occurs |
|  |  |  |  |  | 1 minute | 2 Call received at police Operation Centre |
| 12 | Project 25 | Call to the closest police vehicles and send location information to vehicles' computer |  | Voice | 2 minutes | 3 Operation Centre dispatch sent |
| 12 | Project 25 & LTE | 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 | Request for information from Vehicle’s computer+GIS information | Voice+Data | 3 minutes | 4 Police vehicles on the way to scene |
| 12 | Project 25 & LTE | Getting real time high resolution video from security camera close to the truck and getting GIS information | Sending real time low resolution video from the area | Voice+Data | 7 minutes | 5 Policemen arrive at scene |
| 2 | Project 25 & LTE | Getting real time high resolution video from police helicopter | Sending real time low resolution video from the area | Voice+Data | 12 minutes | 6 Additional police vehicle with 2 chief officers arrives |
| 2 | Project 25 & LTE | Getting real time high resolution video from traffic control camera | Sending real time low resolution video from the area | Voice+Data | 13 minutes | 7 City control vehicle with 2 officers arrives at scene |
| 12 | Project 25 & LTE | Getting real time high resolution video from security camera about the injuries and getting GIS information | Request for GIS information and sending real time high resolution video to command center | Voice+Data | 14 minutes | 8 Four ambulances arrival |
| 3 | Project 25 & LTE | Getting real time medium resolution video from scene and get GIS information | Request for GIS information and sending real time medium resolution video from vehicle camera | Voice+Data | 15 minutes | 9 Fire forces arrival |
| 1 | Project 25 & LTE | Getting real time medium resolution video from scene and getting GIS information | Request for GIS information and sending high resolution pictures | Voice+Data | 16 minutes | 10 Hazardous materials response team arrival |
| 4 | Project 25 & LTE | Video conference , getting real time low resolution video from helicopter and real time high resolution video from scene | Connecting to police database and video conference | Voice+Data | 20 minutes | 11 Front Command and Control deployment |

TABLE 2D-1 (*end*)

| Scenario time line | | | | | | |
| --- | --- | --- | --- | --- | --- | --- |
| No. of users | Used systems | Required action Downlink | Required action Uplink | Link type | Time+ | Part number and event description |
|  | Project 25 & LTE | Total of 36 users who operate 72 applications simultaneously | Total of 36 users who operate 36 applications simultaneously | Voice+Data | 20 minutes | 12 All forces arrived and operational |
|  | Project 25 & LTE |  |  | Voice+ Data | 40 minutes | 13 The ambulances leave the area on the way to hospital |
|  | Project 25 & LTE |  |  | Voice+ Data | 100 minutes | 14 The forces succeeded to isolate the truck and to close the leak |
|  |  |  |  | Voice+ Data | 125 minutes | 15 Chemical material removing to replacement tanks |
|  |  |  |  | Voice+ Data | 200 minutes | 16 Replacements tanks are removed from area |
|  |  |  |  | Voice+ Data | 250 minutes | 17 The area is clean and checked |
|  |  |  |  | Voice+ Data | 360 minutes | 18 End of the event |

Table 2D-2 summarizes the data rate (kbit/s) for each application during the event.

TABLE 2D-2

Application data rate

|  |  |  |  |
| --- | --- | --- | --- |
| UL (kbit/s) | Downlink (kbit/s) | Description | Application |
| N/A (Project 25) | N/A (Project 25) | Voice call | Voice |
| N/A (Project 25) | N/A | Information from the command center | Request for information from vehicle computer |
| 100 | 2 000 | Map of the area of the event | GIS information |
| 2 000 | 2 000 | Real time video | High resolution video |
| 1 000 | 1 000 | Real time video | Medium resolution video |
| 500 | 500 | Real time video | Low resolution video |
| 384 | 384 | Video conference application | Video conference |
| 300 | 300 | Image | High resolution picture |

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](https://www.itu.int/pub/R-REP-M.2441) 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]](#footnote-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.

The LTE UE data (see Report [ITU-R M.2241](https://www.itu.int/pub/R-REP-M.2441) 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 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 (%)

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

TABLE 2D-4

15 MHz reliability results (%)

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

TABLE 2D-5

18 MHz reliability results (%)

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

TABLE 2D-6

18.8 MHz reliability results (%)

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

TABLE 2D-7

20 MHz reliability results (%)

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

## 2D.6 Conclusions of the representative scenario

The reliability results show that the spectrum for this event is 18.8 MHz for the downlink and 15 MHz for the uplink. The heavy loaded application is the high resolution video at the downlink and uplink paths. The limitation path is the Downlink, since more capacity is required; but if additional users would be using additional high resolution video than the uplink path could be the limitation of the spectrum. The growing demand for broadband mobile LTE PPDR 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 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 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 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 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

TABLE 2E-1

Methodology

| IMT-2000 methodology  (Recommendation [ITU-R M.1390](https://www.itu.int/rec/R-REC-M.1390/en)) | 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 i *R*2  Hexagonal cells  2.6 · *R*2  3-sector hex  2.6/3 · *R*2 |
|
|
| **B** Market & traffic |  |
| **B1** Services offered | **B1** Net user bit rate (kbit/s) for each of the four PPDR service environments: narrowband voice, narrowband data, wideband image, broadband video. |
| **B2** Population density  Persons per unit of area within each environment. Population density varies with mobility | **B2** Total PPDR user population within the total area under consideration. Divide PPDR 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** |

TABLE 2E-1 (*cont.*)

| IMT-2000 methodology  (Recommendation [ITU-R M.1390](https://www.itu.int/rec/R-REC-M.1390/en)) | Methodology |
| --- | --- |
|  | Area under consideration. Area within well-defined geographic or political boundaries.  Example: City of Wuhan1550 km2  PPDR user population density  PPDR user population/area  Example: Wuhan 37.5 PPDR/km2 |
| **B3** Penetration rate  Percentage of persons subscribing to a service within an environment. Person may subscribe to more than one service | **B3** Similar table.  Rows are services, such as voice, data and video. Columns are “service environments”, such as narrowband, wideband, and broadband.  May collect penetration rate into each “service environment” separately for each PPDR category and then calculate composite PPDR penetration rate.  Example:  *Category Population* Penetration  (NB Voice)  Regular Police 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% |
| **B4** Users/cell  Number of people subscribing to service within cell in environment | **B4** Users/cell   Pop density  Pen Rate  Cell area |

TABLE 2E-1 (*cont.*)

| IMT-2000 methodology  (Recommendation [ITU-R M.1390](https://www.itu.int/rec/R-REC-M.1390/en)) | Methodology |
| --- | --- |
| **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 | =Traffic/cell (E) |
| Service channels per group | 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](https://www.itu.int/rec/R-REC-M.1390/en)) | Methodology |
| --- | --- |
| **C2** Service channel bit rate (kbit/s) | **C2** Service channel bit rate  Net userbit rate   Overhead factor  Coding factor |
| Equals net user bit rate plus additional increase in loading due to coding and/or overhead signalling, if not already included | 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  Freqes 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  Freqes) |

## 2E.3 Estimation of spectrum 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 km2. It is predicted that population of 2020 will be about 20 million.

The PPDR is categorized as four 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](https://www.itu.int/pub/R-REP-M.2033).

TABLE 2E-6

Spectrum 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 use. 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 |  |  |

TABLE 2E-6 (*cont.*)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  | 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 | km2 |  |
|  | Number of persons per unit of area within the environment under consideration. Population density may vary with mobility Potential user per km2 |  | 37.5 | POP/km2 |  |
| 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 | |

TABLE 2E-6 (*end*)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  |  | Point-to-Point | Point-to-Multipoint |
|  | Busy hour call attempts (BHCA) (Calls/busy hour) | From PSWAC[[17]](#footnote-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 |
|  |  |  |  |  |  |
| 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 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 use. 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 |  |
|  |  | 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 |  |  |

TABLE 2E-7 (*cont.*)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Area under consideration |  | 1 550 | km2 |  |
|  | Number of persons per unit of area within the environment under consideration. Population density may vary with mobility Potential user per km2 |  | 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 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 use. 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 | km2 |  |
|  | Number of persons per unit of area within the environment under consideration. Population density may vary with mobility Potential user per km2 |  | 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 |  |

TABLE 2E-8 (*end*)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  | | 0.40 | |  | |  |
| B4 | The number of cell |  | | 265 | |  | |  |
| Users/cell |  | | 75.19 | |  | |  |
| B5 | Traffic parameters |  | | Uplink | | Downlink | |  |
|  | Busy hour call attempts (BHCA) (Calls/busy hour) |  | 6.00 | | 6.00 | |  | | |
|  | kbit /Image |  | 8 000.00 | | 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 use. 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 | 0.2 |  |
|  |  | 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 |  |  |

TABLE 2E-9 (*cont.*)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Area under consideration |  | 1 550 | km2 |  |
|  | Number of persons per unit of area within the environment under consideration. Population density may vary with mobility Potential user per km2 |  | 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 |  | Uplink | Downlink |  |
|  | Busy hour call attempts (BHCA) (Calls/busy hour) |  | 6.00 | 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 |  |  |  |  |
| D1 |  |  | 25.52 | 9.98 |  |
| D2 | Weighting factor for each environment (α) |  | 1.00 | 1.00 |  |
| D3 | Adjustment factor (β) |  | 1.00 | 1.00 |  |
| D4 | Total Spectrum (MHz) |  | 35.50 | | |

Frequency prediction is summarised in Table 2E-10.

TABLE 2E-10

Example narrowband and wideband spectrum 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 (km2) | 1 550 | (Calculated) | |  |  |
| Cell area (km2) | 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 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 (Mbit/s) | Uplink bandwidth (MHz) | Downlink bandwidth (MHz) |
| Command Centre | 15 | compressed video broadcast |  |  | 7 |
| Ordinary Police Officers | 20 | identity authentication and query |  |  |  |
| Medical Team | 5 | 1 channel D1 video upload and download | 1 | 2 | 2 |
| Fire Fighters | 5 | 1 channel D1 video upload and download | 1 | 2 | 2 |
| Negotiation Experts | 3 | high definition video download |  |  | 4 |
| Strike Team | 10 | 2 channels CIF video upload and download | 0.5 | 2 | 4 |
| Police Helicopter | 1 | 1 channel 1080P video upload and download | 3 | 5 | 1 |
| Reconnaissance Robot | 10 | 1 channel 720P, 1 channel CIF video upload | 3.5 | 6 |  |

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 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]](#footnote-18) and inshore vessel[[19]](#footnote-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 use has been studied and is 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 use when multiple PPDR agencies jointly carry out operation is considered. Korea government is considering integrated public broadband services for PPDR, railway, and inshore vessels in a single nationwide LTE network. Thus, spectrum use for the integrated public broadband service is also analysed.

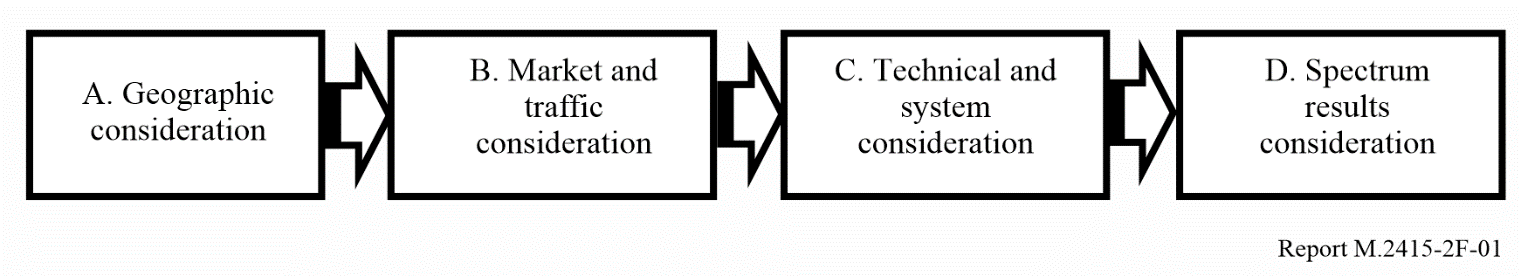
In § 2F.2, spectrum estimation methodology is explained and traffic parameters of each scenario are presented. Section 2F.4 shows spectrum estimation results and conclusions are drawn in § 2F.5.

## 2F.2 Spectrum estimation methodology

The spectrum estimation methodology adopted in this study is based on Recommendation [ITU-R M.1390](https://www.itu.int/rec/R-REC-M.1390/en) which is used for the calculation of IMT-2000 terrestrial spectrum requirements and its use to estimate spectrum for PPDR is shown in Report [ITU-R M.2033](https://www.itu.int/pub/R-REP-M.2033). The spectrum estimation procedure consists of four stages as in Fig. 2F-1.

Figure 2f-1

Spectrum estimation procedure in Rec. [ITU-R M.1390](https://www.itu.int/rec/R-REC-M.1390/en)



In this study, the Recommendation [ITU-R M.1390](https://www.itu.int/rec/R-REC-M.1390/en) methodology is considered but modified to reflect PPDR service characteristics as explained below.

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 use.

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]](#footnote-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 estimate. 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]](#footnote-21).

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 February 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 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 uses are determined so as to meet spectrum use 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 aspects

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 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 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 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 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 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 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 used 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 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 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]](#footnote-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. 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]](#footnote-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]](#footnote-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](https://www.itu.int/pub/R-REP-M.2377)) addressing general PPDR requirements.

A) Narrowband and wideband PPDR spectrum aspects

In particular, Annex 1 of this Report sets out a methodology for determining spectrum aspects of narrow and wideband PPDR systems. The methodology adopted an approach developed for IMT‑2000 technology[[25]](#footnote-25) and adapted this for narrowband and wideband PPDR systems. It results in a relatively high spectrum use 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 used is significantly reduced when using LTE systems to provide packet‑oriented PPDR voice, data and broadband capability[[26]](#footnote-26),[[27]](#footnote-27). For example, if LTE assumptions were substituted in the analysis in Attachment 1.6 to Annex 1, the spectrum 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 aspects

In Annex 2 of this Report, several examples were presented for estimating the broadband PPDR spectrum. While intended to illustrate the minimum spectrum used, 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 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 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 by 50 MHz of high-band TDD spectrum (4.9 GHz) be made available for PPDR[[28]](#footnote-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]](#footnote-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]](#footnote-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]](#footnote-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’.

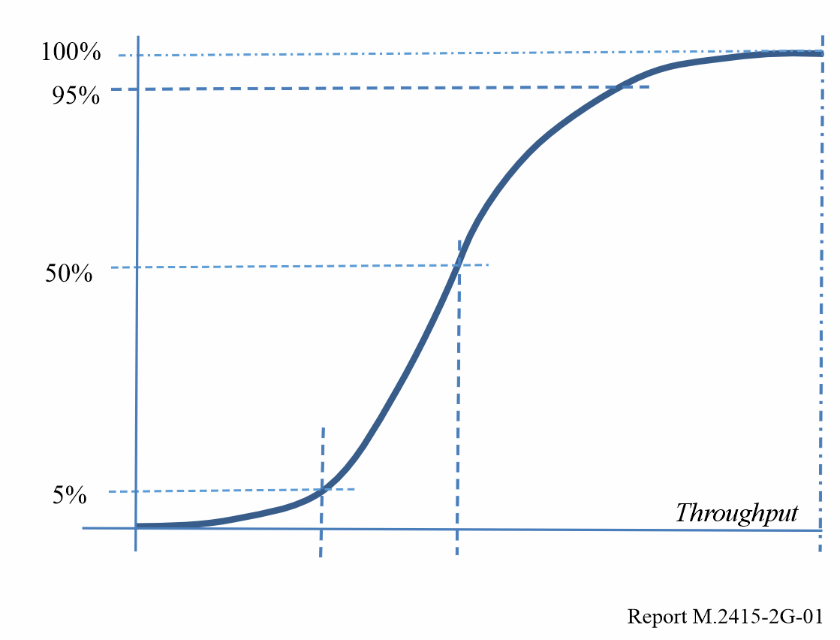
The path loss between relevant serving base-station and a representative user-terminal, along with its SINR, was recorded in each ‘snap shot’, to generate a high-resolution distribution of the resulting raw data.

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

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.

The modelling results for throughput and spectrum efficiency are set out in Table 2G-1 below.

TABLE 2G-1

Sector uplink and downlink throughput and spectral efficiency results

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Scenario | | Urban | Suburban | Rural |
| **Downlink** | **Channel (MHz)** |  |  |  |
| 5th percentile throughput (and spectrum efficiency) | 5  10  20 | 12.3 Mbit/s, 2.4 bit/s/Hz  20.1 Mbit/s, 2.0 bit/s/Hz  40.2 Mbit/s, 2.0 bit/s/Hz | 16.2 Mbit/s, 3.2 bit/s/Hz  32.5 Mbit/s, 3.2 bit/s/Hz  64.9 Mbit/s, 3.2 bit/s/Hz | 14.4 Mbit/s, 2.8 bit/s/Hz  28.8 Mbit/s, 2.8 bit/s/Hz  57.5 Mbit/s, 2.8 bit/s/Hz |
| 50th percentile throughput (and spectrum efficiency) | 5  10  20 | 15.1 Mbit/s, 3.0 bit/s/Hz  28.0 Mbit/s, 2.8 bit/s/Hz  56.0 Mbit/s, 2.8 bit/s/Hz | 18.1 Mbit/s, 3.6 bit/s/Hz  36.1 Mbit/s, 3.6 bit/s/Hz  72.2 Mbit/s, 3.6 bit/s/Hz | 17.0 Mbit/s, 3.4 bit/s/Hz  34.0 Mbit/s, 3.4 bit/s/Hz  67.9 Mbit/s, 3.4 bit/s/Hz |
| *Uplink* |  |  |  |  |
| 5th percentile throughput (and spectrum efficiency) | 5  10  20 | 2.2 Mbit/s, 0.44 bit/s/Hz  2.4 Mbit/s. 0.24 bit/s/Hz  1.7 Mbit/s, 0.09 bit/s/Hz | 3.8 Mbit/s, 0.8 bit/s/Hz  11.1 Mbit/s, 1.1 bit/s/Hz  15.6 Mbit/s, 0.8 bit/s/Hz | 2.2 Mbit/s, 0.4 bit/s/Hz  7.2 Mbit/s, 0.7 bit/s/Hz  8.8 Mbit/s, 0.4 bit/s/Hz |
| 50th percentile throughput (and spectrum efficiency) | 5  10  20 | 4.9 Mbit/s, 1.0 bit/s/Hz  6.7 Mbit/s, 0.7 bit/s/Hz  8.1 Mbit/s, 0.4 bit/s/Hz | 6.9 Mbit/s, 1.4 bit/s/Hz  17.2 Mbit/s, 1.7 bit/s/Hz  28.1 Mbit/s, 1.4 bit/s/Hz | 4.8 Mbit/s, 1.0 bit/s/Hz  13.1 Mbit/s, 1.3 bit/s/Hz  19.5 Mbit/s, 1.0 bit/s/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]](#footnote-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 use than have been previously indicated by studies relying on methodologies such as Recommendation [ITU-R M.1390](https://www.itu.int/rec/R-REC-M.1390/en) 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.

Attachment 1  
to Annex 2G  
  
Model layout and parameters

Figure 2G-2

LTE/LTE-Advanced macro network layout

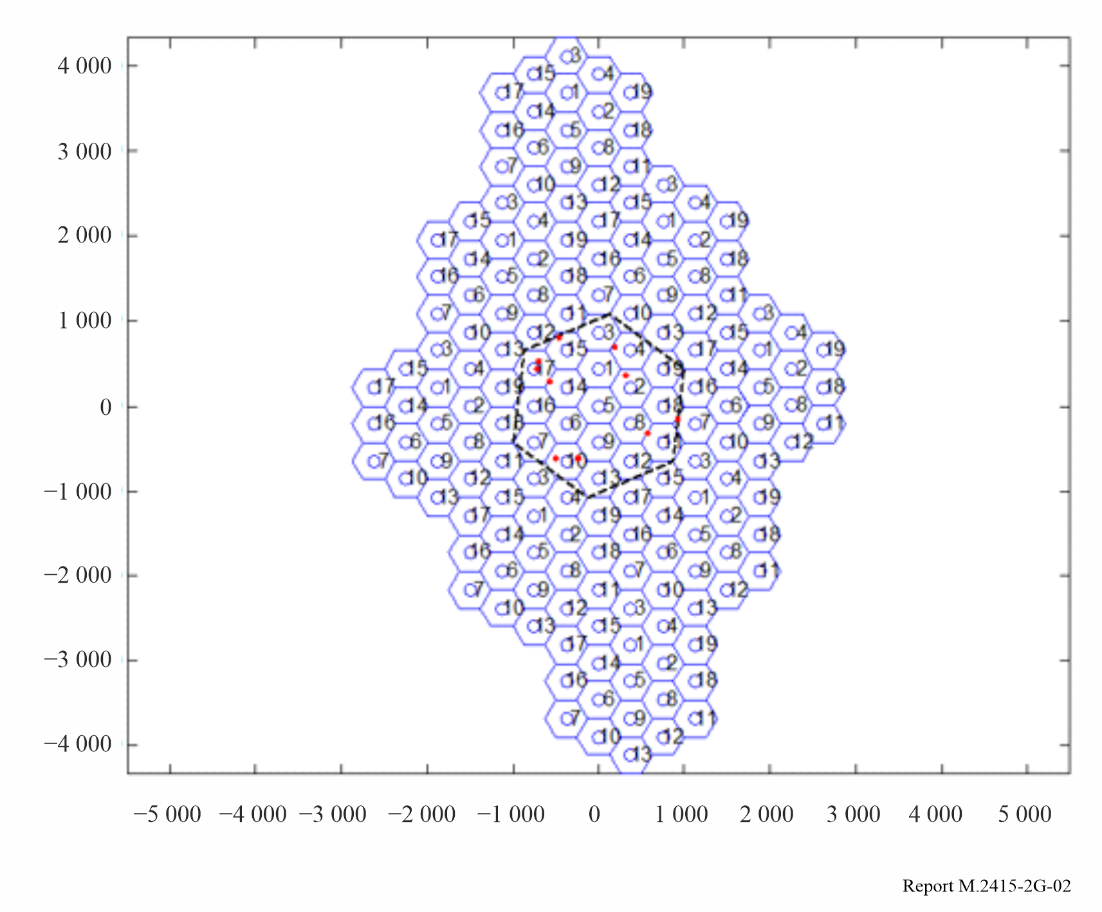
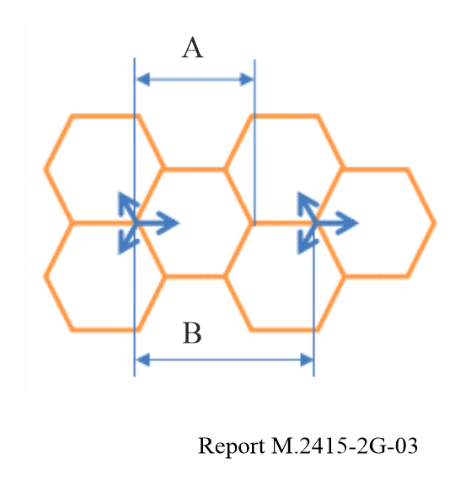


Figure 2G-3

Macro-cell layout[[34]](#footnote-34)



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) for macro urban/suburban scenario |
| Antenna height | 30 m |
| Sectorization | 3 sectors |
| Downtilt | 3 degrees |
| Frequency reuse | 1 |
| Antenna pattern | Rec. ITU-R F.1336 (*recommends* 3.1)  – ka = 0.7  – kp = 0.7  – kh = 0.7  – kv = 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 |

TABLE 2G-2 (*end*)

|  |  |
| --- | --- |
| Base station characteristics / Cell structure | |
| 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/km2 for macro rural scenario  2.16 / 5 MHz/km2 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

A graph with a line

Description automatically generated

Figure 2G-5

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

A graph with a line drawn on it

Description automatically generated

Figure 2G-6

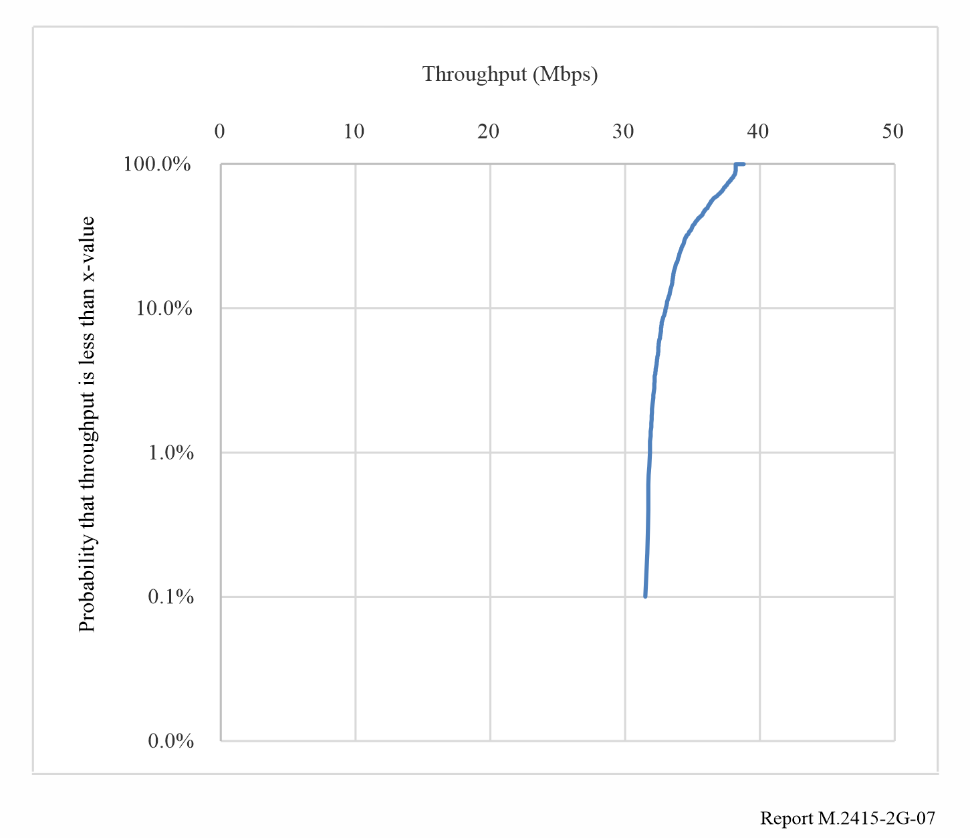
CDF of uplink throughput for suburban network model for 10 MHz channel bandwidth

A graph with a line

Description automatically generated

Figure 2G-7

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



Annex 2H  
  
Spectrum for BB PPDR in Tunisia

## 2H.1 Summary of the spectrum 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.

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”. [↑](#footnote-ref-1)
2. These spectrum estimations, done during the study cycle 2000-2003, estimated spectrum use by 2010. [↑](#footnote-ref-2)
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. [↑](#footnote-ref-3)
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). [↑](#footnote-ref-4)
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). [↑](#footnote-ref-5)
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). [↑](#footnote-ref-6)
7. Report from September 1996, see footnote 3 in Annex 1 § 2 for details. [↑](#footnote-ref-7)
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. [↑](#footnote-ref-8)
9. Source: Police Service Personnel, England and Wales, as of 31 March 1999, by Julian Prime and Rohith Sen-gupta at Home Office, Research Development and Statistics Directorate. [↑](#footnote-ref-9)
10. Includes National Crime Squad (NCS) & National criminal Intelligence Service (NCIS) civilian staffing. [↑](#footnote-ref-10)
11. Not included in totals above. [↑](#footnote-ref-11)
12. Report from September 1996, see footnote 3 in Annex 1 § 2 for details. [↑](#footnote-ref-12)
13. Report from September 1996, see footnote 3 in Annex 1 § 2 for details. [↑](#footnote-ref-13)
14. See ECC Report 199 for more details on methodology used in CEPT. [↑](#footnote-ref-14)
15. Specifically Posen, Illinois was used and their MABAS (Multi-Agency Box Alarm System) “Box Card” was evaluated with interpretation from Posen PS employees. [↑](#footnote-ref-15)
16. 3GPP TS 36.104 version 11.4.0 Release 11 – Table 6.2.1. [↑](#footnote-ref-16)
17. Report from September 1996, see footnote 3 in Annex 1 § 2 for details. [↑](#footnote-ref-17)
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. [↑](#footnote-ref-18)
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). [↑](#footnote-ref-19)
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. [↑](#footnote-ref-20)
21. In LTE system, cell diameter for 700 MHz band is in the range of 2-3 km. [↑](#footnote-ref-21)
22. Ericsson, Coverage and capacity Dimensioning FDD Recommendation, Release 16A. [↑](#footnote-ref-22)
23. *Public Safety Mobile Broadband*, Productivity Commission Research Report, December 2015. [↑](#footnote-ref-23)
24. *Telstra LANES to the rescue*: <http://www.telstra.com.au/aboutus/media/media-releases/telstra-lanes-to-the-rescue.xml>. [↑](#footnote-ref-24)
25. Recommendation [ITU-R M.1390](https://www.itu.int/rec/R-REC-M.1390/en). [↑](#footnote-ref-25)
26. *FirstNet, First responder Network*, <http://www.firstnet.gov/network>. [↑](#footnote-ref-26)
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>. [↑](#footnote-ref-27)
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>. [↑](#footnote-ref-28)
29. Telstra LANES to the rescue: <http://www.telstra.com.au/aboutus/media/media-releases/telstra-lanes-to-the-rescue.xml> [↑](#footnote-ref-29)
30. 9 - G PPDR quality of service functions p.17. [↑](#footnote-ref-30)
31. Visualyse Professional V7, <http://www.transfinite.com/content/downloadsvisualyse> [↑](#footnote-ref-31)
32. Ericsson, Coverage and Capacity Dimensioning FDD Recommendation, Release 16A. [↑](#footnote-ref-32)
33. For example, see: <http://www.lighterra.com/papers/videoencodingh264/>. [↑](#footnote-ref-33)
34. Figure 1, Report [ITU-R M.2292](https://www.itu.int/pub/R-REP-M.2292) – Characteristics of terrestrial IMT-Advanced systems for frequency sharing/ interference analyses, p. 5. [↑](#footnote-ref-34)