CEPT ECC
Electronic Communications Committee

ECC Report 199

User requirements and spectrum needs for future European broadband PPDR systems (Wide Area Networks)

May 2013

0 EXECUTIVE SUMMARY

This ECC Report is the first deliverable in accordance with the ECC WG FM "Implementation Roadmap for the Mobile Broadband applications for the Public Protection and Disaster Relief (PPDR)" [9] . It addresses the user requirements and the spectrum needs for future European broadband PPDR systems (Wide Area Networks). This roadmap envisages that a subsequent ECC Report will address the possible harmonisation options which support the implementation of the user requirements and spectrum needs.

It is recognised that the PPDR sector, including the associated radiocommunications, is a sovereign national matter, and that the PPDR needs of European countries may vary to a significant extent. Therefore, this and future ECC deliverables dealing with the issues related to harmonisation of the PPDR sector in Europe attempt to aid the creation of a high level European regulatory and technical framework for BB PPDR rather than to define the detailed regulatory and technical aspects. Such a framework would enable the deployment "under harmonised conditions" of interoperable BB PPDR systems capable of efficient cross-border PPDR operations (see art.8.3 of the Radio Spectrum Policy Programme [8]).

0.1 CONCEPT OF FUTURE EUROPEAN BB PPDR SYSTEMS

This report is based upon the definitions in the Report ITU-R M.2033 [1]. In developing those definitions further this report assumes that future BB PPDR systems will basically basically consist of:

- BB PPDR Wide Area Network (WAN)
- BB PPDR temporary additional capacity (ad-hoc networks)

The report describes the three PPDR operational environments, namely:

- day-to-day operations (category "PP1")
- large emergency and/or public events (category "PP2")
- disasters (category "DR").

It also addresses the PPDR related airborne communications and Direct Mode Operation capability but to a lesser extent.

Both BB PPDR WAN and temporary additional capacity are supposed to provide radiocommunications to PPDR users in *mission critical* as well as in *non-mission critical* situations. Mission-critical communication requirements are assumed to be more stringent than those in non-mission critical situations.

0.2 USER REQUIREMENTS

In terms of scope, the PPDR *network related requirements* presented in the report focus on the need for interoperability between European PPDR organisations.

For economies of scale a technical solution should be based on a widely used technology. Therefore LTE is taken as a working assumption. A common technology brings the advantage of improving international cooperation. Disaster Relief (DR) could benefit from this in particular as a global interoperable solution is useful in improving the delivery of mutual aid.

Further consideration of the relevant network related requirements, including cost related considerations, are subject for the subsequent ECC Report dealing with the possible harmonised conditions for the implementation of future European broadband PPDR systems.

The core element of the report deals with PPDR *application related requirements.* These are presented in a form of a matrix, which was developed by LEWP/RCEG, and which contains a description of the envisioned PPDR applications (the "LEWP/RCEG Matrix"). This Matrix was later complemented with the spectrum calculation module developed by ETSI TC TETRA WG4 and this makes it useful for a detailed assessment of the necessary spectrum for PPDR communications under different operational scenarios.

0.3 SPECTRUM NEEDS

The calculation of the *minimal spectrum needs for BB PDDR WAN* in this report is made using an incident-based methodology for all three operational scenarios referred to above. This methodology accounts for data communications only. Voice communications may require additional spectrum depending on particular national requirements. The methodology also takes into account the background traffic of PPDR forces in the area of an incident. The reference technology chosen for the calculations is LTE Release 10 and the detailed technical parameters are provided in Annex 2 A2.2. The frequency ranges selected for use in estimating the necessary spectrum bandwidth are 400 MHz and 700 MHz.

The choice of suitable candidate bands is the subject for the subsequent ECC Report.

The following mission-critical operational scenarios were chosen for the calculations. The detailed description of the scenarios was provided by LEWP/RCEG and "Airwave Solutions Ltd." company and can be found in Annex A2.1:

- PP1: road accident scenario and "traffic stop" police operation scenario
- PP2: royal wedding in London in April 2011 (a pre-planned event) and riots in London in August 2011 (an unplanned event)
- DR: no particular scenario due to a huge variation in scale of disaster events.

0.3.1 Spectrum needs for BB data communications

The tables below provide the assessments of the minimal spectrum needs for the respective operational scenarios referred to above[1]:

0.3.1.1 PP1 (day-to-day operations)

Table 1: Total uplink bandwidth requirement for BB data communications

Frequency band	Traffic assumption	Low estimate	Medium estimate
420 MHz	1 incident "cell edge" 3 incidents near cell centre and background communications	8.0 MHz	12.5 MHz
750 MHz	1 incident "cell edge" 2 incidents near centre and background communications	7.1 MHz	10.7 MHz

[1] It should be noted that the calculated spectrum requirements are heavily dependant on the assumed *spectral efficiency*, in particular for the uplink, and that the tables provide *low* and *medium* estimates corresponding to optimistic and less optimistic assumptions respectively.

Table 2: Total downlink bandwidth requirement for BB data communications

Frequency band	Traffic assumptions	Low estimate	Medium estimate
420 MHz	1 incident "cell edge" 3 incidents near centre with background communications	7.6 MHz	10.5 MHz
750 MHz	1 incident "cell edge" 2 incidents near centre with background communications	6.9 MHz	9.0 MHz

The difference between the estimate for 420 MHz and 750 MHz is due to the fact that the size of cells at 400 MHz is larger than that for 700 MHz cells. This implies that more incidents can occur under a 400 MHz cell, causing higher throughput. If there is insufficient spectrum, the size of the 400 MHz cells can be made smaller through network planning. In that case the results for the 700 MHz cells are then also valid for those smaller 400 MHz cells. This means that with proper network planning a spectrum amount in the range of **10 MHz for uplink** and another **10 MHz for downlink** is sufficient to cover the PP1 cases addressed in this report.

0.3.1.2 PP2 (large emergency and/or public events)

The results are given for the uplink bandwidth requirement since uplink communications require more bandwidth than downlink communications.

Total BB data communications results for royal wedding in London in April 2011 (a pre planned event).

Table 3: Total BB data communications results (royal wedding)

Frequency band	Traffic assumption	Less stringent case	Worst case
Independent of frequency band	PP2 traffic scenario with background communications	10.3 MHz	14.3 MHz

Total BB data communications results for London riots in August 2011 (an unplanned event).

Table 4: Total BB data communications results (London riots)

Frequency band	Traffic assumption	Less stringent case	Worst case
Independent of frequency band	PP2 traffic scenario with background communications	5.8 MHz	7.8 MHz

The estimates for PP2 scenarios do not take into account the additional capacity that could be set up in advance of a planned event (such as the specific scenario used in this estimate). It is difficult to quantify which portion of traffic could be diverted towards the additional temporary capacity, but one can expect that in some cases part of the bandwidth estimated in the tables above may be substituted by temporary capacity.

It is considered that **10 MHz of spectrum for the uplink and another 10 MHz for the downlink** provide enough capacity to meet the core requirements of the PP2 scenarios presented in the study. It should be noted that situations can occur where demand could exceed the capacity of the permanent WAN network. In the case of a pre-planned event, additional temporary capacity should be considered to increase the permanent network capacity.

0.3.1.3 DR (Disaster Relief)

This report concludes that the DR spectrum requirements would be of the same magnitude as the requirements for PP2 events, with communication requirements being spread out over a larger geographical area in some DR cases. Therefore **the spectrum requirements for PP2 cover the early needs of a DR event** (this is a simplifying assumption).

0.3.2 Spectrum needs for BB data communications calculated with a different methodology

Using the same LEWP-RCEG Matrix of applications an alternative calculation for the spectrum requirements was made. These alternative calculations are based on one and two simultaneous major incidents and account for the capacity requirements of each application described in the Matrix.

The alternative calculation provides similar results to the incident-based calculations referred to previously. The differences between the two sets of calculations can be explained by the different sets of assumptions used for each methodology (see explanation below).

This alternative analysis concludes that at least **10 MHz is required for the WAN uplink**. With 10 MHz made available, many but not all of the scenarios can be accommodated

At least **10 MHz will also be required for the terrestrial network downlink**. With 10 MHz made available, many of the scenarios which utilise individual calls can be accommodated. All scenarios can be accommodated in a 10 MHz downlink where group calls are optimally used.

This analysis however does not incorporate all demands for voice call, Direct Mode Operation (DMO) or Air-Ground-Air (AGA) communications although some limited air to ground uplink usage is included in some scenarios. Ad hoc networks are also not included in the calculations and additional spectrum may be required for all these additional forms of PPDR communications based on national decisions.

0.3.3 Spectrum needs for voice

The calculations in this ECC Report referred to above have been made for BB data only.

The duplex band 380-385/390-395 MHz, which has been identified for NB PPDR radio applications (primarily for voice) since 1996, is currently utilised by TETRA and TETRAPOL networks in most European countries.

Within the transition to future European BB PPDR systems it is initially expected that BB PPDR WAN will operate together with NB TETRA and TETRAPOL networks and that those networks will continue to provide voice and narrowband services for at least the coming decade. In the future, the broadband technology will be capable of supporting the PPDR voice services as well as the data applications.

The report provides an evaluation of the voice capabilities of a BB network (based on LTE). The calculations show that the future BB technology could provide the voice service with a comparable or better efficiency than the current NB PPDR technologies. It is estimated that **around 2x3.2 MHz would be needed for voice traffic in the future BB PPDR network**.

At this time it is not clear whether the existing NB spectrum would be reused for BB applications or whether additional BB spectrum would be needed to cater for voice communications in the future BB PPDR network. This choice will be made by national administrations, although CEPT administrations may decide to investigate the potential for a harmonised approach in the future.

0.3.4 Spectrum needs for Air-Ground-Air (AGA) communications

In addition to the WAN requirements, PPDR organisations may also have requirements for broadband AGA applications e.g. from UAVs or helicopters to support PPDR operations. These typically involve a video stream being relayed from a camera mounted on a helicopter to a monitoring station on the ground. Some European countries have already reserved spectrum specifically for such use. These PPDR AGA spectrum requirements have not been calculated within this report although some limited air to ground usage is included in few scenarios. However an example of the amount of spectrum needed for AGA communications from a CEPT administration has been included in the report (ANNEX 5:) and two other examples of national decisions are referred to in section 5.9.1.

0.3.5 Spectrum needs for Direct Mode Operation (DMO)

Direct Mode Operation (DMO) is an important PPDR functionality currently used for voice and narrowband (NB) data. It is used primarily in areas with limited or no coverage e.g. in buildings, tunnels etc.

PPDR organisations require that “BB DMO” functionality is also implemented in future European BB PPDR systems which would facilitate ‘device-to-device’ high-speed data communication.

While 3GPP has not finalised the DMO aspects of LTE Release 12 specifications, it remains difficult to assess the amount of the necessary BB DMO-spectrum. It is not known whether there is a need to reserve additional spectrum for BB DMO or it can be integrated within the WAN spectrum. BB DMO capabilities could then either come from the new BB data spectrum or from the migration of the NB spectrum to BB technologies.

0.4 CONCLUSIONS

The main conclusion of this ECC Report is that an amount of spectrum in the range of **2x10 MHz** is needed for future European broadband PPDR Wide Area Networks (WAN).

However there could be additional spectrum requirements on a national basis to cater for Direct Mode Operations (DMO), Air-Ground-Air (AGA), ad-hoc networks and voice communications over the WAN. Harmonisation of spectrum for BB PPDR ad-hoc networks may be a subject for further studies by CEPT.

The results of the spectrum calculations should be seen as an assessment based on current knowledge. The results should be rather rated as the minimum needed amount of spectrum for future European BB PPDR systems without however excluding any spectrum options to be examined. Countries may choose to designate the necessary amount of spectrum, which may be more than the calculated minimum WAN spectrum requirements or less than that, depending on national situations.

It is recognised that the PPDR sector, including the associated radiocommunications, is a sovereign national matter, and that the PPDR needs of European countries may vary to a significant extent. Therefore, future harmonisation of the PPDR sector in Europe needs to be flexible enough to consider different needs such as the amount of available spectrum and the possible use of commercial networks, while at the same time ensuring interoperability between the different countries as well as maximising the economics of scale.
To reflect these different needs while keeping flexibility in mind the concept of harmonised tuning range will be considered. In order to implement this concept the operating bands of future equipment should be wide enough to cover both the minimum requirement calculated in this ECC Report and the individual national needs e.g. for Disaster Relief.

The focus of the subsequent ECC Report will be to identify options how the calculated WAN spectrum requirement can be implemented within the candidate bands for future European BB PPDR systems.

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
3GPP association	The 3rd Generation Partnership Project (3GPP) unites six telecommunications standard development organisations (ARIB, ATIS, CCSA, ETSI, TTA, TTC), known as “Organisational Partners” and provides their members with a stable environment to produce the highly successful Reports and Specifications that define 3GPP technologies. 3GPP is now (2012) working on specifications for PPDR based on LTE Release 12.
Ad-hoc network	A temporary local network for extra capacity to support the additional traffic caused by mass events or disasters and to avoid local overload of the wide area networks. It can also be used for temporary provision of network services in an area where there is no coverage.
Background traffic	Non-incident related communication: During a major incident most of the traffic on traffic on the network base stations close to the scene is due to the PPDR response to the incident. Background traffic is the communication carried on these network base stations by PPDR forces who are engaged in routine/ business as usual communication.
Backhaul network	Connects base stations of the day-to-day network with the base stations of an ad-hoc network e.g. by fibre, microwave links or satellite links.
Broadband (BB)	Broadband applications providing voice, high-speed data, high quality digital real time video and multimedia (indicative data rates in range of 1-100 Mbps) with channel bandwidths dependent on the use of spectrally efficient technologies.
BB PPDR application	PPDR operational application for a certain PPDR communication purpose.
BB PPDR category	The prevalence of PPDR occurrences is divided in groups, called categories. Category A: Equivalent to PP1 (ITU-R M.2033), routine day to day events and incidents (in wide area networks). Category B: Mostly equivalent to PP2 (ITU-R M.2033), mass events and incidents where the location and requirements are known in advance. Category C: Mostly equivalent to DR (ITU-R M.2033), unplanned mass events and major incidents, especially natural disasters where the location and requirements are not known in advance with the possibility of destroyed infrastructure. Significantly higher communication needs at very short notice will occur. In the ITU-R M.2033 the term "scenario" is used instead of the term “category”. Also in different deliverables the terms “scenario” and “category” are not always used consistently.
BB PPDR scenario	A PPDR scenario is an operational activity (e.g. a car accident, or a mass event, such as the royal wedding in London in which a combination of - different applications have to be used to manage the event or incident. Scenarios may differ from country to country because they are based on individual sovereign national instructions or guidelines. Each scenario describes which partners communicate together, where these communication partners are located, and which communication and information paths are required.

Catalogue of BB PPDR applications related requirements	CEPT administrations and PDDR organisations have agreed upon a collection of PPDR applications, addressed to PPDR scenarios and PPDR categories, which require harmonised spectrum.
CEPT	European Conference of Postal and Telecommunications Administrations Conférence Européenne des Administrations des Postes et des Télécommunications
Commercial network	A communication network that is built and operated by profit-oriented operators to offer public communication services.
Commercial technology standard	A standard that is initially / primarily developed for usage in profit oriented systems, e.g. GSM, LTE,
Communication category/communication scenario	see “BB PPDR category” / “BB PPDR scenario”
Cross-border	PPDR organisations have to help each other in certain cases, meaning they have to be able to work in other countries with the local PPDR organisations and with their own organisation.
Day-to-day operation	Day-to-day operations encompass the routine operations that PPDR agencies conduct within their jurisdiction. Typically these operations are within national borders. Generally most PP spectrum and infrastructure requirements are determined using this scenario with extra capacity to cover unspecified emergency events. For the most part day-to-day operations are minimal during DR.
Dedicated network	A network solely designed to fulfil the sovereign PPDR requirements: this can be a GoGo model (Government Owned, Government Operated), but also a service delivered by a third party (CoCo: Company Owned, Company Operated). Another model is GoCo (network owned by Government, but operated by a third party).
Disaster	Disasters can be those caused by either natural or human activity. For example, natural disasters include an earthquake, major tropical storm, a major ice storm, floods, etc. Examples of disasters caused by human activity include large-scale criminal incidents or situations of armed conflict. Generally, both the existing PP communications systems and special on-scene communications equipment brought by DR organisations are employed.
Disaster Relief (DR) radiocommunication	Radiocommunications used by responsible agencies and organisations dealing with maintenance of law and order, protection of life and property, and emergency situations. Disaster relief (DR) Radiocommunications used by agencies and organisations dealing with a serious disruption of the functioning of society, posing a significant, widespread threat to human life, health, property or the environment, whether caused by accident, nature or human activity, and whether developing suddenly or as a result of complex long-term processes.
DL	Downlink
ECC	Electronic Communications Committee
ECO	European Communications Office
EPA	The EPA (Extended Pedestrian A model) is a multipath fading propagation

	model with typical 5 Hz maximum Doppler frequency for delay profile. See also EVA
ETSI	European Telecommunications Standards Institute
EVA	The EPA (Extended Vehicular A model) is a multipath fading propagation model with typical 5 Hz or 70 Hz maximum Doppler frequency for delay profile. See also EPA
Frequency range	see "identified common frequency range"
GNSS	Global Navigation Satellite System
Hybrid networks	Combination of dedicated and commercial networks.
Identified common frequency range	In the context of ITU Res. 646, the term "frequency range" means a range of frequencies over which radio equipment is envisaged to be capable of operating but limited to specific frequency band(s) according to national conditions and requirements.
IMT	International Mobile Telecommunication
Interoperability	PPDR interoperability is the ability of PPDR personnel from one agency/organisation to communicate by radio with personnel from another agency/organisation, on demand (planned and unplanned) and in real time. There are several elements/components which affect interoperability including, spectrum, technology, network, standards, planning, and available resources. Systems from different vendors, or procured for different countries, should be able to interoperate at a predetermined level without any modifications or special arrangements in other PPDR or commercial networks. Interoperability is also needed in a 'multi vendor' situation where terminals from different suppliers are working on infrastructures from other suppliers.
ITU-R	The ITU Radiocommunication Sector
Large emergency/public events	Large emergencies and/or public events are those that PP and potentially DR agencies respond to in a particular area of their jurisdiction. However, they are still required to perform their routine operations elsewhere within their jurisdiction. The size and nature of the event may require additional PPDR resources from adjacent jurisdictions, cross-border agencies, or international organisations. In most cases there are either plans in place or there is some time to plan and coordinate the requirements.
LEWP/RCEG	Radio Communications Expert Group of the Law Enforcement Working Party which is officially reporting to JHA (Justice & Home Affairs) within the Council of the European Union.
LTE	Long Term Evolution
Matrix LEWP/RCEG	Documentation edited by the LEWP/RCEG which contains PPDR applications and their descriptions and specifications. The list of applications is as comprehensive as was needed for the harmonisation work and to demonstrate the PPDR requirements.
Mission critical communications	LEWP defines mission critical operations as follows: "*Mission critical operations*" for PPDR organisations address situations where human life and goods (rescue operations, law enforcement) and other values for society are at risk, especially when time is a vital factor. ▪ This means we define 'mission critical information' as the vital

	information for PPDR to succeed with the operation. ‘Mission critical communication solutions’ therefore means that the PPDR organisations need secure reliable and available communication and as a consequence cannot afford the risk of having failures in their individual and group communications (e.g. voice and data or video transmissions).”
Mixed network	see Hybrid Network
Multi-band	The terms multi-band refers to a radio device supporting multiple radio frequency bands.
NB	Narrowband
OFDM	Orthogonal frequency-division multiplexing
Operations category	see “BB PPDR category”
Operations scenario	see “BB PPDR scenario”
Opportunity costs	Opportunity costs are the costs of any activity measured in terms of the value of the next best alternative that is not chosen.
Public Protection (PP) radiocommunication	Radiocommunications used by responsible agencies and organisations dealing with maintenance of law and order, protection of life, property and other emergency situations.
PPDR specific standard	A radio communication standard that has been developed for PPDR applications or that is a further development of an already existing (commercial) standard.
RR	ITU Radio Regulations
RSC	Radio Spectrum Committee
RSPG	Radio Spectrum Policy Group
RSPP	Radio Spectrum Policy Programme
Roaming	In wireless telecommunications, roaming is a general term referring to the extension of connectivity service in a network that is different from the home network where the service was registered. Roaming ensures that the wireless device is kept connected to a network, without losing the connection. Traditional (GSM)-Roaming is defined as the ability for a cellular customer to automatically make and receive voice calls, send and receive data, or access other services, including home data services, when travelling outside the geographical coverage area of the home network, by means of using a visited network. This can be done by using a communication terminal or else just by using the subscriber identity in the visited network.
Schengen Agreement	Agreement on ‘open borders’. Relevant section is article 44 where cooperation for Public Safety is described regarding mobile cross border communications.
Sharing of spectrum	Spectrum-sharing allows the co-existence of different technologies and/or services in one band, if a regulation can assure compatibility.
TETRA	Terrestrial Trunked Radio based on TDMA.
TETRAPOL	TETRAPOL is a digital professional mobile radio standard based on FDMA.

TAPS	TETRA Advanced Packet Service
TEDS	TETRA Enhanced Data Service
Tuning range	Tuning range is the frequency range over which a receiver, transmitter or other piece of equipment (such as antennas) can be adjusted by means of a tuning control in consideration of a required system performance.
UL	Uplink
Wideband (WB)	It is expected that the wideband technologies will carry data rates of several hundred kilobits per second (e.g. in the range of 384-500 kbps).
WAN	A Wide Area Network in the context of this report is a terrestrial radiocommunication network that enables telecommunication by radio equipment among PPDR forces over a large area (e.g. nationwide coverage through establishing thousands of base stations). It can be deployed as a dedicated, commercial or hybrid network.
WG FM	Working Group Frequency Management within the ECC
WG SE	Working Group Spectrum Engineering within the ECC
WRC	World Radiocommunication Conference

1 INTRODUCTION

This ECC Report is the first deliverable in accordance with the ECC WG FM "Implementation Roadmap for the Mobile Broadband applications for the Public Protection and Disaster Relief (PPDR) Wide Area Network" [9]. It addresses the user requirements and the spectrum needs for future European broadband PPDR systems (Wide Area Networks). This roadmap envisages that a subsequent ECC Report will address the possible harmonisation options which support the implementation of the user requirements and spectrum needs.

The purpose of this and future ECC deliverables dealing with the issues related to harmonisation of the PPDR sector in Europe is aid the creation of a high level European regulatory and technical framework for BB PPDR rather than to define the detailed regulatory and technical aspects. The current European frequency bands for PPDR are addressed in ECC/DEC/(08)05 [22] and ECC/REC/(08)04 [10].

The scope of this ECC Report is described in section 3.1, after the concept of future European BB PPDR systems is introduced.

The report is structured as follows:

- in Chapter 2, a general description of the PPDR operational framework is provided
- in Chapter 3, the concept of future European broadband PPDR systems is described
- in Chapter 4, the network related and applications related user requirements are presented
- in Chapter 5, the minimal spectrum needs for broadband PPDR Wide Area Network are calculated
- in Chapter 6, conclusions are drawn.

2 GENERAL DESCRIPTION OF THE PPDR OPERATIONAL FRAMEWORK

The principle objectives as well as the applications and the spectrum related requirements for solutions to satisfy the operational needs of PPDR organisations around the year 2010 were described in Report ITU-R M.2033 "Radiocommunication objectives and requirements for public protection and disaster relief" (2003)[2] [1]. Report ITU-R M.2033 identifies objectives, applications, requirements, and a methodology for spectrum calculations, spectrum requirements and solutions for interoperability. That report was notably based on the general assumption of a technology-neutral approach.

The general description of the PPDR radio operating environments and major application types, including implementation examples on narrowband (NB), wideband (WB) and broadband (BB) PPDR networks, is provided in this section. It is largely based on the relevant parts of the above mentioned ITU-R Report.

The purpose of this section is to introduce several basic PPDR definitions and descriptions in order to create a background for the specification of typical operational PPDR scenarios which are later used in the assessment of the overall minimum broadband PPDR spectrum needs.

2.1 PUBLIC PROTECTION AND DISASTER RELIEF (PPDR)

There are terminology differences between administrations and regions in the scope and specific meaning of PPDR. The following definitions are provided in Report ITU-R M.2033 [1] "Radiocommunication objectives and requirements for public protection and disaster relief" (2003):

- *Public protection (PP) radiocommunication*: Radiocommunications used by responsible agencies and organisations dealing with maintenance of law and order, protection of life and property, and emergency situations.

- *Disaster relief (DR) radiocommunication*: Radiocommunications used by agencies and organisations dealing with a serious disruption of the functioning of society, posing a significant, widespread threat to human life, health, property or the environment, whether caused by accident, nature or human activity, and whether developing suddenly or as a result of complex, long-term processes.

Further to the ITU-R definitions provided above, it is assumed that the missions carried out by PPDR organisations include:

- law enforcement
- fire fighting
- emergency medical services
- search and rescue
- border security
- event security
- protection of VIPs, dignitaries, etc.
- evacuation of citizens
- response to natural and man-made disasters
- and others.

2.2 MISSION CRITICAL VS NON-MISSION CRITICAL SITUATIONS

ECC Report 102 "Public protection and disaster relief spectrum requirements" (2007) [2] defines the following two types of operational situations addressed by PPDR organisations:

- *Mission critical situations:* the expression "Mission Critical" is used for situations where human life, rescue operations and law enforcement are at stake and PPDR organisations cannot afford the risk

[2] It should be noted that ITU-R WP5A, at its meeting in May 2012, identified this Report for review.

of having transmission failures in their voice and data communications or for police in particular to be ‘eave-dropped’.

- *Non-mission critical situations*: where communication needs are non-critical: human life and properties are not at stake, administrative tasks for which the time and security elements are not critical.

LEWP defines mission critical operations as follows:

”*Mission critical operations*” for PPDR organisations address situations where human life and goods (rescue operations, law enforcement) and other values for society are at risk, especially when time is a vital factor.

- This means we define ‘mission critical information’ as the vital information for PPDR to succeed with the operation.
- ‘Mission critical communication solutions’ therefore means that the PPDR organisations need secure reliable and available communication and as a consequence cannot afford the risk of having failures in their individual and group communication (e.g. voice and data or video transmissions).”

Note: The percentage of mission critical traffic compared to the total PPDR traffic varies from country to country due to individual sovereign instructions or guidelines.

2.3 PPDR RADIO OPERATING ENVIRONMENTS

Various radio operating environments are applicable to PPDR and are explained in this section. The purpose of further explaining distinct radio operating environments is to define PPDR operational scenarios that, from the radio perspective, may impose different requirements on the use of PPDR applications.

Therefore the identified PPDR radio environments form the basis for estimating the minimum spectrum needs.

The PPDR radio operating environments include:

- day-to-day operations
- planned public events
- unplanned events: large emergencies
- disasters.

These may include a variety of cross-border operational activities, e.g. medical emergency, cross-border pursuit according to § 41 of The Schengen Acquis, Air-Ground-Air and Direct Mode Operations.

2.3.1 Day-to-day operations

Day-to-day operations encompass the routine operations that PPDR agencies conduct within their jurisdiction. Typically, these operations are within national borders. Generally, most PP spectrum and infrastructure requirements are determined using this scenario with extra capacity to cover unspecified emergency events. For the most part day-to-day operations are minimal during DR.

Day-to-day operations can be either mission critical or non-mission critical.

PP1 operations: Public Safety will use a variety of communication methods to meet their operational requirements. In addition to coverage from Public Safety terrestrial networks, DMO is used for direct terminal to terminal communication where infrastructure coverage is not available or is inadequate for reliable communications. Aircraft, typically helicopters, are used as observation platforms. These communications methods need to be coordinated with neighbouring countries to aid across border working.

Day-to-day operations are referred to as “*PP1”*.

2.3.2 Large emergency and/or public events

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

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

For large events additional radiocommunications equipment, referred to as *ad-hoc networks,* are brought to the area as required.

Large emergencies or public events are usually mission critical situations.

PP2 operations: Public Safety will use a variety of communication methods to meet their operational requirements. In addition to coverage from Public Safety terrestrial networks, DMO is used for direct terminal to terminal communication where infrastructure coverage is not available or is inadequate for reliable communications. Aircraft, typically helicopters, are used as observation platforms. These communications methods need to be coordinated with neighbouring countries to aid across border working.

Large emergencies or public events are referred to as "*PP2"*.

2.3.3 Disasters

Disasters can be those caused by either natural or human activity. For example, natural disasters include an earthquake, major tropical storm, a major ice storm, floods, etc. Examples of disasters caused by human activity include large-scale criminal incidences or situations of armed conflict.

A 2006 World Bank review of disaster relief activities noted, "Most natural disasters are foreseeable to the extent that it is possible to predict generally where an event is likely to occur at some time in the near future (but not precisely when or its magnitude)."

The more appropriate response would focus on *risk assessment* and *preparedness*. At a basic level, the statistical expectation of loss associated with a specific hazard is simply the product of the probability of a specific disaster occurring multiplied by the damage that would be caused, on average, if it did. One should invest more in preparedness and mitigation where the hazard-specific risk is high. Thus, the threat of an earthquake in Istanbul warrants an intensive response; an equally likely earthquake in a desert, where no one lives, would not warrant much of a response.

Over the past hundred years, there has been a dramatic increase in the number of natural disasters reported and in the associated property damage.

As a notable recent example, a number of European countries, including Poland, Germany, Austria, the Czech Republic, Hungary, Slovakia, Serbia and the Ukraine experienced serious flooding in May, June and August of 2010. Dozens of people have died, tens of thousands have been evacuated, and billions of Euros in damages have been incurred.

Given the large numbers of people impacted by a natural disaster, the considerable potential for property damage, and the risk to social cohesion in the aftermath of a disaster, it is clear that even small improvements in the effectiveness of cross border PPDR operation or international mutual aid could have large benefits. Further, it is clear that there is ample room for improved ability to coordinate and interoperate.

The flooding also demonstrates the potential benefits of loaning PPDR forces from one European country to another. Among the individual EU member states that have so far sent rescuers and equipment are France, Germany, the Baltic nations of Lithuania, Latvia and Estonia, and Poland's neighbour the Czech Republic, which has also been hit by floods."

CEPT is not in a position to estimate the economic magnitude of benefits, but one can reasonably infer that enhanced communications capabilities and enhanced communications interoperability could generate benefits at the times and places where they are sorely needed. The aspect of cross-border interoperability is particularly important in the context of the increasing occurrence of natural disasters in Europe over the recent decades and is reflected in a number of European high-level policy documents [8].

Disasters are always mission critical situations.

In Disaster Relief (DR) operations, Public Safety will use a variety of communication methods to meet their operational requirements. In addition to coverage from Public Safety terrestrial networks, DMO is used for direct terminal to terminal communication where infrastructure coverage is not available or is inadequate for reliable communications. Aircraft, typically helicopters, are used as observation platforms. These communications methods need to be coordinated with neighbouring countries to aid across border working.

In DR scenarios the initial phase of operations typically generates a high traffic load. This can be comparable with the traffic load of PP2 scenarios. This DR scenario traffic can be supported on the mobile terrestrial networks if they are still in operation. In the later steady state phases of DR scenarios the traffic load is shared across different cells and thus becomes quite comparable to day-to-day scenarios.

Nevertheless in many DR situations traffic load will exceed the permanently installed terrestrial land mobile network (WAN) capacity. The European PPDR organisations have not presented unified DR requirements to CEPT/ECC. ECC had previously discussed the option of finding DR spectrum and network solutions nationally in co-operation between CEPT administrations and the relevant national PPDR organisations, special DR organisations and/or military forces. There is an ECC Recommendation [10] addressing frequency related issues of the broadband DR radio applications.

2.4 PPDR APPLICATIONS

Radiocommunication systems serving PPDR should be able to support a broad range of applications, including the simultaneous use of several different applications with a range of bit rates.

Some PPDR users may require the integration of multiple applications, for example, a combination of voice with high-speed broadband data.

Table 5 below gives an overview of the various PPDR applications alongside the particular feature and specific PPDR examples of use. The applications are grouped under the *narrowband*, *wideband* and *broadband* headings to indicate which technologies are most likely to be required to supply the particular application and their features. The detailed choice of PPDR applications and features to be provided in any given area by PPDR is a national or operator specific matter.

Report ITU-R M.2033 [1] provides a basic description of narrowband, wideband and broadband communications and gives a number of references to other ITU-R Reports and Recommendations addressing narrowband and wideband technologies. (Narrowband - Report ITU-R M.2014 [11]) (Wideband - Report ITU-R M.2014, Recommendation ITU-R M.1073 [12] and Recommendation ITU-R M.1457 [13]).

Broadband technology could be seen as a natural evolutionary trend from wideband. Wideband will not be sufficient to meet future PPDR demands. Broadband applications enable an entirely new level of functionality with additional capacity to support higher speed data and higher resolution images.

Examples of possible broadband applications include:

- high resolution video communications from wireless clip-on cameras to a vehicle mounted laptop computer, used during traffic stops or responses to other incidents.
- 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. The remote real time video view of the patient can demand up to 1 Mbps. This demand for capacity can easily be envisioned during the rescue operation following a major disaster. This may equate to a net capacity of over 100 Mbps.
- high resolution real time video from, and remote monitoring of, fire fighters in a burning building.
- the ability to transmit building plans to the rescue forces

It should be noted that all application types listed in Table 5 can be used in all three radio operational environments, namely “Day-to-day operations” (PP(1)), “Large emergency and/or public events” (PP (2)), and “Disasters” (DR) in mission critical as well as in non-mission critical situations.

Table 5: PPDR applications and examples

Application	Feature	PPDR Example
1. Narrowband		
Voice	*Person-to-person*	*Selective calling and addressing*
	One-to-many	*Dispatch and group communication*
	Talk-around/direct mode operation	*Groups of portable to portable (mobile-mobile) in close proximity without infrastructure*
	Push-to-talk	*Push-to-talk*
	Instantaneous access to voice path	*Push-to-talk and selective priority access*
	Security	*Voice*
Facsimile	*Person-to-person*	*Status, short message*
	One-to-many (broadcasting)	*Initial dispatch alert (e.g. address, incident status)*
Messages	*Person-to-person*	*Status, short message, short e-mail*
	One-to-many (broadcasting)	*Initial dispatch alert (e.g. address, incident status)*
Security	*Priority/instantaneous access*	*Man down alarm button*
Telemetry	*Location status*	*GPS latitude and longitude information*
	Sensory data	*Vehicle telemetry/status*
		EKG (electrocardiograph) in field
Database interaction (minimal record size)	*Forms based records query*	*Accessing vehicle license records*
	Forms based incident report	*Filing field report*
2. Wideband		
Messages	*E-mail possibly with attachments*	*Routine e-mail message*
Data Talk around / direct mode operation	*Direct unit to unit communication without additional infrastructure*	*Direct handset to handset, on-scene localised communications*
Database interaction (medium record size)	*Forms and records query*	*Accessing medical records*
		Lists of identified person/missing person
		GIS (geographical information systems)
Text file transfer	*Data transfer*	*Filing report from scene of incident*
		Records management system information on offenders
		Downloading legislative information
Image transfer	*Download/upload of compressed still images*	*Biometrics (finger prints)*
		ID picture
		Building layout maps

Application	Feature	PPDR Example
Telemetry	Location status and sensory data	Vehicle status
Security	Priority access	Critical care
Video	Download/upload compressed video	Video clips
		Patient monitoring (may require dedicated link)
		Video feed of in-progress incident
Interactive	Location determination	2-way system
		Interactive location data
3. Broadband		
Database access	Intranet/Internet access	Accessing architectural plans of buildings, location of hazardous materials
	Web browsing	Browsing directory of PPDR organisation for phone number
Robotics control	Remote control of robotic devices	Bomb retrieval robots, imaging/video robots
Video	Video streaming, live video feed	Video communications from wireless clip-on cameras used by in building fire rescue
		Image or video to assist remote medical support
		Surveillance of incident scene by fixed or remote controlled robotic devices
		Assessment of fire/flood scenes from airborne platforms
Imagery	High resolution imagery	Downloading Earth exploration-satellite images

The table above is provided in this section in order to give a general overview of the typical PPDR applications rather than to attempt to provide detailed descriptions of the applications suitable for the estimate of the minimal spectrum needs. A much more detailed list of envisioned PPDR applications, with a focus on the broadband ones and along with the technical description of all included applications, is provided in Annex A1.1 (the LEWP/RCEG “Matrix of applications”).

3 FUTURE EUROPEAN BROADBAND PPDR SYSTEMS

3.1 THE CONCEPT OF FUTURE EUROPEAN BROADBAND PPDR SYSTEMS

The *function* of future European BB PPDR systems is to provide, based upon the commonly agreed user requirements between CEPT and PPDR organisations e.g. LEWP, the ability to enable PPDR users to efficiently access and share accurate and timely voice and data information. This information sharing has to be ensured during all stages of an emergency event at any geographic location within their PPDR jurisdiction with the appropriate resources, interoperability, robust and reliable capacity and the ability to dynamically scale to changes in the situation.

It is assumed that *future European BB PPDR systems* will consist of the following two basic elements:

- *BB PPDR Wide Area Network (WAN), and*
- *BB PPDR temporary additional capacity.*

BB PPDR *WAN* should have a coverage level that meets the national requirements and which supports PPDR users with high mobility.

BB PPDR temporary additional capacity (also known as “hot-spot” or “local area” networks) are supposed to provide additional local coverage at the scene of the incident in order to provide the necessary communication facilities to PPDR users in addition to those provided through the WAN or where the WAN radiocommunications are limited or not available. This additional capacity may be provided by ad-hoc networks or other means (such as additional temporary base stations of the WAN) and are supposed to have high capacity and support PPDR users with low mobility.

BB PPDR temporary additional capacity such as ad-hoc networks is assumed to be linked into the WAN infrastructure by some means. Ad-hoc networks may operate in the same (i.e. in a form of an ad-hoc micro-cell deployed at the event’s scene) as well as in a different frequency band, taking account of the CEPT harmonised frequency bands for PPDR radio applications.

Both BB PPDR WAN and temporary additional capacity are supposed to provide radiocommunications to PPDR users in mission critical as well as in non-mission critical situations. Mission critical communicatoin requirements are assumed to be more stringent than those in non-mission critical situations.

In general, the mission areas listed in section 2.1 require the coordinated response of several PPDR organisations. The WAN is intended to permit all PPDR users and their support teams to communicate amongst themselves in a seamless manner and to access the important information they need. Enhanced mission-effectiveness results from enhanced situational awareness. Enhanced situational awareness is predicated upon the ability to access information, to communicate across the involved PPDR organisations, and from having Standard Operating Procedures (SOP) that put into effect the new capabilities.

Initially it is expected that BB PPDR WAN systems will operate together with narrowband TETRA and TETRAPOL networks, and those networks will continue to provide voice and narrowband services for at least the coming decade. In the future the broadband technology will be capable of supporting the PPDR voice services as well as the data applications (see section 5.8).

This concept is in line with the provisions related to the requirements for Public Safety and Security (PSS) wireless communication systems as detailed in ETSI System Reference Document (SRDoc) “ETSI TR 102 628 v1.1.1 (2010-08)”[3] [3]. Although the focus of the SRDoc is on the additional spectrum requirements in the UHF frequency band for mission-critical Public Safety and Emergency Communications, it contains several sections dealing specifically with the system level PPDR requirements and applications, hence its relevance to this ECC Report.

[3] ETSI TC TETRA has identified this SRDoc for revision

The emphasis of the ETSI document is spectrum within the tuning range of the technologies considered. That covers both wideband and broadband applications requiring wide area coverage. The applications described in the SRDoc include voice only, voice and data simultaneously and data only including video. At the same time, the SRDoc also provides justifications for and estimates of the new spectrum needed for both narrowband and wideband applications. ETSI however noted the decision of CEPT WGFM that the main focus will be on the BB requirements, since narrowband and wideband requirements should be covered within the tuning range 380 MHz to 470 MHz, as identified in the ECC/DEC/(08)05 [22].

The contents of ETSI TR 102 628 [3] was revised by TC TETRA in 2010 based on the comments from an ETSI-ECC officials meeting, ECC WGFM and its Project Team FM38. In addition, results of a WGFM PPDR Workshop in March 2010 and existing national studies were taken into account in the revised version of the SRDoc. However, it should be noted that this SRDoc does not entirely reflect the views of CEPT administrations.

The focus of this report is on the definition of the applications and network related requirements of the BB PPDR WAN, specification of typical PPDR operational scenarios, usage of BB PPDR applications and the assessment of the spectrum needs for the BB PPDR WAN. The report also addresses spectrum related aspects for the provision of voice, Air-Ground-Air communications and Direct Mode Operations, but to a lesser extent.

Countries may have widely varying BB PPDR WAN needs as evaluated in this report. To reflect these different needs, the operating bands of future equipment should be wide enough to cover both, the minimum spectrum requirement calculated for BB PPDR WAN which would facilitate cross-border operations and individual national needs (e.g. for DR).

Detailed assessment of the possible spectrum requirements for BB PPDR temporary additional capacity (by ad-hoc networks using other frequencies than the WAN) has not been taken into account in the calculations. Till now there are no commonly agreed requirements on temporary additional capacity, meaning a calculation can only be done in a later stage.

In large emergencies and disasters flexibility should be afforded to PPDR organisations to employ various types of communication platforms e.g. HF, satellite, terrestrial, amateur, Global Maritime Distress and Safety System (GMDSS) at the scene of the incident, but nonetheless this issue is not addressed in this ECC Report.

It is planned to address the various implementation related aspects in the subsequent ECC Report in order to satisfy the BB PPDR related requirements identified in this ECC Report.

3.2 BROADBAND PPDR RELATED REQUIREMENTS DEFINED IN OTHER REGIONS

The desk research on the BB PPDR related activities in other regions carried out by the ECO in order to support the work on this ECC Report revealed several relevant public documents referred to below:

- US NPSTC Public Safety Communications Report: “Public Safety Communications Assessment 2012-2022, Technology, Operations, & Spectrum Roadmap, Final Report, June 5, 2012” [14]
- US NYC study: “700 MHz Broadband Public Safety Applications And Spectrum Requirements, February 2010” [15]
- US FCC White Paper: “The Public Safety Nationwide Interoperable Broadband Network: A New Model for Capacity, Performance and Cost”, June 2010 [16]
- APT Report on “PPDR Applications Using IMT-based Technologies and Networks” No. APT/AWG/REP-27, Edition: April 2012 [17]
- White Paper by Iain Sharp of Netovate announced on the 3GPP website: “Delivering Public Safety Communications with LTE”, January 2013 [18]

ECO was also made aware of the ongoing work on the BB PPDR operational requirements for a Canadian public safety mobile broadband network but that work was not completed by the time of finalisation of this ECC Report.

4 USER REQUIREMENTS

4.1 NETWORK RELATED PPDR REQUIREMENTS

Network related PPDR requirements are the requirements from the perspective of PPDR users who are supposed to utilise the communications network in order to fulfil their duties. Network related requirements describe the communications network's capabilities that are observable to the users.

The following categories of network related PPDR requirements have been identified:

- system requirements;
- security requirements;
- interoperability;
- cost related requirements;
- spectrum usage and management;
- regulatory compliance;
- planning.

It is recognised that there is a strong need for interoperability between European PPDR organisations, The *interoperability* of the their respective communication systems is primarily dependant on the ability of communication equipment to comply to the same technical standard and to operate within the tuning range of the frequency bands used by these systems.

It is also emphasised that *cost related* considerations dictate the need for Europe to seek a solution for future European BB PPDR systems which would have as much in common as possible with the respective BB PPDR regulatory and technical frameworks in other regions. This would enable a reduction in the cost of the system, primarily user terminals, by utilising the advantages of economies of scale. Both PPDR organisations and the industry express a strong preference for a global solution for specialist markets like BB PPDR communications.

It is planned to further address the relevant network related and functional requirements (e.g. the cost related items) in the subsequent ECC Report dealing with possible harmonised solutions for the implementation of future European broadband PPDR systems.

4.2 APPLICATIONS RELATED PPDR REQUIREMENTS (LEWP/RCEG MATRIX)

The “Matrix of applications” (the Matrix, see Annex A1.1) described in this section is based on the requirements of the European PPDR organisations under the auspices by the Law Enforcement Working Party (LEWP). The LEWP reports officially to JHA (Justice & Home Affairs) within the European Council.

4.2.1 General description of the Matrix

The different envisioned PPDR applications along with their description are presented in the Matrix which was produced and agreed by the LEWP in June 2011. The scope of the Matrix includes narrowband, wideband and broadband mobile data applications. It was later complemented by ETSI with a spectrum calculation module for user defined operational scenarios.

The Matrix should be viewed as a toolbox of PPDR applications to be used either individually or in different combinations subject to the demands of the operational situation being attended. The applications included in the Matrix are not linked to any specific technology or implementation platform.

The Matrix has been agreed between European PPDR organisations and is recognised by CEPT administrations as being representative in terms of future PPDR applications.

4.2.2 Creation of the Matrix

Step 1: Cooperation of PPDR organisations within LEWP/RCEG

PPDR organisations have created a list of PPDR applications which is based on their current operational experience and their vision of future working practices.

The list of applications is largely based on PPDR studies from Germany, France, Finland, UK, Belgium, the Netherlands and ETSI. These studies involved Governmental PPDR agencies (e.g. police, fire brigades, emergency medical services). Some of these studies were carried out independently but with the cooperation of PPDR organisations. To reduce the risk of users simply creating a 'wish-list' of requirements, guided interviews were conducted during the course of these studies to ensure all requirements had been properly considered by the PPDR organisations.

The results of these studies were presented at meetings of the LEWP/RCEG (Radio Communications Experts Group). After discussions with the EU Member States representatives, the list of applications was consolidated into a single document and adopted as the so called "LEWP/RCEG Matrix of applicatoins" (Annex A1.1).

Step 2: Use of the Matrix for spectrum calculation

The "Matrix" has been used in the assessment of the application requirements for BB PPDR and to support the standardisation process.

This Matrix, as further developed by ETSI, also has a spectrum estimation module.It is included in Annex 3 A3.6.1 and referred to in this report as "LEWP-ETSI Matrix"

4.2.3 Structure of the Matrix

As explained above, a part of the Matrix (Annex A1.1, sheet "Matrix", column A "Type of application + services"), reproduced in Table 6 in section 4.2.4 below for convenience, was developed and agreed by LEWP/RCEG. ETSI took the lead developing technical parameters and definitions associated with each application.

The Matrix comprises of several sections:

- The types of applications and services are described in the sheet "Matrix" (column A). Every row in the Matrix represents a specific user requirement and provides several characteristics per application (columns B to N), e.g. data timeliness requirements, mobility, monthly usage etc.
- A short explanation of each application is given in the sheet "Explanation".

Some of the applications included in the Matrix will be used in *mission-critical* situations.

4.2.4 Overview of the applications categories

An overview of the applications categories included in the Matrix can be seen in the table below.

Table 6: Applications categories used in the Matrix

Type of application + services
LOCATION DATA
A(V)LS data to CCC (persons + vehicles positions)
A(V)LS data return
MULTI MEDIA
Video from/to CCC for following + intervention
Low quality additional feeds
Video for fixed observation
Low quality additional feeds
Video on location (disaster or event area) to and from control room - high quality
Video on location (disaster or event area) to and from control room - low quality
Video on location (disaster or event area) for local use
Video conferencing operations
Non real time recorded video transmission
Photo broadcast
Photo to selected group (e.g. based on location)
OFFICE APPLICATIONS
PDA PIMsync
Mobile workspace + (incl. public internet)
DOWNLOAD OPERATIONAL INFORMATION
Incident information download (text + images) from CCC to fieldunits + Netcentric working
ANPR update hit list
Download maps with included information to field units
Command & control information incl. task management + briefings
UPLOAD OPERATIONAL INFORMATION
Incident information upload (text + images) to CCC + Netcentric working
Status information + location
ANPR / speed control automatic upload to data base incl. pictures (temporally 'fixed' camera's + from vehicles)
Forward scanned documents
Reporting incl. pictures etc.
Upload maps + schemes with included information
Patient monitoring (ECC) snapshot to hospital

Patient monitoring (ECC) real time monitoring to hospital
Monitoring status of security worker (drop detection, stress level, carbon monoxide etc)
ONLINE DATA BASE ENQUIRY
Operational data base search (own + external)
Remote medical database services
ANPR checking number plate live
Biometric (e.g. fingerprint) check
Cargo data
Crash Recovery System (asking information on the spot)
Crash Recovery System (update to vehicles from data base)
MISCELLANEOUS
Software update online
GIS maps updates
Automatic telemetrics incl remote controlled devices + information from (static) sensors
Hotspot on disaster or event area (e.g in mobile communication centre)
Front office - back office applications
Alarming / paging
Traffic management system: information on road situations to units
Connectivity of abroad assigned force to local ccc

5 MINIMAL SPECTRUM NEEDS FOR BB PPDR WIDE AREA NETWORK

5.1 ASSUMPTIONS ON CANDIDATE TECHNOLOGIES AND FREQUENCY RANGES FOR BB PPDR WIDE AREA NETWORK

The reference technology chosen is LTE Release 10. The details of technical parameters are provided in Annex 2 A2.2.

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.

5.2 METHODOLOGY FOR THE CALCULATION OF BB PPDR WIDE AREA NETWORK SPECTRUM REQUIREMNENTS

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

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

5.2.1 Methodology for PP1

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

Step 1: Definition of the incidents (scenarios) (section 5.3.1)

Step 2: Estimate the total traffic requirement per incident including background traffic (section 5.3.1)

Step 3: Calculate the link budgets and cell size (section 5.4.1)

Step 4: Estimate the number of incidents that should be taken into account simultaneously per cell (section 5.4.2)

Step 5: Estimate the total spectrum requirement based on assumptions on number of incidents per cell, location of incidents within a cell and spectrum efficiency per incident (section 5.4.3).

5.2.2 Methodology for PP2

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

Step 1: Definition of the PP2 scenarios (section 5.3.2)

Step 2: Estimate of the PP2 scenarios traffic (section 5.3.2)

Step 3: Estimate the total spectrum requirement based on assumptions on location of users within the cell and spectral efficiency [§6.5].

5.3 ANALYSIS OF TYPICAL MISSION CRITICAL OPERATIONAL SCENARIOS INVOLVING EXTENSIVE USAGE OF BB PPDR APPLICATIONS

5.3.1 PP1 scenarios

For PP1 type of operations two scenarios were identified based on the input from LEWP/RCEG (see Annex A2.1.1 for details):

- road accident
- “traffic stop” police operation.

5.3.1.1 Road accident

Based on the detailed description of the incident, the following communication requirements were defined:

- all information about the car crash is communicated to emergency and medical services (location, pictures).
- mages to helicopter, (NB two types of AGA, low flying helicopters may use terrestrial networks), DL video link to helicopter.
- patient information sent to control room, then sent to ambulance
- video to hospital of patient on accident site (768 kbps UL).

Peak use: 1 video (768 kbps UL+DL) + data transfer (UL+DL) (approx. 512 kbps, voice is provided with TETRA like networks), values based on the matrix (which provides details).

Table 7:

Road accident	Peak WAN traffic (kbps)
UL	1300
DL	1300

Traffic may be real time (video) or non-real time (for some data transfer).

5.3.1.2 ”Traffic stop” police operation

Based on the detailed description of the incident, the following communication requirements were defined:

- video to control room (camera of patrol vehicle) and database query (license plate)
- video feed available on demand (uplink to control room and downlink to backup vehicle near site)
- access database (return with information and possible photo).

Peak use: 1 video (768 kbps UL+DL) + database access (UL+DL) (approx. 512 kbps)

Table 8:

Traffic stop	Peak WAN traffic (kbps)
UL	1300
DL	1300

5.3.1.3 Background traffic

The applications and their data rates averages are taken from the applications matrix. The data averages correspond to users that will not be transmitting all the time (for example a 324 kbps fixed video feed will transmit on average 64 kbps).

The quality video feeds are considered to be used only for the incident scenarios, so they have not been kept for the background communications.

The number of simultaneous applications has been chosen independently of the size of the cell (which is an approximation); the consequence is that the results do not depend on the frequency band considered.

Uplink traffic

The assumption made in the matrix is that there is one low quality feed at cell edge, the rest is considered to be at average spectral efficiency.

Table 9:

Application	Average per user (kbps)	Multiple simultaneous use	Total traffic (kbps)
Low quality additional multimedia feeds	64	9	576
Low quality additional multimedia feeds (cell edge)	64	1	64
Fixed video	64	5	320
Low quality additional feeds	11	20	220
Other applications (location, patient monitoring)			200

Downlink traffic

Similar assumptions to the uplink case are made here. The background traffic is taken from the LEWP -ETSI Matrix, taking into account that video cameras are included in the incidents and not in background traffic.

Table 10:

Application	Average per user (kbps)	Multiple simultaneous use	Total traffic (kbps)
Low quality additional multimedia feeds	64	8	512
Low quality additional multimedia feeds (cell edge)	64	1	64
Other applications (photos, download maps, etc)			300

5.3.2 PP2 scenarios

For PP2, one scenario for a pre-planned event has been identified based on a real situation (royal wedding in London). One should note that this scenario extrapolates future needs since broadband PPDR was not available at the time of the event. A second scenario for an unplanned event is also provided, based on the London riots.

Royal Wedding in London in April 2011

The estimates below are mainly for communications using the permanent wide area network. On site additional capacity may be provided by other means such as a wireless LAN. This additional capacity can be used for local data exchanges between responders on the site or for specific applications (for example if a robot is deployed, the necessary command and control links would be provided locally). This additional local capacity has not been estimated and may be estimated at a later stage.

It should be stressed here that the assumption used is that the possible additional capacity is not linked to the permanent network. However in the case of planned events such as the one described here, the possibility of such a connection to the permanent network can be taken into account. This means that it can be envisaged that some of the traffic described below could utilise the additional capacity.

The information below has been distilled from discussions on 11th September 2012 with London's Metropolitan police on how Public Safety broadband communications might have been used had they been available to them in 2011.

Policing of the Royal Wedding route is managed in sectors. From a communications perspective each section is managed identically. Subject to how the radio infrastructure overlays the Royal Wedding route, there is a strong possibility of one site having to carry the traffic from two adjacent sectors. The estimates below are applicable to one sector only and are in addition to the routine traffic that would be associated with general crowd control.

- 1 video stream from the Royal Coach.
- 2 video streams from each side of the road from close protection officers lining the route – i.e. 4 streams/sector in total. This assumes video cameras on the 500 officers in each section lining the route on the lookout for suspicious activity directly facing the public can be switched on and off remotely as the royal coach makes it way along the route – hence there would be 2 video streams per side.
- 1 high resolution picture sent per minute from the helicopter to the coach and each of the bronze commanders managing each section. Frequency of updates would increase in the event of an incident.
- Selected still pictures from the helicopter and fixed cameras along the route would be sent to the two covert teams mingling with the crowd as and when felt necessary.
- The 60 officers of the two covert teams in each sector provide GPS based location updates every 5 seconds.

'Business as usual' communications are included as background traffic (see section 5.3.1.3)

<u>Summary of communications</u>

Uplink traffic

Table 11:

UL transmission	Nature of transmission	Mean data rate (kbps)
1 video stream on coach	Video at 768 kbps	768
4 video streams along coach path	Video at 768 kbps	4x768
1 high resolution picture from Helicopter to Control centre every minute	Mbytes per picture every minute	250 average, 500 peak to increase delivery speed
Other communications (including GPS updates)	Data	500
Background communications	See section 5.3.1.3 Table 9:	

Downlink traffic
Selected still pictures are sent to the covert teams.

August 2011 London Riots

The estimates below are for communications using the permanent wide area network. On site additional capacity may be provided by other means such as a wireless LAN. This additional capacity can be used for local data exchanges between responders on the site or for specific applications (for example if a robot is deployed, the necessary command and control links would be provided locally). This additional local capacity has not been estimated (but may be estimated at a later stage).

The information in this paper has been distilled from discussions on 16th November 2012 with the Metropolitan police on how Public Safety broadband communications might have been used had they been available to them during the riots in London of August 2011.

The rioting was triggered by a fatal shooting of a 29 year old man by police. The riots started in the Tottenham area of London where the shooting occurred and then rapidly spread to neighbouring areas around Tottenham and areas further afield both within in London and outside of London. Rioting occurred over four consecutive days.

The PP2 scenarios developed here to assist FM49 calculate spectrum requirements assumes there are two focal points of rioting within close proximity to each other – potentially covered by the same radio communications base station. It should be noted that the there could easily have been more focal points of high police activity being supported on a base station given the nature of the rioting in London.

All incidents are managed by a tried and tested hierarchical Gold (strategic level), Silver (tactical level) Bronze (operational level) command structure. A typical bronze commander would in the case of a dynamic situation such as rioting manage locally up to 300 police officers.

Due to the number of rioting focal points in close proximity to each other two sub Bronze Commanders would have been deployed, one for each rioting focal point reporting to a common Bronze Commander.

The geographic spread and scale of rioting in London required 16,000 additional police officers being drafted in from surrounding forces into London to assist the Metropolitan police contain the situation (through an arrangement known as mutual aid). The immediate issue for police is the protection of the public and property. Identifying and arresting the perpetrators of criminality would not be an immediate priority. Analysis of photographs and video captured at the time would be used post riots to identify culprits for later questioning.

The communication requirements for this PP2 scenario can be summarised as below:

- 2 high quality video streams - one from each sub Bronze Command area – being fed back to Gold and Silver Command. The video would be used to help manage the situation and would be recorded remotely for evidential purposes.
- Bronze and Sub bronze commanders receive regular GPS based location updates of the officers under their command.
- Interactive maps are pushed to officers on the ground to help them navigate to where they needed to be and also which areas/streets they should avoid. Particularly important as many of the officers deployed to contain and quell the rioting were not familiar with the area in which they were working.
- An infrared video feed from a helicopter is fed to fire fighters on the ground to help them tactically fight large fires.
- A video feed from a helicopter is fed back to Gold and Silver Command.
- Numerous still pictures captured by police officers are transmitted back to Gold and Silver command to help manage the situation and to be recorded remotely for evidential purposes.

GNSS throughput:

GPS (one of the GNSS systems) updates for 300 officers per bronze commander (1 transaction every 5 or 15 seconds, 80 bytes per transaction): 0.128 kbps*300=40 kbps.

Table 12:

UL transmission	Nature of transmission	Mean data rate (kbps)
2 video streams from sub Bronze command areas	Video at 768 kbps	2x768
Infrared video from helicopter	Video at 768 kbps	768
Video from a helicopter to central command	Video at 768 kbps	768
Pictures from officers transmitted back to central command (and GPS information from officers)		1000

Table 13:

DL transmission	Nature of transmission	Mean data rate (kbps)
Infrared video to fire fighters	Video 768 kbps	
Interactive maps		1000

The above excludes ambulance, fire (except for the down link infrared video feed) and 'business as usual' traffic.

5.4 CALCULATION OF THE NECESSARY OVERALL SPECTRUM BANDWIDTH FOR PP1

5.4.1 Cell size and link budgets

Cell size is determined by the range of a communication link, more precisely an uplink communication. To evaluate this range a reference modulation for the communication link must be chosen.

5.4.1.1 Reference technology and modulation

LTE technology has been chosen as the reference technology. The performances of several LTE modulations are provided in Annex 2, A2.2 (extracted from 3GPP specifications). The critical parameters are the SINR ratio and the spectral efficiency.

The choice of the uplink reference modulation has been determined using the following assumptions:

- Use of 4 Rx antennas on the base station. This assumption is forward looking but deployment of BB PPDR is expected beyond 2015.
- Use of 70% throughput performance. This assumption enables to keep the spectrum efficiency at a good level. The trade-off is that the size of the cell is a bit smaller due to higher SINR than for 30% throughput.
- Use of EVA 70 Hz Low as channel modelling, this corresponds to vehicles. The performance for pedestrian type of mobility (EPA 5 Hz Low) is better.
- Use of 5 MHz channel performance. The SINR values for 5 MHz are similar to the values for 10 MHz (however the spectral efficiency is a bit lower). This enables more flexibility, in the way spectrum is allocated (long term goal is to have channels of 10 MHz or more).

The cell size reference uplink modulation performance is therefore given by:

Table 14:

Uplink LTE modulation	Spectrum efficiency (bps/Hz)	SINR (dB)
QPSK, CR 1/3, 5 MHz, 1x4 antennas, EVA 70 Hz Low	0.31 (70% throughput)	-3.3

The choice of the downlink reference modulation has been determined using the following assumptions:

- Use of 1x2 antenna configuration (as this is the value provided in the 3GPP specifications). Dual receiver antennas UE are a reasonable assumption in medium to long term.
- Use of 10 MHz band as this is the only bandwidth with values in the 3GPP specifications.
- Propagation EVA 5Hz (as the 70 Hz values are not provided)
- Throughput 70% to keep good spectral efficiency.

The reference downlink modulation performance is therefore given by:

Table 15:

Downlink LTE modulation	Spectrum efficiency (bps/Hz)	SINR (dB)
QPSK, CR 1/3, 10 MHz, 1x2 antennas, EVA 5 Hz Low	0.27 (70% throughput)	-1.0

5.4.1.2 Link budget a cell edge

The link budget is calculated using the reference modulation SINR.

Base station antenna gains are provided for different frequency bands. The details of the link budget are provided in Annex 2 A2.3. The result is given as a maximum allowable path loss for the uplink.

5.4.1.3 Size of cell

The cell range is computed using the maximum path loss translated as a distance using the Okumura-Hata model. Annex 3 provides the cell ranges and the associated cell sizes (surface) for each of the frequency bands and for each environment.

The cell sizes (km*) are computed to be:

Table 16:

Frequency band	Urban	Suburban	Open
420 MHz	11.7	33.9	338.0
750 MHz	6.4	22.1	241.2
1450 MHz	2.5	10.9	139.4

NB: The sizes above a given taking a circular cell. Sizes for hexagonal cells (a more realistic description of a deployment) are provided in the annex.

5.4.2 Number of incidents per cell

The number of incident per cell is computed taking into account the population within a cell and the number of PPDR incidents per population. The population in a cell is given by the size of the cell multiplied by the density of population. The number of incidents in the cell is then given by the size of population multiplied by the rate of incidents per population.

5.4.2.1 Number of incidents per population

The number of incidents per population is extracted from the WiK study using German statistics for PP1 PPDR incidents. It sums up numbers for Police, Firemen and Ambulance.

The statistics provided show an average of 54830 incidents per day in the German territory (2285 incidents per hour). To take into account the fact that incidents are not evenly distributed it is considered that the peak hour average is double: 4570 incidents per hour. The incidents happening in the same hour are considered to be simultaneous. The population of Germany is 81 471 000 people. This gives a value of incidents at peak hour per population of: 0.056 per thousand people.

The WiK study proposes to make the assumption that the distribution of incidents per cell may vary. The variation is estimated as a factor 2. So the final number of simultaneous incident per thousand people to consider is:

Peak number of incident per thousand of population: 0.112

It should be noted that this number this value is valid for a specific country and variations may be expected throughout CEPT. Also it is not known whether the number of incidents in these German statistics correspond to an intervention requiring high speed data services.

5.4.2.2 Number of incidents per cell

Using the cell size shown above and the incident statistics the results for the 400 MHz and 700 MHz bands are given below. The graphic shows the number of incidents (y-axis) within one cell versus the population density within the cell (x-axis). There are three graphics that correspond to rural (0 to 300 pop/km^2), suburban (300 to 3000 pop/km^2) and urban cells (over 3000 pop/km^2). The horizontal lines correspond to the number of incidents per cell-sector with the assumption of three sectors per cell.

One notices in the graphics shown on figures 1 to 3 below that there are fewer simultaneous incidents in the 700 MHz cells than in the 400 MHz cells. This is simply due to the fact that 700 MHz cells are smaller than 400 MHz cells.

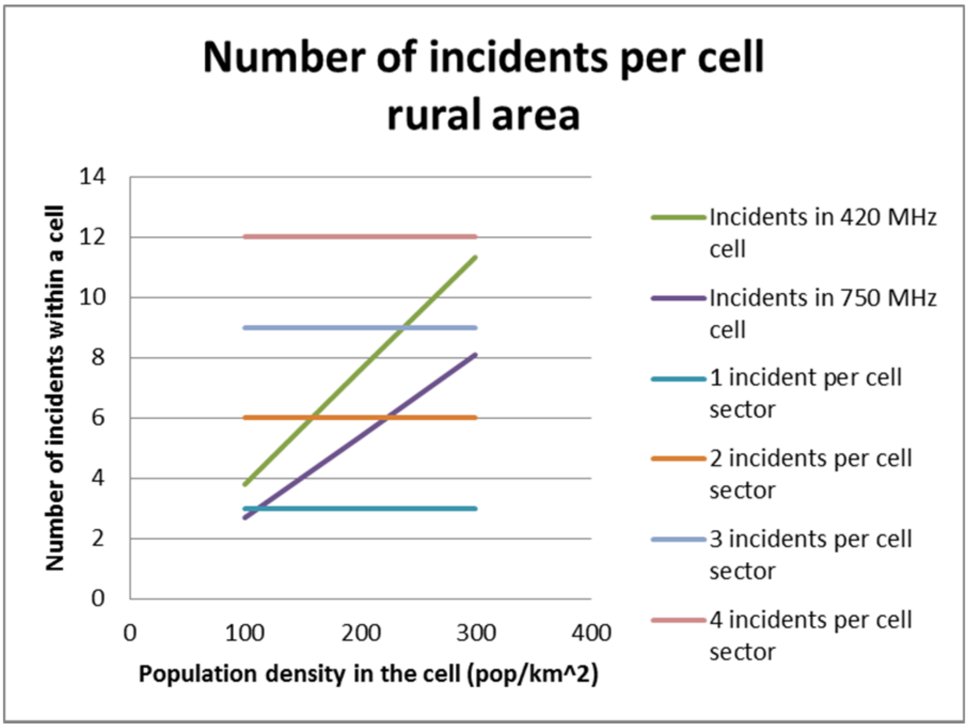


Figure 1: Nnumber of incidents per cell, rural case

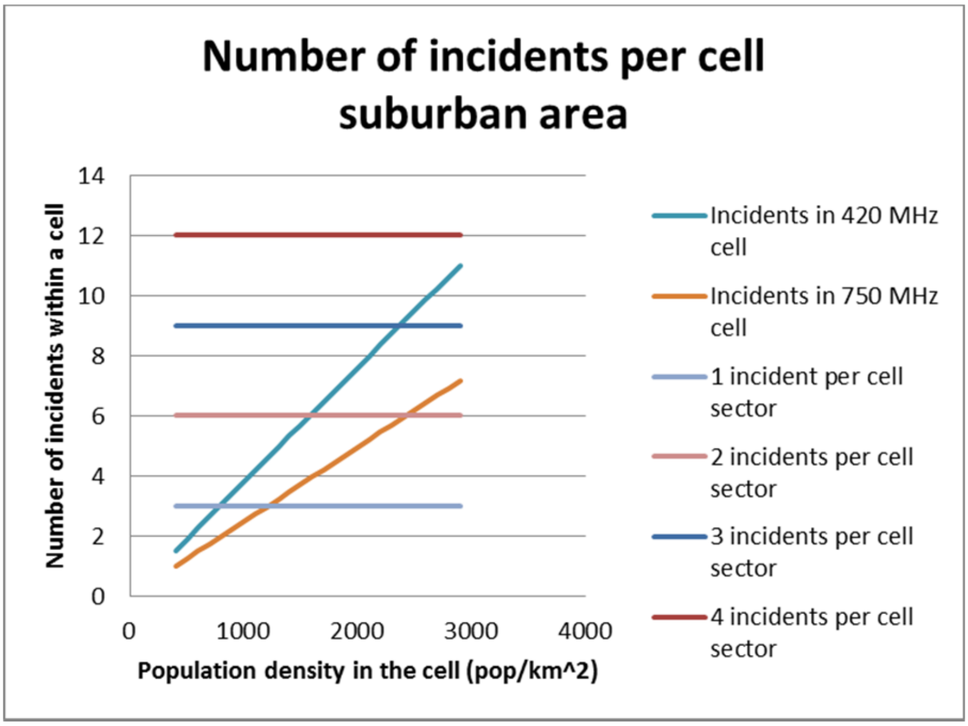


Figure 2: Number of incidents per cell, suburban case

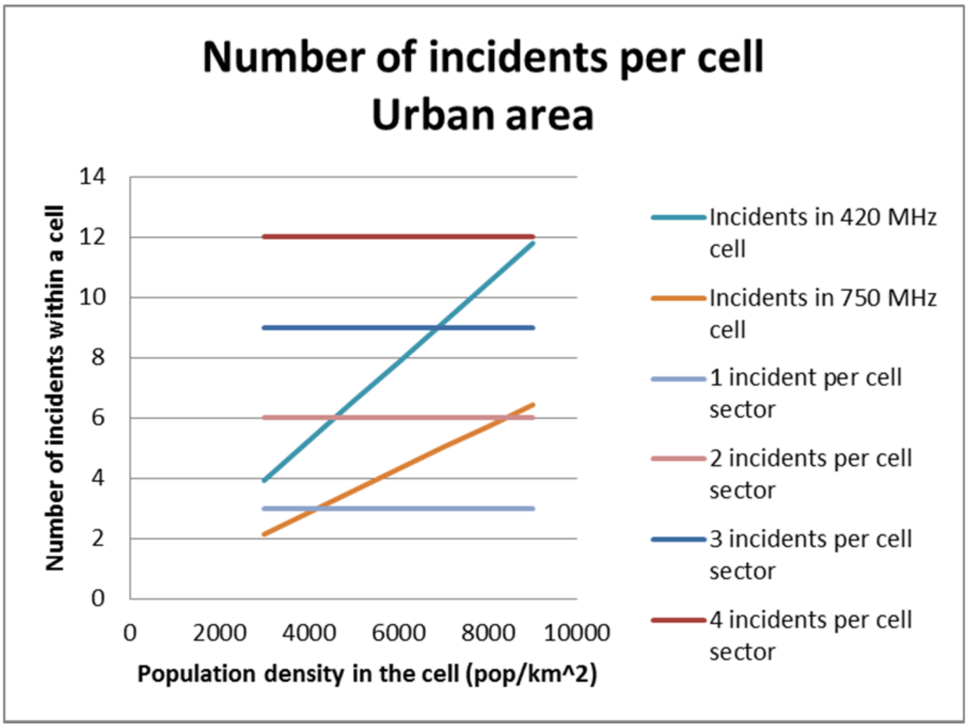


Figure 3: Number of incidents per cell, urban case

The assumptions taken based on the above graphs are the following:

- for a 420 MHz cell, up to 4 incidents per cell sector should be taken into account
- for a 750 MHz cell, up to 3 incidents per cell sector should be taken into account

Note: with the calculation using hexagonal cells (which is more accurate) the assumptionsare the following:

- For a 420 MHz cell, up to 3 incidents per cell sector should be taken into account
- For a 750 MHz cell, up to 2 incidents per cell sector should be taken into account

5.4.3 Total spectrum requirement

5.4.3.1 Location of incidents within the cell and spectral efficiency

1 incident is considered to be at “cell edge”, other incidents benefit from a better spectral efficiency. This distribution of incidents takes into account (by averaging) the possible movements of users within and outside the cell.

Uplink spectral efficiency

UL Efficiency at “cell edge”
The spectral efficiency for “cell edge” is the one calculated for the “reference modulation” as provided in Annex A2.2 Table 48:. This reference modulation has been used to calculate the cell range. The spectral efficiency of this UL reference modulation is 0.31 bps/Hz.

It should be noted that LTE-Advanced performance evaluations (for ITU-R as in 3GPP TR 36.912 [21]) show a cell edge efficiency of 0.06 – 0.1 bps/Hz. The “cell edge” values are strongly dependent on scenarios for adjacent cell load (and also cell size).

The spectral efficiency chosen has a major impact on the spectrum necessary for a given amount of communications.

UL efficiency “well within the cell”

The assumption used is that a 16 QAM 3/4 modulation may be used well within the cell. Depending on the required SINR, spectral efficiency can be expected between 0.64 and 1.49 bps/Hz (see Annex 2).

This is well within the average expected for an LTE-Advanced cell (between 1.33 and 2.27 bps/Hz depending on the use of MIMO, see 3GPP TR 36.912 [21]).

It is proposed to provide those two above values for uplink efficiency as low and average values for spectral efficiency of incidents closer to the cell centre.

Summary of uplink spectral efficiency

Table 17:

Location of incident	Spectral efficiency (Hz)
1 incident at cell edge	0.31
Other incidents within the cell (pessimistic)	0.64
Other incidents within the cell (optimistic)	1.49

Downlink spectral efficiency

DL Efficiency at “cell edge”

The spectral efficiency for “cell edge” is the one calculated for the “reference modulation” as provided in Annex A2.2 Table 49:. The spectral efficiency of this DL reference modulation is 0.27 bps/Hz.

It should be noted that LTE-Advanced performance evaluations (for ITU-R) show a cell edge efficiency of 0.09 – 0.12 bps/Hz (3GPP TR 36.912 [21]).

The spectral efficiency chosen has a major impact on the spectrum necessary for a given amount of communications.

The efficiency at cell edge value chosen for the downlink is lower than the value for the uplink.

DL efficiency “well within the cell”

The assumption used is that either a 16 QAM 1/2 modulation or a 64 QAM 3/4 may be used within the cell. Depending on the required SINR, spectral efficiency can be expected between 0.88 and 1.89 bps/Hz.

This is well within the average expected for an LTE-Advanced cell (between 2.69 and 3.43 bp/s/Hz depending on the use of MIMO, see 3GPP TR 36.912 [21]).

It is proposed to provide those two above values for downlink efficiency as low and average values for spectral efficiency of incidents closer to the cell centre.

Summary for downlink spectral efficiency

Table 18:

Location of incident	Spectral efficiency (Hz)
1 incident at cell edge	0,.27
Other incidents within the cell (pessimistic)	0.88
Other incidents within the cell (optimistic)	1.89

5.4.3.2 Spectrum requirement per incident and background communications

Uplink spectrum per incident

Table 19:

Location of incident	Traffic (kbps)	Spectral efficiency (/Hz)	Bandwidth
Incident at “cell edge”	1300	0.31	4.2 MHz
Incident well within the cell (pessimistic)	1300	0.64	2.0 MHz
Incident well within the cell (average)	1300	1.49	0.9 MHz

Downlink spectrum per incident

Table 20:

Location of incident	Traffic (kbps)	Spectral efficiency (Hz)	Bandwidth
Incident at “cell edge”	1300	0.27	4.8 MHz
Incident well within the cell (pessimistic)	1300	0.88	1.5 MHz
Incident well within the cell (average)	1300	1.89	0.7 MHz

Uplink spectrum for background communications

Some traffic is considered to be at cell edge and for this traffic the corresponding spectral efficiency is used:

Table 21:

	Traffic (kbps)	Spectral efficiency (Hz)	Bandwidth
Background communications at cell edge	64	0.31	0.2 MHz

The rest of the traffic is considered to be well within the cell resulting in the following values for bandwidth where two possible values for spectral efficiency are used:

Table 22:

	Traffic (kbps)	Spectral efficiency (Hz)	Bandwidth
Background communications well within the cell (pessimistic)	1316	0.64	2.1 MHz
Background communications well within the cell (average)	1316	1.49	0.9 MHz

The addition of the traffic at cell edge and within the cell gives for uplink communications (where two estimates are provided according to the assumptions on spectral efficiency):

Table 23:

Frequency band		Low estimate	Medium estimate
Independent of frequency band	Background communications	1.1 MHz	2.3 MHz

<u>Downlink for background communications</u>

Some traffic is considered to be at cell edge and for this traffic the corresponding spectral efficiency is used:

Table 24:

	Traffic (kbps)	Spectral efficiency (Hz)	Bandwidth
Background communications well within the cell (pessimistic)	64 kb/s	0.27	3.3 MHz

The rest of the traffic is considered to be well within the cell resulting in the following values for bandwidth where two possible values for spectral efficiency are used:

Table 25:

	Traffic (kbps)	Spectral efficiency (Hz)	Bandwidth
DL Background communications well within the cell (pessimistic)	812 kb/s	0.88	0.9 MHz
DL Background communications well within the cell (average)	812 kb/s	1.89	0.4 MHz

The addition of the downlink traffic at cell edge and within the cell gives for uplink communications (where two estimates are provided according to the assumptions on spectral efficiency):

Table 26:

Frequency band		Low estimate	Medium estimate
Independent of frequency band	DL background communications	0.7 MHz	1.2 MHz

5.4.3.3 Total Results

Total uplink bandwidth

Table 27:

Frequency band		Low estimate	Medium estimate
420 MHz	1 incident “cell edge” 3 incidents near cell centre and background communications	8.0 MHz	12.5 MHz
750 MHz	1 incident “cell edge” 2 incidents near centre and background communications	7.1 MHz	10.7 MHz

Total downlink bandwidth

Table 28:

Frequency band		Low estimate	Medium estimate
420 MHz	1 incident “cell edge” 3 incidents near centre with background communications	7.6 MHz	10.5 MHz
750 MHz	1 incident “cell edge” 2 incidents near centre with background communications	6.9 MHz	9.0 MHz

5.5 CALCULATION OF THE NECESSARY BANDWIDTH FOR PP2

The calculation for the PP2 scenarios does not critically depend on the frequency band considered, since all communications are considered to be within a small area which is completely contained within the cell (where in PP1 there was a difference included).

5.5.1 Assumptions for the Royal Wedding scenario

There are 5 active cameras, 4 along the path and 1 on the coach (as described in Annex A2.1.1).
It can be assumed that at least 3 cameras are in the vicinity of the coach. These three cameras can be at cell edge simultaneously. The worst case scenario is that all 5 video cameras are at cell edge. A less stringent assumption is that only 3 video cameras are at cell edge and the two other ones are at a location closer to the cell centre. The results for these two assumptions are provided below.

The reference modulation chosen for “cell edge” gives a spectral efficiency of 0.31 bps/Hz for uplink (see Annex A2.2 Table 48:). Communications from the helicopter can be considered to be at average spectral efficiency.

5.5.2 Results for worst case

Table 29:

	Traffic (kbps)	Spectral efficiency (bps/Hz)	Bandwidth
5 Video cameras at cell edge	5x768	0.31	12.5 MHz
Pictures from helicopter (and other data such as GPS)	1000	1.49	0.7 MHz
Background traffic	See section 5.3.1.3		1.1 MHz

5.5.3 Results for less stringent assumptions

Table 30:

	Traffic (kbps)	Spectral efficiency (bps/Hz)	Bandwidth
3 Video cameras at cell edge	3x768	0.31	7.5 MHz
2 Video cameras well within the cell	2x768	1.49	1.0 MHz
Pictures from helicopter (and other data such as GPS)	1000	1.49	0.7 MHz
Background traffic	See section 5.3.1.3		1.1 MHz

5.5.4 Total results for the Royal Wedding scenario

Table 31:

Frequency band	Traffic scenario	Less stringent case	Worst case
Independent of frequency band	PP2 traffic scenario with background communications	10.3 MHz	14.3 MHz

5.5.5 Assumptions for London riots PP2 scenario

There are two different assumptions for the video cameras of the two sub-bronze commanders. In the worst case the two cameras are at cell edge. In the less stringent case only one camera is at cell edge. For the videos from the helicopter (both normal and infrared) a good spectral efficiency is assumed as it would be close to line of sight propagation.

Bandwidth analysis uplink (worst case):

Table 32:

	Traffic (kbps)	Spectral efficiency (bps/Hz)	Bandwidth
2 Video camera from Bronze commander at cell edge	2x768	0.31	5 MHz
Video from helicopter	1x768	1.49	0.5 MHz
Pictures from officers transmitted back to central command (and GPS information from officers)	1000	1.49	0.7 MHz
Infrared Video from helicopter	1x768	1.49	0.5 MHz
Background traffic	See section 5.3.1.3		1.1 MHz

Bandwidth analysis uplink (less stringent scenario assumptions):

Table 33:

	Traffic (kbps)	Spectral efficiency (bps/Hz)	Bandwidth
1 Video camera from Bronze at cell edge	1x768	0.31	2.5 MHz
1 Video camera from Bronze at better efficiency	1x768	1.49	0.5 MHz
Video from helicopter	1x768	1.49	0.5 MHz
Pictures from officers transmitted back to central command (and GPS information from officers)	1000	1.49	0.7 MHz
Infrared Video from helicopter	1x768	1.49	0.5 MHz
Background traffic	See section 5.3.1.3		1.1 MHz

Bandwidth analysis downlink:

Table 34:

	Traffic (kbps)	Spectral efficiency (bps/Hz)	Bandwidth
Infrared Video to fire fighters	1x768	1.49	0.5 MHz
Interactive maps	1000	1.49	0.7 MHz
Background traffic	See section 5.3.1.3		1.1 MHz

5.5.6 Total results for the London Riots scenario

The results are given for the uplink bandwidth requirement since uplink communications require more bandwidth than downlink communications:

Table 35:

Frequency band	Traffic scenario	Less stringent case	Worst case
Independent of frequency band	PP2 traffic scenario with background communications	5.8 MHz	7.8 MHz

5.6 SPECTRUM REQUIREMENT CALCULATED WITH A DIFFERENT METHODOLOGY

Based on the LEWP-RCEG Matrix of PPDR applications (Annex A1.1) a different computation for the spectrum requirements is provided in ANNEX 3:. This calculation is based on an estimation of needed capacity for each application.

5.6.1 Comparison of incident based approach with LEWP-ETSI Matrix calculations

The computation based on the LEWP/RCEG Matrix provides similar results to the scenario based approach presented in Chapter 5 above. The differences between the two can be explained by the different sets of assumptions used for each methodology (see explanation below).

The spectrum calculations presented in sections 5.4 and 5.5 have been derived using the incidents defined by the LEWP-RCEG. The defined PP1 incidents are limited in scope with generally only one video being sent back to the command centre. The number of incidents per cell has been computed using general occurrence statistics for incidents (statistics provided by a specific country) which include all kind of incidents (even minor ones). This means that depending on the size of the cell there can be up to 4 simultaneous PP1 incidents. The background traffic therefore consists mostly of routine communications and is therefore limited.

The “Matrix” spectrum calculations are based on one and two simultaneous major incidents (with 4 high quality videos and a number of low quality videos for an individual incident). However background communications include communications that cover small scale incidents happening anywhere within the cell. Therefore the Matrix provides results in PP2 scenarios only (with PP1 background load also included in the calculations), as PP2 scenarios are more demanding. In this estimation there is therefore more background communications when compared with the calculations in section 5.5.

Differences between the incident based approach (secions 5.1 to 5.5) and the methodology used for the LEWP-ETSI Matrix-based calculations (this section) are further discussed in Annex A3.4.

These two estimations are in good agreement when identical technical assumptions for the spectrum efficiency are used.

The calculations are as mentioned above in Annex A3.5.

5.6.2 Conclusions

The summary results in the tables below show the range of results for the different scenarios, with one and two incidents within a cell or sector for uplink and downlink, and with individual call or mixed individual and group calls in the downlink. The variation in results is due to both the offered load in the various scenarios, and also the placement of the incident(s), whether at an optimistic location in the cell, or where one incident occurs at the edge of the cell.

Table 36:

Uplink, MHz						
	Optimistic spectrum efficiency			Pessimistic spectrum efficiency		
	Minimum	Maximum	Average	Minimum	Maximum	Average
1 incident	6.1	10.5	8.0	6.1	17.1	10.7
2 incidents	6.7	14.8	11.1	7.1	21.2	13.8

Table 37:

Downlink, MHz							
		Optimistic spectrum efficiency			Pessimistic spectrum efficiency		
		Minimum	Maximum	Average	Minimum	Maximum	Average
1 incident	Individual only	7.0	11.4	9.3	7.2	14.3	9.3
	Group+Individual	5.3	7.7	6.4	6.6	9.4	7.9
2 incidents	Individual only	7.1	12.5	9.0	7.4	15.3	9.9
	Group+Individual	5.5	8.3	6.8	6.7	10.2	8.4

Concluding from the analysis, **at least 10 MHz is required for the terrestrial network (WAN) uplink**. With 10 MHz made available, many but not all of the scenarios can be accommodated. The 'average' 2 incident demand with optimistic edge of cell spectrum efficiency at 11 MHz is 10% higher than this figure, which implies that arrangements for additional bandwidth may be needed in some circumstances.

At least 10 MHz will also be required for the terrestrial network (WAN) downlink. With 10 MHz made available many of the scenarios which utilised individual calls can be accommodated. All scenarios can be accommodated in a 10 MHz downlink where group calls are optimally used.

Note that, as mentioned previously, this analysis does not incorporate the demands for voice call, Direct Mode Operation and Air-Ground-Air communications except for some limited uplink traffic included in some scenarios. These will require additional or separate spectrum.

5.7 CONCLUSIONS OF SPECTRUM CALCULATIONS

Estimates for PP1 and PP2 operations are provided separately. PP1 operations correspond to day-to-day operations and can be considered as the minimum requirement for PPDR activity. PP2 operations correspond to large emergencies and/or public events, the size of which and preparation time may vary a lot. Generally, additional radiocommunications equipment for pre-planned large events is brought to the area as required. Therefore it is more difficult to provide exact bandwidth values for PP2 requirements and those are provided separately below.

In the values shown below only the uplink requirements are presented as they are the most constraining (see section 5.4 (PP1) above for the downlink values).

5.7.1 Spectrum needs for PP1 scenarios

Table 38:

Frequency band	Uplink	Low estimate	Medium estimate
420 MHz	1 incident “cell edge” 3 incidents near cell centre and background communications	8.0 MHz	12.5 MHz
750 MHz	1 incident “cell edge” 2 incidents near centre and background communications	7.1 MHz	10.7 MHz

The difference between the low and medium estimate is not in the traffic scenarios (both have identical radio throughput) but in the assumptions used for spectral efficiency.

The difference between the estimate for 420 MHz and 750 MHz is due to the fact that the size of cells at 400 MHz is larger than the size for 700 MHz cells. This implies that more incidents can occur, causing more throughput. However if there is not enough available spectrum, the size of the 400 MHz cells can be made smaller through network planning. In that case the results for the 700 MHz cells are then valid for those smaller 400 MHz cells. This means that **with proper network planning a spectrum requirement in the range of 10 MHz for uplink and another 10 MHz for downlink can enable to cover the PP1 cases** used in this report.

Note:The calculations for PP1 are made for the terrestrial network (WAN).

As indicated in section 2.3.1, PPDR is also using DMO and AGA in PP1 and PP2 operations. The spectrum related aspects of DMO and AGA are dealt with in more detail in section 5.9.

5.7.2 Spectrum needs for PP2 scenarios

The PP2 estimate is based on a two PP2 scenarios (one for a planned event and the other one for an unplanned event). The final estimate chosen for PP2 is based on the most traffic heavy scenario (the royal wedding in London in April 2011). This estimate does not take into account possible additional capacity that could be set up in case of a planned event (such as the specific scenario used in this estimate). It is difficult to quantify what portion of traffic could be diverted towards the additional temporary capacity, but one can expect that in some cases part of the bandwidth estimated in the table below may be substituted with temporary capacity.

Table 39:

Frequency band	Uplink	Less stringent case	Worst case
Independent of frequency band	PP2 traffic scenario with background communications	10.3 MHz	14.3 MHz

The difference between the worst case and the less stringent case is not in the traffic scenarios (both values correspond to identical throughput) but in the assumptions used for spectral efficiency. It is considered that a **bandwidth in the range of 10 MHz for the uplink and another 10 MHz for the downlink provide enough capacity to meet the core requirements of the PP2 scenarios** presented in this report. It should be noted that situations can occur that would exceed the capacity of the permanent network. In the case of pre-planned event, this means that additional temporary capacity should be considered to increase the permanent WAN network capacity.

5.7.3 Spectrum needs for DR

The assumption in this report is that DR spectrum requirements would be in the same range as the requirements for planned or unplanned PP2 events (with in some cases communication requirements being spread out over a larger geographical area). Therefore **the spectrum estimate for PP2 covers the early needs of a DR event** (noting that this is a simplifying assumption).

5.8 VOICE

The calculations presented in this report are only for BB data. The assumption is that mission critical voice will be carried in most countries by the existing dedicated mission critical voice (+ NB data) TETRA and TETRAPOL networks for many years (10-15 years). At the moment for mission critical voice there is a harmonised European NB PPDR allocation of 2x5 MHz in the 380-400 MHz band.

It is expected that eventually the NB network would migrate to BB technology within the present NB spectrum or that BB-voice and BB-high speed data would use the same newly designated BB spectrum. This last possibility would have an impact on the BB spectrum requirements presented in section 5.7 above.

The case where the NB spectrum migrates to BB PPDR technology enables more voice capacity to be provided in the current NB spectrum through more advanced BB technology. The extra capacity, a sort of technological dividend, could be used for different purposes such as DMO.

In the case where the current NB spectrum is released to other users the BB network (based on LTE) has to also support PPDR voice capacity requirements. The total BB data transmission capacity would then need to be higher. This scenario has the advantage of using a single network for all types of communications. It could be less expensive, less complex and easier to manage than two networks. 3GPP is currently working to include group voice communication functionality into the LTE standard. The expectation is that in the future LTE can offer this service. This will mean that the existing mission critical voice networks may migrate to BB technology or are not needed anymore. At this moment it is not known if the NB spectrum will be reused or if extra BB spectrum will be needed for the extra capacity in the LTE network as result of the extra bandwidth needed for the voice application. This choice is left to national decisions in terms of full flexibility. However CEPT administrations may decide to investigate the potential for a harmonised approach in the future.

In ANNEX 4: there is an evaluation of the voice capabilities of a BB network (based on LTE) compared with current NB networks (such as TETRA and TETRAPOL). The calculation shows that the future BB technology could provide the voice capacity with a comparable (or better) efficiency to current NB PPDR technologies (according to the calculation, **it is estimated that 2x3.2 MHz would be needed for voice traffic**).

In ANNEX 6: the TCCA (TETRA + Critical Communications Association) “Voice → BB data/voice” roadmap is presented for information.

5.9 DMO & AGA

The calculations in sections 5.4, 5.5 and 5.6 are restricted to high speed data communications in the terrestrial network (WAN). The underlying assumption is that voice communications are provided through the current communication capacity in the 380-385/390-395 MHz band.

As indicated in section 2.3.1 PPDR is also using Direct Mode Operation (DMO) and Air-Ground-Air (AGA) communications in PP1 and PP(2) operations These can be a also used in DR situations. In this section the spectrum related aspects of DMO and AGA are discussed.

5.9.1 Air-Ground-Air (AGA)

There are a few NB channels in the 380-385/390-395 MHz band that are currently identified for AGA communications. The use of these channels varies on a national basis and they need to be cross-border coordinated.

In addition to the terrestrial PPDR network requirements discussed so far, PPDR organisations may also have requirements for Broadband airborne applications as used in the terrestrial PPDR network (WAN), e.g. from UAVs or helicopters to support PPDR operations. These typically involve a video stream being relayed from a camera mounted on a helicopter to a monitoring station on the ground. The application is effectively a point-to-point link but because the helicopter is moving it is difficult to deploy very directional antennas, so there is a risk of interference over a fairly wide area.

Ideally the airborne PPDR communication system should be compatible (i.e. within the tuning range) with the terrestrial BB networks (WAN).

Some countries have already reserved spectrum specifically for such use, for example the UK has aggregated approximately 42 MHz between 3.1 GHz and 3.4 GHz for digital video from airborne vehicles, and Germany has allocated spectrum in the 2.3 GHz band.

At the moment, there is no harmonised frequency band for public safety air to ground applications in Europe. Given the nature of such applications, the same level of functionality including access to data applications such as GIS and data bases etc as terrestrial based units is required. AGA operation can cover a very wide area and have potential benefit for cross-border operations. Therefore PPDR AGA communication is envisioned to become an integral part of future European BB PPDR systems. Harmonisation of AGA spectrum would have many advantages (in particular regarding cross-border coordination).

The spectrum requirements for PPDR airborne communications have not been calculated within this report. An estimation by a CEPT administration has been included in ANNEX 5: which provides an example of possible spectrum requirements.

5.9.2 Direct Mode Operation (DMO)

DMO is an important means of communicating voice and NB data.

DMO is now used in NB systems in several ways:

- when there is no coverage (e.g. in buildings, tunnels etc), or when there is a risk of loss terrestrial coverage, which is especially important for the police and fire organisations
- to extend coverage by enabling a low powered person-worn hand portable terminal to communicate with a higher powered vehicle mounted terminal located within the coverage range of the terrestrial infrastructure.
- as extra capacity e.g. in case the terrestrial network (WAN) is congested
- as a fallback when the terrestrial network fails
- for foreign units crossing the border etc.

The expectation is that ”BB data DMO” capability will also be needed to facilitate ‘device-to-device’ data communication.

3GPP is working on the inclusion of DMO into the LTE specifications Release 12.

While 3GPP has not finished the DMO part of the specificationsit is difficult to make a correct assessment of the spectrum related implications. It is not known whether there is a need to reserve spectrum for BB data DMO or whehter it can be integrated within the WAN spectrum. DMO capabilities could then either come from the BB spectrum or from the migration of the NB spectrum to BB technologies.

6 CONCLUSIONS

The results of the spectrum calculations should be seen as an assessment based on current knowledge. The results should be rather rated as the minimum needed amount of spectrum for future European BB PPDR systems without however excluding any spectrum options to be examined. Countries may choose to designate the necessary amount of spectrum, which may be more than the calculated minimum WAN spectrum requirements or less than that, depending on national situatoins.

It is recognised that the PPDR sector, including the associated radiocommunications, is a sovereign national matter, and that the PPDR needs of European countries may vary to a significant extent. Therefore, future harmonisation of the PPDR sector in Europe needs to be flexible enough to consider different needs such as the amount of available spectrum and the possible use of commercial networks, while at the same time ensuring interoperability between the different countries as well as maximising the economics of scale.

To reflect these different needs while keeping flexibility in mind the concept of harmonised tuning range will be considered. In order to implement this concept the operating bands of future equipment should be wide enough to cover both, the minimum requirement calculated and individual national needs e.g. for DR.

6.1 SPECTRUM NEEDS FOR PP1 SCENARIOS

Depending on the frequency band and the scenario assumptions the PP1 spectrum requirement for Wide Area Network (WAN) has been estimated between 7.1 MHz and 12.5 MHz. Somewhat higher estimations were obtained when using the “LEWP-ETSI Matrix” calculation depending on assumptions for incidents and spectrum efficiency parameters. An amount of spectrum in the range of 10 MHz for uplink and another 10 MHz for downlink is considered to cover most needs of PP1 scenarios as described in section 5.4 above).

6.2 SPECTRUM NEEDS FOR PP2 SCENARIOS

For the most traffic heavy PP2 scenario (a pre-planned event), the spectrum need has been estimated between 10.3 MHz and 14.3 MHz. Somewhat higher estimations were obtained when using the “LEWP-ETSO Matrix” calculation depending on assumptions for incidents and spectrum efficiency parameters. Taking into account that in some cases, such as pre-planned events, some additional temporary capacity may be provided, the same 2x10 MHz for WAN is considered to cover most needs of the PP2 scenarios as well as PP1 scenarios as described in section 5.5 above.

6.3 OVERALL SPECTRUM NEEDS FOR BB PPDR WAN

The values provided in this study for spectrum requirement for a BB PPDR Wide Area Network show a range of results based on a set of assumptions. This shows that the spectrum requirement values are scenario dependent. It is however relevant to try to provide a single spectrum requirement figure that provides the capacity to deal with most situations. Taking into account PP1 and PP2 scenarios the value of **2x10 MHz (10 MHz uplink, 10 MHz downlink) covers most needs for both types of PPDR operational scenarios**. It should be noted that the spectrum requirement may be adjusted to national situations.

6.4 SPECTRUM NEEDS FOR DISASTER RELIEF

In general it is considered that the estimated spectrum requirements for PP2 scenarios are sufficient to cover basic DR spectrum requirements when the permanent terrestrial network (WAN) has not been disabled.

6.5 SPECTRUM NEEDS FOR VOICE, AGA, DMO AND AD-HOC NETWORKS

6.5.1 Voice

The spectrum requirement presented in section 6.3 above has been calculated for broadband data communications only in a future BB PPDR terrestrial network (WAN). Voice traffic has not been taken into account. However, it is expected that future BB networks will carry voice traffic.

Two solutions are possible:

- either the migration of current NB voice and data networks to BB technology, or
- the release of the current NB spectrum and the inclusion of the voice traffic within the future BB spectrum used for BB PPDR.

It should be noted that the decision for BB migration or release of the NB PPDR spectrum will not be taken in the short term and could be subject to national considerations.

Based on the calculation in ANNEX 4:, voice communications needs can be provided by BB technologies with less than the 2x5 MHz of NB PPDR spectrum available today. **A spectrum estimate for voice in a future BB PPDR terrestrial network (WAN) indicates a need of around 2x3.2 MHz**.

Any possible additional spectrum need for voice will depend on the reuse of the NB PPDR spectrum.

6.5.2 Air-Ground-Air communications

The mentioned in the section 6.5.1 above spectrum requirements for voice are identified for the terrestrial Wide Area Network (WAN). However some PPDR organisations also use aircraft and there could be a need for BB AGA communications within the WAN. As national studies show this could have an impact on the overall spectrum needs, but this has not been evaluated in this report (although some limited air to ground usage is included in few scenarios). An example of the amount of spectrum needed for AGA communications from a CEPT administration has been included in the report (ANNEX 5:) and two other examples of national decisions are referred to in section 5.9.1.

It should be noted that harmonised AGA spectrum facilitates cross-border coordination.

6.5.3 Direct Mode Operation

DMO capability is another need specific to PPDR operations. DMO traffic has not been included in the scenarios studied in this report as all communications that were included were considered to utilise the permanent terrestrial network (WAN). However there are some cases where DMO communications are envisaged (see section 5.9.2). Depending on the technical implementation of DMO into the future BB PPDR solutions, DMO operations could use spectrum designated for the permanent terrestrial network or would need reserved frequencies. This could have an impact on the overall spectrum needs but this has not been evaluated in this report.

6.5.4 Ad-hoc networks

Spectrum requirements for BB PPDR ad-hoc networks have not been estimated in this report. However harmonisation of spectrum for BB PPDR ad-hoc networks may be a subject for further studies by CEPT.

The focus of the subsequent ECC Report will be to identify options how the identified user requirements and calculated WAN spectrum needs can be implemented within the candidate bands for future European BB PPDR systems.

ANNEX 1: LEWP/RCEG MATRIX OF APPLICATIONS

This Annex contains the “Matrix of applications” developed and agreed by LEWP/RCEG group. It contains an overview of the envisioned PPDR applications, with a short description and specific characteristics for each application.

At a later stage there was cooperation between LEWP/RCEG and ETSI TC TETRA WG4. ETSI added many technical details to the Matrix and also complemented it with a spectrum calculation module. This made the Matrix capable of detailed assessment of the necessary spectrum for PPDR communications under different operational scenarios. The Matrix with the spectrum calculation capability is referred to in this report as “LEWP-ETSI Matrix” and can be found in Annex A3.6.1

A1.1 MATRIX OF APPLICATOINS

LEWP/RCEG Matrix

ANNEX 2: ASSUMPTIONS FOR SPECTRUM CALCULATIONS (CHAPTER 5 EXCEPT SECTION 5.6)

A2.1 DESCRIPTION OF PPDR OPERATIONAL SCENARIOS

A2.1.1 Input from LEWP-RCEG

The document included below is an input from LEWP-RCEG containing a detailed description of the following scenarios used for spectrum calculations in Chapter 5:

- Road accident (a PP1 scenario referred to in the LEWP-RCEG input as “Response to car crash” in sub-section 2.2.1 EMS: Routine Patient Services
- “Traffic stop” police operation (a PP1 scenario referred to in the LEWP-RCEG input as “2.2.2 Law Enforcement: Traffic stop scenario”)
- Royal wedding in London in April 2011 (a preplanned PP2 scenario referred to in LEWP-RCEG input as “2.1 A royal wedding scenario”); this scenario was created based on the discussion with London’s Metropolitan police in September 2011.

Input from
LEWP-RCEG

A2.1.2 Input from “Airwave Solutions Ltd.” company (UK)

The document included below is an input from the “Airwave Solutions Ltd.” company based in the UK. It provided this input following a meeting with London’s Metropolitan police:

- London Riots in August 2011 (an unplanned PP2 scenario).

Input from Airwave
Solutions Ltd.

A2.2 LTE MODULATIONS PERFORMANCES

The values provided below are extracted from 3GPP performance specifications (LTE Release 10).

Uplink SNR performance (PUSCH)

Performance given by Table 8.2.1.1-3, 3GPP TS 36.104 Release 10 [19].

Propagation conditions: EPA 5 Hz Low (see Annex B of 3GPP TS 36.104 Release 10).

The SNR are given for 2 Rx antennas and 4 Rx antennas.

Table 40:

QPSK, 1/3

Bandwidth	SNR 2 Rx antennas	SNR 4Rx antennas	Max throughput (Mbps)	Fraction of max throughput	Effective spectral efficiency (bps/Hz)
5 MHz	-4.7	-7.1	2.216	30 %	0.13
5 MHz	-0.7	-3.8	2.216	70 %	0.31
10 MHz	-4.2	-6.8	5.160	30 %	0.15
10 MHz	-0.4	-3.5	5.160	70 %	0.36

Table 41:

16 QAM, 3/4

Bandwidth	SNR 2 Rx antennas	SNR 4Rx antennas	Max throughput (Mbps)	Fraction of max throughput	Effective spectral efficiency (bps/Hz)
5 MHz	10.4	7.6	10.68	70 %	1.49
10 MHz	10.8	7.5	21.384	70 %	1.49

Table 42:

64 QAM, 5/6
Propagation conditions EVA 70 Hz Low:

Bandwidth	SNR 2 Rx antennas	SNR 4Rx antennas	Max throughput (Mbps)	Fraction of max throughput	Effective spectral efficiency (bps/Hz)
5 MHz	18.0	14.4	18.336	70 %	2.56
10 MHz	18.3	14.7	36.696	70 %	2.56

Table 43:

QPSK, 1/3

Bandwidth	SNR 2 Rx antennas	SNR 4Rx antennas	Max throughput (Mbps)	Fraction of max throughput	Effective spectral efficiency (bps/Hz)
5 MHz	-4.5	-6.9	2.216	30 %	0.13
5 MHz	-0.1	-3.3	2.216	70 %	0.31
10 MHz	-4.1	-6.7	5.160	30 %	0.15
10 MHz	+0.1	-2.9	5.160	70 %	0.36

Table 44:

16 QAM, 3/4

Bandwidth	SNR 2 Rx antennas	SNR 4Rx antennas	Max throughput (Mbps)	Fraction of max throughput	Effective spectral efficiency (bps/Hz)
5 MHz	4.4	1.2	10.68	30 %	0.64
5 MHz	12.3	8.3	10.68	70 %	1.49
10 MHz	4.5	0.7	21.384	30 %	0.64
10 MHz	12.6	8.0	21.384	70 %	1.49

Downlink SNR performance (PDSCH)

Performance given by Table 8.2.1.1.1-2 (3GPP TS 36.101 rRelease 10 [20])

Antenna configuration: 1x2 dual receiver antenna (correlation matrix: Low).

Table 45:

QPSK R=1/3
Propagation conditions: EVA5 (see 3GPP TS 36.101 rel 10)

Bandwidth	SNR (dB)	Max throughput (Mbps)	Fraction of max throughput	Effective spectral efficiency (bps/Hz)
10 MHz	-1.0	3.953	70 %	0.27

Table 46:

16 QAM R=1/2
Propagation conditions: EVA5

Bandwidth	SNR (dB)	Max throughput (Mbps)	Fraction of max throughput	Effective spectral efficiency (bps/Hz)
10 MHz	6.7	12.586	70 %	0.88

Table 47:

64 QAM R=3/4
Propagation conditions: EVA5

Bandwidth	SNR (dB)	Max throughput (Mbps)	Fraction of max throughput	Effective spectral efficiency (bps/Hz)
10 MHz	17.7	27.294	70 %	1.89

Proposal for PPDR spectrum requirements:

Uplink:
For determining the cell size a reference uplink modulation must be chosen. The following technical assumptions are proposed:

- Use of 4 Rx antennas on the base station. This assumption is forward looking but deployment of BB PPDR is expected beyond 2015.
- Use of 70% throughput performance. This assumption enables to keep the spectrum efficiency at a good level. The trade-off is that the size of the cell is a bit smaller due to higher SINR than for 30% throughput.
- Use of EVA 70 Hz Low as channel modelling, this corresponds to vehicles. The performance for pedestrian type of mobility (EPA 5 Hz Low) is better.
- Use of 5 MHz channel performance. The SINR values for 5 MHz are similar to the values for 10 MHz (however the spectral efficiency is a bit lower). This enables more flexibility, in the way spectrum is allocated (long term goal is to have channels of 10 MHz or more).

The reference uplink modulation performance is therefore given by:

Table 48:

Uplink LTE modulation	Spectrum efficiency (bps/Hz)	SINR (dB)
QPSK, CR 1/3, 5 MHz, 1x4 antennas, EVA 70 Hz Low	0.31 (70% throughput)	-3.3

Downlink

The downlink link budget is not critical since the base station's power is higher than the terminal power: downlink modulation does not determine cell size.

However a reference modulation at cell edge should be chosen for determining the spectral efficiency at cell edge.

- Use of 1x2 antenna configuration (as this is the value provided in the 3GPP specifications). Dual receiver antennas UE are a reasonable assumption in medium to long term.
- Use of 10 MHz band as this is the only bandwidth with values in the 3GPP specifications.
- Propagation EVA 5Hz (as the 70 Hz values are not provided)
- Throughput 70% to keep good spectral efficiency.

The reference downlink modulation performance is therefore given by:

Table 49:

Downlink LTE modulation	Spectrum efficiency (bps/Hz)	SINR (dB)
QPSK, CR 1/3, 10 MHz, 1x2 antennas, EVA 5 Hz Low	0.27 bit/s/Hz (70% throughput)	-1.0

A2.3 LINK BUDGET AND CELL SIZE

The cell size is determined by computing the link budget for a reference uplink modulation due to the limited power available to the user equipment.

Uplink budget

Table 50:

User equipment e.i.r.p.

Parameter	Value
Tx Power (dBm)	23
Antenna gain (dB)	0
Body loss (dB)	2
e.i.r.p. (dBm)	21

Table 51:

Receiver sensitivity

Parameter	Value
Rx Noise figure (dB)	3
Bandwidth (MHz)	5
kTB x NF (dBm)	-104
SINR (dB)	-3.3
Sensitivity (dBm)	-107.3

Table 52:

Computation of Maximum path loss:

Parameter	+ / -	Value
e.i.r.p. (dBm)	+	21
Fade margin (dB)	-	9
Interference margin (dB)	-	3
Rx antenna gain (dB)	+	[frequency dependent]
Feeder loss (dB)	-	2
Reference sensitivity (dBm)	-	-107.3
Max path loss (dB)		[frequency dependent]

Table 53:

Antenna gain and maximum path loss:

Frequency band	Base station antenna gain	Max path loss
400 MHz	13.5 dB	127.8 dB
700 MHz	15.5 dB	129.8 dB
1500 MHz	17.0 dB	131.3 dB

The maximum allowable path loss enables a calculation of the maximum cell size within which communications are possible. The path loss is translated into distance using the Okumura-Hata model.

In addition to the choice of a propagation model, assumptions are made for the height of the antennas:

- 30 m high base station
- 1.5 m high user terminal.

The Okumura-Hata provides three different values corresponding to different type of urbanisation (rural, suburban, and urban).

The maximum cell range is calculated according to the different cell type of urbanisation for each frequency band. Cell size (surface) is then determined (with a circular pattern and a tri-sector hexagonal pattern).

Table 54:

400 MHz band (calculated at 420 MHz)	Urban	Suburban	Open
Cell range [km^2]	1.9	3.3	10.4
Cell size – circular [km^2]	11.7	33.9	338
Cell size – hexagon ([km^2]	7.2	21.0	209.9

Table 55:

700 MHz band (calculated at 750 MHz)	Urban	Suburban	Open
Cell range [km^2]	1.4	2.6	8.8
Cell size – circular [km^2]	6.4	22.1	241.2
Cell size – hexagon [km^2]	4.0	13.7	149.7

Table 56:

1450 MHz band	Urban	Suburban	Open
Cell range [km^2]	0.9	1.9	6.7
Cell size – circular [km^2]	2.5	10.9	139.4
Cell size – hexagon [km^2]	1.6	6.8	86.5

ANNEX 3: ETSI SENSITIVITY ANALYSIS FOR SPECTRUM CALCULATIONS

A3.1 PURPOSE:

Three scenarios have been investigated using the "LEWP-ETSI Matrix" which captures the user application requirements proposed by the LEWP in a broadband data environment, and calculates load and spectrum requirements based on assumptions made jointly between LEWP and ETSI.
Calculations have been made for PP2 scenarios only, with a background load of PP1 traffic, as these will be the more demanding cases.

A3.2 SPECTRUM CALCULATION SENSITIVITY ANALYSIS SUMMARY

The method of calculation made use of the user requirements matrix provided by the Law Enforcement Working Party Radio Communications Experts Group (LEWP/RCEG Matrix of applications, see A1.1).

The method consisted of the following steps:

- Describe the applications used in peak busy hour normal conditions and in emergency situations.
- Estimate the number of users in a cell using an application, and the number of transactions per user for that application in both peak busy hour normal conditions and during an emergency or incident.
- Estimate the data requirements for each application.
- Apply the data requirements to scenarios
- Estimate the spectral efficiency of an appropriate technology such as LTE in the scenarios
- Calculate the spectrum needed in each scenario from the above inputs.

The steps are described in detail in the following sections of this document.

Note that the method concentrates on data applications in the terrestrial network only. There is some limited uplink load in two of the scenarios for air to ground use, but otherwise air to ground use is excluded. Direct Mode Operation (DMO) is excluded from the analysis. Voice traffic is also excluded. The spectrum requirements for DMO and voice, and further Air-Ground-Air load would need to be calculated separately.

A3.3 METHODOLOGY

A3.3.1 User applications

The applications required for a broadband network to serve the PPDR community were tabulated in the LEWP/RCEG Marix of applications (A1.1).

A3.3.2 Number of users in a cell or sector

The number of users in a cell or sector during a peak busy hour condition and during an emergency incident in an urban environment in a large city was estimated in joint meetings between the end user community, represented by the LEWP/RCEG, and technical experts from ETSI using those users' experience to make a generic model of load conditions.

As usage of applications can be asymmetrical between the uplink and downlink (e.g. several users send video concerning an incident to a control room, but video is only sent back to one supervisor in the field), the number of users making use of the application on the uplink and downlink were estimated separately.

A3.3.3 Use of groups

In some cases, the same information can be sent to many members of a single group. Therefore for the use of applications on the downlink, the number of different groups whose members would receive the same sets of data was estimated.

NOTE: The purpose of this was to enable alternative calculations of downlink spectrum requirements if the technology adopted can provide a true group addressed service, as opposed to a technology which requires the same information to be sent individually to each group member.

A3.3.4 Transactions per user

For each application, the number of transactions per user in a peak busy hour in normal conditions was estimated using the end users' experience.

A multiplication factor for emergencies was also estimated, as use of some applications will increase during an emergency, and use of some others (for example those associated with more routine operations) will decrease.

A3.3.5 Data requirements for each application

For each application, the size of a data transaction was estimated both for the uplink and the downlink. These were estimated either as the data requirement for each discrete transaction (number of bytes of information required), or as the bit rate of a streamed application.

To estimate the data requirements per hour per user for transactional applications, the data size for each transaction is multiplied by the number of transactions per user per hour. For streaming applications, the number of minutes per hour that each user would need to make use of that application was estimated, and then the resulting fraction of an hour was multiplied by the data rate.

A3.3.6 Network data loading per application

For each application, the data loading was then calculated by the Matrix for uplink and downlink and in normal peak busy hour conditions and emergency conditions.

For normal peak busy hour conditions, the number of users for each application is multiplied by the application data requirements for each of uplink and downlink. Where an application can use a true group addressed service, an alternative calculation is made where the same data is sent to groups rather than individuals. A group addressed transmission may have an increased overhead compared with an individually addressed transmission as extra forward error correction may be needed if individual selective retransmission is not possible in the normal way; therefore an extra factor is used to estimate the increased loading caused in a group addressed transmission.

NOTE: not all group addressed services will incur an extra overhead; for example real time video transmission will be sent with an amount of forward error correction, but the receiving codec mitigates for lost data rather than requesting a retransmission. This will be the same whether the transmission is individually addressed or group addressed, hence there would be no overhead for groups with this service.

For emergency incident conditions, the same calculations are made. However the multiplication factor is also taken into account to allow for an increase or reduction in the use of that application in emergency conditions.

A3.3.7 Spectrum efficiency in scenarios

The spectrum requirements calculations for each scenario were then made using the Matrix.

During an incident or emergency, some users will be located at the incident scene; others will be spread out across the cell as part of the background load. Those at the incident will incur spectrum efficiency for their data exchanges depending on their distance from the centre of the cell. Those spread out across the cell can be averaged out with an average spectrum efficiency. It is therefore important to recognise which applications are incident centric and which are used by users distributed throughout the cell.

For each application, a decision was taken as to whether it was incident centric, or a background application spread out across the cell.

The spectrum calculations then consisted of:

- For background applications spread out across the cell, multiply the data demands for uplink and downlink by the average spectrum efficiency of the technology. This provides the non incident related load on the cell.
- For applications centric to an incident, multiply the data demands by the spectrum efficiency estimated for the incident.

In both cases, separate spectrum efficiencies are estimated for the uplink and the downlink.

A3.3.8 Variations in spectrum efficiency

Variations were made in the spectrum efficiency applied in the matrix in order to consider both the effects of user distribution for different applications, the effects of group calls, and the effects of network planning.

A3.3.8.1 Effects related to different applications

A modification was made in the event of applications which are normally spread out across the cell and which have low numbers of users utilising that application, specifically video used in a chase scenario. In this case it is assumed that one user will from time to time require to use the application at a different (lower) spectrum efficiency than the average spectrum efficiency of the cell as the user will travel to and across the cell boundaries, and therefore allowance is made for one user to receive a different spectrum efficiency for these specific applications.

A3.3.8.2 Bandwidth limitations in edge of cell conditions

If a streamed user application demands a high bandwidth where spectrum efficiency is low, i.e. at the edge of a cell, a simple calculation may result in an unrealistic demand for spectrum. In practice, the handset may simply not have sufficient output power on the uplink to be able to transmit across the bandwidth required; and instead in practice the application will be forced to drop to a lower bit rate (thus reducing the spectrum demand). On the downlink, the base station may simply not be able to deliver the quality of service requested by the application, and again the application will be forced to lower its bit rate. These aspects have been taken into account in the Matrix by imposing a spectrum cap on both uplink and downlink video transmissions so that the maximum spectrum which can be demanded by any one instance of the application is limited to a preset figure.

A3.3.8.3 Effects of group call technology

As described previously, group calls may provide a more efficient means of distributing the same information to multiple users on the downlink than individual unicast transmissions. However the implications on the technology are not yet known. If one user is close to the cell edge or in poor reception conditions, then an adaptive group call will have to account for this worst case situation, and will incur a low spectrum efficiency figure. It is also possible that a future group call in a technology such as LTE may not be able to dynamically adapt the transmission according to the user with the worst link budget (as this will vary from time to time between different users) and the solution may simply transmit with a constant spectrum efficiency which may be that appropriate to the edge of a cell. The Matrix therefore allowed group call spectrum efficiency to be determined independently of individual call spectrum efficiency, and has typically been set to the edge of cell figure. As a result of this, in some scenarios individually transmitted downlink transmissions for a few users may be more spectrally efficient than a group call. Therefore where group call is used, the Matrix compares the overall spectrum demand of a group call with that of an individual call per user on a per application basis, and selects only the most efficient figure of the two as an ‘optimised’ group call result.

A3.3.8.4 Effects of network planning

A network may be planned with large cells, which has the advantage that there will be fewer base stations and so lower cost but the disadvantage that throughput at the cell edges will be relatively low, or with small cells which permits better cell edge throughput at the expense of greater network cost. The Matrix was used with different cell edge spectrum efficiencies to show the effect of this variation with network planning. The technology used in the network such as Multiple Input Multiple Output (MIMO) antenna technology, beam forming antenna technology and so on will also affect the spectrum efficiency, with the more complex technologies yielding improvements in both cell edge throughput and spectrum efficiency.

A3.4 DIFFERENCES BETWEEN INCIDENT BASED APPROACH AND MATRIX CALCULATIONS

The differences in approach to the assessment of the input requirements and the resulting spectrum calculations by using the method and Matrix described in this Annex, and the incident based approach adopted in section 5 (except section 5.6 which provides the main results of the calculations presented in this Annex) of this report are as follows:

- Section 5 sums the traffic from several small incidents separately. In the Matrix, small incidents are combined together into the peak load in the peak busy hour or as background load on a cell during incident conditions without identifying those incidents separately.
- Because of the previous point, the Matrix incorporates video applications within the background load.
- Section 5 uses a top down approach to background load traffic which is separate from the incidents, assuming certain loads due to the characteristics of the likely applications. The Matrix uses a bottom up approach, where the estimated traffic from each individual user application and the number of users of that application are used in creating the load.

A3.5 SPECTRUM CALCULATIONS

A3.5.1 Spectrum calculation scenarios

The original LEWP-ETSI Matrix assumed a generic worst case set of conditions for either peak busy hour in a big city, or a generic emergency incident situation (such as an aeroplane crash or terrorist attack) in the same city. These figures were used for the first generic scenario for which different spectrum efficiencies were used in order to estimate possible variations in spectrum requirements.

Two other scenarios based on real life events were then taken, where the user numbers and applications were provided as inputs. In each case, the numbers of users for each application and the application data requirements (if different from the generic requirements) were modified in the Matrix to match the data provided in each scenario. In each case, the background data load was left almost unchanged from the generic LEWP input as the users assume that there will still be other load in the cell or sector which continues independently of the emergency. The scenarios are listed in the following paragraphs.

The British Royal Wedding in April 2011 was used as one scenario. The numbers of users was taken from user input, and applied to the matrix. Some variation was applied to the background load was made to account for increased personal location transmissions from a specified group of covert users.

The London Riots in August 2011 was used as the second scenario. One foreground application, which was video transmission from helicopters, was applied as an increase in background load, as it is unlikely that an airborne user will experience edge of cell conditions, and so the calculation should always include these at an average spectrum efficiency.

All of the three scenarios can be considered to be examples of PP2 scenario, although the Matrix also includes a background load of PP1 business as usual traffic of applications not associated with the PP2 incidents.

A3.5.2 Load in each scenario

A3.5.2.1 LEWP Matrix generic scenario

The table below shows the offered load in the scenarios incorporated into the generic Matrix:

Table 57:

	Data Load, kbps		
	Uplink	Downlink	Downlink with optimised Group call (sum of individual and multicast data)
LEWP Matrix 121130			
Peak busy hour conditions	3561	7297	6915
Incident conditions:			
Background load during incident	2641	7688	6783
Load per incident	4038	1557	917
Total load with one incident	6679	9245	7700
Total load with two incidents	10718	10802	8617

The ‘Uplink’ and ‘Downlink’ figures show the offered data load assuming all use is unicast (individual transactions for each user). The ‘Downlink with Group call’ column shows the reduced data load where any transaction that can be sent with a group call uses multicast transmission in optimised conditions (where the spectrum demand using multicast is less than that using unicast, but not otherwise), and then the remaining transactions use unicast: i.e. the table shows the sum total of unicast and multicast transmission data rates on the downlink.

The background load includes video from two chase situations. A reduced background load was also adopted where data load from a single chase only was included, to examine the effect in the worst case scenario with two incidents.

Table 58:

	Data Load, kbps		
	Uplink	Downlink	Downlink with optimised Group call (sum of individual and multicast data)
LEWP Matrix 121130			
Reduced background load during incident	1873	4616	3711
Load per incident	4038	1557	917
Total load with one incident	5911	6173	4628
Total load with two incidents	9949	7730	5545

A3.5.2.2 Royal Wedding scenario

Table 59:

	Data Load, kbps		
	Uplink	Downlink	Downlink with optimised Group call (sum of individual and multicast data)
Royal Wedding Scenario			
Background load during incident	2985	7688	6783
Load per 'sector' (= incident)	4257	266	294
Total load with one incident	7242	7954	7078
Total load with two incidents	11500	8220	7372

The increase in uplink background load in this scenario compared with the generic LEWP matrix was due to the scenario applying an increased rate of personal location transmissions to a set of covert users above the rate set in the matrix.

A3.5.2.3 London Riots scenario

Table 60:

	Data Load, kbps		
	Uplink	Downlink	Downlink with optimised Group call (sum of individual and multicast data)
London Riots Scenario			
Background load during incident	4177	7688	6783
Load per incident	1078	922	864
Total load with one incident	5255	8611	7648
Total load with two incidents	6334	9433	8512

The increase in uplink background load was due to the scenario adding in a number of video feeds from helicopters. These were added as background rather than incident load to ensure that they always caused a load at average spectrum efficiency, even if incidents took place at edge of cell.

A3.5.3 Spectrum efficiencies applied

Spectrum efficiency figures were applied for an ‘average’ location in a cell and for edge of the cell. The figures adopted were chosen in consideration of 3GPP TS 36.912 [21] and those in ITU-R M.2198 [23] which included performance reports on LTE for an IMT-Advanced technology, applied in a macrocell condition (considered a likely PPDR solution).

It is assumed that a spectrum efficiency of 1.5 bps/Hz is achievable on average in a PPDR network on the downlink, and 1.0 bps/Hz on the uplink.

Two edge of cell spectrum efficiency figures are used to provide a sensitivity analysis. The more pessimistic is a spectrum efficiency of 0.1 bps/Hz uplink and 0.15 bps/Hz downlink (similar or slightly optimistic compared with 36.912). The more optimistic assumes that the network is designed to provide a higher bit rate at the cell edges as proposed in section 5.4.1 of this report, and has been rounded to 0.3 bps/Hz for both uplink and downlink.

The figures above were applied in both individual and group downlink cases.

A3.5.4 Spectrum demand results

The results from the calculations of spectrum in the various scenarios are given in the following sections. In each case, the table lists uplink and downlink spectrum demands calculated by the Matrix for the various scenarios as the number and position of incidents is varied. The tables also show variation in results with more optimistic and more pessimistic spectrum efficiency values.

A3.5.4.1 LEWP Matrix 121130 – pessimistic edge of cell spectrum efficiency

Table 61:

	Spectrum requirements, MHz		
	Uplink	Individual Downlink	Optimised Group DL
Edge of cell spectrum efficiency:	0.1 bps/Hz	0.15 bps/Hz	0.15 bps/Hz
Average spectrum efficiency:	1 bps/Hz	1.5 bps/Hz	1.5 bps/Hz
Peak busy hour	4.4	4.9	4.7
1 incident at average position	7.5	8	7.2
1 incident at edge of cell	17.1	14.3	9.4
2 incidents at average position	11.5	9.1	8
2 incidents, 1 at edge of cell	21.2	15.3	10.2
2 incidents, 1 at edge of cell, reduced background load	20.4	13.2	6.6

A3.5.4.2 LEWP Matrix 121130 – optimistic edge of cell spectrum efficiency

Table 62:

	Spectrum requirements, MHz		
	Uplink	Individual Downlink	Optimised Group DL
Edge of cell spectrum efficiency:	0.3 bps/Hz	0.3 bps/Hz	0.3 bps/Hz
Average spectrum efficiency:	1 bps/Hz	1.5 bps/Hz	1.5 bps/Hz
Peak busy hour	3.9	4.9	4.6
1 incident at average position	7.1	7.8	5.9
1 incident at edge of cell	10.2	11.4	7.7
2 incidents at average position	11.1	8.9	6.5
2 incidents, 1 at edge of cell	14.3	12.5	8.3
2 incidents, 1 at edge of cell, reduced background load	13.5	10.4	5.8

A3.5.4.3 Royal Wedding scenario – pessimistic edge of cell spectrum efficiency

Table 63:

	Spectrum requirements, MHz		
	Uplink	Individual Downlink	Optimised Group DL
Edge of cell spectrum efficiency:	0.1 bps/Hz	0.15 bps/Hz	0.15 bps/Hz
Average spectrum efficiency:	1 bps/Hz	1.5 bps/Hz	1.5 bps/Hz
1 'sector' at average position	8.1	7.2	6.6
1 'sector' at edge of cell	16.3	8.8	7.9
2 'sectors' at average position	12.3	7.4	6.7
2 'sectors', 1 at edge of cell	20.6	8.9	8.1

A3.5.4.4 Royal Wedding scenario – optimistic edge of cell spectrum efficiency

Table 64:

	Spectrum requirements, MHz		
	Uplink	Individual Downlink	Optimised Group DL
Edge of cell spectrum efficiency:	0.3 bps/Hz	0.3 bps/Hz	0.3 bps/Hz
Average spectrum efficiency:	1 bps/Hz	1.5 bps/Hz	1.5 bps/Hz
1 'sector' at average position	7.6	7	5.3
1 'sector' at edge of cell	10.5	7.7	5.9
2 'sectors' at average position	11.9	7.1	5.5
2 'sectors', 1 at edge of cell	14.8	7.8	6.1

A3.5.4.5 London Riots scenario – pessimistic edge of cell spectrum efficiency

Table 65:

	Spectrum requirements, MHz		
	Uplink	Individual Downlink	Optimised Group DL
Edge of cell spectrum efficiency:	0.1 bps/Hz	0.15 bps/Hz	0.15 bps/Hz
Average spectrum efficiency:	1 bps/Hz	1.5 bps/Hz	1.5 bps/Hz
1 'sector' at average position	6.1	7.6	7
1 'sector' at edge of cell	9.1	10	9.1
2 'sectors' at average position	7.1	8.2	7.7
2 'sectors', 1 at edge of cell	10.2	10.6	9.7

A3.5.4.6 London Riots scenario – optimistic edge of cell spectrum efficiency

Table 66:

	Spectrum requirements, MHz		
	Uplink	Individual Downlink	Optimised Group DL
Edge of cell spectrum efficiency:	0.3 bps/Hz	0.3 bps/Hz	0.3 bps/Hz
Average spectrum efficiency:	1 bps/Hz	1.5 bps/Hz	1.5 bps/Hz
1 incident at average position	6.1	7.4	5.8
1 incident at edge of cell	6.6	9.3	7.5
2 incidents at average position	6.7	8	6.4
2 incidents, 1 at edge of cell	7.7	9.9	8.1

A3.5.4.7 Average results across the three scenarios – pessimistic spectrum efficiency

The table below averages the results using pessimistic edge of cell spectrum efficiency across the three scenarios, with the various different combinations of incident number and positioning. Whereas an average in this way does not relate to any individual scenario anymore, it can serve to give a single indication taken from a range of situations. The final rows in the table provide further averaging of all results within the table for the different positioning of incidents.

Table 67:

	Spectrum requirements, MHz		
	Uplink	Individual Downlink	Optimised Group DL
Edge of cell spectrum efficiency:	0.1 bps/Hz	0.15 bps/Hz	0.15 bps/Hz
Average spectrum efficiency:	1 bps/Hz	1.5 bps/Hz	1.5 bps/Hz
1 incident at average position	7.2	7.6	6.9
1 incident at edge of cell	14.2	11.0	8.8
2 incidents at average position	10.3	8.2	7.5
2 incidents, 1 at edge of cell	17.3	11.6	9.3
Average 1 incident	10.7	9.3	7.9
Average 2 incidents	13.8	9.9	8.4

A3.5.4.8 Average results across the three scenarios – optimistic spectrum efficiency

This table provides average results, as for the previous table, except with the more optimistic edge of cell spectrum efficiency.

Table 68:

	Spectrum requirements, MHz		
	Uplink	Individual Downlink	Optimised Group DL
Edge of cell spectrum efficiency:	0.3 bps/Hz	0.3 bps/Hz	0.3 bps/Hz
Average spectrum efficiency:	1 bps/Hz	1.5 bps/Hz	1.5 bps/Hz
1 incident at average position	6.9	7.4	5.7
1 incident at edge of cell	9.1	9.5	7.0
2 incidents at average position	9.9	8.0	6.1
2 incidents, 1 at edge of cell	12.3	10.1	7.5
Average 1 incident	8.0	8.4	6.4
Average 2 incidents	11.1	9.0	6.8

A3.5.5 Discussion of results

The spectrum demands are dependent on a number of factors, both related to the technology and use of group call services, and the network planning, and also to the scenario. Large incidents at the edge of cell create the greatest spectrum demands.

A3.5.5.1 Uplink demand

Uplink demand in peak busy hour is considered distributed evenly across the cell, and is relatively insensitive to the cell edge spectrum efficiency. The LEWP Matrix scenario for peak busy hour uplink demand changed from 4.4 to 3.9 MHz when the spectrum efficiency was improved from 0.1 bps/Hz to 0.3 bps/Hz. Similar results are seen where incidents take place in average cell positions; for example the Royal Wedding scenario demand only changed from 12.3 to 11.9 MHz when two ‘sectors’ (incidents) are located in average positions and spectrum efficiency is similarly improved.

Uplink demand is very sensitive to cell edge spectrum efficiency where an incident is located at the edge of a cell. In the LEWP Matrix scenario with two incidents, one at edge of cell, the spectrum demand increased from 14.3 to 21.2 MHz with the change from 0.3 to 0.1 bps/Hz. Similar effects are seen in the other scenarios: The Royal Wedding scenario demand increases from 14.8 to 20.6 MHz, and the Riots scenario demand increased from 7.7 to 10.2 MHz.

If the more optimistic spectrum efficiency for the uplink is assumed with appropriate network planning, the demand with two incidents, one at edge of cell, varies from 7.7 MHz (London Riots scenario) to 14.8 MHz (Royal Wedding scenario). If only one incident takes place in the cell but at the cell edge, the demand reduces to 10.5 MHz in the Royal Wedding scenario (the worst case of the scenarios investigated).

In all cases, a background load is incorporated into the results. Where the background load was reduced in the LEWP Matrix scenario with two incidents at edge of cell, there was a reduction in spectrum demand of approximately 800 kHz, reducing the demand by 4-6% for pessimistic and optimistic spectrum efficiency cases respectively. It can be seen that the reduction is not particularly significant compared with the remaining load.

The average spectrum demand across all scenarios and incident positions for the uplink was 13.8 MHz for two incidents with the pessimistic spectrum efficiency of 0.1 bps at edge of cell, falling to 11.1 MHz for the more optimistic 0.3 bps/Hz figure.

A3.5.5.2 Downlink demand

Downlink demand is similarly sensitive to edge of cell spectrum efficiency where incidents occur at the edge of cell. However the use and technology associated with a group call also has a heavy influence.

Considering individual call only scenarios, the demand for the worst case conditions with two incidents where one is at the edge of the cell, varies from 12.5 MHz to 15.3 MHz in the LEWP Matrix (worst scenario) and from 7.8 MHz to 8.9 MHz in the Royal Wedding scenario (best scenario) when the spectrum efficiency at edge of cell is changed from 0.1 bps/Hz to 0.3 bps/Hz. On examination of the offered load in the scenarios, this is because of the dominant nature of the background load in each scenario, where background load is considered to be evenly distributed across the cell.

Use of optimised group call, where the use of group call is chosen only where it has an advantage over a set of individual calls, reduces the demand for spectrum. In the LEWP Matrix scenario, the reduction is from 15.3 MHz to 10.2 MHz for the two incident case and 0.15 bps/Hz edge of cell spectrum efficiency, and from 12.5 MHz to 8.3 MHz with 0.3 bps/Hz spectrum efficiency, with similar reductions in other scenarios.

The sensitivity to background load was also examined by reducing the background load in the LEWP Matrix scenario with two incidents at the edge of cell. The reduction is around 2 MHz in the individual downlink case (16-20% depending on edge of cell spectrum efficiency); and greater (30-35%) in the group call case. The effect is therefore greater than that seen on the uplink; however the uplink has the dominant demand in any case.

The average spectrum demand for the downlink for two incidents with pessimistic 0.1bps/Hz edge of cell spectrum efficiency was 9.9 MHz, falling to 9.0 MHz with the optimistic 0.3 bps/Hz figure. When group call is used, the demand fell to 8.4 MHz and 6.8 MHz respectively.

A3.5.5.3 Summary of spectrum demands from scenarios

The summary results in the tables below show the range of results for the different scenarios, with one and two incidents within a cell or sector for uplink and downlink, and with individual call or mixed individual and group calls in the downlink. The variation in results is due to both the offered load in the various scenarios, and also the placement of the incident(s), whether at an optimistic location in the cell, or where one incident occurs at the edge of the cell.

Table 69:

Uplink, MHz						
	Optimistic spectrum efficiency			Pessimistic spectrum efficiency		
	Minimum	**Maximum**	**Average**	**Minimum**	**Maximum**	**Average**
1 incident	6.1	10.5	8.0	6.1	17.1	10.7
2 incidents	6.7	14.8	11.1	7.1	21.2	13.8

Table 70:

Downlink, MHz							
		Optimistic spectrum efficiency			Pessimistic spectrum efficiency		
		Minimum	**Maximum**	**Average**	**Minimum**	**Maximum**	**Average**
1 incident	Individual only	7.0	11.4	9.3	7.2	14.3	9.3
	Group+Individual	5.3	7.7	6.4	6.6	9.4	7.9
2 incidents	Individual only	7.1	12.5	9.0	7.4	15.3	9.9
	Group+Individual	5.5	8.3	6.8	6.7	10.2	8.4

Concluding from the analysis, at least 10 MHz is required for the terrestrial network uplink. With 10 MHz made available, many but not all of the scenarios can be accommodated. The ‘average’ 2 incident demand with optimistic edge of cell spectrum efficiency at 11 MHz is 10% higher than this figure, which implies that arrangements for additional bandwidth may be needed in some circumstances.

At least 10 MHz will also be required for the terrestrial network downlink. With 10 MHz made available, most of the scenarios which utilised individual calls can be accommodated. All scenarios can be accommodated in a 10 MHz downlink where group calls are optimally used.

Note that, as mentioned previously, this analysis does not incorporate the demands for voice call, air to ground (except some limited uplink included in some scenarios), or Direct Mode Operation. These will require additional or separate spectrum.

A3.5.6 Users and applications

The tables below list the user numbers and application types during each of the scenarios.

A3.5.6.1 Generic LEWP matrix – users and applications

The table below provides the LEWP users’ estimates for the number of users in a cell for each application under peak busy hour and incident/emergency conditions in a heavily loaded cell in a heavily populated urban environment (such as London). This data is input to the matrix for the generic peak busy hour and incident situations.

Table 71: Generic peak busy hour and incident situations

Type of application + services	Transaction per peak hour per user	Multiplication factor in emergency	Uplink users per cell (peak) for this application	Uplink users per cell (emergency)	Downlink users per cell (peak) for this application	Downlink users per cell (emergency)	Groups per cell instead of users (peak)	Groups per cell instead of users (emergency)	User distribution: i: incident, s: spread over cell, x: ignore
LOCATION DATA									
A(V)LS data to CCC	240	1	500	2000					s
A(V)LS data return	60	2			50	100			i
MULTI MEDIA	-	-	-	-	-	-	-	-	-
Video to/from CCC: following + intervention	1	1	2	2	8	8	2	2	s
Low quality additional feeds	1	1	6	6	8	8			s
Video for fixed observation	1	0.5	5	5					s
Low quality additional feeds	1	0.5	20	20					s
Video on location to/from CCC - high quality	1	1	0	4		1			i
Video on location to/from CCC - low quality	1	1	0	10					i
Video on location for local use	1	1	0	20		10		1	x
Video conferencing operations	1	0.1	1	6	1	6			i
Non real time recorded video transmission	1	1	5	5	5		1		i
Photo broadcast	2	1			500	2000	2	2	s
Photo to selected group	2	1			500	2000	10	10	s
OFFICE APPLICATIONS	-	-	-	-	-	-	-	-	-
PDA PIMsync	2	0.2	500	2000	500	2000			s
Mobile workspace	5	0.2	50	100	50	100			s
DOWNLOAD OPERATIONAL INFORMATION	-	-	-	-	-	-	-	-	-
Incident information download	2	1			500	1000	10	20	i
ANPR update hit list	1	1			300	1200	1	1	s
Download maps	1	2			50	200	10	20	s
Command & control information	1	4			500	1000	10	20	i
UPLOAD OPERATIONAL INFORMATION	-	-	-	-	-	-	-	-	-
Incident information upload	1	4	50	200					i
Status information + location	5	1	500	2000					s

Type of application + services	Transaction per peak hour per user	Multiplication factor in emergency	Uplink users per cell (peak) for this application	Uplink users per cell (emergency)	Downlink users per cell (peak) for this application	Downlink users per cell (emergency)	Groups per cell instead of users (peak)	Groups per cell instead of users (emergency)	User distribution: i: incident, s: spread over cell, x: ignore
ANPR or speed control automatic upload	50	0	30	30					s
Forward scanned documents	0.1	30	10	25					i
Reporting incl. pictures etc	1	0.1	100	100					s
Upload maps + schemes	1	4	10	20					i
Patient monitoring (ECC) snapshot	1	12	5	100					i
Patient monitoring (ECC) real time	1	1	5	10					s
Monitoring status of security worker	120	1	10	100					i
ONLINE DATA BASE ENQUIRY	-	-	-	-	-	-	-	-	-
Operational data base search	2	0.1	300	1000	300	1000			i
Remote medical database services	2	2	10	100	10	100			i
ANPR checking number plate live	5	0.1	300	1200	300	1200			s
Biometric (eg fingerprint) check	1	0.1	300	600	300	600			i
Cargo data	1	0.5	10	50	10	50			s
Crash Recovery information request	1	0.5	10	50	10	50			i
Crash Recovery System update	0.1	0			10	50			i
MISCELLANEOUS									
Software update online					0	0			x
GIS maps updates					0	0			x
Authomatic telemetrics	60	1	100	100					s
Hotspot on disaster or event area									x
Front office - back office applicaties	3	0.1	300	1200	300	1200			s
Alarming / paging	1	1	100	100	100	100	15	15	s
Traffic management system	4	2			50	200	10	20	s
Connectivity of foreign force to local ccc									x

A3.5.6.2 London Riots scenario: users and applications

The data in the following tables shows the number of users of each application required in the London Riots scenario. To assist recognising the difference with the generic matrix data, applications related to the incident are shaded orange, and changed figures are highlighted as **bold** text. Further notes relating to the use of applications are listed below the table.

Table 72: London Riots scenario

Type of application + services	Transaction per peak hour per user	Multiplication factor in emergency	Uplink users per cell (peak) for this application	Uplink users per cell (emergency)	Downlink users per cell (peak) for this application	Downlink users per cell (emergency)	Groups per cell instead of users (peak)	Groups per cell instead of users (emergency)	User distribution: i: incident, s: spread over cell, x: ignore	Notes
LOCATION DATA										
A(V)LS data to CCC	240	1	500	2000					s	
A(V)LS data return	60	2			50	**1.5**			i	1
MULTI MEDIA										
Video to/from CCC: following + intervention	1	1	2	**4**	8	8	2	2	s	2
Low quality additional feeds	1	1	6	6	8	8			s	3
Video for fixed observation	1	0.5	5	5					s	3
Low quality additional feeds	1	0.5	20	20					s	3
Video on location to/from CCC - high quality	1	1	0	**1**		1			i	4
Video on location to/from CCC - low quality	1	**1**	0	**0**					i	5
Video on location for local use	1	1	0	20		10		1	x	6
Video conferencing operations	1	**1**	1	**1**	1	**1**			i	7
Non real time recorded video transmission	1	1	5	**0**	5	**0**	1		i	5
Photo broadcast	2	1			500	2000	2	2	s	
Photo to selected group	2	1			500	2000	10	10	s	
OFFICE APPLICATIONS										
PDA PIMsync	2	0.2	500	2000	500	2000			s	
Mobile workspace	5	0.2	50	100	50	100			s	
DOWNLOAD OPERATIONAL INFORMATION										
Incident information download	2	1			500	**300**	10	20	i	8

Type of application + services	Transaction per peak hour per user	Multiplication factor in emergency	Uplink users per cell (peak) for this application	Uplink users per cell (emergency)	Downlink users per cell (peak) for this application	Downlink users per cell (emergency)	Groups per cell instead of users (peak)	Groups per cell instead of users (emergency)	User distribution: i: incident, s: spread over cell, x: ignore	Notes
ANPR update hit list	1	1			300	1200	1	1	s	
Download maps	1	2			50	200	10	20	s	9
Command & control information	1	4			500	**0**	10	**0**	i	5
UPLOAD OPERATIONAL INFORMATION										
Incident information upload	1	4	50	**300**					i	10
Status information + location	5	1	500	2000					s	
ANPR or speed control automatic upload	50	0	30	30					s	
Forward scanned documents	0.1	30	10	**0**					i	5
Reporting incl. pictures etc	1	0.1	100	100					s	
Upload maps + schemes	1	4	10	**0**					i	5
Patient monitoring (ECC) snapshot	1	12	5	100					i	11
Patient monitoring (ECC) real time	1	1	5	10					s	
Monitoring status of security worker	120	1	10	**0**					i	5
ONLINE DATA BASE ENQUIRY										
Operational data base search	2	0.1	300	**0**	300	**0**			i	5
Remote medical database services	2	2	10	100	10	100			i	11
ANPR checking number plate live	5	0.1	300	1200	300	1200			s	
Biometric (eg fingerprint) check	1	0.1	300	**0**	300	**0**			i	5
Cargo data	1	0.5	10	50	10	50			s	
Crash Recovery information request	1	0.5	10	**0**	10	**0**			i	5
Crash Recovery System update	0.1	0			10	**0**			i	5
MISCELLANEOUS										
Software update online					0	0				
GIS maps updates					0	0				
Authomatic telemetrics	60	1	100	100					s	
Hotspot on disaster or event area									x	6
Front office - back office applicaties	3	0.1	300	1200	300	1200			s	
Alarming / paging	1	1	100	100	100	100	15	15	s	
Traffic management system	4	2			50	200	10	20	s	

Type of application + services	Transaction per peak hour per user	Multiplication factor in emergency	Uplink users per cell (peak) for this application	Uplink users per cell (emergency)	Downlink users per cell (peak) for this application	Downlink users per cell (emergency)	Groups per cell instead of users (peak)	Groups per cell instead of users (emergency)	User distribution: i: incident, s: spread over cell, x: ignore	Notes
Connectivity of foreign force to local ccc									x	

Notes

1. Number of users in cell remains as for original LEWP matrix; this would include incident users
2. The intervention and fixed video users are unchanged as this is the assumed background load on the cell not connected with the incident. However, the helicopters have been added in here. We can assume that the helicopters never reach an edge of cell spectrum efficiency, hence adding them here rather than together with the incidents ensures that they are grouped with the 'average' spectrum efficiency.
3. No change, as background load assumed to as LEWP scenario
4. One feed per incident per scenario
5. Not mentioned in scenario so reduced to zero.
6. Not included in calculation as carried locally
7. Assume that at least one video conference needed per incident, for bronze commander to communicate with silver command. Factors here allow a single 10 minute call per incident, considered appropriate by LEWP experts.
8. Incident users reduced to 300 per incident according to scenario. Download operational info is estimated to same data size as maps, therefore this is equivalent to the map + other info download to officers at the incident points
9. Background load download map load infomation unchanged; it is assumed that others in the cell need directions related to the incident (to reach it or avoid it, or other related purposes).
10. Changed to 300 users per incident to upload operational information including pictures.
11. Unchanged, as presumed to be still required by ambulance service

A3.5.6.3 Royal Wedding scenario: users and applications

The data in the following tables shows the number of users of each application required in the Royal Wedding scenario. To assist recognising the difference with the generic matrix data, applications related to the incident are shaded orange, and changed figures are highlighted as **bold** text. Further notes relating to the use of applications are listed below the table.

Table 73: Royal Wedding scenario

Type of application + services	Transaction per peak hour per user	Multiplication factor in emergency	Uplink users per cell (peak) for this application	Uplink users per cell (emergency)	Downlink users per cell (peak) for this application	Downlink users per cell (emergency)	Groups per cell instead of users (peak)	Groups per cell instead of users (emergency)	User distribution: i: incident, s: spread over cell, x: ignore	Notes
LOCATION DATA										
A(V)LS data to CCC	240	1	500	**2240**					s	1
A(V)LS data return	60	2			50	**1**			i	2
MULTI MEDIA	-	-	-	-	-	-	-	-	-	
Video to/from CCC: following + intervention	1	1	2	2	8	8	2	2	s	3
Low quality additional feeds	1	1	6	6	8	8			s	3
Video for fixed observation	1	0.5	5	5					s	3
Low quality additional feeds	1	0.5	20	20					s	3
Video on location to/from CCC - high quality	1	1	0	**4.5**		**0**			i	4
Video on location to/from CCC - low quality	1	1	0	**10**					i	5
Video on location for local use	1	1	0	20		10		1	x	
Video conferencing operations	1	**0.5**	1	**1**	1	**1**			i	6
Non real time recorded video transmission	1	1	5	**0**	5	**0**	1		i	7
Photo broadcast	2	1			500	2000	2	2	s	
Photo to selected group	2	1			500	2000	10	10	s	
OFFICE APPLICATIONS	-	-	-	-	-	-	-	-	-	
PDA PIMsync	2	0.2	500	2000	500	2000			s	
Mobile workspace	5	0.2	50	100	50	100			s	
DOWNLOAD OPERATIONAL INFORMATION	-	-	-	-	-	-	-	-	-	
Incident information download	**6**	1			500	**60**	10	**1**	i	8

Type of application + services	Transaction per peak hour per user	Multiplication factor in emergency	Uplink users per cell (peak) for this application	Uplink users per cell (emergency)	Downlink users per cell (peak) for this application	Downlink users per cell (emergency)	Groups per cell instead of users (peak)	Groups per cell instead of users (emergency)	User distribution: i: incident, s: spread over cell, x: ignore	Notes
ANPR update hit list	1	1			300	1200	1	1	s	
Download maps	1	2			50	200	10	20	s	9
Command & control information	1	**60**			500	**1.5**	10	**1**	i	10
UPLOAD OPERATIONAL INFORMATION	-	-	-	-	-	-	-	-	-	11
Incident information upload	1	4	50	**300**					i	
Status information + location	5	1	500	2000					s	
ANPR or speed control automatic upload	50	0	30	30					s	7
Forward scanned documents	0.1	30	10	**0**					i	12
Reporting incl. pictures etc	1	**1**	100	**160**					s	7
Upload maps + schemes	1	4	10	**0**					i	13
Patient monitoring (ECC) snapshot	1	12	5	**5**					i	
Patient monitoring (ECC) real time	1	1	5	10					s	7
Monitoring status of security worker	120	1	10	**0**					i	
ONLINE DATA BASE ENQUIRY	-	-	-	-	-	-	-	-	-	
Operational data base search	2	0.1	300	**0**	300	**0**			i	7
Remote medical database services	2	2	**10**	10	10	**10**			i	14
ANPR checking number plate live	5	0.1	300	1200	300	1200			s	
Biometric (eg fingerprint) check	1	0.1	300	**0**	300	**0**			i	7
Cargo data	1	0.5	10	50	10	50			s	
Crash Recovery information request	1	0.5	10	50	10	**0**			i	7
Crash Recovery System update	0.1	0			10	**0**			i	7
MISCELLANEOUS										
Software update online					0	0				
GIS maps updates					0	0				
Authomatic telemetrics	60	1	100	100					s	
Hotspot on disaster or event area									x	
Front office - back office applicaties	3	0.1	300	1200	300	1200			s	
Alarming / paging	1	1	100	100	100	100	15	15	s	
Traffic management system	4	2			50	200	10	20	s	

Type of application + services	Transaction per peak hour per user	Multiplication factor in emergency	Uplink users per cell (peak) for this application	Uplink users per cell (emergency)	Downlink users per cell (peak) for this application	Downlink users per cell (emergency)	Groups per cell instead of users (peak)	Groups per cell instead of users (emergency)	User distribution: i: incident, s: spread over cell, x: ignore	Notes
Connectivity of foreign force to local ccc									x	

Notes

1. The number has been increased to allow for the 120 covert officers sending data every 5 seconds. The original number allowed 2000 users sending data every 15 seconds, therefore the covert users will send 120x2=240 more updates per 15 seconds than other users
2. If there are two sub bronze commanders per section, then we need 1 per incident (as incident is mapped to section).
3. The intervention and fixed video users are unchanged from the matrix as this is the assumed background load on the cell not connected with the incident.
4. Four feeds per section, plus one feed on the coach. As the coach only keeps one feed where it moves between sections, 'half' a feed becomes one feed in the two section scenario. This will only contribute half a feed at an edge of cell if one seciton is at the edge of a cell - but it is probable that of the four other feeds, not all will be worst case, so this will somewhat compensate for that. No downlink feed identified in the scenario
5. Scenario calls for individual feeds from up to 500 officers to be selected for high quality use. We assume that a number of low quality feeds will be required so that the commander/control room know which to select to high quality. Therefore the LEWP proposed 10 low quality feeds per incident have been retained.
6. Assume that at least one video conference needed per incident, for bronze commander to communicate with silver command. The multiplication factor can determine the length of the call: 0.5 allows 5 minutes.
7. Not mentioned in scenario so reduced to zero.
8. Incident users are included as the covert users who receive pictures from helicopters and fixed cameras as necessary. 60 covert users per sector used for the number of users. Assumed one picture every 10 minutes per user. Also assumed that all users in the same section receive the same information, i.e. only 1 group is needed per section.
9. Background load download map load infomation unchanged; it is assumed that others in the cell need directions related to the incident (to reach it or avoid it, or other related purposes).
10. The scenario calls for one high resolution picture per minute to the coach and to the bronze commanders. This is captured here. As with the camera feeds, the coach has been divided between the two incident/bronze commanders, which will reduce the effect at the edge of cell somewhat. If a group call, only one group would be needed. The data will be increased from 50kbytes to 1Mbyte for a reasonably high resolution picture."
11. Changed to 300 users per incident to upload operational information including pictures; this will cover the uploads from fixed cameras, and could also be used to identify which cameras to switch to video stream
12. Incorporates load from helicopters on UL

13. The number of users in the scenario has been reduced to 5, the same as the LEWP peak busy hour figure, as in this incident, medical issues will be mainly small incidents (fainting etc) in the crowd. The multiplication factor allows 1 snapshot per 5 minutes, same as LEWP emergency case.
14. As with patient data, the number of users has been reduced to the same as peak busy hour numbers from LEWP, as this is a peaceful incident. The multiplication factor allows 4 transactions per hour, same as LEWP emergency case.

A3.6 LEWP-ETSI SPECTRUM CALCULATING MATRIX

The matrix included below performs the spectrum calculations used in Annex 3, and can be adapted for other scenarios to suit particular needs.

A3.6.1 LEWP-ETSI Matrix with the spectrum calculation module

User and application information is entered in the “Data” worksheet. The descriptions of the applications are in column A, and these align with the LEWP/RCEG Matrix of applications (Annex A1.1) applications which are also listed in the “Matrix” worksheet. Within the “Data” worksheet, the expected numbers of users can be entered for peak and incident/emergency situations in columns B to I; and the data estimated for each application is entered in columns J to R. Columns T and U allow the mode of calculation related to the user location to be set. The remaining columns contain calculations and results, and should not be edited. The “Key” worksheet provides more description about the information to be entered.

The “Spectrum Results” worksheet provides the peak data throughput demands on the network, and the spectrum results indicate uplink and downlink spectrum demands in peak and emergency conditions, and with and without group call being available on the downlink. The spectrum efficiency figures are also entered on this sheet to allow variation according to the position of load and the network design.

The “App. Explanation” worksheet describes the list of applications from the LEWP-ETSI Matrix.

LEW-ETSI Matrix
with spec. calculation

ANNEX 4: ESTIMATION OF VOICE SPECTRUM REQUIREMENTS

A4.1 INTRODUCTION

The purpose of this document is to estimate the relative spectrum efficiencies of TETRA group call speech with an alternative solution based on LTE MBSFN, and to use this to estimate the amount of broadband spectrum that would be required to carry PPDR speech.

A4.2 ARCHITECTURE OF LTE MULTICAST TRANSPORT

Group voice is assumed to be transported using the multicast-broadcast channel contained in specific sub-frames called MBMS sub-frames. The MBMS sub-frames may be transmitted synchronously by several base stations, offering a simulcast capability over a MBSFN area.

However, not all sub-frames can be allocated to multicast-broadcast traffic and this allocation is semi-static. Some information on the DL control channel indicates the change of multicast-broadcast configuration from time to time, and the mobile terminals monitor such information to maintain up-to-date configuration information.

In the case of a FDD channel, the maximum number of sub-frames than may be allocated to multicast broadcast is 6 sub-frames every frame (i.e. 6 out of every set of 10 consecutive sub-frames).

A4.3 ARCHITECTURE OF A VOICE OVER LTE CHANNEL

For the purposes of this analysis, we will assume that MBSFN "macro-cell" is made of 4 synchronously transmitting elementary cells (or micro-cells). Each of these micro-cells inside the macro-cell (MBSFN area) use the same set of MBSFN sub-frames in a time multiplexed sequence to transmit the same information. As the frequency reuse pattern is equal to one, it is clear that neighbouring cells not belonging to the same MBSFN area, i.e. not transmitting the same information, cannot use the same sub-frames due to interference. Therefore the surrounding macro-cells do not transmit any information in these sub-frames to avoid causing interference. This creates a time reuse pattern similar to a frequency reuse pattern in this case with a pattern repeat of 4 macro cells as shown in the figure below.

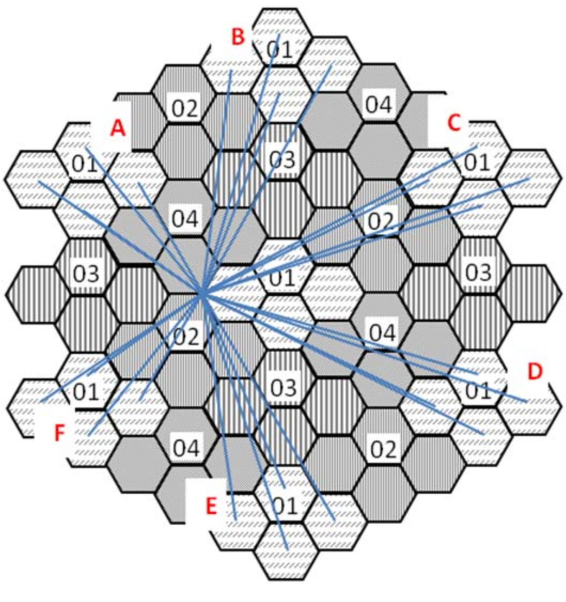


Figure 4: Reuse pattern of MBSFN time multiplexing sequence

As can be seen in Figure 4: aboveFigure 4: each macro cell is therefore surrounded by six other interfering macro cells, in each of which four cells contribute interference according to their distance from the wanted point in the wanted cell. Assuming a worst case situation where an MS is on the extreme edge of a macrocell, each of the interfering cells contribute interference that attenuated by distance. Using a 35 dB/decade law, the summed interference from these 6x4 interferers gives a C/I ratio of 13.3 dB.

For successful MBSFN area operation, the modulation which may be chosen for the transport of the multicast-broadcast blocks must have a SNR equal to the corresponding (summed) attenuation of the interfering signals minus an appropriate slow fading margin (6-8 dB), i.e. 5.3 dB to 7.3 dB.

A4.4 IMPLICATION FOR LTE CHANNELS

An MBSFN broadcast channel can take one 1 msec sub-frame per 10 msec frame in its simplest form. Other variations, such as one sub-frame per multiple frames, or multiple sub frames per frame, are possible; however for the purposes of this paper, one sub frame per 10 msec frame will be assumed.

MBSFN channel performance is given in the simulation results from R4-101492, which provides an estimate of performance, but without an implementation margin. These simulations can be taken and compared with the UE specification for MBSFN reception in 3GPP TS 36.101 [20] to work out this implementation margin, and then with the coding rates of the different Modulation and Coding Schemes (MCSs) for the different available CQI (Channel Quality Information) sets given in 3GPP TS 36.213 [24], the appropriate CQI can be chosen, hence the number of bits available per subframe can be estimated.

For a 10 MHz channel using QPSK 1/3, the more pessimistic of the curves in R4-101492 indicate that 1.8dB SINR is needed for 1% BLER. If the voice channel can operate in 3% BLER conditions, approximately 1dB SINR is needed from the curve. The specification in Table 10.1.1-2 of TS 36.101 [20] below specifies 4.1 dB SNR for 1% BLER, therefore indicating that there should be an approx 2.3 dB implementation margin above the more pessimistic curve in R4-101492. This implies that the actual SINR required for 3% BLER is approximately 3.3 dB.

Rate 1/3 coding would be achieved with a CQI=4 (coding rate 308/1024 bits), and would require approx 3.3 dB SINR as stated previously. As 5.3 dB SINR is available from the interference pattern, QCI = 5 can be chosen. The transport block size – how many bits can be transmitted per sub-frame – is given in Table 7.1.7.2.1-1 of 3GPP TS 36.213 [24] (Physical Layer Procedures). In a 10 MHz channel, which supports 50 resource blocks of 180 kHz each, 4392 bits are available. If one sub-frame per frame is used for the MBSFN, 439 kbps throughput can be supported.

Each MBSFN macro cell is part of a four cell repeat pattern, and so the MBSFN complex is consuming 4/10 of the resources of the 10 MHz channel, giving it an equivalent consumption of 4 MHz of spectrum. The spectrum efficiency is therefore 439/4000 = 0.11 bps/Hz.

The spectrum required for a speech channel will depend on the speech codec used. A codec rate of 10 kbps should allow the TETRA or equivalent quality codec to be used taking the various overheads for channel management and networking (e.g. IP) into account. A higher rate would give the end users an improvement in audio quality.

A 10 kHz codec rate will have an equivalent spectrum demand of 91 kHz per voice 'channel' as 44 voice channels can be supported in 4 MHz. A higher equivalent bandwidth may be demanded if better speech quality was desired.

A4.5 SPECTRUM EFFICIENCY FOR TETRA

The System Reference Document for PPDR Broadband ETSI TR 102 628 [3] makes some comparisons with previous results for the reuse factor possible in TETRA, based on ERC Report 052 [6], ECC Report 042 [7] and some other calculations. If we adopt a C/I requirement of 17 dB (similar to that suggested in ETSI TR 102 628 [3], and a figure closer to practice than the 19 dB maximum limit in the TETRA specification) with an 8 dB slow fade margin and a geometry factor of 7, then the method of ECC Report 042 [7] with a path loss factor of 3.5 indicates a practical frequency repeat pattern of 28 cells.

The TETRA codec requires 4.567 kbps for one speech channel, and this occupies an equivalent of 6.25 kHz bandwidth (as four channels are contained in 25 kHz). The effect of the frequency repeat pattern will cause this to scale to one channel in 6.25*28 = 175 kHz.

A4.6 SPECTRUM EFFICIENCY COMPARISON

If we compare these two results, the LTE MBSFN in a 10 MHz channel will be more efficient than TETRA by 175/91 = 1.9x .

A4.7 SPECTRUM REQUIREMENT FOR GROUP CALL VOICE OVER LTE

Existing TETRA networks require at least 5+5 MHz to provide group call services in large urban areas. In some cases additional spectrum of up to 2+2 MHz is utilised, although the total spectrum includes air to ground and Direct Mode use, which will reduce the trunked mode wide area requirement to a maximum of 6+6 MHz.

If we assume that the LTE network is 1.9x as efficient for group calls as a TETRA network, then **spectrum required for group call voice over LTE will be of the order of 3.2+3.2 MHz**.

A4.8 SENSITIVITY ANALYSIS

The method above has been repeated with variations in the cell repeat pattern and LTE channel bandwidth.
A 3x3 cell pattern could use less capacity in an LTE carrier for MBSFN use, as only three sub-frames would need to be reserved for group call use.

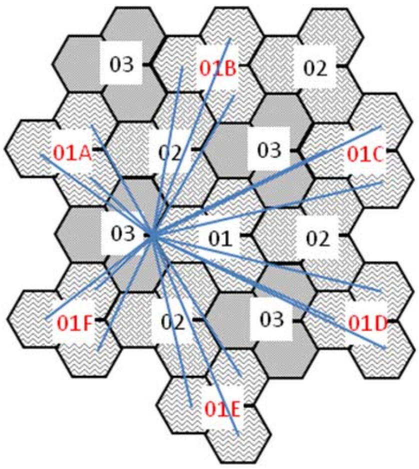


Figure 5: 3x3 Macro cell repeat pattern

However, the closer nature of the cells increases the interference, and the edge of the MBSFN macro cell only achieves 7.5 dB SINR. With the slow fading margin, only 0 dB SINR is likely to be achieved. This reduces the CQI to 2, and 222 kbps throughput – i.e. approximately half of the throughput for a saving of only 1/4 of the bandwidth of the channel. Therefore the 4x4 pattern is more efficient.

Larger patterns of 5 or 7 cells per macro cell with a 3 macro cell repeat pattern improve the performance; the 5 cells per macro cell achieves similar spectrum efficiency to the 4x4 cell pattern, and the 7 cell per macro cell case achieves better spectrum efficiency. However the larger the macro cell cluster, the greater the chance that the MBSFN area does not match the operational area of a group; and inefficiencies in this will reduce the overall spectrum efficiency of the system. Therefore the 4x4 cell pattern used here seems to have the optimum efficiency.

The 4x4 pattern was repeated for 1.4 MHz LTE. In this case, the curves in R4-101492 suggest a 4.2 dB SINR as required for 1% BLER, which when compared with the 6.6 dB SINR requirement in Table 10.1.1-2 of 3GPP TS 36.101, implies a 2.4 dB implementation margin. For the 3% BLER case, the curves indicate approximately 3 dB SNR, which implies that the pattern needs to provide 5.4 dB SINR. As the result for the pattern with slow fade margin gives 5.3 dB, a CQI of 4 can be used, providing 408 bits per block, or 41 kbps/sec; thus supporting 4 voice channels in effectively 560 kHz (4/10 of a 1.4 MHz channel). This gives a spectrum efficiency of 140 kHz/voice channel, 1.25x improved compared with TETRA. In this case, 6+6 MHz of TETRA spectrum would require 4.8+4.8 MHz of LTE spectrum.

The 4x4 pattern was also checked to see whether a second and third tier of interfering cells would influence the result. The difference in adding in the next 12 macro cells (hence 48 interfering cells) made 0.3 dB difference to the SINR, and so was neglected.

ANNEX 5: EXAMPLE OF BROADBAND AIR-GROUND-AIR SPECTRUM REQUIREMENT

The requirements for Air-Ground-Air (AGA) broadband PPDR spectrum has not been evaluated in the report. However some countries have provided a national estimate of their BB AGA spectrum needs, of which one example is provided below.

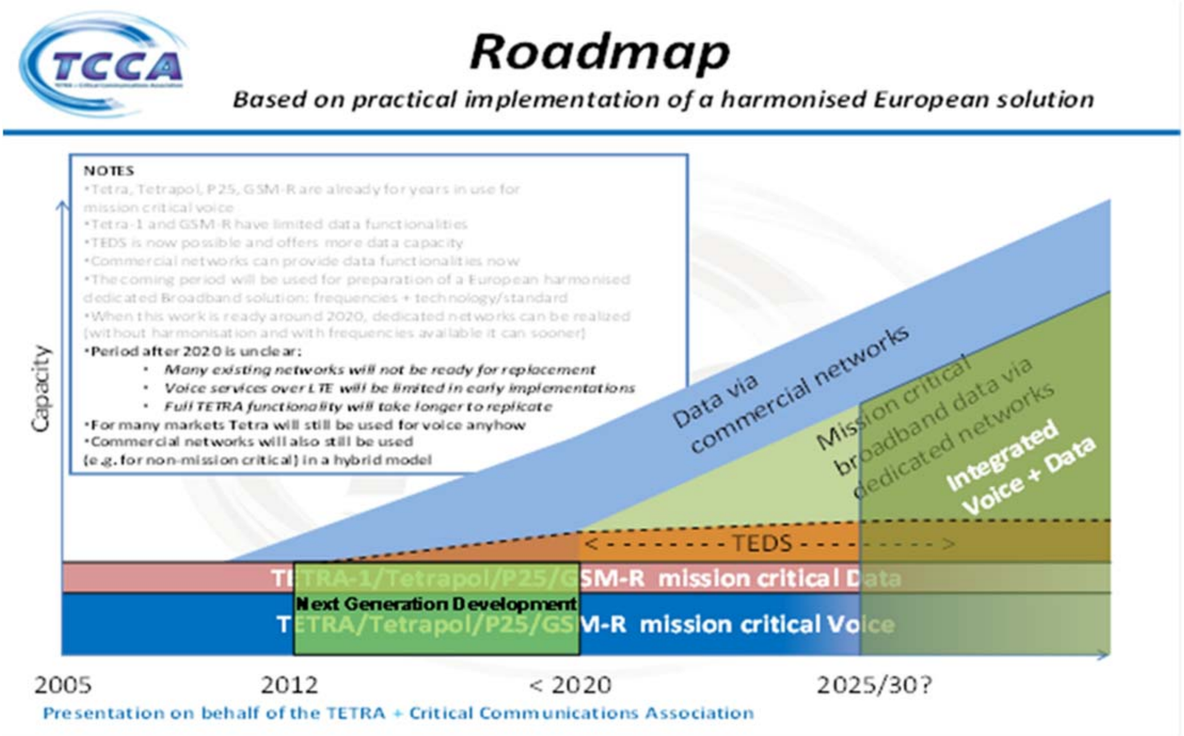
The frequency requirement is dependent on the assumed demand for airborne video links, the estimated bandwidth per link, and the extent to which frequencies can be re-used. As operational applications may require relatively high resolution, a bit rate of several Mbps may be required, which would imply an RF bandwidth of at least 2.5 MHz. Frequency re-use for terrestrial DVB-T networks is generally between 4 and 6; in the case of air-ground use it is assumed that the higher value would apply (due to the wide area visibility of airborne platform), which would imply a minimum spectrum requirement of 15 MHz. This additional spectrum may be required locally, depending on individual national circumstances.

For example, PPDR Germany has evaluated that they have simultaneous requirements for up to four video streams at a single incident, which would imply that up to 60 MHz could be required nationally (to allow for a 6:1 re-use and up to 4 x 2.5 MHz channels at each location); however, such a high level of demand is most unlikely. A more realistic estimate for airborne PPDR would probably be 22.5 MHz.

This would address **the base requirement of 15 MHz for normal PPDR airborne operations,** plus sufficient additional spectrum (3x2.5 MHz) to provide up to three additional video links at any one location at any given time in order to address exceptional scenarios where multiple links are required.

ANNEX 6: TCCA ROADMAP "VOICE → BB DATA/VOICE"

The TCCA[4] Roadmap below shows a possible migration path from the existing voice/NB data networks towards fully integrated LTE-based BB data/voice networks. A full integration with available terminals is in this Roadmap envisioned around the year 2025 at the earliest.



[4] The TETRA MoU Association Ltd, now known as the TETRA and Critical Communications Association (TCCA), was established in December 1994 to create a forum which could act on behalf of all interested parties, representing users, manufacturers, application providers, integrators, operators, test houses and telecom agencies. Today the TCCA represents more than 160 organisations from all continents of the world.

ANNEX 7: LIST OF REFERENCE

[1] Report ITU-R M.2033 “Radiocommunication objectives and requirements for public protection and disaster relief”, 2003
[2] ECC Report 102 “Public protection and disaster relief spectrum requirements”, January 2007
[3] ETSI TR 102 628 v1.1.1 (2010-08) “Additional spectrum requirements for future Public Safety
[4] and Security (PSS) wireless communication systems”
[5] in the UHF frequency rangewireless communication systems in the UHF frequency range
[6] ERC Report 052 “Methodology for the assessment of PMR systems in terms of spectrum efficiency, operation and implementation”, December 1997
[7] ECC Report 042 “Spectrum efficiency of CDMA-PAMR and other wideband systems for PMR/PAMR”, February 2004
[8] Decision 243/2012/EU of the European Parliament and of the Counicl of 14 March 2012 establishing a multiannual radio spectrum policy programme (RSPP)
[9] WGFM “Implementation Roadmap for the Mobile Broadband applications for the Public Protection and Disaster Relief (PPDR)”, doc FM(12)084_Annex14
[10] ECC Recommendation (08)04 “The identification of frequency bands for the implementation of Broad Band Disaster Relief (BBDR) radio applications in the 5 GHz frequency range”, October 2008
[11] Report ITU-R M.2014 “Digital land mobile systems for dispatch traffic”
[12] Recommendation ITU-R M.1073 “Digital cellular land mobile telecommunication systems”
[13] Recommendation ITU-R M.1457 “Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications-2000 (IMT-2000)”
[14] US NPSTC Public Safety Communications Report: “Public Safety Communications Assessment 2012-2022, Technology, Operations, & Spectrum Roadmap, Final Report, June 5, 2012”
[15] US NYC study: “700 MHz Broadband Public Safety Applications And Spectrum Requirements, February 2010”
[16] US FCC White Paper: “The Public Safety Nationwide Interoperable Broadband Network: A New Model for Capacity, Performance and Cost”, June 2010
[17] APT Report on “PPDR Applications Using IMT-based Technologies and Networks” No. APT/AWG/REP-27, Edition: April 2012
[18] White Paper by Iain Sharp of Netovate announced on the 3GPP website: “Delivering Public Safety Communications with LTE”, January 2013
[19] 3GPP TS 36.104 “Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception” (Release 10)
[20] 3GPP TS 36.101 “Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception” (Release 10)
[21] 3GPP TS 36.912 “Feasibility study for Further Advancements for E-UTRA (LTE-Advanced)”
[22] ECC Decision (08)05 of 27 June 2008 “on the harmonisation of frequency bands for the implementation of digital Public Protection and Disaster Relief (PPDR) radio applications in bands within the 380-470 MHz range”
[23] Report ITU-R M.2198 “The outcome of the evaluation, consensus building and decision of the IMT-Advanced process (Steps 4 to 7), including characteristics of IMT-Advanced radio interfaces”, October 2010
[24] 3GPP TS 36.213 “Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures”