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Study for the
Public Safety & Security Community

Safety First

Reinvesting the Digital Dividend in Safeguarding Citizens

Authors: Kenneth R. Carter and Val Jervis

wik-Consult GmbH
Rhöndorferstr. 68
53604 Bad Honnef
Germany

and

Aegis Systems Limited
30 Anyards Road
Cobham
Surrey KT11 2LA
United Kingdom

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THIS REPORT HAS BEEN ENDORSED BY THE FOLLOWING INDIVIDUALS AND ORGANIZATIONS:

- Astrid
- BAPCO
- Manfred Blaha
  Brigadier-General
  Austrian Ministry of the Interior and Representative, International Chapter of APCO International
- Bundesnetzagentur für Elektrizität Gas Telekommunikation Post und Eisenbahnen
- C2000
- Chris van Diepenbeek
  Ex-Chairman
  Electronic Communications Committee of CEPT
- European Aeronautic Defence and Space Company (EADS)
- Motorola
- National Policing Improvement Agency, UK (NPIA)
- PSC Europe
- Selex Communications
- TETRA Association

Abstract

Public Safety and Security (PSS) service responders provide us with indispensable police, fire and other emergency services. Each individual in our society has the growing expectation of, if not the right to, emergency services. In turn, society expects that its government will expend the necessary resources to aid those in emergency need. The provision of emergency services extends beyond the social contract and invokes a moral obligation to protect life, welfare, and property.

In order to fulfil this obligation to save lives and property, PSS organisations and their personnel require wireless access not only to voice and simple data services (narrowband) but also increasingly to broadband data services. The ability to utilise broadband services requires more spectrum than the two 5 MHz-wide blocks currently harmonised across Europe. Already some countries have had to provide access to further spectrum to support voice services. Calculations show that approximately two additional 15 MHz-wide blocks are required but the question is where this spectrum can be found that can economically support the longer ranges needed to provide geographic coverage in rural areas. One possible solution is to allocate spectrum from the transition to digital terrestrial television, the so called Digital Dividend.

In this White Paper, we examine the social welfare gained through the reallocation of Digital Dividend spectrum to PSS mission critical networks. We marshal the arguments for further dedicated spectrum for mission critical PSS communications, as well as provide a detailed view of the technical and operational characteristics of next generation PSS radio systems. The Digital Dividend can fulfil this necessary communications role, within the timescales needed by PSS users and provide a clear evolution path for essential day to day wireless mission critical communications.

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Nowadays, for commercial use, spectrum management organisations strive for technological and service neutrality, with the aim of improving access to and efficient use of the radio spectrum. Moreover, economic principles are used when licensing spectrum for such use. Somewhat at odds to this is the need for spectrum access for non-commercial use, where allocations must be made on the basis of the society's needs, and where economic principles are less important.

At the same time, new, broadband technologies enable public safety organisations to do their jobs better than ever before, and society requires them to do so. By providing its public safety organisations with broadband technology, society fulfils its moral obligation to protect its citizens, as well as to provide organisations like police, ambulance and fire brigade with the tools they need to perform optimally in their jobs with the minimum amount of risk.

Access to the required spectrum resources will mean a huge step forward for the efficient operation of a communication system by public safety organisations. International Telecommunication Union Resolutions recognize that the unhindered use of telecommunications/ICT equipment is indispensable for the provision of effective and appropriate humanitarian assistance and instruct the Director of the Radiocommunications Bureau to assist Member States with their emergency radiocommunication preparedness. A relevant basic consideration is that harmonisation of spectrum rules and elaboration of operational standards bring economic benefits for government and result into efficient and effective use of the radio spectrum.

The best proof is the success of the common approach in Europe for Public Safety in the 380 – 400 MHz band. Spectrum harmonisation made this success possible. In 1996, a CEPT/ERC Decision produced a harmonised allocation of spectrum for Public Safety and Security. For more than a decade, Europeans have benefited from interoperable voice and narrowband data services which their emergency responders have utilised in both their everyday activities as well as emergency situations. Applications and services available on these networks have increased, while costs to governments have fallen.

The time to act has come again, but now for broadband communications. Europe has a significant opportunity to improve the safety, security and quality of life of its citizens, by deciding on a harmonised, dedicated spectrum band for Public Safety and Security mission critical broadband communications. We must act at an early stage to empower industry with the necessary certainty to develop equipment and governments with the necessary time to deploy networks.

Chris van Diepenbeek
Ex-Chairman
Electronic Communications Committee of CEPT
Netherlands, April 2008

Executive Summary

The Digital Dividend is one of the most important and far reaching opportunities for communications policy issues of the past several decades, and even possibly for several decades to come. The term Digital Dividend typically refers to the portion of the radio spectrum which will become available as decades old analogue terrestrial broadcast television migrates to digital systems (DTV). These frequencies can be utilised by any number of services due to their excellent technical and propagation characteristics.

As Europe decides how to take advantage of this nearly unprecedented opportunity, one possible user of the Digital Dividend spectrum has received surprisingly little attention. Given its importance to society, it is shocking that Public Safety and Security (PSS) use is not a top priority in reallocating this spectrum. An appropriate allocation of spectrum to broadband mission critical PSS communications could help protect billions of Euros worth of property and save thousands of lives every year.

PSS services are indispensable. Responders include police, fire and other emergency services. Each individual in our society has the growing expectation of, if not the right to, emergency services. In turn, society expects that its government will expend the necessary resources to aid those in emergency need. The provision of emergency services extends beyond the social contract and invokes a moral obligation to protect life, welfare, and property regardless of their ability to pay. Not only must society provide PSS organizations with the resources they need to complete their jobs, but it must also provide the necessary modern communication tools which will minimise the risks to PSS personnel themselves and this requires mission critical wireless communications.

In 1996, ERC and ECC decisions produced a harmonized allocation of PSS spectrum. This resulted in the adoption of Europe-wide PSS communications systems – using either TETRA or Tetrapol. For more than a decade, these decisions have been an unqualified success. Interoperable voice and narrowband data services have been available to PSS organizations, increasing in functionality and price performance. Narrowband services were successful because harmonised spectrum was identified at an early stage providing the necessary certainty to industry to develop equipment to meet the needs of PSS organisations. However, the forces of change are now raising challenges to that continued success. In our primary research, we consistently heard from the PSS community that given the growing PSS communications demands on this spectrum it is already clear that the current allocations will not suffice in the future. In fact, not only are they insufficient for future needs, some existing networks in European cities are already operating at full capacity. The future needs are also fuelled by an ever-growing appetite for broadband services and applications.

It has become widely accepted that we should never be without access to e-mails, the Internet and even photographs and videos. Broadband communications are rapidly becoming an essential input for PSS operations as well. Next generation services will vary according to the type of PSS agency, but most organizations will seek an efficient mobilization of its workforce. PSS mission critical broadband communications will empower PSS organizations to move human resources into field, increasing situational awareness and facilitating command and control. Broadband communications will be used to collect and disseminate timely information such as medical records, details of dangerous substances, maps, pictures and video to the various emergency responders. Broadband communications can, for example, support

- remote checking of information such as passport and biometric details:
- the sending of detailed photographic images of children lost or people wanted to officers out in the field so they can act on requests immediately;
- providing access to the Fire services Gazetteer – a document containing information on what hazardous materials might be kept on a premises;
- transmission of live video information to the central command and control personnel so they can have access to the same visual information as their personnel in the field;
- relaying of ad-hoc video and surveillance camera real time information to patrol cars responding to incidents; or
- sending of full data on a patient’s condition from the ambulance to the hospital.

Whether a wireless network can economically provide broadband communications is based on physical constraints directly connected to the available frequency band and the amount of spectrum (bandwidth) available. Most mission critical operations depend on voice communications and currently have only two 5 MHz-wide blocks available in the harmonised spectrum. There are already problems with supporting voice traffic at major incidents and planned events. Some countries have already started to provide access to further spectrum in the band 400 MHz to support voice services. The integrated broadband data services which are emerging for PSS organizations require more bandwidth - ideally two 15 MHz-wide blocks. PSS organisations require this dedicated spectrum and their own networks because of the flexibility it affords – the ability to meet their own specific requirements so that they can maximise the advantages provided by broadband services. Dedicated networks employing a dedicated spectrum band are widely used today because it is considered the best way to provide secure, robust and immediate communications for PSS radio systems.

The ideal spectrum for these networks is between 400 MHz and approximately 800 MHz as higher frequencies have propagation characteristics that begin to present unworkable constraints. The Digital Dividend provides an ideal opportunity to policy-makers to repeat the success of the 1996 decisions, and perhaps even more so. The spectrum released can provide access to spectrum in the amounts and within the timescales needed by PSS organizations. Another alternative might be spectrum below 380 MHz but there is less clarity on whether this could be made available. Ideally the allocation should be Pan-European even though different parts of the same frequency bands might be utilised in each country.

This study was funded by a consortium of European Aeronautic Defence and Space Company (EADS) and Motorola, two leading and respected suppliers of PSS solutions for Europe. This paper gives voice to the concerns raised by PSS organisations in respect of their need for access to higher speed data services and therefore access to further spectrum PSS service responders provide us with indispensable police, fire and other emergency services. To give voice to these concerns, our research methodology relied extensively on discussions and interviews with individuals in the community. These individuals represented a diverse set of organizations including first responders, equipment manufacturers, network operators and government regulators. The information provided in this report has been obtained through these interviews, case studies and from documents available in the public domain.

This work is as important as it is timely. Spectrum needs to be made available, or at a minimum identified, over the next 12 to 18 months. Early announcement of the available spectrum for PSS would help underpin the potential for an evolutionary path and provide users with certainty to begin planning their next generation systems and services.

1 Introduction

1.1 Overview

Public Safety and Security (PSS) provide indispensable police, fire and other emergency services to respond to emergency situations ranging from the routine (accidents, house fires, events, etc.) to the extreme (terrorist attacks, earthquakes, massive floods). Each individual in our society has the expectation of, if not the right to, emergency services. In turn, society expects that its government will expend the necessary resources to aid those in such emergency situations. The provision of emergency services extends beyond the social contract and invokes a moral obligation to protect and save life, welfare, and property. Modern society holds a moral obligation to provide PSS services to its citizens regardless of their ability to pay. Here, we choose principal over economic efficiency.

In order to fulfil this obligation to save lives and property, PSS services require mission critical communications and information. These services will become increasingly dependent on broadband communications, enabling rapid transmission of large amounts of information from multiple sources and in multiple forms. Broadband communications are fast becoming essential to establish command and control and to disseminate timely information such as medical records, details of dangerous substances, maps, pictures and video to the various emergency responders. Whether a wireless network can economically provide broadband communications is based on physical constraints directly connected to the available frequency band and the amount of spectrum (bandwidth) available. Mission critical PSS communications networks require a further allocation of sub-1GHz radio spectrum beyond what has currently been allocated for existing services which are based on current generation, essentially narrow band network design and technologies. Indeed, some existing networks in European cities are already operating at full capacity. While cellular networks can fulfil certain PSS communications needs, those networks are optimized for financial return on investment and not designed to cater to the stringent requirements of PSS organizations.

This study was funded by a consortium of European Aeronautic Defence and Space Company (EADS) and Motorola who are key European respected suppliers of the PSS solutions. It gives voice to the concerns raised by PSS organisations in the form of a "white paper" that can be used in their lobbying efforts needed to secure additional spectrum.[1] Our objective is to marshal the arguments for and against a dedicated

1 The analyses and conclusions contained herein are those of the authors. We are solely responsible for any errors or omissions. This work has benefited by contributions and comments from professionals directly involved in PSS communications in Europe and the United States who have

spectrum band for mission critical PSS communications necessary for future development broadband services. We provide a detailed view of the technical and operational characteristics of next generation PSS radio systems to offer guidance for the European Commission, Member States and the PSS community in order to achieve appropriate allocations of scarce radio spectrum resources for future PSS services. [2] To give voice to these concerns, our research methodology relied extensively on discussions and interviews with individuals in the community. These individuals represented a diverse set of organizations including first responders, equipment manufacturers, network operators and government regulators. These persons gave generously of their time and a complete list of interviewees appears in **Annex A. Interviewees**. The information provided in this report has been obtained through these interviews, case studies and from documents available in the public domain.

1.2 Digital Dividend

Fortunately, governments have available to them a unique, but time-limited window of opportunity to address this problem. This opportunity has been colourfully dubbed, 'the Digital Dividend'. The Digital Dividend typically refers to the radio spectrum which will become available as decades old analogue terrestrial broadcast television migrates to new, highly efficient digital systems. These frequencies can be utilised by any number of services. Due to its excellent propagation characteristics, these sub-1GHz frequencies are highly sought after. The spectrum expected to be freed up by the transition from analogue to digital TV is ideally suited to meet the developing needs of PSS and Disaster Relief (DR). However, PSS services are but one possible recipient among the potential new users of this sub-1GHz spectrum. Given its value, numerous interest groups, including the broadcasters have sought access to these frequency bands with each one claiming the greatest social benefit.

given generously of their time. We remind the reader that these views expressed are those of the individual and are not necessarily attributable to their organizations.

2 While we evaluate PSS communications from a variety of standpoints – operational, managerial and engineering –it is not our intent to favour any particular technical standard, in this report. We eschew any promotion of technology in favour of a technology neutral approach which is most likely to provide maximum flexibility for PSS services and allow technologies, networks and services to evolve over the longer term.

> "The problem is technical; the solution is political."
>
> - Philippe Lefebvre
> Principal Administrator,
> European Commission[3]

The amount of spectrum that will be released, the specific frequencies, and the timing is likely to vary from country to country, but it has been estimated that up to 375 MHz of radio spectrum could be made available between 472 and 862 MHz. A number of international organisations are addressing the digital dividend and at the 2007 World Radio Conference it was agreed to designate the frequency band 790 – 862 MHz for future use by IMT (International Mobile Telecommunications). However, it will not be easy for all countries to make this spectrum available. At an earlier regional[4] ITU Conference in 2006, a complex plan for digital TV broadcasting (Geneva 06 plan) was agreed for the UHF band. Spain, Portugal and Belgium, for example, will all require spectrum at frequencies above 790 MHz to implement their digital TV networks. Some countries, like Sweden and Finland, have completed the analogue switchover and the released frequencies could therefore be re-allocated. In other countries, the switchover will not be complete until 2012 but even though the switchover date is later it should be noted that there is the potential to award the spectrum earlier. This is the case of the UK, for example, where the intention is to award the spectrum using a market approach in 2009.

1.3 Towards Efficient Allocation and Assignment

The term "Digital Dividend" itself is not a particularly apt description of the problems and the opportunities present in the reassignment of terrestrial broadcast television from analogue to digital. Dividends are payments made to owners based on the profits generated by assets. If owners believe that retained profits will generate super-normal returns, then they will forgo dividend payouts in lieu of reinvesting the dividends. So, here too, policymakers, managers of the public's spectrum assets, must seek the best way to reinvest the Digital Dividend.

The modernisation and liberalisation of spectrum policy in recent years has led to market based approaches being increasingly used in the management of the radio spectrum. Since 1994, governments have used auctions to determine efficient award of spectrum licences. However, the organizations which provide indispensable PSS services lack the financial and administrative abilities to participate in complicated and expensive auctions. In addition, because of their independent and diverse financial and budgeting structures aggregating these organizations for a unified set of bid would be

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3 Keynote Address, European Digital Dividend Conference, Brussels, Belgium (Tuesday, 4 March 2008).

4 Europe, the Middle East and Africa (Region1).

difficult. In addition, it is hard to value PSS communications like a stream of cash flows derived for commercial services. Beyond being altruistic, when lives hang in the balance, the value of emergency services cannot be fairly assessed.[5] Thus, an efficient market clearing price for PSS spectrum cannot be derived.

Further, unlike commercial uses of spectrum, looking at an average level of usage gives regulators little guidance as to how much radio spectrum and which bands to allocate to PSS. The utilization rate of public spectrum ranges from near constant (e.g. some radar systems and fixed point to point radio links), to mostly idle (e.g. some emergency communications spectrum). The regulator making an administrative determination regarding the amount of spectrum to set aside for PSS may regard average utilization and decide that much of PSS spectrum is “unused” at any given moment. However, despite the fact that the particular carrier waves in the band are not being utilized to transmit information at any given moment; this spectrum is merely idle, not unused. Much like an “idle” fire extinguisher, the spectrum is being used to provide the benefit that it could be instantly available should an emergency arise. Thus, there is a significant risk that basing the award of spectrum on price or average utilization will fail to provide PSS users with sufficient spectral resources.

So, how is the regulator to make an efficient choice between competing demands when reinvesting the Digital Dividend? The regulator requires additional guidance with regard to an optimal spectrum allocation to take advantage of the latest technical advances, international harmonization, economies of scale, and to ensure sufficient spectral resources for PSS. We intend to demonstrate that while commercial and PSS are competing interests for the Digital Dividend spectrum, if accomplished properly, the assignment of this spectrum need not make the uses mutually exclusive. Therefore, informed guidance requires a detailed view of the technical and operational characteristics of PSS radio services.

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5 See Section 3.2.2 Social Cost.

2 PSS Mission Critical Needs and Radio Technology

2.1 PSS Overview and Definitions

PSS users include police, fire, ambulance, security, and customs and border control. Other users such as the lifeboat service may also share PSS networks as they deal with safety of life issues. PSS organisations address 3 types of operation that have been defined as:

- PP (Public Protection) 1 – Routine day to day operations within the agencies jurisdiction (normally within the geopolitical boundary) and as such the networks require wide area coverage on a permanent basis providing voice, narrowband and wideband communications.
- PP (Public Protection) 2 – Large emergencies or public events where it may be necessary to use resources from other agencies outside the jurisdiction (including across national boundaries). Examples of PP2 include transportation incidents or military exercises.
- DR (Disaster Relief) – The disaster may be natural or caused by human activity and there is a need for rapid deployment of incident networks in addition to the PP communications systems.[6]

Each of these three types of operations require 'mission critical communications'. By definition, mission critical communications is any information which must be transmitted because it is crucial to the successful resolution of the emergency operation. Mission critical networks require:

- Communications coverage everywhere, rural as well as densely populated geographic areas;
- Instant access to communication resources;
- Fixed and deployable networks;
- Ability to support mixed traffic (voice and data);
- Flexibility;
- Security;
- Resilience; and
- Extra-network operation (Direct Mode Operation "DMO").

6 ECC Report 102, "Public Protection and Disaster Relief Spectrum Requirements"

Before proceeding, we address and explain some concepts which are key to our discussion. We describe two important characteristics of spectrum: the location and the width of the tuning range of wireless networks. The location of the tuning range is determined but the centre of the identified frequencies. The width of tuning range is determined by the upper and lower reaches of the defined range. Further, in this White Paper we use the terms public and commercial networks to describe the legal status of the network. We define public networks to be those which are assigned to and controlled by public sector organisations. Commercial networks are those which are owned and operated by for-profit private-sector organizations. Oftentimes, people refer to commercial networks as “public” since they are open and available to paying members of the general public. We do not use this definition of public networks order to avoid confusion with public meaning governmental bodies.

2.2 Narrow band services and Beyond

> The early identification of spectrum for narrowband systems made possible the deployment European wide of PSS networks supporting the needs for voice and low rate data services. Unless suitable spectrum is allocated for wideband and broadband systems there will be limited opportunities for PSS organisations to utilise new services that will increase their effectiveness in the field.

2.2.1 Overview of Narrowband (TETRA and Tetrapol)

The Terrestrial European Trunked Radio (TETRA) standards were developed in ETSI starting from the early 1990s to serve the specific needs of various branches of Professional Mobile Radio (PMR) communications from emergency services to transportation, energy production and distribution, and specialised professional field operations. One important target of the standardisation work was to provide European PSS users with tools and means for efficient cross-border cooperation. The development of TETRA standards still continues in ETSI with new services and capabilities being introduced. In parallel to the TETRA standard, Tetrapol, was developed and can provide similar services, operating in the same frequency band.

In 1993, an ERC Recommendation (T/R 02-02) was adopted which identified harmonized radio frequency channel arrangements for the emergency services in the band 380 – 400 MHz. This recommendation followed a request[7] in 1991 to the ERC to identify suitable harmonized spectrum for the exclusive use by the police and security

7 The “Telecom” working party of the Signatories to the Schengen Treaty

services across Europe. It was recognized in the Recommendation T/R 02-02 that the frequencies would not be required in most countries until about 1996 to 2000. In practice the first systems were deployed around 1997 and new networks are still being deployed today. The Emergency Services spectrum allocation was confirmed in ERC Decision (96)01, and has led to true European harmonisation of the narrowband PSS radio frequencies.

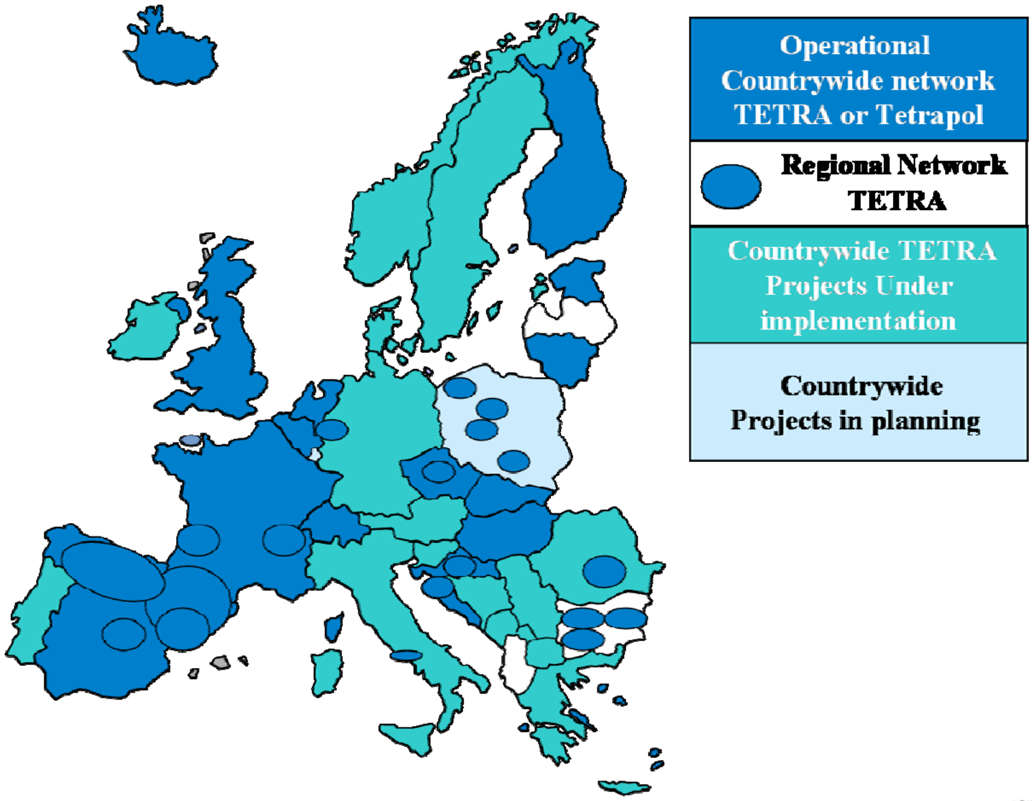
The introduction of digital radio communication, the TETRA standard and the harmonised frequencies for the national Emergency Services were developed in response to the requirements of the Schengen Treaty obligations. A common specification was developed by Schengen Telecom for PSS which detailed the operational requirements and ETSI advised that these could be met by the TETRA standard. TETRA is narrowband and supports voice and data services including mission critical messaging, information access, field reporting and location services.

The move towards digital, trunking and narrow-band TDMA technology offered by TETRA, combined with its services and facilities specifically designed to maximise traffic loading, increased spectrum efficiency compared with previous analogue technologies used by public safety organisations. This has been one of the reasons for migration to TETRA. Like the evolution of GSM to 2G and 3G, TETRA is also evolving from Release 1 (V+D) to Release 2 (TEDS) which includes the TETRA Enhanced Data Service (TEDS). The recently approved wideband TETRA (TEDS) standard will support data with a rate of between 30 – 150 kbit/s which will allow data rich services such as images, maps, video clips and identification.

2.2.2 Countries Invested in Narrowband Networks

Figure 1 below, from the TETRA Association, shows the Public Safety networks in Europe in the first quarter of 2008. In Europe, most emergency services have already deployed TETRA, with the exception of a few countries like France, which have adopted Tetrapol. The PSS sector represents the largest market for TETRA, representing 48% of World Contracts. In Autumn 2007, there were a total of 1676 reported TETRA contracts across the world, in 97 countries.

Figure 1: European PSS Networks First Quarter 2008



Source: Tetra Association

2.2.3 Why invest in digital Narrowband Networks?

Table 3 in **Annex C. Summary of TETRA Networks** provides more detail on the reasons why countries have invested in digital narrowband networks, the benefits perceived from these networks and the method of procurement and funding. The main benefits of the new narrowband systems over the existing analogue systems were:

- Increased capacity;
- Common frequencies and ability to share the resources (interoperability);
- Security;
- Increased coverage;
- Provision of data services; and
- Price preformance.

2.2.4 The Future?

The current deployed narrowband TETRA and Tetrapol networks are ideal for voice and low rate data (e.g. SMS) communications. However, they cannot deliver the following services that would be of great benefit to PSS users:

- Video conferencing;
- Video streaming (CCTV on scene);
- Full Satellite Navigation (AVLS works well on narrowband but not as comprehensive);
- Passport and bio-metric checks (secure information) undertaken remotely as this requires data rates just above those available on narrowband;
- Fire Services on-line access to Gazetteer (provides information on what might be kept at premises that could be a problem e.g. propane gas bottles as well as other data that might be required) requires around 100 kbit/s;
- On-line access to contacts data base that can be shared so know all those organisations / people that should be contacted depending on, for example, the incident;
- Full e-mail;
- Intranet browsing;
- Improved transfer of files (maps and pictures);
- Transfer of medical information;
- Ability to move the back office into the field;
- Increased use of over the air key re-programming; and
- Increased over the air downloads of new software updates. Allows the staff to be kept operational which could be a significant cost and operational benefit.[8]

Certain governments are now moving forward with advancements in communications available in current generation networks. The British Government, through the National Policing Improvement Administration (NPIA), has provided £50 million to encourage data use in PSS. There have been trials, not only testing technologies, but also applications. For example, there have been trials involving video where cameras have been mounted on police helmets and the information sent back to a central point.[9]

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8 Comments of Malcolm Quelch, Sepura plc
9 Comments of Peter Wickson, NPIA

There are indications that the police may want to do this in the future. Similarly in the Netherlands[10], France, and almost all Member States there are trials ongoing with broadband data communications and it is clear that there will be a need for a nationwide network to support such services within the next 2 to 3 years. A request for additional spectrum has already been submitted to the Dutch Administration. Desired applications include:

- Sending detailed photographic images of children lost, people wanted to speak to officers in the field so they can act on the requests immediately. Currently with narrowband can only send small pictures and they are often not enough for identification.
- Relaying ad-hoc video camera and surveillance camera real time information to patrol cars responding to incidents so they are fully prepared when they arrive at the scene.
- Sending detailed maps and plans that can be used at an incident, e.g. a fire.
- Sending biometric data such as finger prints from an incident so it can be acted on at that time, rather than having to return to the office.

2.3 Next Generation Broadband Services

2.3.1 Overview of Broadband Mission Critical Applications and Standards

Work to define next generation mission critical applications for PP1, PP2 and DR has been ongoing within a number of different groups. These groups include ETSI[11], Project MESA[12] and the CEPT.[13]

The emergency services communication requirements are explained in Section 5 of ETSI technical specification TS 102 181, "Emergency Communications (EMTEL); Requirements for communications between authorities/organizations during emergencies". The aim of communications networks is to ensure that timely, relevant and accurate information is available to the correct person or organization. Section 5.2 of TS 102 181 lists the following examples of situations where an effective radio network is required:

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10 Comments of C2000 network

11 ETSI TS 102 181, "Requirements for communications between authorities/organizations during emergencies". European Technical Standards Institute.

12 "Project MESA is an international partnership producing globally applicable technical specifications for digital mobile broadband technology, aimed initially at the sectors of public safety and disaster response." http:///www.projectmesa.org.

13 European Conference of Postal and Telecommunications Administrations, http://www.cept.org.

- Mobilization of the teams and people;
- Updates on the emergency – situational reports;
- Updates on requirements to other organisations so they can prepare e.g. informing hospitals on likely number of casualties and individual patients and their needs;
- Sending of command and control information to the incident area;
- Requesting of information from the incident area e.g. building plans, chemical information; and
- Sending of still and video images from the incident area.

The services required to support the above include:

- Voice services (one to one and group calling);
- High level security encryption with multiple keys and Over The Air Re-keying (OTAR)
- Video teleconferencing to assist in coordination between the services and also to provide information from the incident area back to the control rooms;
- Data services (the requirements included in TS 102 181 are replicated in Table 1 below); and
- Status monitoring and location services, including, for example, measuring exposure to environmental conditions, reporting PSS responders' vital signs and determining their physical proximity, all in real time.

Table 1: Data services included in ETSI Technical Specification 102 181

Service	Throughput	Timeliness	Robustness
E-mail	Medium	Low	Low
Imaging	High	Low	Variable
Digital mapping / Geographical information services	High	Variable	Variable
Location services	Low	High	High
Video (real time)	High	High	Low
Video (slow scan)	Medium	Low	Low
Data base access (remote)	Variable	Variable	High
Data base replication	High	Low	High
Personnel monitoring	Low	High	High

Source: European Telecommunications Standards Institute

In the Annexes of the Project MESA Statement of Requirements,[14] the requirements for a number of different users are presented. Timely major events[15] at the time had an impact on the Project MESA Statement of Requirements; "Such events have served as a warning sign to public safety agencies throughout the world that there is a need for better technology, improved interoperability, comprehensive planning and improved international standards".

2.3.2 Mission Critical Broadband Services

In all areas of communications, advanced applications and services are fuelling an ever growing appetite for broadband communications. This trend towards broadband communications, such as the growing xDSL market, is also present in PSS mission critical communications.[16] Voice is the central means for command and control. It is the number one mission critical application and requires a minimum level of quality of service.[17] TETRA and Tetrapol voice communications are already very efficient implementations. Both work well for voice, because of their group calling mechanisms

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14 MESA TS 70.001 V3.2.1 (2006-01), Service Specification Group – Services and Applications

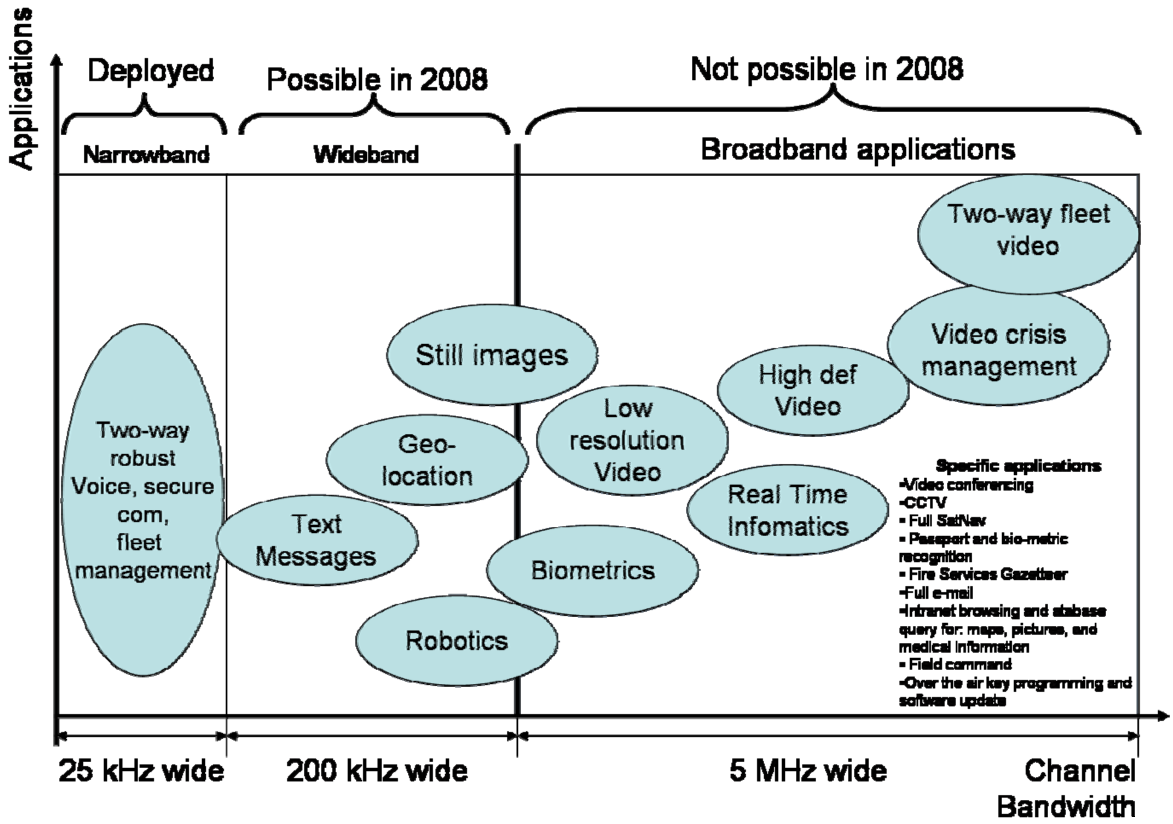
15 New York World Trade Center bombing, the bombing of the Oklahahoma City Federal Center, Hurricane Andrews in the state of Florida, the Rodney King riot in Los Angeles, California, and Loma Prieta and Northbridge, California earthquakes and major fires such as those in Yelolowstone Natiopnal Park".

16 See. Phillip J. Weiser, Communicating During Emergencies: Toward Interoperability and Effective Information Management, 59 Federal Communications Law Journal at p. 116 (2007).

17 Comments of Manuel Torres, Motorola and Comments of Mark Yates Hertfordshire Fire Service.

and use of trunking technology. The use of low bit rate data applications such as SMS is increasing[18] and PSS organizations are also looking at new non-voice applications and services requiring greater data throughput capabilities.[19] Data applications are not yet well defined, but PSS user initiatives to will articulate the necessary requirements in the near term future.[20] The diagram below demonstrates the difference between narrowband, wideband and broadband networks and the services that such networks could support.

Figure 2: PSS Network Applications and Required Bandwidth



Source: Motorola

Next generation services will vary according to the type of PSS agency, but most organizations still will seek an efficient mobilization of its workforce.[21] This requires the ability to conduct database inquiries and reporting.[22] Some PSS users are currently

18 Comments of Jaakko Saijonmaa EADS.
19 Comments of Christian Mouraux, Astrid.
20 Ibid.
21 Comments of Manuel Torres, Vice President, Motorola.
22 Ibid.

satisfied using PDAs to log information and upload the information to the system on their return. Other users need the immediacy of transmitting the information in real time using radio communications.

Those PSS organization which are not satisfied with the current capabilities and limited data rates offered by the current generation of narrowband systems, have been looking outside of these TETRA network to meet their data requirements. For example, in the UK, fire, police and ambulance services are utilizing General Packet Radio Service (GPRS) over cellular.[23] The commercial GPRS networks currently in use for certain types of data services which are not mission critical. However, these cellular networks arrangements will not be sufficient as a longer term solution, as data usage has evolves to mission critical applications and minimum quality of service obligations must be met.[24] One driver of this increased demand on data networks is the fact that PSS agencies are increasingly moving to field command. There are distinct advantages with being on site such as increased situational awareness. Granted, current visions of moving to the field do not include attempting to duplicate the office in the street, there are different functions performed, but it would allow the officers in the field to do their work and to maintain command and control resources in the field.[25] Field commanders need mobile command communications and these systems are typically vehicle mounted.[26]

> "Technology is huge, and we rely on it every day. I can run a tag on a car that I stop and find out if he's a murderer, and I know it before I get out of the car. It saves lives, and the productivity outweighs the cost by thousands of dollars."
>
> - Neil Dent, police chief for Lone Oak Police Department, Texas

Improving situational awareness is a driving factor for such uptake in the longer term. This will require the collection and dissemination of information online all the time, from a range of sensors (e.g. wind, radiation, environmental and hazard sensors) and cameras.[27] The Dutch PSS network operator C2000 is currently trialling broadband data communications and expects that demand for broadband data to grow quickly overtime. This will be dependent on matching work processes and C2000 is exploring everything from gathering information from data bases, sending photo material on lost or wanted people to receiving detailed maps of incidents, sending and receiving information on finger

23 See Section **3.2.7 Current Allocation Insufficient for Future Needs**.
24 Comments of Jaakko Saijonmaa, EADS.
25 Comments of C2000. While a centralized command and control facilities will not disappear in the near term, there is a trend towards operational management deploying to field. For example, the Helsinki Rescue department has vehicles with built-in mobile field command centres, that it uses for major events and incidents. Comments of Jaakko Saijonmaa, EADS
26 Ibid.
27 Ibid.

prints. There is also an increasing interest in broadband services which include transmission and reception of real time video surveillance.[28]

The requirement for monitoring information may increase quickly as the situation develops. The aim would be to send back still images and video, for example, of demonstrations and marches and any interviews so the evidence can be captured and not refuted later.[29] Selex Communications believes that video transmission over the mobile network is of great importance to its PSS clients.[30] Its concept of video monitoring is that it requires low, constant bit rate communications for low resolution images. However, should the situation escalate and require greater situational awareness, higher resolution images and enhanced video comprising higher data transfer rates can be provisioned. Providing the necessary quality for video requires broadband technology incorporating enhancements beyond what the current generation networks can support.[31]

> PSS users want to have the same services in day-to-day operations as they need for an emergency, and on the same network.
>
> - Manuel Torres
> Vice President, Motorola

The access to databases while mobile allows the police to maintain a presence in the community while accessing data and reporting in. Further, location-based information could prove vital to such services. Similar to police database inquiries, ambulance services will be equipped with in-vehicle access to patient records and other telemedicine applications. On the futuristic, cutting edge, fire services are considering the need for two-way video such as helmet mounted cameras and the ability to transmit building plans to rescue workers. All PSS responders could benefit from applications such as status monitoring of vital signs exposure and their physical location.[32]

A recent survey conducted by Motorola and APCO (The Association of Public-Safety Communications Officials) of more than 200 public safety administrators and officers in the top 100 U.S. markets made several significant findings about current and future use of communications technology. According to the survey results:

- 72 percent report using systems that enable cross-departmental; communications

- 72 percent report using computer mapping technology to enhance response time;

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28 Comments of C2000.
29 Comments of Peter Wickson, NPIA.
30 Comments of Annamaria Raviola, Selex Communications.
31 Ibid.
32 ETSI technical specification TS 102 181, Section 5, “Emergency Communications (EMTEL); Requirements for communications between authorities/organizations during emergencies”.

- 68 percent report using personal digital assistants to perform “back office” work in the field;
- 44 percent report using traffic light sensors for approaching emergency vehicles; and
- 42 percent report using mobile video systems and video surveillance devices in public places

On the “wish lists” for future applications:

- 47 percent of PSS officials believe tracking solutions such as satellite tracking of vehicles are necessary;
- 37 percent of PSS officials want “recognition/identification” technologies including facial recognition;
- 41 percent of PSS officials want automatic license plate recognition;
- 26 percent of PSS officials want rugged notebooks;
- 30 percent of PSS officials mobile video systems;
- 31 percent of PSS officials want traffic light sensors;
- 35 percent of fire departments would like more mapping technologies;
- 63 percent of police officials want mobile video systems; and
- 51 percent of police officials and 20 percent of fire departments want improvements in interoperability of communications.

An important consideration will be whether there is a business case for such services.[33] Nonetheless, PSS users want to have the same services in day-to-day operations as they need for an emergency, and on the same network.[34] However, in all of these cases, the limiting factor is spectrum.[35] The digital dividend seems a unique possibility to safeguard PSS interests for technology support over the medium and long term.[36]

33 Comments of Peter Wickson, NPIA.
34 Comments of Manuel Torres, Motorola.
35 Ibid. and Comments of Mark Yates.
36 Comments of Annamaria Raviola, Selex Communications

2.4 Harmonization across EU

TETRA was designed for optimum mobile operation in the 300 to 1000 MHz frequency range. The harmonized allocation for PSS spectrum is between 380 – 470 MHz, however, only two 5 MHz-wide blocks are in actual use by PSS. Much of this spectrum is already utilised to provide "commercial" PMR and PAMR services. Within the CEPT administrations the frequency bands for emergency services were harmonized through ERC and ECC Decisions with, in March 1996, ERC/DEC/(96)01 being published which required the frequency bands 380 – 383 / 390 – 393 MHz and 383 – 385 / 393 – 395 MHz to be available from 1 January 1998 for use by a single harmonised digital land mobile system for emergency services. This facilitated fast roll-out of the TETRA networks although in some cases, such as the Czech Republic, Tetrapol networks were deployed in the same frequency band. Within the CEPT WGFM 38 has been tasked to find spectrum that can be used to provide the needed spectrum capacity for public safety users of TETRA wishing to deploy wideband services (TEDS, also known as TETRA2) and to introduce Broad Band Disaster Relief (BBDR). A 'tuning range' concept is being developed in CEPT ECC WGFM as a solution to accommodate the deployment of TEDS covering the 380 – 400 MHz, 410 – 430 MHz and 450 – 470 MHz bands and correspondingly for the BBDR a solution is being considered around 5 GHz.[37] In reality it is already clear that the tuning range concept for TEDS will not be sufficient to identify the radio channels required in all CEPT countries, because these bands are loaded with existing applications. This demonstrates the challenge in finding suitable spectrum for next generation PSS networks and services as there is no significant un-used spectrum in the EU and CEPT regions between 300 and 1000 MHz except that which will be released through analogue TV switch over. Also the use of 5 GHz is not ideal for PPDR if the hot spot extends over any sizeable area but it is extremely difficult to identify around 50 MHz of harmonised spectrum at any lower frequencies.[38]

> "Public safety is aware that the biggest threat to safety in our communities – and as a nation – is a natural disaster. A natural disaster can have a greater impact on more people than a terrorist event."
>
> - Richard Mirgon
>   first-vice president
>   APCO International

Mark Yates, the Deputy Chief Fire Officer of Hertfordshire Fire Service, noted that emergencies, such as the recent flooding in the UK, were over large geographic areas and it was necessary for any communications to operate over distances in excess of 3 kilometres. This has also been the case with the fires in Greece and with the potential for further similar disasters, anticipated due to global warming. It is important to recognise that the use of ad-hoc networks at 5 GHz will not meet these requirements.

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37 FM PT38 is currently drafting a new ECC Recommendation on 5 GHz BBDR.
38 Comments of Peter Wickson, NPIA.

There is a need to provide broadband services in frequency bands where the necessary coverage can be achieved cost effectively.

The Netherlands requested a further two 5 MHz-wide blocs spectrum in the 450 – 470 MHz band to provide an interim solution to support the need for higher speed data services but in the longer term it is envisaged there will be a need to access further spectrum e.g. 700 – 800 MHz released by the transition to digital broadcasting.

2.4.1 Intranational and International Interoperability

There have been a number of major events where the importance of interoperability and the ability to combine resources and continue to communicate on a highly controlled and effective basis have been highlighted

In addition to the major disaster scenarios, there is a need to strengthen the cooperation of agencies during daily fire fighting, law enforcement etc operations and that need is widely recognised among the European Public safety agencies. One of the key drivers for the shared multi-agency public safety networks in Europe was the need to ensure fluent cooperation of the forces in the field. Experiences from major incidents (e.g. cross boarder fires in Germany and the Netherlands and explosions at the boarder between France and Belgium) were triggering national decisions to this direction.

There are three aspects to consider in cross border communications:

- A dedicated solution for each country will be expensive (high price of terminals as will have to pay for their support / availability)
- When cross-border officer still needs contact with their own data bases and easiest way to do this if the neighbouring country is utilising a compatible technology / frequency band.
- When cross-border the officer may need access to that countries data bases (there are also issues here of data administration)[39]

2.4.2 Cross Border Cooperation and Coordination

Increasing globalization of terrorism and other security threats makes it important to ensure that future PSS systems are capable of working across national borders. Neighbouring countries' networks must interoperate with one another for both routine day-to-day operations and disaster relief. There is therefore likely to be benefit in

39 Comments of C2000.

identifying at least some internationally harmonized spectrum so as a minimum can support “direct mode” operation (DMO) where equipment operates independently of any controlling network. A co-coordinated approach to frequency planning will also be required to avoid interference arising between neighbouring countries. Such interference was often a problem in legacy analogue systems, a notable example being in the UK where base and mobile transmit frequencies were not aligned with continental Europe.[40]

On the Continent, the political agenda of the EU was one of the important reasons behind the harmonisation of Public Safety radiocommunications spectrum. The Schengen Treaty was created to enable the internal market and manage the free flow of goods and people across internal borders. The Articles of the Schengen Acquis – later integrated in the EU - mandate cooperation of police forces and customs officials across the national borders and also identify the communication procedures to support the cooperation. The introduction of new digital nationwide radio systems provided the opportunity to adopt a single, harmonized frequency band for PSS radio services throughout Europe, replacing the legacy of country-specific analogue bands, which were often assigned on an organization-specific basis (i.e. different frequencies would be used by police, fire and other services with no interoperability between them). Several countries now have national PSS networks which can be accessed by all the accredited PSS agencies, examples include the Airwave Solutions Limited network in the UK and the VIRVE network in Finland.

Harmonisation of the radio spectrum for narrowband Emergency Services radio communication was done successfully on a European level. As a digital system, TETRA enabled the simultaneous conveyance of voice and data over the PSS radio networks and provided improved coverage (by facilitating cellular planning and handover) and resilience to interference. However, along with the evolution of communications technologies and the users’ needs for even more efficient tools Europe is facing a new challenge to extend the harmonisation of the PSS communication to also include new evolving services requiring wideband and broadband radio channels. Currently there are no clear solutions agreed to achieve this. Utilisation of common spectrum will allow PSS users to continue to operate effectively when it is necessary to cross borders.

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40 There still remains co-ordination issues between neighbouring countries unless there is one central organisation that does all the frequency assignments. This is the reason for the HCM Agreement (previously known as the Vienna and the Berlin agreement) which includes a Harmonised Calculation Method for cross-border interference. The example in the UK is in the 450 – 470 MHz band and still exists.

2.4.3 Economies of Scale

It is important that when investing in PSS networks that there is a sound and viable business and financial case underpinning the decision. If it is possible to identify common technologies as well as spectrum there is the potential to lower the cost of the network and terminals and also ensure there is the required support, range and availability of terminals. Also it is increasingly the case that vendors will not develop products unless they see a sufficiently large market.[41] There are exceptions but because of the lack of economies of scale this means equipment will often be expensive. Economies of scale offer operational efficiencies and commercial-off-the-shelf (COTS) technologies do much to ease budgetary pressures for government.[42]

So in identifying spectrum it will be important to take into account potential constraints such as the need for a sufficient size market for the development of equipment by vendors and the cost of ownership of networks required to support the services and the match against future budgets. The use of tuning ranges is being considered for PSS equipment but it is expensive to develop equipment with an infinite tuning range. There is support for use of 50 MHz in the 5 GHz NATO band for disaster relief because this matches with Regions 2 and 3 and provides economies of scale of equipment and potential for inter-operability in the case of collaboration on major disasters.

2.4.4 Commercial Networks in Europe

There is a wide a range of commercially available equipment, services and networks that are available to meet the requirements of the PSS users and there are PSS organizations which do rely on these networks for some services. In the UK, GPRS over cellular networks is currently being used to provide data capability for some police forces. While cellular mobile networks can fulfil certain of PSS communications needs, and are currently used by some organizations, those networks are optimized for different objectives, namely meeting consumer experience, service and price demands. These networks are not hardened and designed to cater to the stringent requirements of PSS organizations. To meet the need for guaranteed access commercial cellular networks in the UK have employed a technology called ACCOLC which can be used to provide priority network access to PSS users by locking out or switching off access to non-priority users.[43] However there are difficult decisions to be made when balancing the needs of the public versus operational requirements and invoking ACCOLC may have an impact on the operation of other services involved in the emergency

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41 Indepen and Aegis study for Ofcom into the impact of Harmonisation and Standardisation.
42 Comments of Général Alain Silvy, Minstry of Defence, France.
43 Access overload class (AACCOLC) - normal users are assigned a priority from 1 to 10 and emergency users priorities 11 to 15. The network will selectively disable the lower priority users to provide capacity for PSS.

response[44]. By comparison, Universal Mobile Telecommunications System (UMTS) networks currently incorporate no means for guaranteeing priority access to PSS organizations.

The mission to protect property and save lives places on PSS organizations specific requirements for robust communications systems in terms of access, redundancy and quality of service. These demands make commercial networks particularly ill-suited for mission critical communications. However, it is recognised that some of the services offered by commercial networks are suitable for certain public safety applications and if simply matching on the basis of capacity and mobility there are a number of current and emerging technologies that could provide the capability to carry voice and data. Table 2 below demonstrates that there is no combined network / technology solution currently available that can meet the needs of PSS going forward. PSS organisations require their own spectrum to deploy whatever technologies can meet their service and application needs in an appropriately designed network to meet their operational requirements.

Table 2: Comparison of PSS requirements and available technologies

	Capacity	**Mobility**	**Coverage / QoS / Robustness**	**Availability of Products**
TETRA	x	√√√√√	√√√√√	√√√√√
UMTS	√	√√√√√	√√√	√√√√√
UMTS with HSDPA	√√	√√√√√	√√√	√√√
CDMA 2000	√√	√√√√√	√√√	√√√√√
WiMAX (802.16e)	√√	√√√ (depends on frequency band)	√√√ (depends on frequency band)	√√
UWB	√√√√√	√	√	√√√
TEDS	√	√√√√√	√√√√√	Products planned but not yet available

Source: Aegis Systems

Given that it is difficult for commercial technologies and networks to meet the needs of PSS communications tends to explain why there are few implementations of such.

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44 Report of the 7 July Review Committee, published by the Greater London Authority, June 2006, commented in sections 3.4 – 3.10 on the reliance on mobile phones http://www.london.gov.uk/assembly/reports/7july/report.pdf.

2.5 Case Study: The Buncefield Fire – PSS Communications in Action

On Sunday, 11 December 2005, the Hertfordshire Fire and Rescue Service was called to an incident in the Buncefield Area of Hemel Hempstead in the UK. There had been 3 explosions at the UK's fifth largest fuel distribution depot which stored over 100 million litres of fuel (oil, petrol and kerosene), the resultant fire involved 22 fuel tanks. The fire led to the closure of the M1 motorway for 12 hours, 2,000 people living near the site were evacuated, and 1,000 fire fighters were involved in fighting the blaze and maintaining a foam blanket for 26 days. Properties were damaged up to 3 kilometers away but there was no loss of life or major injury.

Mark Yates, the Deputy Chief Fire Officer, who was in charge of the Buncefield incident provided the following personal views and information:

At Buncefield there was a mix of VHF, UHF and mobile phone (cellular) that were used. The operation was based on the extensive use of voice communications to relay information but there were problems in obtaining good voice clarity across all of the incident area. In this case the cellular networks delivered for Buncefield and there were no requirement to ask for priority access to the networks. However this was due to Buncefield not being people oriented – it was a Sunday morning, no casualties were involved and the incident was over a long period (26 days).

Mark considered there could have been benefits in setting up a local area network that would allow tough books on appliances to be linked to the central command post. This would allow up to date information on building plans, products stored etc to be sent and would have also provided true mobile voice communications across the incident ground.

At Buncefield a police helicopter sent video of the incident area from above. This had limited benefit but what would have been helpful to assess the level of damage and devastation would have been if the sector commanders could send live high quality video of what they were seeing back to HQ (Command and control). This would have facilitated conversations on evacuation and resources needed, for example the Fuji building was devastated and should the urban search and rescue team be deployed. Use of helmet cameras, products which are already available, would require p-mp transmission over a wide area.

Robotics would have had limited usefulness at Buncefield. Probably the most effective use of robotics would be in the case of in building fires / building collapse incidents. Also the use of cameras (high definition video) would allow command and control to monitor what is happening within a building and make assessments of whether it is necessary, for example, to evacuate. Such capabilities might have been helpful in Warwickshire where 4 fire-fighters were killed inside a building this year.

However it would be essential that such services are reliable and depending on the circumstances might require infra red or thermal imaging cameras.

Looking to the future, if someone was to offer him a present to assist the firefighters in their duties, Mark proposed that a solution which would allow the location of fire fighters within a building to be reliably identified and also provide real time plans of the building would be of benefit. This would allow the incident commander to have up to date information on which to base decisions such as building evacuation. In storage depots, which are particularly high risk buildings; the ability to quickly locate causalities, the source of fires and the real-time structural awareness would be extremely beneficial.

3 Dedicated Broadband Spectrum PSS Communications

As previously discussed, from a variety of standpoints – operational, managerial and engineering – a dedicated network in a dedicated spectrum band allocated and assigned to PSS users is the best way to ensure secure, robust and immediate radio communications. This is what is widely used today. However, certain economic and political realities present growing challenges to this regime going forward. What we have heard consistently from the PSS community is that given the growing PSS communications demands on existing spectrum it is already clear that the current allocations will not be sufficient in the future. Thus, a new allocation of sub-1 Ghz frequencies must be made available for PSS communications.

> From a variety of standpoints, a dedicated network in a dedicated spectrum band allocated and assigned to PSS users is the best way to ensure secure, robust and immediate radio communications. This is what is widely used today.

3.1 Overview

Dedicated, proprietary networks currently provide PSS responders with immediate, secure and reliable radio communications for day-to-day operations and emergency situations in EU Member States and other developed nations. These mission critical systems are special-purpose networks for the exclusive use of PSS services, controlled by the Government and operated and maintained either by the Government or by a dedicated entity. In Europe, the current generation of trunked radio systems are capable of supporting voice communications, and also are capable of supporting light data functionalities such as slow IP packet data and short messaging. However, three ongoing trends apparent in the area of PSS radio communications present significant challenges going forward. These are:

i) migration from analogue to digital technology;

ii) consolidation of disparate, service-specific networks to single, shared and interoperable networks; and

iii) increasing reliance on data and multimedia capabilities in parallel to voice communication.

Newer systems employing such standards as the TETRA Release 2 TEDS component, are capable of supporting more advanced data communications, however this still falls short of the capabilities expected in the future and the data transfer rates now being delivered over commercial third generation (3G) mobile networks. The emerging range of new field applications and services will fuel a growing appetite for similar high bandwidth communications for PSS networks as will the everyday personal use of data services.

Despite improvements in spectral efficiency through the deployment of new technologies which will yield some relief to the spectrum shortage, demand growth for frequencies is likely to outstrip growth of supply into the foreseeable future. The spectrum available to existing PSS systems will not satisfy future needs for these essential services. One example of this is the current situation with TETRA TEDS in that not all EU Members States are able to identify radio channels. Therefore, communications policy must evolve to empower new systems by reallocating spectrum from the Digital Dividend to PSS mission critical communications. This decision is not to be taken lightly since it sits on the critical path for numerous other decisions necessary before deploying next generation PSS networks. Historically, it has been the usual practice to identify suitable spectrum well in advance because of the timescales for releasing the spectrum, development of standards and equipment. It may require as long as 10 years to plan and deploy such networks. Adding to the urgency of the matter is the growing need for new services to emerge due to the increase in terrorist threats, frequency of natural environmental disasters, and normal population growth.

The Digital Dividend spectrum is ideally suited to meet the developing needs of PSS PP1, PP2, and DR. One of the requirements that differentiate PSS networks from public networks is the need for ubiquitous coverage. Spectrum between current PSS allocations (around 380 MHz) and 862 MHz is essential to cost effectively meet this need because the achievable cell radius is much larger in lower frequency bands and RF waves can go around small obstacles so line-of-sight is not always necessary. Considering frequency bands that have recently been awarded or may be awarded shortly, there is potentially a 350% increase in cell radius when comparing the 700 MHz and 5.8 GHz frequency bands. In order to cover the same geographic area using the 5.8 GHz band would require 23 cells[45], while employing frequencies in the 700 MHz band would require using only one cell.[46]

The cells employing lower frequencies also do so with fewer “dead spots” in coverage. Although between 700 and 800 MHz there is currently a need for additional cell sites to provide the same coverage as the 400 MHz band it is anticipated that technical solutions will become available that allow the existing sites to be re-used.[47] Indeed, simply moving up the tuning range from the 400MHz to 700 – 800 MHz bands would significantly increase the required network investment.[48] Hence, this is the reason for

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45 A cellular network is a radio network made up of a number of discrete radio base stations. The term “cellular” network derives its name from fact that these radio base stations are organized in a system of localized sites to give overlapping coverage, fitting together like cells in a tissue. See A Michael Noll, Principles of Modern Communications Technology at 191-94 (2001).

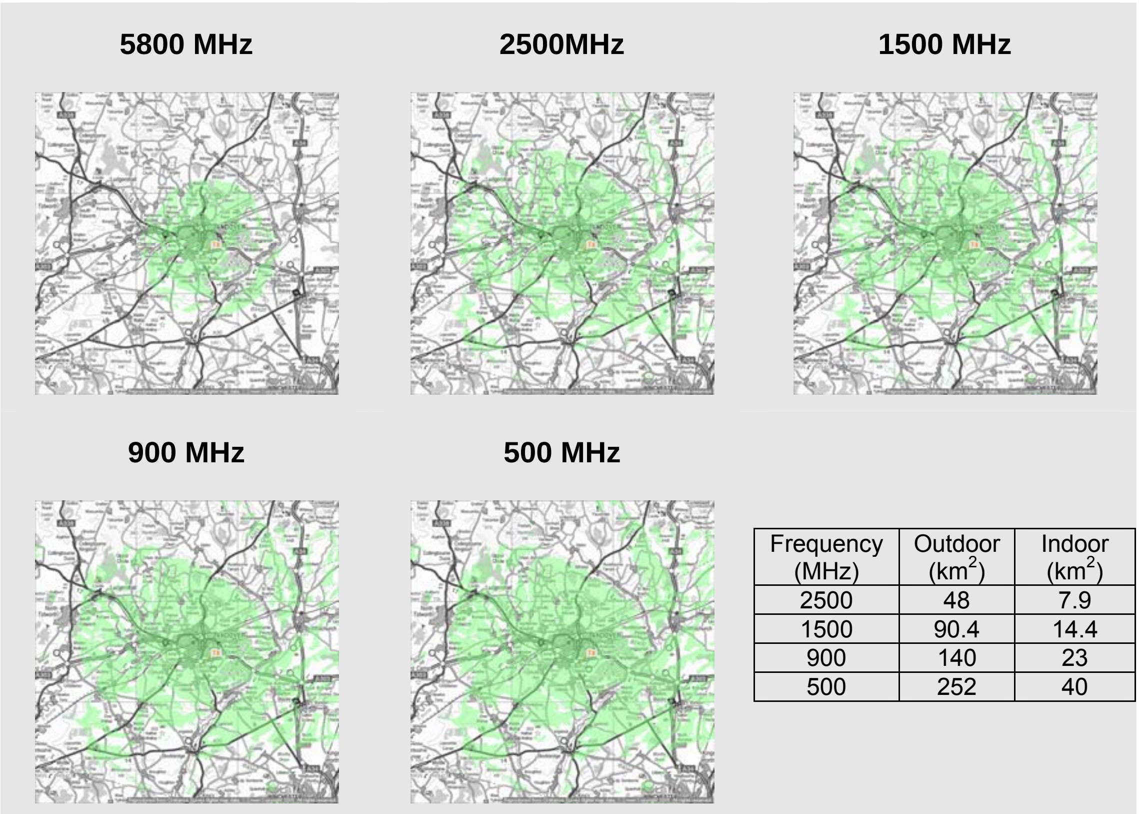
46 In most commercial networks frequency reuse is an important design criterion, thus it may be preferable to utilise cells of smaller sizes and use higher frequency bands. However, mission critical PSS networks require wide area coverage and non-line-of-sight penetration and hence lower frequency bands. See discussion in Section **3.2.5 Technical and Operational Considerations**.

47 Comments of C2000.

48 Comments of Jaakko Saijonmaa, EADS. Operation in the 700 - 800MHz band would require another set of antennas, feeders, combiners for the existing 400 MHz installations. This might have the effect of doubling the necessary investment in radio hardware.

request for two 5 MHz-wide blocks as interim solution. An allocation at 450 MHz would be ideal since networks can re-utilise existing sites, leased lines etc. While the 800 MHz band would be less efficient, there is a greater potential in terms of amount of bandwidth available.[49]

Figure 3: Comparison of Propagation Characteristics with Frequency



Frequency (MHz)	Outdoor (km^2)	Indoor (km^2)
2500	48	7.9
1500	90.4	14.4
900	140	23
500	252	40

Source: Aegis Systems Ltd.

Figure 1 demonstrates the propagation characteristics of different frequency bands, using engineering data. The maps were created using the new ITU-R propagation model P.1812 to predict effective cell coverage (in green) based on propagation loss.[50] The table uses the COST Hata rural model and provides indicative values for rural

49 Comments of C2000.

50 The predictions have been arranged to give the same median received power (-69dBm) at the receiver, assuming an isotropic antenna (1.5m above ground) at all frequencies. Transmit power is 200W ERP at all frequencies, from an aerial at 25m above ground.

areas of the outdoor and indoor coverage that could be provided by a 120 degree sector antenna in different frequency bands.[51]

3.2 Policy

In this section, we examine the policy debate regarding the reallocation of Digital Dividend spectrum to PSS mission critical networks. We set forth the arguments which support such policy undertakings and the critiques of those arguments.

3.2.1 Moral Obligation

PSS services responders provide indispensable police, fire and other emergency services to respond to emergency situations ranging from the routine (sports events, automobile accidents, house fires) to the extreme (terrorist attacks, earthquakes, massive floods). Each individual in our society has the expectation of, if not the right to, emergency services. In turn, society expects that its government will expend the necessary resources to aid those in emergency need. The provision of emergency services extends beyond the social contract and invokes a moral obligation to protect life, welfare, and property.

We owe a debt in return to those individuals who have answered this calling and put on the uniform. Society must provide the necessary resources which will minimise the risks to PSS personnel by providing them with modern communication tools. Not only does this protect their well being, but also allows first responders to be deployed more effectively out in the field and able to be pre-armed with information to help them deal with an incident. With easier access to databases by all PSS organizations can maximise the benefits from their sources which will likely improve the chance of an accident victim surviving by direct communications with the hospital when they are being treated by the ambulance personnel or increase the likelihood that criminal will be apprehended before he can commit more crimes. In order to save lives and property, while guarding their own, PSS organisations and their personnel require mission critical wireless communications access.

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51 For indoor coverage it is assumed that there are additional losses which have been assumed to be around 15 dB.

3.2.2 Social Cost

Aside from being simply tragic, the loss of life and property bears societal cost. In the terms of the 'dismal science', the loss of life and property implies a loss of income. If the person who loses his life is near the end of his lifecycle, the lost contributions to society and the economy are small. However, if the person is young or survives but requiring lifelong, specialized medical care, the economic burden to society could be quite high. Further, the loss of infrastructure as well as the intellectual capital of the individual (education, training, intelligence, etc.) limits growth for us all.

A monetary valuation of public safety services is hard to assess, frustrating any calculation of the monetary value of one of its critical inputs: public safety spectrum. Nonetheless, the consequences of having insufficient PSS spectrum resources could be huge, if not simply even catastrophic. Witness the New York City fire-fighters who tragically died in the 11 September 2001 attacks because their radios were not able to receive the evacuation order.[52] While actuarial science might calculate a monetary value to those lives lost, an efficient, market clearing price for emergency services, and hence, an efficient price for the communications which are an input to those services cannot be known. This is due in part to the fact that there is no competition in emergency services, nor should there be competition. Such competition price for services would likely result in morally perverse outcomes. For instance, a millionaire may be willing to outspend for spectrum to check his email from his yacht than the fisherman who places a distress call for a rescue at sea. This is a 'death bid' for which a rational person might pledge his entire net worth and all future earnings. This is simply a perverse outcome, and it has occurred in the past.

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52 See The Final Report of the National Commission on Terrorist Attacks Upon the United States (9/11 Commission Report) at 297 - 302.
At 9:59 a.m. on September 11, 2001, the first of many evacuation orders was transmitted to police and firefighters in the World Trade Center's North Tower. Police heard the order, and most left safely. But firefighters could not receive the order on their communications equipment—even as people watching television at home knew of the tragedy unfolding. When the tower fell 29 minutes after the first evacuation order, 121 firefighters were still inside. None survived.
Jon M. Peha, "Improving Public Safety Communications", Issues Science and Technology, http://www.issues.org/23.2/peha.html (Winter 2007).

Figure 4: A Fire Mark Indicating an Insured Building in 18th Century London

Source: London Fire Brigade

This may sound like an extreme example, but it is not far fetched. Subsequent to the Great Fire of London in 1666, insurance companies were granted charters to provide fire assurances organizing for-profit private fire brigades. These private fire brigades, using the latest equipment, put out fires in buildings insured by the various firms. To denote which buildings were insured, and hence to be saved, the insurance companies issued a metal badge or fire mark which was affixed to the outside of a building (See Figure 4). This led to predictably perverse outcomes. Uninsured buildings, or ones whose insurer's fire brigade did not arrive, were frequently left to burn.[53] If the private fire brigade did arrive, the building owner's problems might not be ended. Often the fire brigade would ask for more money before putting out the fire. In purely economic terms, the fire brigade would merely be extracting greater rents from the building owner whose willingness to pay has been increased by watching his home burn to the ground.

Modern society holds a moral obligation to provide PSS services to its citizens regardless of their ability to pay. Here, we choose principal over economic efficiency.

3.2.3 Risk Profile for PSS Services

Overall, Governments present the best risk profile for deploying and managing public safety networks. With their power to levy and assess taxes, governments can spread costs across diverse populations and geographic regions. Thus, while one area in a country may be affected by a natural disaster, this cost can be spread across areas which are not affected. In turn, unaffected areas will share their risk with all other areas of the nation. Further, governments can reduce the associated with business and business cycles, such as insolvency. By not relying on a private sector actor, governments can achieve a minimum level of risk that mission critical PSS communications networks will be available today and in the future. This level of risk is that which associated with society as a whole, and not a single entity. As we note in

53 See History of the London Fire Brigade. http://www.london-fire.gov.uk/about_us/our_history/the_great_fire_of_london.asp

Annex B, the company Frontline Wireless, proved to be too risk a financial investment and lost its backing to bid in the auction the license and had to withdraw from the auction in the recent FCC 700 MHz band D-Block.[54]

Furthermore, data protection laws within the EU are extremely strict. They provide substantial penalties for breaches of data security. Since extremely sensitive and confidential information flows over PSS networks, the risk of a data breach could reduce the number of companies willing to accept that risk, thereby chilling investment. Investors may feel that the potential liability stemming from a data breach could outweigh the gains associated with investing in such a network.

This is not to say that the operation and maintenance of the radio network could not be done by a commercial operator and there are existing examples of that kind of arrangements in EU member states. The essential thing is maintaining control of the service level agreements, quality of the service, information security and related issues in the Government domain and ensuring continuation of the service under any circumstances. See Section 3.2.6.

3.2.4 International Harmonization

One of the driving forces at the heart of the European Union is that of harmonization. Such harmonization can take place along a variety of different dimensions. Notable to our discussion is harmonization across rules and policy regarding spectrum usage. This is important for achieving economies of scale and for resolving cross-border interference issues. Also important to this discussion is the harmonization of technologies and standards. However, there is a growing trend towards technology neutrality in the provision of radio communication services, particularly in the commercial sector, but also in some cases for PSS applications.[55] Whilst dedicated standards like TETRA and its derivatives may provide appropriate platforms on which to base future broadband PSS systems, it is also possible that other evolving standards such as LTE, WiMAX and the various IMT-2000 platforms could develop to be suitable.[56] A technology neutral approach provides maximum flexibility to licensees on how they utilise the spectrum.[57] Since we urge technological neutrality in PSS spectrum policy, it is beyond the scope of this paper to evaluate the technical merits of these emerging standards.

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54 See Section **Annex B. Reinvesting The Digital Dividend** in the US: FCC Auction #73 D-Block.
55 The European Commission and CEPT are urging technology neutrality for all future spectrum allocations.
56 However, since there have few implementations to date, we cannot confirm or reject the technical merits of this argument. See Section 2.4.4 Commercial Networks in Europe.
57 Comments of Emergency Services Spectrum Manager, Ofcom.

The Digital Dividend is an ideal opportunity for longer term harmonization, leading to the development of technical solutions that would allow the re-use of existing sites and needed economies of scale.[58] A dedicated, harmonized band for PSS systems encourages a single market since vendors are more likely to view the market as sufficiently large to justify product development. PSS communications systems are a niche market. Indeed, in 2007, approximately 1 billion GSM handsets were sold compared to approximately 1 million PSS handsets. Such economies of scale will ensure that equipment will be less expensive. It is significantly less costly to develop and produce radio equipment which operates in a limited number of bands or a single, predetermined band.[59] So in identifying spectrum it will be important to take into account potential constraints such as the need for a sufficient size market for the development of equipment by vendors and the cost of ownership of networks required to support the services and the match against future budgets.

Despite being a niche market, PSS communications have significantly benefited from the economies of scale afforded by harmonization. The 1996 decision regarding for 380-385/390-395 MHz has proven to be highly successful. Most European countries have or are in the process of deploying nationwide shared PPDR networks based on that decision. The introduction of TETRA also provided the opportunity to adopt a single, harmonized frequency band for PSS radio services throughout Europe, replacing the legacy of country-specific analogue bands, which were often assigned on an organization-specific basis (i.e. different frequencies would be used by police, fire and other services with no interoperability between them). Several countries now have national PSS networks which can be accessed by all the accredited PSS agencies. In the final analysis, the real question is, what comes after narrowband and how to create the rules necessary to ensure sufficient spectrum for next generation PSS mission critical services. The PSS community has greatly benefited from competition, innovation, specialized products and improved cost-benefit performance.

As noted earlier in Section 2.2.1 on TETRA, despite the identification of a harmonised spectrum band for emergency services the deployment of new networks may require a significant lead time. It is therefore important that additional spectrum is identified now to cater for more advanced services as has been the case for 2G and then 3G cellular. A dedicated band for PSS spectrum in and across each Member State will make great strides towards the harmonization that international assistance and a common market require. Divvying up the band may serve to frustrate this effort. An example of effective international harmonization is the implementation of 112 emergency calling. Following the Universal Service Directive (2002/22/EC), 38 European countries have instated 112 as a common emergency number 112 for landline phones and the GSM mobile phone

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58 Comments of C2000.

59 Granted, advanced technologies such as SDR and cognitive radio have the potential to mitigate costs of gaining access to spectrum, but they do not alleviate the fundamental engineering and economic challenges of multi-band and multi-mode operation.

standard. This universal emergency services telephone number allows a caller to contact local emergency services for assistance using a number that can be easily remembered and dialled quickly.

3.2.5 Technical and Operational Considerations

There are several technical concerns regarding the design, deployment, and management of mission critical PSS broadband communications networks which warrant separate and dedicated spectrum allocations. Among these requirements are the coverage, capacity, reliability, and redundancy requirements of such networks.

> "When every second counts – an everyday situation – emergency services need the capacity to reach one another in an instant. This has been borne out by many disasters and crises in the past. A professional communications system is simply essential. In order to illustrate the important role C2000 plays for our emergency services, a documentary was made as a part of the final evaluation.
>
> - J.W. Remkes
> Minister of the Interior and
> Kingdom Relations
> Netherlands

One of the requirements that differentiate PSS networks from commercial networks is the need for ubiquitous coverage. PSS networks need to be provisioned widely so that they can provide availability to as much as 99 percent of populated areas.[60] PSS networks have to be pre-deployed anywhere first responders may need communications should an incident arise. This differs from the deployments of commercial wireless networks and their spectrum allocation. Commercial wireless networks build their networks for coverage and capacity based on where their customers are located.[61] Spectrum allocations granted to commercial users could therefore be divided into different bandwidths depending on whether it is required in an urban, sub-urban or rural region. Given the geographic coverage requirements of PSS mission critical networks, the selection of tuning range for is of great importance. The selection of frequency bands affects the useful range of radio communications. Using frequency bands above 350 MHz and below 900 MHz provides greater flexibility in cell sizes. The size of cells can always be made smaller by reducing the transmitter power of the base stations. Mission critical PSS networks require wide area coverage and non-line-of-sight operation which is only possible using lower frequency bands. Narrower tuning ranges enable networks and handsets to be designed and deployed at reasonable costs.

60 Comments of Heidi Hattendorf, Motorola.
61 Comments of Jeppe Jepsen, Motorola.

The use of the 5 GHz band, currently under discussion in FM38, is only considered to be suitable for localised disaster relief. The only way of economically meeting the wideband and broadband needs for PSS on a national basis is in frequencies below 1 GHz. As such the Digital Dividend spectrum is very interesting because it is likely to be the largest amount of sub 1 GHz spectrum released and it is unlikely that any more spectrum will become available in sufficient quantity in the immediate future. However the timescales for the auction of the spectrum in the UK are such that it will be extremely difficult for the PSS to put in place a business case to secure the necessary funding to purchase the required spectrum.[62]

Further, PSS networks have stringent capacity requirements. PSS usage involves long periods of low usage and short periods of intensive peak usage during emergency situations, with high requirements of availability and reliability at all times. Other types of PSS usage, like police communications are near constant. This so-called offered load holds different implications for PSS networks than it does for commercial wireless networks. PSS users cannot depend on commercial networks because they may be overloaded at peak times during an emergency. One example of an emergency case, which the commercial wireless network was not capable of handling, was a football game in Madrid where ETA phoned in a bomb threat. The threat turned out to be false, but the cellular network was not capable of handling the increased traffic at the stadium.[63] Further, PSS users require rigorous tolerances for response and availability. PSS networks have to be capable of nationwide call set up with latencies of less than 0.5 seconds.[64]

Perhaps the most important factor in PSS networks is reliability. These networks must be built to provide so-called “five nines reliability.” This means they must be engineered to be available to carry and deliver services for 99.999 percent of the time, despite adverse conditions. Also, peak demand may come at the same time that the network is undergoing physical and environmental stress. In the case of natural disasters, energy black-outs or other adverse conditions PSS networks are needed most and network outages cannot be tolerated.[65] Therefore, power supply redundancy is essential. This in and of itself may be justification for separate networks.[66] In comparison commercial networks are designed according to commercial quality standards to provide the highest return to the investors. If a commercial network is unable to offer service, it represents only a loss of business revenue opportunity to the provider. When a PSS network is out of service, lives may hang in the balance.[67]

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62 Comments of Peter Wickson, NPIA.
63 Comments of Heidi Hattendorf, Motorola.
64 Comments of Jeppe Jepsen, Motorola.
65 Comments of Annamaria Raviola, Selex Communications.
66 Comments of C2000.
67 Comments of Manuel Torres, Motorola.

In practical terms the major differences between a PSS network and a commercial network are:

- Resilience of network components 1+1 or 1+n redundancy;
- Resilient architecture of back-bone and back-haul connections;
- Enhanced uninterruptible power back-up, typically 6 to 8 hours; and
- Priority classes in accordance to the user / mission to reserve the network resources for the most urgent operations[68]

Because of these criteria the PSS community has typically eschewed shared public and commercial network solutions.[69] For example, the City of London bombing which showed the critical nature of voice communications and where after the bombings, the press and other private GSM users kept calls open to ensure they did not lose their access to the networks. The ability to shut down civil users in the GSM network does not work well.[70] In Section 3.5, we consider certain limited conditions under which pre-emption may be possible with commercial services riding on spectrum and networks dedicated to PSS communications, but not *vice-versa*.

Mission critical PSS communications networks have little overlap with the architectures and geographic coverage of commercial wireless networks. Granted, in future there may be some overlap the radio technologies employed. Nonetheless, since these criteria cannot be compromised for PSS networks, and a joint allocation will inevitably result in significant dangers for PSS first responders. Therefore, the need to preserve life and property requires availability and performance that is difficult to achieve by other means than a dedicated network infrastructure.

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68 Comments of Annamaria Raviola, Selex Communications.

69 Ibid. "[E]ven in today's Internet-connected world, [US] public safety agencies continue to rely on single-purpose technologies that do not afford economies of scale, network flexibility, or broader functionalities routinely used by the military or private sector enterprises." Phillip J. Weiser, Communicating During Emergencies: Toward Interoperability and Effective Information Management, 59 Federal Communications Law Journal at p. 102 (2007). See also, Larry Irving, "Land Mobile Spectrum Planning Options, app. At 1 (19 October 1995), http://www.ntia.doc.gov/osmhome/re[prts/slye_rpt/appendix.html and Jason Chapman, "Europe's Standard Shows Way Forward for Private Mobile Radio", Gartner Research Brief, at p. 3 (8 July 2003).

70 Comments of Jaakko Saijonmaa, EADS. Giving priority on GSM networks proved problematic during the 07-07 Madird bombings. Comments of Mark Yates, Hertsforshire Fire Brigade. During the Buncefield fire, emergency responders were able to get access on GSM networks for priority voice communications because the incident took place starting on a Sunday in an industrial area where there were few non-emergency personnel present. Ibid. See Section 2.5 for more on the Buncefield fire.

3.2.6 Corporate Form

> "The business case is radically different for our government customers. If a commercial network [sic] is down, it represents only a loss of business. When the cost concerned with disaster is the loss of life, it is completely different."
>
> \- Manuel Torres
> Vice Preseident
> Motorola

For-profit corporate organizations are poorly suited to providing the types of public goods which government bodies can offer. Private corporations will offer a level of services which maximizes profit, while government organizations will offer a level of service which it believes to be a public optimum. This is due to the diverging incentives officers of the two types of organizations have. Corporate managers seek to maximize return on investment in part because their financial rewards may be tied to it and because the equity owners have the power to remove management. Public officials have a similar motivation. If they do not provide a level of service which the public believes fulfils its needs, they will remove the public officials in the next election cycle. Both types of organizations fulfil important social needs and both are subject to perverse outcomes. It is very difficult to value the cost of a disaster. It might be possible to put an economic value on an incident such as the pipeline break at Miyorka, but not necessarily possible for the loss of life. "A commercial plan might look one way on paper, until there is the first incident. This is why the needs of mission critical must be considered and designed in up front."[71]

The level of investment required to bring commercial networks up to these stringent requirements would not be economically viable without government support. In addition, governments must bear the cost of private return on investment in such 'gold-plated' networks. Another factor which makes commercial networks poorly suited to PSS communications is the lifecycle of PSS networks is much longer and perhaps beyond corporate return horizons.[72] This is due to training and reliability concerns. Thus, terminals must be the same for at least 5-6 years.[73]

Moreover, this increased level of network investment may afford an unfair competitive advantage for the commercial network which is awarded a contract to provision a PSS network. In order, to level the playing field and limit cross-subsidization it may be

71 Comments of Heidi Hattendorf, Motorola.

72 "It can take several years to select the technology for PMR enhancements and process the tenders for building the networks. PMR is a large financial investment and government is involved in the decision-making. This means a considerably longer sales cycle for vendors selling equipment to TETRA operators. Unlike mobile operators, which are driven by the need to sell new services and terminals to users, private sector operators need more stability from their networks and terminals." Jason Chapman, "Europe's Standard Shows Way Forward for Private Mobile Radio", Gartner Research Brief, at p. 5 (8 July 2003).

73 Comments of Manuel Torres, Motorola.

necessary to impose certain separation and accounting requirements.[74] Two other problems are presented when a for-profit corporate entity is used to provide PSS users with mission critical communications. These include the possibility that the provider could become insolvent or go out of business and the possibility of its raising prices in the future.[75] A PSS agency may find itself beholden to a single organization.[76] In order to prevent this untenable situation, the corporate entity must be subject to rigorous legal and regulatory requirements.

> "If the [US FCC 700 MHz] D-Block auction had produced a licensee, the needs of public safety would have been chained to one 'monopoly' private carrier with major uncertainties as to the financing, construction and maintenance of the network. That approach was sure to bring years of additional delay and conflict,"
>
> - John Kneuer, Senior VP Strategic Planning and External Affairs Rivada Networks

Beyond a high level of investment to ensure adherence to the rigorous standards of performance for functional, operational, resilience, QoS, and other requirements for PSS mission critical communications, a government would require a high level of control over spectrum, the operation of the PSS network, and the corporate operator. In practice, where governments have outsourced such networks, they have still retained assurances against transfer of ownership of the operator; its continued guaranteed financial viability; and the option to take management control of the operator when needed. This has been the case in UK, Portugal, Austria, Denmark, and Hungary. The level of control necessary for a PSS network may inhibit the competitive responses of the corporate entity and may make it a *de facto* a governmental organization, though it may be a private corporate form.

Somewhat ironically, a commercial network which offers PSS services may face unfair competitive disadvantages. A commercial PSS network may find itself a victim of a monopsony, an inefficient market where there are many sellers but only a single buyer. After a high level of investment to bring its network up to specifications, private operators would only be able to contract with PSS users. They could also be constrained to signing service level agreements, for the provision of PSS services, for only a limited period of time. In point of fact, the user contracts for the Airwave Solutions Limited network in the UK will start to run-out as early as 2016.[77] According to NPIA there is no guarantee that contracts will be renewed, which places Airwave in a

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74 It is not our intent to evaluate the merits of functional or accounting separation in this report.
75 Comments of Robert Gurss, APCO International.
76 See Jeffrey Silva and Dan Meyer, *As auction wanes, public safety weighs its options: Former NTIA Chief says it's OK that D-Block bidding languishes, other disagree*, RCR Wireless News (March 14, 2008), available at: http://www.rcrnews.com/apps/pbcs.dll/article?AID=/20080314/SUB/823685201/1005/700MHzmain.
77 Comments of Peter Wickson, NPIA.

very difficult situation when bidding for spectrum as they are dependent on a limited set of customers, which increases its risk premium and raises its cost of capital. Such legal constraints would impede traditional telecoms operators in capital markets. Either way, relying on commercial providers for PSS networks has a distorting effect on competition in the mobile communications services market.

In sum, control of the service level, quality and availability of the service should remain within the public sector to secure the right service to the right users in the right places every day. The actual investment in most cases today comes from the public budget, but private financing options are also possible and sometimes used. How the practical operation and maintenance of the network is organised is more a national option depending on the political preferences and economical capabilities in each country. It is recognised that a fully Government owned and managed system would be the contractually and logistically simplest solution to manage.

3.2.7 Current Allocation Insufficient for Future Needs

Opponents to any further PSS spectrum allocation often point to the current allocation between 380 – 470 MHz of spectrum. As indicated earlier, only two 5 MHz-wide blocks are available for use by PSS.[78] The same spectrum is allocated to narrowband

78 A total of two 5 MHz-wide blocks (or a total of 10 MHz) have been allocated to PSS use in Europe. By comparison, in the United States, PSS organizations have access to more than 97.2 MHz of spectrum - a nearly ten-fold difference in allocation. As part of the transition to digital television in 2009, the US Federal Government intends to plans to transfer 24 MHz to public safety use. (Jon M. Peha, "Improving Public Safety Communications", Issues Science and Technology, http://www.issues.org/23.2/peha.html (Winter 2007).) Furthermore, the spectrum available to PSS organizations in Europe is fully used by voice traffic and some data usage.

PSS Spectrum Allocations

Frequency Band	**United States** Tuning Range (MHz)	**United States** Available Bandwidth MHz	**Europe** Tuning Range (MHz)	**Europe** Available Bandwidth MHz
VHF Low band*	25 - 50	6.3		
VHF High band*	150 - 174	3.6		
220 MHz band*	220 - 222	0.1		
UHF band*			380 - 385	5
	450 - 470	3.7	390 - 395	5
700 MHz band	764 - 776	12		
	794 - 806	12		
800 MHz band*	806 - 821	1.75		
	851 - 866	1.75		
NPSPAC band	821 - 824	3		
	866 - 869	3		
4.9 GHz band	4940 - 4990	50	Under Consideration	
Total		**97.2**		**10**

(* denotes approximate avaiable bandwidth)

Source: Kevin J. Martin, Chairman, Federal Communications Commission, *Report to Congress on the Study to Assess Short-Term and Long-Term Needs for Allocations of Additional Portions of the Electromagnetic Spectrum for Federal, State aAnd Local Emergency Response Providers, Submitted Pursuant to Public Law No. 108-458* (December 19, 2005)., available at http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-262865A1.pdf The Wideband Decision in Europe for 380-470 MHz does give the PPDR community some extra data capability, but the actual

(TETRA) and also wideband (TEDS). This spectrum is insufficient for needs in the near term future as it is already fully utilised for TETRA leaves no room for improved efficiency. Also it is not anticipated that increasing use of data services will reduce voice traffic and it may even increase the need for voice communications. The 410 – 430 MHz and 450 – 470 MHz bands are already occupied by a variety of analogue and digital narrowband technologies as well as CDMA 450 for non-public safety users and operators.

The effect of this limited spectrum allocation is that there has always been an issue with capacity at major incidents and planned events.[79] The fire and ambulance services rely heavily on data services and TETRA is a narrowband system so the data rates are limited. Some British police forces are looking outside of Airwave to meet their data requirements and using, for example, GPRS/3G and paying for access (which is reasonably cheap) as other users. However the concern is that GPRS will not be able to continue to support such needs as data becomes more mission critical.[80] Also, at an incident there could be high demand from all cellular subscribers and therefore insufficient capacity to meet PSS needs. Therefore, looking to the future there is no guarantee that the needs of PSS will be met so ongoing use requires further consideration.

The main requirement for the police is access to databases and form completion and the main perception is that the data speeds over TETRA are too low to support such requirements and also there is insufficient capacity to cater for the volumes of such data traffic.[81] There are ways that the amount of data could be reduced by stripping off superfluous information so only the actual requested information could be transmitted. However such solutions are likely to require an interface at the back-end of TETRA and also modifications to the forces databases to optimise the data transferred.[82] In many case the perception is that TETRA has insufficient capacity and speed to support any useful data services perhaps other than resource location. However, TETRA is very useful for voice, status messages and GPS based services.

Integrated services such as those described in Section 2.3.2 require more bandwidth. Ideally, to provide broadband mobile access for PSS communication requires two, 15 MHz-wide blocks.[83] Furthermore, dedicated PSS spectrum is necessary to ensure interoperability and the current allocations do not offer enough capacity for interoperability between PSS users in the near-term future. It may be argued that additional spectrum allocations are not necessary to ensure interoperability. This is

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spectrum situation does not enable high speed data as required for future enhancements of public investments.

79 Comments of Peter Wickson, NPIA.

80 Ibid.

81 Ibid.

82 See Section 3.2.5.

83 Comments of Annamaria, Selex Communications

based on the premise that there are at present solutions to interoperability which are not spectrum-based. IP networking technologies can be used to bridge legacy public safety radio base stations to enable talk paths and talk groups among first responders using different radio networks, operating on different frequencies. Such an approach would enable PSS users to continue operations using their existing radio assets.

An IP solution is not a panacea for all interoperability problems. For instance, any network-oriented solution cannot provide interoperability if the base stations are out of service or are beyond the range of first responders' handsets. Only a spectrum-based solution could provide interoperability under those circumstances.[84] IP patch systems as such are an excellent interim step; however, in the longer term public safety will need and will see integrated solutions as being necessary for interoperability.[85] Integrated interoperability will require a peer-to-peer solution that is accomplished directly from radio unit to radio unit. For example, if the trunking network were to fail the radio units would have to switch to DMO, frustrating any interoperability based on IP solutions alone. Yet, even a radio solution would not be interoperable if the radio units employ different air interfaces. In addition, each PSS network may be using different frequencies which gives rise to interoperability problems. Solving this problem requires infrastructure which tends to occupy significant quantise of spectrum. Therefore more dedicated spectrum is needed to provide unit-to-unit interoperability.[86]

3.2.8 Dedicated Networks and Dedicated Spectrum

> "Outsourcing a PSS network investment to a commercial player inherently increases the cost, as eventually the government must finance 100% of it, adding with the profit margin of the commercial party."
>
> - Jaakko Saijonmaa EADS

Beyond the question of the corporate form of the organization running the PSS network, we examine the questions whether spectrum and networks should be dedicated to PSS use or shared with commercial users. These are separate, albeit related, decisions. As we discuss at length in Section 3.2.6, the answers are based on a single concept: effective control of the network. Spectrum can be allocated as a band dedicated to PSS use. Alternatively, that band could be shared between commercial and PSS users. A separate decision is whether the network itself is used by PSS users or a combination of PSS and commercial users. It is unlikely that any PSS network today will not make use of some components of commercial networks, although it may be as simple as shared antenna towers.

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84 Comments of Robert Gurss, APCO International.
85 Ibid.
86 Ibid.

In the past, it was not permissible to use shared networks (with commercial subscribers) for mission critical PSS communications. This was due to the rigorous demands of a public safety network.[87] It is, however, permissible for PSS organizations to use commercial networks for non-mission critical communications.[88] Examples of communications which are not mission critical include certain kinds of voice and paging. Nonetheless, advances in technology may now afford some relief. Sharing networks with commercial subscribers would allow for shared network and maintenance costs, and the ability to piggyback on commercial R&D by using off-the-shelf technologies.[89] However, rights and privileges of the PSS users must be clearly defined.[90] Any shared elements of the network would have to be subject to so-called 'ruthless preemption'.[91] In other words, PSS users must be able to easily and instantly override other communications at the push of a button. Moreover, PSS communications must have its own spectrum in order to ensure sufficient capacity, coverage and reliability are available.[92] Thus, the future may see dual use networks, but if and only if, these networks incorporate dedicated spectrum for mission critical PSS users. It remains to be demonstrated whether or not this can be effectively done in practice.[93] In an emergency the focus of activities would change and so could this basic spectrum's focus. The 'Golden Rule' in disaster management is never use a system that is dedicated for that instance due to the need to ensure the network is fully operational on a daily basis and so the users are comfortable with the system when they will be force to work with it under stress conditions.[94]

> "Would you like fries with that, Chief?"
>
> - a non-mission critical communication which could be carried on a commercial network

Other considerations that need to be considered when using commercial networks include:

- Security and the need for adequate firewalls between the commercial and dedicated PSS networks.

- Coverage. WiMAX may well be attractive in cities, along motorways and other areas of dense usage but it is unlikely to be available in rural areas. Similarly for 3G cellular and therefore in rural areas will revert to lower speed 2G networks.

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87 See notes 69 – 70 and accompanying text.
88 Comments of Robert Gurss, APOC International.
89 Comments of Robert Gurss, APCO International.
90 Ibid.
91 See Section **3.5 Preemptable Spectrum Allocation** for a further discussion.
92 Comments of C2000
93 Comments of Christian Mouraux, Astrid.
94 Comments of C2000.

- Availability/QoS. In the case of an incident or major event PSS communications cannot be blocked due to other users on the network.[95]

Figure 5: Likely outcome of Spectrum and Network Decisions

Network		Spectrum: Dedicated	Spectrum: Shared
	Dedicated	Optimal	Not possible for Mission Critical applications Possible for non-mission critical applications
	Shared	Suboptimal: Possible with clearly defined rights and duties. Network must be robust, reliable, and available to accommodate PSS users.	Not possible for Mission Critical applications

Source: wik-Consult/Aegis Systems

95 Comments of Malcolm Quelch, Sepura plc.

The issues with using a commercially available network are whether it is possible to obtain the required:

- Grade of service
- Priority of access
- Security (confidentiality, availability, resilience).

For example, there need to be re-routing options to ensure that there is no potential for single point failures in the network. Also commercial networks are generally rolled out in areas of higher population density and traffic demand. Therefore it would be necessary for the commercial network to extend the coverage and / or capacity to low population areas – this would be surmountable if PSS, for example, paid the cost for the increased coverage.

> "With the realisation of C2000, we now have a single nationwide communications system for all our emergency services. Communication is of the greatest importance in the day-today work of our emergency service staff: police officers, fire fighters, and ambulance staff and customs officers. C2000 has already been dubbed the most significant governmental partnership in history. 600 parties, each with their own modus operandi, organisational culture and objectives all came together to make this happen. And not a minute too soon.
>
> - J.W. Remkes
> Minister of the Interior and
> Kingdom Relations
> Netherlands

There is a strong preference in some areas for a dedicated network but there has to be a business case. Such a business case would take into account the economic impact of loss of life, loss of business and public expectation, but probably more indirectly than directly.

There are no networks currently that can replace TETRA for secure voice. [96]

> "We must keep the control of these public safety or emergency networks which must be dedicated and not mix them with commercial networks. It is of great importance that we could use this safety network both in conference and point to point modes"
>
> - Général Alain Silvy
> Ministry of Defence
> France

96 Comments of Peter Wickson, NPIA.

Motorola finds that its government customers are different from commercial users in that they must have control over the terminal equipment.[97] For safety reasons the terminals must have the same user interface and all operate in the same way and have to be available and supported for at least 5-6 years.[98] This is the complete opposite from the commercial world where the manufacturers and network operators try to determine which features will be demanded and market those features on the basis that users will replace their terminals every 12 to 24 months. The sophisticated PSS user also tests for compatibly usability, traceability, and other criteria motivated in part on legal liability concerns.

A system whereby PSS organizations and commercial users have dedicated spectrum, but share a network may be emerging in the United States. However this is not with out significant problems.[99] Spectrum must be under the control of these public safety or emergency networks which must be dedicated and not mix them with commercial networks. Further, since a dual purpose commercial-PSS network is not likely have any efficiency, the best solution is a single use network.[100] For example, rural areas not covered by GSM, and in order to fully provision PSS services would require extension of the network which would have no benefit for the commercial business case. Sub 1 GHz spectrum is needed in order to cost effectively service rural areas.[101] It is a problem to manage a network shared between commercial and PSS users. Due to the fact that it is difficult to identify civilian users in GSM networks in order to give priority to PSS organizations. Finally, nature of use may be extremely different between commercial and PSS users. PSS users need not only point-to-point communications but point-to-multipoint modes as well.[102]

According to Ofcom, it will be the decision of individual PSS organizations how they gain access to spectrum so they will need to decide whether their requirements are best met through using commercial networks, third party providers or whether they need to follow a public provider route.[103] It was note that several nations including Germany looked at using GSM networks at least as a partial solution before opting for a full TETRA PSS network.[104]

> "Commercial operators like to see their networks run close to saturation… PSS networks look to overbuild their networks to ensure there is 'margin'."
>
> - Christian Mouraux, Astrid

It could be argued that there will be a range of commercially available equipment, services and

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97 Comments of Manuel Torres, Vice Preseident, Motorola.
98 Ibid.
99 See Section **0 Annex B. Reinvesting The Digital Dividend** in the US: FCC Auction #73 D-Block.
100 Comments of Jaakko Saijonmaa, EADS
101 Ibid.
102 Comments of Général Alain Silvy, Ministry of Defence, France
103 Comments of Emergency Services Spectrum Manager, Ofcom.
104 Ibid.

networks that will meet the requirements of the PSS. In the UK GPRS over cellular networks is currently being used to provide data capability by some police forces. However the concern is that GPRS will not be able to continue to support such needs as more users on the cellular networks utilise higher speed data services. Also, at an incident there could be high demand from all cellular subscribers as they will want to contact their relatives and friends to tell them they are Okay, or to call the emergency services to get assistance. The experience with ACCOLC in the UK also strongly suggests that commercial cellular networks are not well suited to providing priority access to those PSS users.

Another consideration is there is no guarantee that there will be reliable coverage, or sufficient capacity on commercial networks as they are specifically designed to match with population density / user demand. Typically cellular networks provide coverage in urban and sub-urban areas and along major roads and in other geographic areas service is unreliable or non-existent. “Commercial operators like to see their networks run close to saturation.”[105] In other words, commercial network operators engineer and market their networks so that as much capacity is being sold for profit at any giving time. By contrast, “PSS networks look to overbuild their networks to ensure there is ‘margin’.” [106]

A system whereby PSS organizations and commercial users have dedicated spectrum, but share a network may be emerging in the United States. However this is not with out significant drawbacks.[107]

A specific example of the need for robust communications is the requirement for the networks to continue operation even where there is failure of the primary power supply. In the case of, for example, the C2000 network in the Netherlands there are 500 Government sites and at each one there is a 10 hour back-up power supply and in addition there are transportable power generators that can be deployed for longer periods. For a commercial provider it would cost too much to provide equivalent standby power at all their sites and they would not get sufficient return on such an investment even if it was used by the PSS.[108]

Another consideration is that commercial networks are not specifically designed to meet the stringent requirements of PSS and the owner of these networks will have control of who can use it and how the networked is maintained, extended and developed to provide new services and applications. However, it is recognised that some of the services offered by commercial/public networks are suitable for certain public safety applications and if simply matching on the basis of capacity and mobility there are a

105 Comments of Christian Mouraux, Astrid.
106 Ibid.
107 See Section **0 Annex B. Reinvesting The Digital Dividend** in the US: FCC Auction #73 D-Block.
108 Comments of C2000.

number of current and emerging technologies that could provide the capability to carry audio, and data. We did, however, find an example of commercial users making use of a dedicated PSS network. In Belgium, Astrid allows certain commercial customers on its network. However, these are not members of the general public. They tend to be users closely involved with PSS activities, like utilities. I fact common talk groups with PSS organizations and utilities may facilitate the work of both.[109] A notable example is fired services and gas utilities.

3.3 Market-Based Spectrum Policy

> "Markets are good servants, but poor masters."

It is generally agreed that market economies are much more efficient at distributing scarce resources to those individuals with the highest monetary value of use than command economies are. We do not dispute that; however, markets cannot solve all problems. The analysis surrounding PSS spectrum is somewhat more complicated than the resource allocation problem suggests. It is often said in economics that, "Markets are good servants, but poor masters." That is to say market mechanisms while they are highly efficient at distributing scarce resources to their highest value uses, they are particularly ineffective at achieving public policy goals, without at least some form of regulatory intervention.

The modernisation and liberalisation of spectrum policy in recent years has sought not only to encourage efficient use but efficiency in assignment of licenses as well. This has been accomplished by introducing market signals in the form of price information into policy determinations. Since 1994, governments have used auctions to determine efficient assignments. Auctions have worked quite well with regards to commercial users.

Following on the successes of auctions for commercial allocations, there has been a to extend auctions to all spectrum users, both public and commercial. In the UK, a report drafted by the distinguished professor Martin Cave argues convincingly that in the future it is expected that the spectrum requirements of PSS organisations will be met via market processes:

> At first sight it may seem incongruous to require a public sector body such as a fire service or a defence force to compete in a market place for spectrum with commercial providers of services such as mobile broadcasting. However, this is exactly how public sector organizations acquire other inputs

109 Comments of Christian Mouraux, Astrid.

> – such as employees, vehicles, and office space. In relation to these inputs (with the exception of a compulsory military draft in the case of labour) public sector bodies have to go into the market, for example, buying or selling land, hiring workers, or leasing buildings.[110]

PSS organisations must compete in the market with commercial users to acquire other resources such as labour, equipment, fuel, so why not spectrum.[111] An example is whether to purchase land (maybe even bid in an auction for it) in Central London for an additional police station – the relevant Governmental Department is responsible for weighing up the socio-economic issues, including safety of life requirements, and then determining whether there might be other options or whether they do need to purchase the land. The duty of the Governmental Departments is to ensure they have all the necessary measures to meet their needs.[112] Chris Williams, media and telecoms partner at Deloitte, has called on Ofcom and the British government to consider an alternative model where public funding complements the regulator's market-led approach:

> Broadcasting as well as other potential uses of the spectrum also produces socially desirable outcomes that would not be taken into account in the price bid in auctions unless there is explicit public funding. Arguably, allocating the spectrum on the basis of a market-led approach, when combined with appropriate public funding, is the most effective way to ensure that the opportunity cost of using the spectrum is taken into account while the desirable social outcomes are delivered at a transparent cost.[113]

Public organizations are beginning to follow suit in this line of reasoning. The PSSPG (Public Safety Services Policy Group) and the Ministry of Defence (MoD) are fully supportive of this approach. The Governmental Departments are gearing up so they can continue to gain access to new spectrum and the SSIG (Spectrum Strategy Implementation Group) are looking at various options, for example band managers.[114] In Ofcom's recent 410 – 430 MHz award, there was pressure for spectrum for DMO and in this instance the spectrum was divided and it was not necessary for PSS to bid for spectrum in an auction. It is Ofcom's view that this is unlikely to happen again in the future.[115]

While the approach presented in the Cave Report is well reasoned, it remains to be demonstrated whether it mitigates the significant risk that in basing the award of

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110 Martin Cave, et al, "Is public sector spectrum management different?", in Essentials of Modern Spectrum (Cambridge University Press 2007).

111 Ibid.

112 Comments of Emergency Services Spectrum Manager, Ofcom.

113 Guy Dixon, *Ofcom lines up multi-billion pound 'digital dividend' auction But analysts warn against pure market-led approach*, http://www.vnunet.com 14 Dec 2007.

114 Comments of Emergency Services Spectrum Manager, Ofcom.

115 Ibid.

spectrum on price, PSS organizations may fail to obtain sufficient spectral resources, thereby reducing the ability to provide their indispensable services to society as a whole. Peter Wickson, Head of Engineering at the National Policing Improvement Agency (NPIA), which recently replaced PITO, noted that the first step has to be the allocation of spectrum, as was the case for Airwave in the UK, and without this it is highly unlikely that an organisation will bid in a competition to obtain spectrum to roll-out a PSS network. Certain concerns make PSS entities ill suited to participating in such auctions. First of all is an ever-present budget pressure. The acquisition of spectrum requires significant planning, unlike the acquisition of fuel or vehicles. PSS organizations at the present moment have neither the financial nor administrative nor experience to participate effectively in complicated and expensive auctions. This is in part because of their independent and diverse financial, operational and budgeting structures. Also, transaction costs to aggregate sufficient PSS spectrum to meet all demands could be prohibitive and could lead to fragmented spectrum. Are we to believe that according to economic logic, PSS users are not high value users since they do not have the budgetary resources necessary to compete in auctions for spectrum real estate against commercial interests with the deep pockets of commercial providers?

The German federal communications regulator, BNetzA, feels that administrative proceedings are best. It favours “bilateral negotiations” with the respective parties. And in so doing it hears all the arguments of the concerned parties. This administrative proceeding weighs the needs of public and commercial interests in frequency spectrum enabling an agreement which is acceptable to all.[116] The Finnish Communications Regulatory Authority prefers this approach as well.[117]

Considering these characteristics, traditional market mechanisms may fall short in determining an appropriate allocation of spectrum to PSS communications. We do not argue, however, that PSS organizations should get a "free ride" on all spectrum assets. Recent studies have argued that even a modest increase in the financial cost of access to spectrum, by applying administrative incentive pricing (AIP), can lead to organisations increasing the efficiency of its use. In response to the Cave Independent Audit, the UK Government stated that: "The Government agrees with the Audit that administrative incentive pricing (AIP) remains an important tool for promoting efficient use, that it should be applied more consistently, and should more accurately reflect the market value of the spectrum."[118] Methods have been developed to place an administrative price on the spectrum by comparing with comparable fees per unit of spectrum with similar frequencies used for commercial services. The method of calculation of AIP charges in the case of PSS spectrum could be set, for example, at a

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116 Comments of Stefan Mayer-Bidmon, Bundesnetzagentur fuer Elektrizität Gas Telekommunikation Post und Eisenbahnen.

117 Comments of Ficora.

118 Cabinet Official Committee on UK Spectrum Strategy (UKSSC) in consultation with Ofcom, “Independent Audit of Spectrum Holdings”, Government Response and Action Plan, at p. 4 (March 2006) http://www.spectrumaudit.org.uk/220306.htm.

level that may exceed the opportunity cost of the alternative service opportunities. AIP raises funding and incentive issues for publicly funded PSS organizations who would need further funds to cover the costs of increased spectrum fees, but it still likely to improve efficiently of spectrum use.[119]

In the UK, Ofcom has been introducing spectrum fees across all services and spectrum users.[120] For example in a recent study on applying AIP to the Maritime and Aeronautical sectors it was noted that "AIP could raise funding and incentive issues primarily for the MCA (maritime Coastguard Agency) as they are primarily publicly funded and so would need to negotiate with the Department for Transport or make efficiency improvements to cover the costs of increased spectrum fees. Most other spectrum users are privately funded and would face commercial pressures from AIP to use spectrum more efficiently."[121] The individual government departments are looking at their own socio-economic issues.[122] By contrast in Finland, the regulator has not promulgated rules the principle of pre-emptible spectrum or spectrum leasing. Nor has it considered the possibility of spectrum trading in detail. However, it does collect normal spectrum fees from spectrum users, including from PPDR users.[123]

3.4 Technology-Based Spectrum Policy

Another important policy trend is an increasing reliance on technology to solve spectrum use issues. There is a sort of cognitive dissidence in certain circles that technology will solve all problems and obviate the need for spectrum policy. Yet, through this lens, we can see the transition from analogue terrestrial broadcast television to digital as being in context of a much broader transformation of wireless communications. This is really the first of a series of "Digital Dividends" paid for by emerging technologies which can afford ever-increasing spectral efficiency by employing filtering, sharing, and opportunistic use

> There is a sort of cognitive dissidence in certain circles that technology will solve all problems and obviate the need for spectrum policy. New, efficient radio technologies such as cognitive radio and Software Defined Radio will afford new sources of spectrum to meet society's most important needs, not by creating new spectrum, but by wasting less.

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119 See, Independ Consulting, Ltd and Aegis Systems, Ltd., Aeronautical and Maritime Spectrum Pricing, (April 2007) available at: http://www.aegis-systems.co.uk/download/1824/aipreport.pdf.
120 Comments of Emergency Services Spectrum Manager, Ofcom.
121 Ibid.
122 Ibid.
123 Comments of Ficora.

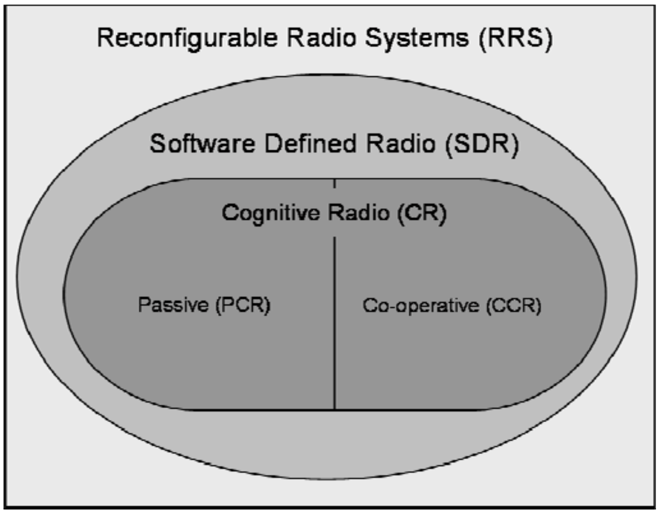
technologies. This accelerating technological trend will enable new sources of spectrum to meet society's most important needs, not by creating new spectrum, but by wasting less.

There are a number of new pre-emptive technologies including Software Defined Radio (SDR) and cognitive radio (CR) which are expected to solve problems associated with access priorities and spectrum sharing.[124] SDR enables the cognitive radio to reconfigure its emissions characteristics to enable the radio to adapt its behaviour according to the environment in which it operates. Cognitive radios, also called 'smart radios', can sense the presence of other transmissions in the local area and automatically switch to unused channels. The cognitive functions are performed by applying a process where a sequence of 'observe', 'orient', 'decide' and 'act' is implemented. SDR enables the cognitive radio to reconfigure its emissions characteristics to enable the radio to adapt its behaviour according to the environment in which it operates. In future, it may be possible for cognitive radios to interact or negotiate with other, existing spectrum users.

In the case of CR, there are two principal approaches to sharing spectrum using cognitive radio. Passive cognitive radio (PCR) makes decisions on frequency use autonomously and SDR it is not until WRC-11 that there is an item on without any interaction with the licensed user, whereas co-operative cognitive radio (CCR) works interactively with the licensed user. It is clearly easier to detect continuous duty, high antenna height signals such as TV broadcasts than terrestrial low power mobile signals. It is possible that the cognitive radio device may be shielded from another user's transmitter and may proceed to transmit, causing interference to a nearby receiver that is not shielded (sometimes referred to as the "hidden node" problem); however as wireless technologies become increasingly tolerant to low levels of interference it may be appropriate to question whether the traditional noise limited approach is appropriate for future spectrum allocations. Nonetheless, in future, it may be possible for cognitive radios to interact or negotiate with other, existing spectrum users. This could, in theory, allow for PSS organizations to have priority user and to share the spectrum with commercial users.

124 ETSI has recently formed a Technical Committee (TC) on Reconfigurable Radio Systems (RRS) which will be looking at SDR and CR technologies as a means to spectrum sharing challenges and increased spectral efficiency. http://www.etsi.org/WebSite/technologies/RRS.aspx.

Figure 6: Spectrum Sharing Technologies



Source: wik-Consult GmbH

In addition, a part of technology-based spectrum policy is an effort to find permissible uses for the “TV White Spaces”. These frequencies are allocated, but unassigned frequencies between broadcast television channels. The White Spaces are used as guard bands to prevent interference to existing television services and are currently under utilized. Since digital television is more robust to sources of interference than conventional analogue broadcast television, it may be possible to offer wireless broadband and other innovative services in these bands. It may be possible to make use of individual TV frequencies in areas where these are not being used locally for broadcasting. As already noted, there could be scope for the sharing of frequencies with TV services in the UHF band, either on a pre-emptive or geographically co-ordinated basis.

It would be a misinterpretation of our work to conclude that this first Digital Dividend is unimportant for PSS use and thus it does not matter if PSS cannot get access to the analogue television spectrum because more spectrum will be available at a later date. To the contrary, PSS users need further spectral resources now, and that need is likely to grow into the future as new, efficient technologies are also introduced. There is a need for an evolutionary route in terms of technology and spectrum as provided in the commercial arena for 2G to 3G to LTE (4G / long term evolution) and for PSS it could result in similar technologies (e.g. OFDMA) but the focus on the needs would be different. The use of such technologies now would be premature in providing access for PSS as they are still mainly untried and tested. In this evolution to new highly spectrally efficient technologies and flexible usage of spectrum, policy makers have to deal with hard reallocation first: the analogue-to-digital television.

The fact that the introduction of new efficient technologies will eventually free other spectral resources does not lessen the need to get this transition right and reinvest the Digital Dividend in the uses most likely to generate the best returns for society.

3.5 Preemptable Spectrum Allocation

We have observed that a dedicated band is the only approach that has convincingly shown to work in fulfilling the needs of PSS mission critical communication. However, it is possible that the Commission or NRA may be unable or unwilling to allocate as much spectrum as PSS could ideally use in such instances. Thus, one future way in which market signals and sharing technologies may be introduced to PSS spectrum in Europe could be through a preemptable spectrum allocation. Preemptable spectrum is spectrum that can be cleared for public safety use during emergency situations.[125] This allocation of preemptable spectrum for PSS use would be in addition to core dedicated, exclusive spectrum, and would only be accessed in certain limited circumstances. Preemption can only work in one direction with commercial services taking advantage of spectrum and networks dedicated to PSS communications, and with PSS being able to 'ruthlessly' invoke emergency use at the expense of commercial use.

The availability of workable preemption networks is beyond the time horizon of our analysis. However, to begin with it has to be recognised that virtually all spectrum assignments are *de jure* preemptable. Under all modern spectrum regulatory regimes, the government can at its discretion withdraw license permissions and/or issue Special Temporary Authorities to address the needs of a crisis. Operationalizing this policy into a set of rules for dynamic day-to-day use, enables PSS uses to be matched with commercial uses.[126] Certain NRAs are already entertaining these debates. Ofcom is allowing individual PSS organizations to address the decision on whether to use pre-emptible spectrum. It will be possible for the licensees to lease spectrum and set certain requirements such as requiring the spectrum when certain emergency situations arise.[127] Germany prefers a different approach. The regulator argues that the spectrum should be allocated based on regular utilisation rates and not peak or exceptional cases, such as during crises or war. Thus, it feels the commercial demand to outweighs

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125 Mark M. Bykowsky and Michael J. Marcus, "Facilitating Spectrum Management Reform via Callable/Interruptible Spectrum", Federal Communications Commission (September 13, 2002) at http://tprc.org/papers/2002/147/SpectrumMgmtReform.pdf.

126 Comments of Robert Gurss.

127 Ofcom would consider this to be a commercial agreement and not require its involvement. Comments of Emergency Services Spectrum Manager, Ofcom temporary spectrum demand in assignment during peacetime.[128] However, it recognizes that pre-emptible spectrum could be used to provide broadband access in rural areas and to provide mobile TV.

Thus, the Commission and NRAs should consider augmenting an allocation of exclusive use spectrum with a larger allocation of "burstable" spectrum that would be pre-empted in an emergency situation. The economic arguments for such an approach seem to be strong, but one would have to carefully weigh (1) the risks that pre-emption fails when needed, (2) the cost of loss of service during pre-emption, and (3) the impact on service providers, users and manufacturers of designing pre-emption. Careful attention must be paid to the practical matters of how such an arrangement might function.

As already noted, the nature of certain types of PSS operations, such as DR, have "average" or long-term spectrum requirements which are very different from the peak requirements that arise during major incidents. In addition, DR PSS services are also prone to high localized traffic. However, dedicated does not necessarily mean that the entire band of spectrum has to remain exclusive to PSS all the time. Hence there is likely to be benefit in a combination of dedicated and shared use spectrum, where the shared use spectrum is used to cater for the peaks as and when they arise. For example, commercial operators could use the spectrum in the presence of a tone, but when the tone is gone, they would automatically clear the spectrum for PSS use. Users of the interruptible spectrum in other areas would remain unaffected. This would provide an essentially failsafe system.[129] Clearly, a preemptable arrangement would not be workable for PP1 or PP2 communications as the offered load of communications traffic on the network is more constant. In the absence of a major incident, PSS networks still require a significant minimum amount of basic spectrum to be used for PP communications under normal situations.[130] In an emergency, the focus of activities would change and so could this basic spectrum's focus.[131]

Despite certain engineering drawbacks, premptable, non-core PSS spectrum allocations promise significant economic benefits. Properly designed preemptable spectrum policy can, to some degree, introduce market signals which lead to efficient use by lowering the economic cost of idle spectrum. It allows highest value commercial use, but retains priority for PPS uses.[132] Like Wi-Fi, spectrum still has value even if it cannot be used all the time. Such highly desirable spectrum would be attractive for

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128 Comments of Stefan Mayer-Bidmon, Bundesnetzagentur fuer Elektrizität Gas Telekommunikation Post und Eisenbahnen.

129 Mark M. Bykowsky and Michael J. Marcus, "Facilitating Spectrum Management Reform via Callable/Interruptible Spectrum", Federal Communications Commission (September 13, 2002) at http://tprc.org/papers/2002/147/SpectrumMgmtReform.pdf.

130 Comments of C2000.

131 Ibid.

132 Ibid.

“best efforts” networks or networks which are not used during emergencies. Examples of such networks might include fixed broadband consumer Internet access or fleet radios for a private company’s dispatch operations. Further, preemptable spectrum lowers barriers to entry, allowing spectrum users to acquire usage rights without the need to obtain a full and inflexible license at auction.

Since it is more complicated, such a system also suffers certain drawbacks. One notable drawback is that an interruptible system requires more expensive equipment and engineering. However, these costs could be offset with funds from commercial use. Finally, a radio which comprises all these functions may have an unacceptable impaction on cost, form factor and performance.

Achieving an appropriate balance in allocating dedicated, exclusive core and preemptable spectrum requires careful consideration. There are costs associated with both over- and under-allocation (see Figure 7). Being subject to possible preemption affects the valuation of commercial uses. The value is diminished by the occurrence and variability of preemption. At the highest level of analysis, such a valuation would be its use value, less a discount for the incremental cost of equipment able to handle preemption and a discount for the probability of preemption. The under allocation of core and preemptable spectrum is thus the worst possible outcome. It exposes society to unnecessary risk. The consequences of having insufficient PSS spectrum resources could far outweigh these economic costs, and could even be catastrophic.[133] Over allocation of preemptable spectrum is nominally better but still suboptimal. It reduces the opportunity for commercial use of the spectrum. However, over time, the market will gain the knowledge that certain amounts of spectrum are rarely, if ever, preempted. That spectrum will eventually be considered *de facto* private use and will reflect that value. While over allocation is preferable to under allocation, the goal of preemptable spectrum allocation is a societal optimum.

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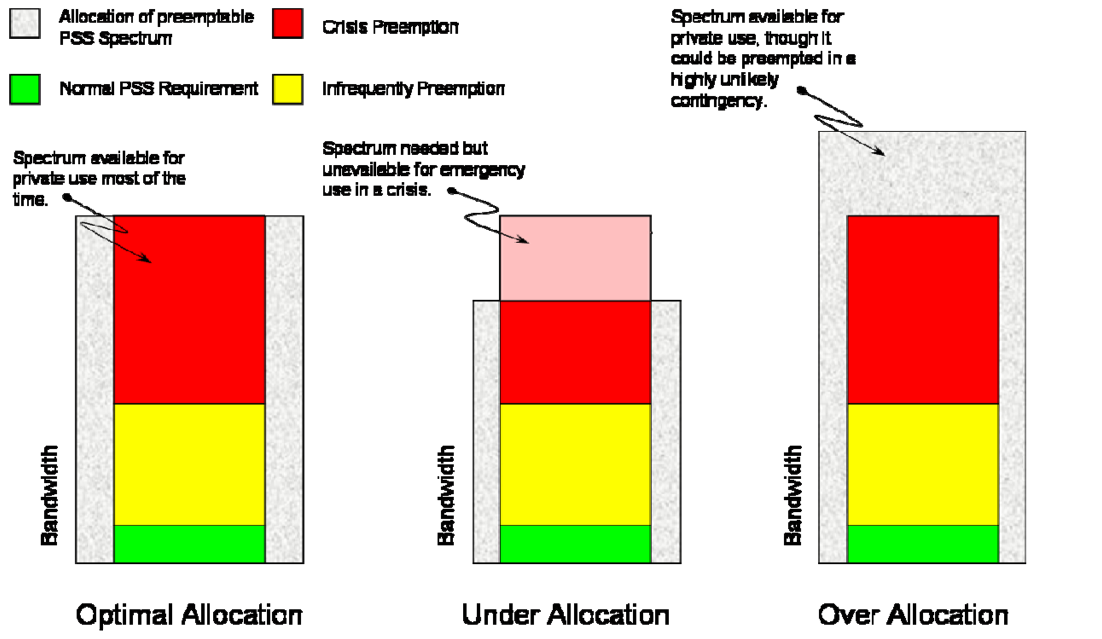
133 See Section 3.2.2 Social Cost.

Figure 7: Optimizing PSS Spectrum Allocations



Source: wik-Consult/Aegis Systems

Some consideration should be paid on how to handle the revenues derived from commercial use of preemptable PSS spectrum. It is a mistake to make PSS spectrum users a reseller.[134] While it is perhaps most efficient to have those revenues deposited with the treasury or revenue service a trust fund for relocation and next generation PSS equipment capable of handling preemption must also be established. Finally, there must be a penalty to ensure PSS users do not misuse or abuse their powers of preemption. This is akin to penalties for ringing false alarm.

There is a need when considering access to spectrum to make a balance between market driven solutions and the requirements of people's lives and national security. Spectral efficiency cannot and should not be the sole consideration. [135]

134 See Adele C. Morris, and Martin Cave Getting the Best out of Public Sector Spectrum (2005).
135 Comments of Malcolm Quelch.

3.6 Time Horizon

Time is of the essence, and the window for action is now. Spectrum needs to be made available, or at a minimum identified, over the next 12 to 18 months. Early announcement of the available spectrum for PSS would help underpin the potential for an evolutionary path and provide users with certainty to continue down the data path. This timescale takes into account the following process:

- acquire spectrum;
- design infrastructure;
- purchase equipment;
- deploy network;
- deploy terminals and handsets;
- develop uses and applications; and
- train personnel

before PS organisations will derive benefits. These decisions require a long time horizon in order to coordinate disparate interests. The planning and roll-out of a large scale PSS network takes from 4 to 6 years. However, this process can take 10 years to plan and deploy such networks. For example, Finland reached its decision to deploy TETRA in 1995, while in Poland there has been no decision yet regarding what type of PSS network to deploy. And even when a decision is reached not all geographic areas receive coverage instantly and simultaneously as networks are normally gradually rolled out starting in areas of highest need.

Historically, it has been the usual practice to identify suitable spectrum well in advance because of the timescales for releasing suitable spectrum, development of standards and equipment which can satisfy the user requirements takes. Product development usually requires from 18 months to 2 years. From a manufacturer's point of view, it is important to get early commitment of spectrum availability to start investments in the development of the technology.[136] Thus, the decisions which the EU addresses now will not have their impacts felt until perhaps the year 2015. There is already a requirement for higher speed data services as well as additional network capacity. And, over the near-term future, the demand for PSS mission critical spectrum will continue to grow, driven by the emergence of new spectrum-hungry services, increases in terrorist threats, natural environmental disasters, and simple population growth. C2000 feels that

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136 Annamaria Raviola Selex Communications

within 2 to 3 years there will be a need for a nationwide mobile data service for mission critical PSS communications.[137]

Among the individuals in the PSS community we were able to interview, there was strong consensus that they could not have a decision for additional spectrum for mission critical communications soon enough since these decisions require a significant amount of lead time. While the ideal time scale is as soon as possible, some we interviewed stated spectrum must be available by 2010 or 2011, but not later than 2012.[138] C2000's projection of demand for data services requires a decision period with 9 months, to be followed by a building period of 1 to 2 years).[139] Astrid is planning a pilot deployment for TEDs or other next generation system starting in 2009. This will be followed by a limited deployment in 2010-11.[140] At least one interviewee felt a more pressing deadline around 2010 to be reasonable.[141] Therefore, access to spectrum is needed as soon as is practicable. Ideally this should be sub 1 GHz to provide the necessary geographic coverage economically and to be compatible spectrum to that is already available.[142]

The reason why narrowband digital communications has been a success story for PSS organizations has been the availability at an early stage of suitable spectrum. The only way this can be repeated is to identify as soon as possible, ideally now, suitable and sufficient spectrum.

137 Comments of C2000.
138 Jaakko Saijonmaa, EADS.
139 Comments of C2000.
140 Comments of Christian Mouraux, Astrid.
141 Comments of Général Alain Silvy and Comments of Jaakko Saijonmaa, EADS.
142 Comments of Peter Wickson, NPIA.

4 Conclusion

4.1 Findings

PSS services provide indispensable police, fire and other emergency services to each and every individual in our society. This is our moral obligation to protect life, welfare, and property of its citizens regardless of their ability to pay. While almost all organizations need the ability to gain access to wideband and broadband wireless services in order to increase efficiency, make it easier to share information, reduce costs, PSS users require access using wireless, while on the move, and using networks which are secure, reliable, resilient and available across a wide geographic area regardless of population density.

In order to fulfil this obligation to save lives and property, PSS services require mission critical communications and information. These services will become increasingly dependent on broadband communications, enabling rapid transmission of large amounts of information from multiple sources and in multiple forms. Broadband communications are fast becoming essential to establish command and control and to disseminate timely information such as medical records, details of dangerous substances, maps, pictures and video to the various emergency responders.

A dedicated network employing a dedicated spectrum band is the best way to provide secure, robust and immediate communications for PSS radio systems, from a variety of standpoints – operational, managerial and engineering. We have heard consistently from the PSS community is that given the growing PSS communications demands on this spectrum it is already clear that the current allocations will suffice in the future. To obtain the necessary, mission critical PSS communications networks require a further allocation of sub-1GHz radio spectrum beyond what has currently been allocated for existing services.

PSS services are but one possible recipient among the potential new users of this sub-1GHz spectrum. It is for them a unique opportunity for decades to come to gain access to spectrum that can provide efficient broadband nationwide services cost effectively. Since 1994, governments have used auctions to determine efficient assignments for spectrum that will be used to deploy commercial networks (e.g. cellular and wireless access). Auctions have worked quite well with regards to commercial users; however, indispensable PSS services are not so easily valued. Hence, traditional market mechanisms may fall short in determining an appropriate allocation of spectrum to PSS communications.

4.2 Recommendations

> We recommend two blocks of 15 MHz allocated between 400 MHz and approximately 800 MHz band be allocated from the Digital Dividend spectrum to public safety use on a Pan-European basis. This is roughly equivalent to spectrum allocations from the release of analogue TV in the US.

We recommend an allocation of Digital Dividend spectrum to public safety first. This is the preferred allocation, since under certain circumstances commercial users can take advantage of PSS communications network, and not the other way round. In an ideal situation, Public Safety Services would have two blocks of 15 MHz allocated between 400 MHz and approximately 800 MHz. This allocation should be Pan-European even though different parts of the same frequency bands might be utilised in each country. Such an allocation is roughly equivalent to spectrum allocations from the release of analogue TV in the US.[143]

Radio propagation considerations argue convincingly for this allocation being in the lower part of the UHF band. The lowest viable frequency is probably 200 MHz and the highest is approximately 800 MHz, since higher than that, the propagation characteristics begin to present unworkable constraints. The lower propagation losses around 500 MHz compared to 800 MHz would enable a national network to be rolled out with considerably fewer base stations and would provide improved coverage within individual cells. Proximity to existing PSS allocations in the 380 – 470 MHz region may also be advantageous in terms of sharing existing network infrastructure. However, some flexibility in the frequencies that can be used in different countries might be helpful in terms of facilitating coexistence with planned digital TV services.

An allocation at 5 GHz, being considered for Disaster Relief, is only suitable for limited geographic areas (hotspots) and would not be suitable for major fires, floods and other such much wider based occurrences. Aside from the spectrum released in the Digital Dividend, there are only isolated pockets of spectrum such as they freed up by MoD in the UK that could become available within the required timescales.[144]

> "Without access to Digital Dividend spectrum there is no certainty that the journey in developing enhanced services for PSS will be undertaken."
>
> \- Malcolm Quelch Sepura plc

In arriving at this recommendation, it is not our intent to favour any particular technical standard, but to provide maximum flexibility

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143 See footnote 78 and Annex B. Reinvesting The Digital Dividend in the US: FCC Auction #73 D-Block
144 Comments of Malcom Quelch.

for PSS services and allow technologies, networks and services to evolve over the longer term. Therefore, in this report, we eschew any promotion of technology in favour of a technology neutral approach.

4.3 Historical Lessons

We may regard the PSS communications policies for the Digital Dividend as a widow to the future. However, if we return to first principles, we find that the essential need for emergency communications to have been the mother of spectrum policy, nearly a century ago. The basic framework for nearly all wireless communications regulation today finds its origins in the sinking of RMS Titanic in April of 1912. In the wake of this tragic disaster and staggering loss of life, governments around the world began to put in place the rules necessary not only to enable wireless communications but also to insure that those in peril with the ability to make distress calls. Could there possibly be anything more important?

Annex A. Interviewees

Dedicated Networks

Organisation	Interviewee	Title	Country
Astrid	Christian Mouraux	Marketing Manager	Belgium
Ministry of Defence	Général Alain Silvy		France
C2000	Herman van Sprakelaar, Maarten Nacinovic Hans Borgonjen	Head, Tactical Management, Unit Control Room Systems Head Research and Innovation International Standardisation	Netherlands

Manufacturers

Organisation	Interviewee	Title	Country
EADS	Jaakko Saijonmaa		France
Motorola	Heidi Hattendorf Manuel Torres	Director of TETRA Marketing GM & VP EMEA	UK Spain
Selex Communications	Annamaria Raviola	Director, Marketing and Business Development	Italy
Sepura plc	Malcolm Quelch	CTO	UK

Users & Associations

Organisation	Interviewee	Title	Country
NPIA National Policing Improvement Agency	Peter Wickson	Head of Engineering	UK
APCO International (Association of Public-Safety Communications Officials)	Robert M. Gurss	Director, Legal & Government Affairs	USA

Hertfordshire Fire Brigade	Mark Yates	Deputy Chief Fire Officer	UK

Regulatory Agencies

Organisation	Interviewee	Title	Country
Bundesnetzagentur fuer Elektrizität Gas Telekommunikation Post und Eisenbahnen (BNetzA) Federal Network Agency for Electricity Gas Telecommunications Post and Railway	Stefan Mayer-Bidmon		Germany
OFCOM (Office of Communications)	Kuha Sithamparanathan	Emergency Services Spectrum Manager.	UK
Ficora (Finnish Communications Regulatory Authority)	Harri Jores		Finland

Annex B. Reinvesting The Digital Dividend in the US: FCC Auction #73 D-Block

On 20 March 2008, the US Federal Communications Commission concluded an auction for spectrum licenses in the 700 MHz band, which will redistribute the frequencies reclaimed in the transition to DTV. Notable as a case study is the so-called D-Block of that auction. The winning bidder of the D-Block license would be granted a nationwide license in the band. However, one stipulation of this license is that the licensee would be obligated to negotiate with a public safety trust organization and to a build ubiquitous, robust and reliable nationwide network. This network would be jointly used by public safety entities and have to be capable of employing the not only the licensee's commercial spectrum holdings, but also 10 MHz of Digital Dividend spectrum assigned to the trust organization for the purpose of PSS communications.[145] Since at the time of writing, full results were not available and the FCC has committed to an investigation of the D-Block auction, we can only offer tentative conclusions here.

By the close of the auction, the D Block had attracted only one bid for US$ 472 million, far below the reserve price of US$ 1.3 billion set by the FCC in order for the licence to be awarded. The failure to clear the reserve price may be due to a variety of reasons. Most visible is the withdrawal of Frontline Wireless, one of the two certified bidders for the D-Block. Immediately prior to the start of the auction, Frontline was unable to secure risk capital to participate in the auction. Another less obvious reason may be the absence of clear, concise, and actionable *ex ante* rules. The FCC has the power to adjudicate disputes between these two parties. While the FCC is intended to be independent of the political process, the post-September 11 political climate is such that any public official cannot afford to be characterized as being 'weak on national security'. Thus, the FCC may have a perverse incentive to unfairly side with the public safety trust organization and against the D-Block licensee in any dispute. This fact may have served to breed regulatory uncertainty, having the effect of reducing the available pool of risk capital, participation in the D Block auction and investment in such a mixed use network.

Further, the FCC may have misunderstood the cost burden of deploying a dual use network and the practicalities inherent in establishing priorities within that network. The investment needed for a dual purpose network is not likely to lead to any greatly increased efficiency over either single network alone. For example, rural areas not covered by mobile wireless, and in order to fully provision PSS services would require extension of the network which would have no benefit for the commercial business case. In addition, it is difficult to identify the right civil users in deprioritizing them and to manage a network shared between commercial and PSS users. This spectrum must be under the control of these public safety or emergency networks which must be

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145 By comparison, PSS use in Europe only has 10 MHz allocated to it in total. See note 78.

dedicated and not mix them with commercial networks. It is at this time unclear when and whether mission critical PSS communications networks using 700 MHz band will be available United States.

Annex C. Summary of TETRA Networks

Table 3. TETRA Investments

Country	Reasons for investment	Method of funding
Belgium	The old analogue systems: • Could not meet the requirements of the emergency and security services. • Could not connect to information databases (e.g. those containing information on people, vehicles and weapons) • Had the potential for eavesdropping • Were different between the participating services at major incidents as so were using different frequencies making it impossible to co-ordinate communications. Advantages of new ASTRID system: • Network sized to give all users maximum resources • Easy choice of who to communicate with through talk groups or call groups and ability to set up new talk groups in the case of major incidents • Radio coverage in tunnels and buildings where it was not available with the analogue system • Fast dispatch of resources through integration with the command and control systems.	In 1998 the Belgium Government decided to acquire a new network for all the emergency and security services. ASTRID (All-round Semi-cellular Trunked Radio communication network with Integrated Dispatching) is government-owned (shares are held by the Federal State (61%) and the Joint Municipalities Holding Company (39%)) and they operate and maintain the network.
Finland	The new network was required because it was becoming increasingly expensive to maintain the analogue networks and also they did not have sufficient capacity to meet the users' demands. Benefits of the VIRVE system include: • Cost effective as it brings all the different governmental departments onto a common network and so avoids the need for overlapping networks • Group calls can be made on a national basis so can support wide area operations easier and more efficient • Fast access to data • Computer aided dispatch based on	In 1995 the Finnish government decided to invest in a new shared network for the emergency and fire & rescue services, the Police, the Defence Forces, the Frontier Guard, Social and Health Services, Finnish Maritime Administration and different government departments. VIRVE is controlled and maintained by State Security Networks Ltd, which is owned by the Finnish Government.

	automatic vehicle location information from GPS.	
Netherlands	The main goals of the C2000 network were to: • Provide interoperability between the emergency services – the fireworks catastrophe in Enschede and the café fire in Volendam had highlighted this requirement for a common nationwide system • Enhance law enforcement and public safety through the use of encryption • Provide interoperability with neighbouring countries, Belgium and Germany, as required under the Schengen agreement	In 1999, a contract was awarded for a TETRA network in the Netherlands to provide services for all the Dutch public safety organisations including the police, fire brigade, ambulance services and the military police. TetraNed[146] was the prime contractor and system integrator for the project and the ITO (government agency of the Ministry of Interior) was responsible for implementing and deploying the system.
UK	Airwave was rolled-out to replace the outdated, individual police force analogue radio systems. The benefits of the Airwave network are: • Improved radio coverage, speech clarity, security and encryption of communications • Enhanced operational flexibility and improved radio interoperability between those services using the network • Scope for mobile data applications.	The TETRA network that was procured by the NPIA for the police forces and is provided by Airwave Solutions under a Private Finance Initiative. The service was also made available to other organisations concerned with public safety such as the ambulance and fire services and there is an agreed list of Airwave users. As users migrate to Airwave this is releasing spectrum for other uses. The organisations using Airwave have to pay to have access to the network.

Source: Aegis Sytems

146 Dutch joint venture between KPN and Getronics, radio communications suppliers in the Netherlands.

Annex D. Arguments Pro and Con a Dedicated Spectrum Band for PSS

	Argument	Counter Argument (Opposition)	Comments
1.	PSS represent a unique set of services, which society has a moral obligation to provide	Communications networks could be outsourced to commercial networks.	Private, profit maximising firm will engineer network and service level of service, and not necessarily a public optimum.
2.	Aside from being simply tragic, the loss of life and property bears societal cost.	Actuarial science might calculate a monetary value to those lives lost, as it can for insurance and tort law purposes.	A monetary valuation of public safety services is hard to assess, frustrating any calculation of the monetary value of one of its critical inputs: public safety spectrum. There is no competition in emergency services, nor should there be competition. Such competition price for services would likely result in morally perverse outcomes.
3.	Governments present the best risk profile for deploying and managing public safety networks. Governments can spread risk across diverse populations and geographic regions. Further, governments can reduce the associated with business and business cycles, such as insolvency.	Private firms can address and mitigate risk better than the public sector.	By not relying on a private sector actor, governments can achieve a minimum level of risk that mission critical PSS communications networks will be available today and in the future. Data protection laws within the EU are extremely strict and provide substantial penalties for breaches of data security. Since extremely sensitive and confidential information flows over PSS networks, the risk of a data breach could chill private investment.

4.	One of the driving forces at the heart of the European Union is that of harmonization. The Digital Dividend is an ideal opportunity for longer term harmonization, leading to the development of technical solutions that would allow the re-use of existing sites and needed economies of scale. In 1996, European Unioin decisions produced a harmonized allocation of PSS spectrum, resulting n widespread adoption of Europe-wide PSS communications systems – using either TETRA or Tetrapol. These decisions have been a resounding success.		A dedicated, harmonized band for PSS systems encourages a single market since vendors are more likely to view the market as sufficiently large to justify product development. Despite being a niche market, PSS communications have significantly benefited from the economies of scale afforded by harmonization.
5.	The stringent requirements of coverage, capacity, reliability, and redundancy (99.999 reliable, 99 available) for PSS networks warrant separate and dedicated mission critical broadband communications networks and spectrum allocations.	Private sector firms can address the technical concerns regarding the design, deployment, and management of PSS networks.	Commercial wireless networks build their networks for coverage and capacity based on where their customers are located. Commercial network operators engineer and market their networks so that as much capacity is being sold for profit at any giving time. By contrast, PSS networks must be overbuilt to ensure there is 'margin' in capacity.

6.	PSS Networks must be government owned and controlled. For-profit corporate organizations are poorly suited to providing the types of public goods which government bodies can offer. The level of investment required to bring commercial networks up to these stringent requirements would not be economically viable without government support. In addition, such ‘gold-plated’ networks may distort competition.	In practice, where governments have outsourced such communications networks could be outsourced to commercial networks.	When network have been outsourced, governments they have still retained assurances against transfer of ownership of the operator; its continued guaranteed financial viability; and, the option to take management control of the operator when needed. This has been the case in UK, Portugal, Austria, Denmark, and Hungary. The level of control necessary for a PSS network may inhibit the competitive responses of the corporate entity and may make it a *de facto* a governmental organization, though it may be a private corporate form.
7.	The current spectrum allocation is insufficient for future needs, and in some cases current needs. The integrated broadband data services which are emerging as an important PSS need require more bandwidth. Ideally, to provide broadband mobile access for PSS communication requires two 15 MHz-wide blocks.	Opponents to any further PSS spectrum allocation often point to the current allocation between 380 – 470 MHz of spectrum. Some may suggest that such an allocation would be a waste. PSS spectrum usage tends to be markedly different from that of other radio users.	Of this allocation, only two 5 MHz-wide blocks are available for use by PSS. The effect of this limited spectrum allocation is that there has always been an issue with capacity at major incidents and planned events. More important, it is sufficient for broadband communications. The utilization rate of public spectrum ranges from near constant (e.g. some radar systems and fixed point to point radio links), to mostly idle (e.g. some emergency communications spectrum). Despite the fact that the particular carrier waves in the band are not being utilized to transmit information at any given moment; this spectrum is merely idle, not unused. Much like an “idle” fire extinguisher, the spectrum is being used to provide the benefit that it could be instantly available should an emergency arise.

8.	PSS networks should be dedicated to PSS use and employ dedicated spectrum resources. This is based on a single concept: effective control of the network. Moreover, PSS communications must have its own spectrum in order to ensure sufficient capacity, coverage and reliability are available. In an emergency the focus of activities would change and so could this basic spectrum's focus.	In the past, it was not permissible to use shared networks (with commercial subscribers) for mission critical PSS communications. This was due to the exacting demands of a public safety network. However, advances in technology may now afford some relief. Sharing networks with commercial subscribers would allow for shared network and maintenance costs, and the ability to piggyback on commercial R&D by using off-the-shelf technologies.	under certain limited conditions pre-emption may be possible with commercial services riding on spectrum and networks dedicated to PSS communications, but not *vice-versa*. The rights and privileges of the PSS users must be clearly defined and any shared elements of the network would have to be subject to so-called 'ruthless preemption'. Thus, the future may see dual use networks, but if and only if, these networks incorporate dedicated spectrum for mission critical PSS users.

Annex E. Glossary of Terms

Note to the reader: In this report, we have included this Glossary of Terms. It is intended to be useful to the uninitiated or novice reader, by providing definitions and explanations of commonly used terms. Not every entry appears in the main body of the text. However, these terms have appeared in our interviews and research. This Glossary may also be helpful to those more experience in the field by providing consistent acronyms and abbreviations.

A

AACCOLC (Access overload class): a network technology employed in commercial cellular networks in the UK which will selectively disable, lock out or switch off access to non-priority users in order to provide capacity for PSS users involved in emergency response. Under this arrangement normal users are assigned a priority from 1 to 10 and emergency users are assigned priorities 11 to 15.

AVLS (Automatic Vehicle Location System)

AM (Amplitude Modulation): a type of radio transmission which uses the amplitude of the carrier wave to transmit information. Amplitude Modulation is used in either the standard radio broadcast band, shortwave broadcasting, and in some private radio services such as citizens band (CB) and aviation.

Analogue Signal: a method that uses continuous changes in the amplitude or frequency of a radio transmission to convey information.

APCO International (Association of Public-Safety Communications Officials): an industry association for professionals involved in public safety communications in government and industry. It clams the world's largest organization dedicated to public safety communications.

B

Bandwidth: the term generally used to refer to the capacity of a channel to carry signals. More technically, bandwidth refers to the width of the range of frequencies that a signal occupies. The necessary bandwidth is the amount of spectrum required to transmit the signal without distortion or loss of information.

Base Station: a land station in the land mobile service and is interconnected with other base stations via a land-line switched network.

BBDR (Broad Band Disaster Relief): the rapid deployment of advance PSS networks to respond to an incident (hotspot) networks in addition to the PP communications systems.

Bit (Binary Information Unit): The smallest unit of digital information. It is equivalent to a "yes" or a "no".

Bits per Second (bps): A unit used to express the number of bits passing a designated point per second.

Bluetooth: a short-range wireless protocol envisioned as a cable replacement technology that is used to connect computer devices and peripherals devices at a range of up to 30 feet with a maximum transmission speed of 1 Mbps. Bluetooth is named for 10th Century Danish King and is a trademark for the standard promulgated by a trade association called the Bluetooth Special Interest Group (SIG).

Broadband: a descriptive term for evolving digital technologies that provide consumers a signal switched facility offering integrated access to voice, high-speed data service, video-demand services, and interactive delivery services.

Byte: a set of bits that represent a single character. Eight bits comprise a Byte.

Bundesnetzagentur (the German Federal Network Agency)

C

CCTV (Closed Circuit Television)

CDMA (Code Division Multiple Access): a multiple access systems using a method of spreading spectrum transmission for digital wireless personal communications networks that allows a large number of users simultaneously to access a single radio frequency band without interference.

CEPT (European Conference of Postal and Telecommunications Administrations): an organization, established in 1959 by 19 countries, of former monopoly postal and telecommunications administrations. CEPT's activities included co-operation on commercial, operational, regulatory and technical standardisation issues.

CMRS (Cellular Mobile Radio Telephone System): a land mobile telephone system in which channels assigned to the system are divided among several geographical "cells" covering a defined service area. These cells encompass localized, low power base stations to cover a specific area. The base stations are sited to give overlapping coverage, fitting together like cells in a tissue, allowing frequencies to be reutilized in adjacent clusters.

Co-channel Interference or Crosstalk: a form of interference which occurs when a receiver on one communications channel inadvertently receives information being transmitted on a neighbouring communications channel.

CODECs (coder decoder): encoding devices which permit the digitalization and digital transmission of analogue information.

Cognitive Radio (CR): also called “smart radios”, can sense the presence of other transmissions in the local area and automatically switch to unused channels. The cognitive functions are performed by applying a process where a sequence of ‘observe’, ‘orient’, ‘decide’ and ‘act’ is implemented.

Co-operative cognitive radio (CCR): one of two principal approaches to sharing spectrum using cognitive radio which works interactively with the licensed user.

D

DiffServ (Differentiated Services): a protocol which enables hop-by-hop traffic management, whereby selected packets can be marked as having application requirements other than best efforts.

Direct Sequence Spread Spectrum (DSS): the most widely used type of spread spectrum system. It is a digital modulation technique achieved by modulating a narrow band radio frequency carrier with a high speed spreading code sequence. The spreading code spreads the narrow band signal over a wider band of spectrum. Because the total power of the original signal is now spread over a much broader bandwidth, the power level at any given frequency is very low. This feature allows direct sequence spread spectrum systems to operate in the presence of narrow band systems without interfering. (See Spread Spectrum).

DMO (Direct Mode Operation): radio communication from handset to handset without the use of fixed network or repeaters.

DR (Disaster Relief): the immediate PSS response to a disaster cause either by natural or caused by human activity.

DWDM: (Dense Wave Division Multiplexing), see WDM.

E

ECNP (Electronic Communications Network Provider): a provider of an Electronic Communications Network (ECN). An ECN is a transmission system and, where applicable, switching or routing equipment and other resources which permit the conveyance of signals by wire, by radio, by optical or by other electromagnetic means, including satellite networks, fixed (circuit- and packet-switched, including Internet) and mobile terrestrial networks, electricity cable systems, to the extent that they are used for the purpose of transmitting signals, networks used for radio and television broadcasting, and cable television networks, irrespective of the type of information conveyed. (*Framework Directive*, Article 2).

ECSP (Electronic Communications Service Provider): a provider of electronic communications service (ECS). An ECS is a service normally provided for remuneration which consists wholly or mainly in the conveyance of signals on electronic communications networks, including telecommunications services and transmission services in networks used for broadcasting, but exclude services providing, or exercising editorial control over, content transmitted using electronic communications networks and services; it does not include information society services, as defined in Article 1 of Directive 98/34/EC, which do not consist wholly or mainly in the conveyance of signals on electronic communications networks. (Framework Directive, Article 2).

EEA (European Economic Area): area established by an agreement between the European Union and the EFTA providing for the participation of the EFTA countries in the European Single Market.

ETSI (the European Telecommunications Standards Institute): an independent, non-profit, telecommunications standardization organization in Europe. ETSI comprises equipment makers and network operators and has has been successful in standardizing the GSM cell phone system and the TETRA professional mobile radio system.

F

FCC (Federal Communications Commission): the U.S. regulatory authority for telecommunications.

FDMA (Frequency Division Multiple Access): a radio system access technology that enables spectrum sharing by allocating different users separate carrier frequencies within a single band of the radio spectrum.

FM (Frequency Modulation): a signalling method that varies the instantaneous frequency of a carrier wave in accordance with the signal to be transmitted.

Frequency: the number of cycles occurring per second of an electrical or electromagnetic wave; a number representing a specific point in the electromagnetic spectrum.

Frequency Hopping Spread Spectrum: a form of signal spreading in which the frequency of the transmitted signal “hops” from channel to channel many times, commonly less than 10 milliseconds, in accordance with a pseudo-random list of channels. The receiver hops in strict conjunction with the transmitter, thereby collecting all data transmitted in order to avoid interference both to and from conventional users. (See Spread Spectrum).

G

GHz (Gigahertz): the oscillation of a wave at 1,000,000,000 Hz or cycles per second.

GPRS (General Packet Radio Service): a packet-oriented mobile data service available on GSM and IS-136 mobile phones. It provides data transfer rates from 56 up to 114 kbps. GPRS can be used for services such as Short Message Service (SMS), Multimedia Messaging Service (MMS), email and Internet access.

GPS (Global Positioning System): a satellite-based radio system maintained by the U.S. Government which allows receiver sets to determine their geographic position with extreme accuracy.

GSM (Global System for Mobile communications, originally from Groupe Spécial Mobile): an ETSI standard which employs TDMA to provide cellular mobile networks operating in the 900 MHz or 1800 MHz bands.

H

HiperLAN: a European wireless data networking standard operating in two bands within the 5 GHz range on a licensed-exempt basis. However, the HiperLAN2 bands, is slightly different than the US U-NII bands. While the two share the 5.15 – 5.25 GHz portion, the HiperLAN2 upper band is 5.470 – 5.725 GHz.

Hotspot: a wireless data network access point. Service providers are beginning to offer portable internet hotspot access for laptops and handheld computers in airports, hotels, cafes and other public places.

HSPDA (High Speed Packet Data Access): a standard for third generation wireless services for GSM-based networks.

Hz (Hertz): a frequency measurement unit which is equivalent to one cycle per second.

I

ICT (information and communication systems): technologies designed to support the exchange and management of information.

IEEE (Institute of Electrical and Electronics Engineers): an international non-profit, professional organization for the advancement of technology related to electricity, which claims more than 365,000 members in around 150 countries.

IMT (International Mobile Telecommunications).

Interference: a radio emission from another transmitter at approximately the same frequency, or having a harmonic frequency approximately the same as, another emission of interest to a given recipient, and which impedes reception of the desired signal by the intended recipient. Interference can only ever occur at a radio receiver.

IP (information packet or Internet Protocol): Internet Protocol, along with TCP, is a standard developed by the U.S. military, which allows computers to communicate with one another over long distance, digital networks. IP is responsible for moving packets of data between nodes. TCP/IP forms the basis of the Internet, and is built into every common modern operating system. For information packet, see packet switching.

ITU (the International Telecommunications Union): a standards organization, founded as the International Telegraph Union in Paris on May 17, 1865, dedicated to international radio and telecommunications. It focuses on standardizing allocations of the radio spectrum and organizing interconnection arrangements between different countries to enable international telephone calls.

J - K

Kilohertz (KHz): the oscillation of a wave at 1,000 Hz or cycles per second.

L

LAN (Local Area Network): a local data network that is used to interconnect the computers and computer equipment.

LTE (Long Term Evolution): the name given to a project within the Third Generation Partnership Project to improve the UMTS mobile phone standard to cope with future requirements. Goals include improving efficiency, lowering costs, improving services, making use of new spectrum opportunities, and better integration with other open standards. The LTE project is not a standard, but it will result in the new evolved release 8 of the UMTS standard, including mostly or wholly extensions and modifications of the UMTS system.

M

Megahertz (MHz): the oscillation of a wave at 1,000,000 Hz or cycles per second.

Monopsony: an imperfectly competitive market where many sellers face only ne buyer, called "monopsonist".

N

Narrowband: a term commonly referring to analogue facilities and to digital facilities operating at low data transfer rates which are capable of carrying only voice, facsimile images, slow-scan video images, and slow data rate transmissions.

NRIC (the Network Reliability and Interoperability Council): an industry advisory council to the US FCC.

NGN (Next Generation Network): an advanced communications network which delivers a wide range of services, including the full range of capabilities that we expect from the PSTN/PLMN today. Notably, an NGN is IP-based.

NPIA (National Policing Improvement Administration): an organization in Great Britain dedicated to supporting the police service by providing expertise in areas as diverse as information and communications technology, support to information and intelligence sharing, core police processes, managing change and recruiting, developing and deploying people.

O

OECD (Organization for Economic Co-operation and Development): an Organisation of 30 member countries committed to democracy and the market economy.

OFDM (Orthogonal Frequency Division Multiplexing): a modulation scheme that divides a single digital signal across 1,000 or more signal carriers simultaneously (FDM). The signals spaced at precise frequencies which prevents the demodulators from seeing frequencies other than their own (hence, orthogonal) so they do not interfere with each other OFDM offers multiple access and signal processing and allows wireless networks to pack high efficiencies into relatively small bandwidths.

P

Packet switching: a communications paradigm in which packets (units of information carriage) are routed between nodes over data links shared with other traffic. In each network node, packets are queued or buffered, resulting in variable delay. This contrasts with the other principal paradigm, circuit switching, which sets up a constant bit rate and constant delay connection between the two nodes for their exclusive use for the duration of the communication.

Paging System: a one-way mobile radio service where a user carries a small, lightweight miniature radio receiver capable of responding to coded signals.**Passive cognitive radio (PCR):** one of two principal approaches to sharing spectrum using cognitive radio, whereby the radio can make decisions on frequency use autonomously and without any interaction with the licensed user.

PLMN (Public Land Mobile Network): a wireless communications network intended for use for telephone communications or data and Internet access.

PMR (Professional Mobile Radio, also known as Private Mobile Radio in the UK and Land Mobile Radio (LMR) in North America): field radio communications systems which use portable, mobile, base station, and dispatch console radios. These networks are designed for dedicated use by specific organizations.

PP1 (Public Protection 1): routine day to day operations within the agencies jurisdiction (normally within the national boundary) and as such the networks require wide area coverage on a permanent basis providing voice, narrowband and wideband communications.

PP2 (Public Protection 2): large emergency and / or public event where it may be necessary to use resources from other agencies outside the jurisdiction (including across the national boundary).

PSS (Public safety and security): services responders including police, fire and other emergency services to respond to emergency situations.

PSSPG (Public Safety Services Policy Group)

PSTN (Public Switched Telephone Network): the network of public circuit-switched telephone networks, originally fixed-line analogue telephone systems. The PSTN is now almost entirely digital.

Q – R

Radar (Radio Detection and Ranging): a radio determination system based on the comparison of reference signals with radio signals reflected, or retransmitted, from the position to be determined.

RF (Radio Frequency): See Spectrum.

Roaming: the use of a wireless device outside of the “home” service area defined by a service provider.

S

SDR (Software Defined Radio): a radio using programmable software for digital signal processing that allows the radio’s fundamental characteristics such as modulation types, operating frequencies, and access schemes to be easily changed.

Security: the protection against accidental or unlawful destruction or accidental loss, alteration, unauthorised disclosure or access, and against all other forms of unlawful processing of data.

Service Application, or Application: a suite of bundles, documentation, and support software that together form an application that provides a utility to the Service User.

Service User: the person that receives the benefits of a Service Application.

Service Provider: the organization that procures or develops Service Applications and deploys these applications via a Service Deployment Manager on Service Platforms.

SMR (Specialized Mobile Radio Services): a private, two-way radio system providing land mobile communications service to eligible persons on a commercial basis for such uses as dispatch communications or multi-site construction jobs.

spam (Single Post Addressed to Multiple lists): unsolicited email sent indiscriminately and in bulk.

Spectrum: the range of electromagnetic radio frequencies, ranging from 9 kHz to 3,000 GHz, used in the transmission of sound, data, and video images.

Spectrum Allocation and Spectrum Management: the coordination and assignment of available spectrum use to maximize efficiency and to prevent interference.

Spectrum Auction: a public sale of spectrum access in which the price is increased by bids until the highest bidder becomes the purchaser.

Spread Spectrum: a wireless communication system using special modulation techniques that spread the energy of the signal being transmitted over a very wide bandwidth. This increases the number of users that can share a particular band of frequencies, rather than assigning a discrete frequency to each user. Devices currently marketed in the United States primarily use one of two forms of spread spectrum signal: direct sequence spread spectrum and frequency hopping spread spectrum.

Spurious Emission: any radio emission or part of it which appears outside of the authorized bandwidth.

Surveillance Systems: a system which operate as a “security fence” by establishing a stationary RF perimeter field and detecting the intrusion of persons or objects in that field.

T

TDM (Time Division Multiplexing) or (TDMA Time Division Multiple Access): a method of digital transmission for wireless communications systems that allows a large number of users simultaneously to access a single radio frequency band without interference by dividing use of a set of frequencies by time.

TEDS (TETRA Enhanced Data Service or TETRA Release 2): a new air interface standard to increase TETRA data speeds up to 30-150kbit/s.

Teledensity: the number of communications access (or other metrics) in a given population or geographic area.

TETRA (Terrestrial European Trunked Radio): an open digital standard defined within ETSI and was expected to be deployed in the 300 to 1000 MHz frequency range. TETRA uses digital TDMA for its air interface and offers voice (including interconnection to the PSTN) and low bit rate data with four user channels on one radio carrier and 25 kHz spacing between carriers. It can support both point-to-point and point-to-multipoint transfer can be used.

TETRAPOL: a digital Professional Mobile Radio standard currently in use by closed professional user groups, such as public safety, military, industry and transportation worldwide. TETRAPOL employs a digital, FDMA access via terminals and base stations. The standards publicly available specifications are written in compliance with rules defined by ETSI.

U

UHF (Ultra High Frequency): the part of the radio spectrum from 300 to 3000 megahertz.

Ultra-Wideband Devices (UWB): a technology which relies on extremely short pulses that generate signals with very wide bandwidths, sometimes up to several gigahertz. UWB signals go undetected by most conventional receivers, minimizing their threat as harmful interferers. UWB technologies are currently being used in a variety of applications such as ground penetrating radar and are likely to be used in a variety of emerging applications such as through-wall imaging and high-speed data transmission.

UMTS (Universal Mobile Telecommunications System) is one of the third-generation (3G) cell phone technologies, which is also being developed into a 4G technology. Currently, the most common form of UMTS uses W-CDMA as the underlying air interface. It is standardized by the 3GPP, and is the European answer to the ITU IMT-2000 requirements for 3G cellular radio system.

Unlicensed Wireless Devices (also, License-exempt): radios that are permitted to emit RF energy, but require no specific device or user authorization, either through registration or grant of a license.

V

Vehicular Radar Systems: devices able to detect the location and movement of objects near a vehicle, enabling features such as near collision avoidance, improved airbag activation, and suspension systems that better respond to road conditions.

VHF (Very High Frequency): the part of the radio spectrum from 30 to 300 megahertz.

VoD (Video on Demand): Video on Demand enables end-users to select and watch video content over a network.

VoIP (Voice over IP): a set of data communications protocols and technologies to enable voice to be sent over individual IP-based networks or over the Internet.

VPN: a virtual private network.

W – Z

Wide Area Network (WAN): a data network used to interconnect remote sites or widely-dispersed computer equipment.

WDM (Wave(length) Division Multiplexing): a technology allowing to multiplex multiple optical carrier signals on a single optical fibre by using different wavelengths (colours) of laser light to carry different signals. This allows for a multiplication in capacity, in addition to making it possible to perform bidirectional communications over one strand of fibre. Current WDM systems can handle up to 160 signals and can thus expand a basic 10 Gbit/s fibre system to a theoretical total capacity of over 1.6 Tbit/s over a single fibre pair. Thus, WDM systems allow carriers to expand network capacity without laying more fibre.

Wi-Fi (Wireless Fidelity): the suite of IEEE 802.11 standards adopted starting in 1999, for short-range wireless digital connectivity. It is by far the most widely adopted WLAN standard and performance and speed these standards can provide rivals that of 10BaseT wired Ethernet networks.

WiMax (Worldwide Interoperability for Microwave Access): the IEEE 802.16 standard intended to wireless data communications over long distances in both point-to-point links to full mobile cellular type access. The name *WiMAX* was created by the WiMAX Forum, which was formed in June 2001 to promote conformance and interoperability of the standard. The forum describes WiMAX as "a standards-based technology enabling the delivery of last mile wireless broadband access as an alternative to cable and DSL."

W-LANs (Wireless Local Area Networks): LANs which use wireless data connections to provide short-range, high-speed wireless digital communications.