Consultation Paper No. 15/2017

Telecom Regulatory Authority of India

Consultation Paper

on

'Next Generation Public Protection and Disaster Relief (PPDR) communication networks'

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Written Comments on the Consultation Paper are invited from the stakeholders by 20th November, 2017 and counter-comments by 4th December, 2017. Comments and counter-comments will be posted on TRAI's website www.trai.gov.in. The comments and counter-comments may be sent, preferably in electronic form, to Shri S. T. Abbas, Advisor (Networks, Spectrum and Licensing), TRAI on the email ID advmn@trai.gov.in with subject titled as 'Comments / counter-comments to Consultation Paper on Next Generation Public Protection and Disaster Relief (PPDR) communication networks'

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CHAPTER I: INTRODUCTION

1.1 India with its geo-climatic conditions, high density of population, socio-economic disparities and other geo-political reasons, has high risk of natural and man-made disasters. In respect to natural disasters, it is vulnerable to forest fires, floods, droughts, earthquakes, tsunamis and cyclones. Other than the natural disasters, the nation is also vulnerable to man-made disasters like:

- War, terrorist attacks, and riots;
- Chemical, biological, radiological, and nuclear crisis;
- Hijacks, train accidents, airplane crashes, shipwrecks, etc.

1.2 One of the most significant impact of natural disasters is the breakdown or interruption of traditional communications networks. The communication networks get entirely or partially damaged by disasters or become congested with exceptionally high levels of traffic. This adversely affects emergency responders in their rescue operations.

1.3 In the immediate hours and days following a disaster, the demand for communication networks increases. During that time, it is critical that rescue workers and government officials synergises their efforts to provide relief and support to those affected. Rescue operation cannot be stopped or delayed even though the responding agencies are unable to communicate with one another. In these time-sensitive and mission critical situations, even few minutes lost can mean the difference between life and death for victims in need of rescue.

1.4 The Indian Ocean tsunami[1] of December 2004 highlighted the cost of communications breakdowns during disasters. While seismic monitoring stations throughout the world detected the massive sub-sea earthquake

[1] https://www.nyu.edu/ccpr/pubs/NYU-DisasterCommunications1-Final.pdf

that triggered the tsunami, a lack of procedures for communicating these warnings to governments and inadequate infrastructure in the regions at risk delayed the transmission of warnings. Therefore, it is clear that better communications can save several lives.

1.5 Many times public safety agencies become limited in their ability to communicate and share information with other agencies. Though such agencies have communication network and technology in place to do so within their own organization, however their networks mostly are not inter-operable/compatible with the networks of other agencies. This makes the inter-department coordination a difficult and complex task. When network connections are limited/unavailable/ incompatible, effective coordination becomes further complicated, and the lack of a comprehensive communication structure can result in delays in action.

1.6 In United States of America (USA), public safety agencies have joined together to design, develop and deploy information and communications technologies to support policing, criminal justice, public safety and homeland security. Inter-agency collaboration initiatives of this nature resulted in the creation of Public Protection and Disaster Relief (PPDR) communication networks. PPDR communication networks allow for the rapid deployment of networks in situations where capacity is needed on an expedited basis.

1.7 Frequency and intensity of natural or man-induced disasters have increased over the last few decades, accounting for great cost owing to life lost and destruction of infrastructure. The threats to public safety can be reduced or contained by having effective and efficient PPDR services. A fire that is put out early clearly saves property and human lives. A timely evacuation of an area ahead of a natural disaster can save many lives. Containing and isolating a terrorist attack may save society of untold horrors.

1.8 PPDR supports a wide range of public services such as the maintenance of law and order, protection of life and property, disaster relief and emergency responses. PPDR communication system has two components namely Public Protection (PP) radio communications and Disaster Relief (DR) radio communications and these are defined by the ITU-R[2] as follow:

- **Public protection (PP) radio communication:**
  Radio communications used by responsible agencies and organizations dealing with maintenance of law and order, protection of life and property, and emergency situations.
- **Disaster relief (DR) radio communication:**
  Radio communications used by agencies and organizations dealing with a serious disruption of the functioning of society, posing a significant, widespread threat to human life, health, property or the environment, whether caused by accident, nature or human activity, and whether developing suddenly or as a result of complex, long-term processes.

1.9 PPDR services (law enforcement, emergency medical service, firefighting, search and rescue, border security etc.) are provided by various PPDR agencies. PPDR agencies, also known as first responders, are the primary forces that deal with incident response. These agencies are responsible for day-to-day public protection and also respond to any disaster and deploy the required services in the disaster prone area. They would typically be public protection personnel grouped into mission oriented categories, such as police, fire brigades, emergency medical response,

[2] http://wiki.oevsv.at/images/2/2f/ITU_R-REP-M.2033-2003-PDF-E.pdf

Armed forces etc. For disasters, the scope of responders may increase to include other government personnel or civilians.

1.10 PPDR is of vital importance and the emergency services are mandated by law to deliver the highest possible quality of service to society. Whilst saving lives and protecting property, PPDR personnel work under dangerous conditions and governments have responsibility of ensuring that they have the best possible tools to perform these jobs.

1.11 In India, primary PPDR communication systems are designed and run by many independent state agencies. Currently, PPDR communication infrastructure in India is either old Analog Systems or it uses narrowband radios[3]. These radios employ narrowband channels and are operated on spot frequencies that are assigned to different public safety entities on a case-by-case basis. The narrowband nature of these radios limits them to only 2-way voice communications with no inherent support for high-bandwidth transmission requirements such as interactive video communication, remote video surveillance of security or disaster sites etc. Such systems suffer from problems like interoperability failures, inefficient use of spectrum, and higher costs. Such systems do not provide the level of secure communication required by India's security forces resulting in easy leak of information to unwanted entities.

1.12 With the prolieration of digital technologies there is a growing need in PPDR communication for significant enhancement in operational data capabilities. High speed mobile data capabilities that can be relied upon in adverse situations are becoming increasingly necessary in the public safety community for increasing the situational awareness of first responders as well as resource allocation by operational centers.

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[3] http://wpc.dot.gov.in/DocFiles/IITB_proposal_Spectrum-for_Public_Safety.pdf

1.13 By their nature, PPDR operations can derive significant benefits from the ability to access a wide variety of information, including informational databases, access to instant messaging, high-quality images and video, mapping and location services, remote control of robots, and other applications. In future, large deployments and proliferations of robotics, Machine-to-Machine (M2M) communication, Internet of Things (IoT) etc. will have a significant impact on PPDR operations and emergency rescue operations.

1.14 PPDR applications, such as transmission of high resolution images and real time video, requires much higher bit-rates than what current narrowband PPDR technology can deliver. Although narrowband and wideband systems will continue to be used simultaneously to meet PPDR requirements in the near term, there is a growing need for broadband networks to support improved data and multimedia capabilities, which require higher data rates and higher capacity. An adequate amount of spectrum may need to be made available on a national basis to meet these growing needs.

1.15 Mobile technologies capable of sending and receiving bandwidth-intensive data can help emergency responders do their jobs more effectively and safely. PPDR agencies need mobile broadband networks that enable them to share streaming real-time video, detailed maps and blueprints, high-resolution photographs and other files.

1.16 Currently, all the mission-critical organizations operate their own voice centric networks on a variety of frequency bands and a variety of technologies, and thus are generally not interoperable with each other. Interoperability issue can be overcome in broadband PPDR if the broadband PPDR network operates on a common standard nationwide. The world's emergency services are increasingly looking at LTE as the technology of choice for mobile broadband PPDR network. The 3GPP LTE standard has been endorsed internationally as the preferred technology[4] standard to support commercial and mobile broadband networks for PPDR.

1.17 TRAI is acutely aware of the role of robust and reliable communication setup for PPDR. Accordingly, some steps have been taken by TRAI in the recent past to address certain primary issues in this area. In November 2013, TRAI sent its recommendations on priority routing of calls of persons engaged in response and recovery. This is partially implemented by the Government. If this is fully implemented, it can facilitate inter-agency communication over commercial networks at the time of first response to an emergency. It is a known fact that the networks get overloaded during emergencies resulting in denial of service to first responders. Another initiative by the Authority was its recommendations on single number based Integrated Emergency communication and response system (IECRS). Government has accepted this recommendation and has adopted 112 as the single emergency number in India and guidelines have been issued to implement IECRS across the country.

1.18 A responsive and efficient PPDR network is an essential requirement of a nation. Having felt the need to have advanced, reliable, robust and responsive PPDR network, the Authority has suo-motu taken up the issue of "Next Generation Public Protection and Disaster Relief (PPDR) communication networks" for public consultation as per Section 11(a) of TRAI Act, 1997.

1.19 For drafting this consultation paper, various documents available in the public domain, published by government agencies/departments, telecom

[4] http://www.analysysmason.com/About-Us/News/Insight/LTE-advances-public-safety-Oct2012/

regulators of many countries, research agencies/institutions, academic institutions, telecom vendors, operators and international agencies/forums etc were referred with the purpose to make the consultation paper balanced and comprehensive. Excerpts from certain documents, which had domain relevance, are also included in this CP.

1.20 In this consultation paper, Chapter-II deals with the technical requirements and execution models for broadband PPDR and Chapter-III deals with the spectrum availability and future requirements for broadband PPDR. In chapter-IV international practices in regulating the PPDR communication services are covered and the Chapter-V provides the summary of issues for consultation.

CHAPTER II: TECHNICAL REQUIREMENTS AND EXECUTION MODELS FOR BROADBAND PPDR

A. Ideal characteristics of PPDR communication networks

2.1 PPDR communication networks are different from normal commercial networks in many ways. This is mainly due to the mission critical traffic which flow through these networks. The ideal characteristics[5] of PPDR communication networks are:

- **Availability:** PPDR effectiveness is undermined by network downtime, especially in emergencies. Networks should be available at least 99.99% of the time.
- **Capacity:** The PPDR network should have sufficient capacity and redundancy to handle traffic during the peak operational conditions.
- **Coverage:** PPDR communication networks coverage has to be extensive. It should provide coverage in the whole geographic area of the mission, which may have the dimensions of a metropolitan area network or even wider. In addition, indoor coverage configurations must also be available, especially in basements and tunnels or large and crowded infrastructures.
- **Easily and Rapidly Deployable:** The traditional networks already in existence break down during disasters hence PPDR communication networks should be easily and rapidly deployable.
- **Interoperability:** Interoperability is a crucial requirement of PPDR communication networks for the effective and efficient operation and cooperation amongst PPDR agencies. Interoperability implies that PPDR agencies are able to continuously share information with each other at all times.

[5] http://www.cs.wustl.edu/~jain/cse574-14/ftp/disaster/index.html,
www.**ppdr**tc.eu/userfiles/deliverables/**PPDR**-TC-**D2.2**-v2.10_137165.pdf,
http://www.era.europa.eu/Document-Register/Documents/FinalReportEN.pdf

- **Mobility:** PPDR communication networks are deployed in highly dynamic environment, which translates to a wide variety of mobility requirements. Hence, PPDR communication networks are generally wireless because it provides enhanced mobility.
- **Performance:** The response in PPDR communication networks should be real-time and have low latency.
- **Quality of service:** The PPDR networks should meet very high QoS standards so that missions are not affected due to poor quality, as the stakes are high and most of the communications are mission critical in nature.
- **Reliable:** PPDR communication networks should be reliable as it would be required to operate in hostile environments.
- **Security:** Communication through PPDR communication networks should be capable of only being heard by the intended recipient for safety and confidentiality purposes.
- **Scalability and Reconfiguration:** The scale and nature of each disaster is different. Hence, PPDR communication networks deployed should be easily reconfigurable and scalable to accommodate these requirements.

B. Operating environment

2.2 PPDR activities are omnipresent and continuous in nature. It ranges from day to day routine security and policing activity to event specific disaster relief. Based on the activity type, three[6] distinct operating environments are defined that impose different requirements on the use of PPDR services.

- **Day-to-day:** The routine operations that PPDR agencies conduct within their zone. These operations are generally within national borders.

[6] **Book-Mobile Broadband Communications for Public Safety: The Road Ahead Through LTE technology** By Ramon Ferrus, Oriol Sallent

- **Large emergency or public events:** The operations need to be performed by PPDR agencies in addition to routine operations in case of large emergency or public events. The size and nature of the event may require additional resources from adjacent jurisdictions, cross border agencies or international organizations.
- **Disasters:** There is a sudden requirement of PPDR operation in case of disasters. Disaster can be natural or due to human activity. Effective cross-border PPDR operation or international mutual aid could be beneficial in this operating environment.

C. PPDR communication services

2.3 The nature and scope of PPDR communication varies with the event at hand. It can range from basic voice communications to complex video and data communications. A brief detail on various forms of communication services on a PPDR network is given below:

2.4 **Voice Services:** Voice service is primary for PPDR communication. The key elements of voice service in mission critical situation[7] are:

- *Direct or Talk Around:* It provides PPDR agencies with the ability to communicate unit-to-unit when out of range of a wireless network or when working in a confined area where direct unit-to-unit communications is required.
- *Push-to-Talk (PTT):* It provides the ability to address a particular individual or group at the press of a single button. This is a time-saving tool first responders rely on in urgent situations.
- *Group Call:* It provides communications from one-to-many members of a group and is of vital importance to the PPDR. The ability to define and redefine talk groups quickly is essential for effective teamwork.

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[7] http://www.npstc.org/download.jsp?tableId=37&column=217&id=2055&file=Mission%20Critical%20Voice%20Functional%20Description%20083011.pdf

- *Talker Identification:* It provides the ability to a user to identify who is speaking at any given time and could be equated to caller ID available on most commercial cellular systems today.
- *Emergency Alerting:* It is essentially an alarm button with overriding priority which indicates that a member of the group is in needs to communicate immediately.
- *Audio Quality:* This is a vital element for mission critical voice. The listener must be able to understand without repetition, and can identify the speaker, can detect stress in a speaker's voice, and be able to hear background sounds as well without interfering with the prime voice communications.

2.5 **Data Services:** While voice services will remain an important component of PPDR operations, data and video services are expected to play a key role increasingly. PPDR agencies today are using narrowband data applications such as pre-defined status messages, data transmissions of forms and messages, access to databases and wideband data applications such as short messages, email, and compressed video. There is a need for broadband technology to transmit video or high resolution images, to use geographic information systems (GIS) and to access the internet at high speeds. Data services are used to provide a large number of applications which can have widely differing requirements in terms of capacity, timeliness and robustness of the data service. Table 2.1 shows the diverse needs of data applications.[8]

[8] www.etsi.org/deliver/etsi_ts/102100_102199/102181/01.02.../ts_102181v010201p.pdf

Table 2.1: Requirements on data applications

Service	Throughput	Timeliness
Email	Medium	Low
Imaging	High	Low
Digital mapping / +Geographical info services	High	Variable
Location services	Low	High
Video (real time)	High	High
Video (slow scan)	Medium	Low
Data base access (remote)	Variable	Variable
Data base replication	High	Low
Personnel monitoring	Low	High

Throughput: data volume in a given time.
Timeliness: importance of the information arriving within an agreed timeframe.

D. Technologies that are used for PPDR services based on data rates

2.6 There can be three types of technologies that are used for PPDR based upon data rates:[9]

a. **Narrowband:** speed or bit rate up to 64kbps which is one voice channel in a radio system

b. **Wideband:** carry data rates of several hundred kilobits per second (e.g. in the range of 384-500 kbit/s)

c. **Broadband:** data rates in range of 1-100 Mbit/s

2.7 While narrowband systems offer a rich set of voice centric services, the data transmission capabilities of narrowband systems are rather limited. Wideband/broadband systems are used to provide data services. Table

[9] http://wiki.oevsv.at/images/2/2f/ITU_R-REP-M.2033-2003-PDF-E.pdf

2.2 shows classification of PPDR application based on the above technologies.

Table 2.2: Classification of PPDR application[10]

APPLICATION	***FEATURE***	***PPDR EXAMPLE***
1.Narrowband		
Voice	person-to-person	selective calling and addressing
	one-to-many	dispatch and group communication
	talk-around/direct mode operation	groups of portable-to-portable (mobile-mobile) in close proximity without infrastructure
	push-to-talk	push-to-talk
	installation access to voice path	push-to-talk and selective priority access
	security	voice
Facsimile	person-to-person	status, short message
	one-to-many (broadcasting)	initial dispatch alert (eg: address, incident status)
Messages	person-to-person	status, short messages, short e-mail
	one-to-many (broadcasting)	initial dispatch alert (eg: address, incident status)
Security	priority / instantaneous access	man down alarm button
Telemetry	location status	GPS latitude and longitude information
	sensory data	vehicle telemetry/status
		EKG(electrocardiograph) in field
Database interaction (minimal record size)	forms based records query	accessing vehicle license records
	forms based incident report	filing field report
2. Wideband		
Messages	emails possibly with attachments	routine email messages
Data Talk Around/Direct Mode Operation	direct unit to unit communication without additional infrastructure	direct handset to handset , on-scene localized communication
Database Interaction (Medium Record Size)	forms and record query	accessing medical records
		lists of identified person/missing person
		GIS(geographical information systems)
Text File Transfer	data transfer	filling report from scene of incident
		records management system information on offenders
		downloading legislative information

[10] http://www.erodocdb.dk/docs/doc98/official/pdf/ECCRep199.pdf

Image Transfer	download/upload of compressed still images	biometrics (finger prints)
		ID picture
		building layout maps
Telemetry	location status and sensory data	vehicle status
Security	priority access	critical care
Video	download/upload compressed video	video clips
		patient monitoring (may require dedicated link)
		video feed of in-progress incident
Interactive	location determination	2-way system
		interactive location data
3. Broadband		
Database Access	intranet/internet access	accessing architectural plans of buildings , location of hazardous materials
	web browsing	browsing directory of PPDR organization for phone number
Robotics Control	remote control of robotic device	bomb retrieval robots, imaging/ video robots
Video	video streaming, live video feed	video communication from wireless clip-on cameras used by in building fire rescue
		images or video to assist remote medical support
		surveillance of incident scene by fixed or remote controlled robotic devices
		assessment of fire/flood scenes from airborne platforms
Imagery	high resolution imagery	downloading earth exploration – satellite images

E. Standards used for mobile PPDR communication

2.8 Multiple technologies are deployed in the field of PPDR communication. Some narrowband PPDR standards are Tetra, Tetrapol, Project 25 (P25) etc. Standard for wideband PPDR is TEDS (TETRA Enhanced Data Services). Standard for mobile broadband PPDR is LTE. Brief technical descriptions[11] of these technologies are given in Annexure-I.

[11] http://forum.ameradio.com/usr/doc/Tait_White_Paper_Digital_Radio_Adv_and_Disad_20130130.pdf

2.9 LTE provides unprecedented capabilities for mobile broadband networks. It has been declared by public safety and communications experts to be the technology of choice for First Responder/Public Protection and Disaster Relief (PPDR) mobile broadband networks for years to come. Table 2.3 shows comparison between different mobile PPDR standards.

Table 2.3: Comparison between different mobile PPDR standards[12]

FEATURES	***TETRA***	***TETRAPOL***	***P25***	***LTE***
Spectrum Deployment	400/800 MHz band	80/400 MHz band	VHF/UHF/700/800/900 MHz band	FDD & TDD 3GPP LTE bands
Channel Bandwidth	25 kHz 25,50,100,150 kHz With Teds	12.5 kHz	12.5 kHz	1.4/3/5/10/15/20 MHz
Duplex Mode	FDD	FDD	FDD	FDD/TDD
Multiple Access	TDMA	FDMA	FDMA(Phase 1) TDMA(Phase 2)	OFDMA
Voice Service	Integrated	Integrated	Integrated	Over The Top First; Integrated From 3GPP Release 13
Text Service	Integrated	Integrated	Integrated	Integrated
Data Service	Narrowband And Wideband (Teds)	Narrowband	Narrowband	Broadband
Video Service	Low Quality With Teds	No	No	Yes
Data Rates	28.8kbps @4-slot 25 kHz Upto 154kbps @50 kHz	7.6kbps	9.6kbps	100Mbps @20 MHz
Deployment	WAN	WAN	WAN	Wan/Small Cell

F. Advantages of LTE for mobile broadband PPDR communication compared to previous generation of mobile technologies

2.10 Mobile technology continues to evolve. The latest generation technology is LTE, a fourth generation (4G) technology. LTE technology is based on open international standards set by the 3rd Generation Partnership Project (3GPP) and updated on an 18–24 month cycle. LTE has various

[12] http://www.tandcca.com/Library/Documents/TETRA_Resources/Library/Presentations/NAtour2012GrayP25.pdf, **Book- Wireless Public Safety Networks Volume 1: Overview and Challenges** By Daniel Câmara, Navid Nikaein

enhancements compared to previous mobile technologies. The ITU-R[13] released a report detailing the advantages of LTE for PPDR broadband compared to previous generation mobile technologies. These include:

- Better coverage and capacity, and more reliable services
- Simplified, IP (internet protocol)-based architecture
- Low latency and low packet loss, which are important for real time applications
- Greater interoperability due to commercially standardized protocols and interfaces
- Better security features and capabilities
- Quality of service and prioritization
- Can be flexibly deployed with a wide range of channel sizes/carrier bandwidths.

G. PPDR network models

2.11 Besides dedicated PPDR networks, with the advancement of technology, there are different models adopted in various countries to optimally use the spectrum resource. PPDR networks can be categorized into two broad types:

(a) Spectrum based models

(b) Network deployment strategy based models

2.12 3GPP LTE or LTE-Advanced ecosystem has matured and consequently commercial networks are being rapidly deployed throughout the world. Based on open standards such as 3GPP LTE or LTE-Advanced, broadband PPDR systems may be realized through various ways viz: deployment of dedicated PPDR networks using exclusive spectrum, priority access over commercial networks, or via a hybrid approach using either dedicated spectrum in a partitioned commercial network or a

[13] https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-M.2291-2013-PDF-E.pdf

combination of dedicated and commercial networks. When comparing the different alternatives, each approach may be seen as offering both advantages and disadvantages. Eventually the choice of implementation is a national matter.

i. **Spectrum based models**

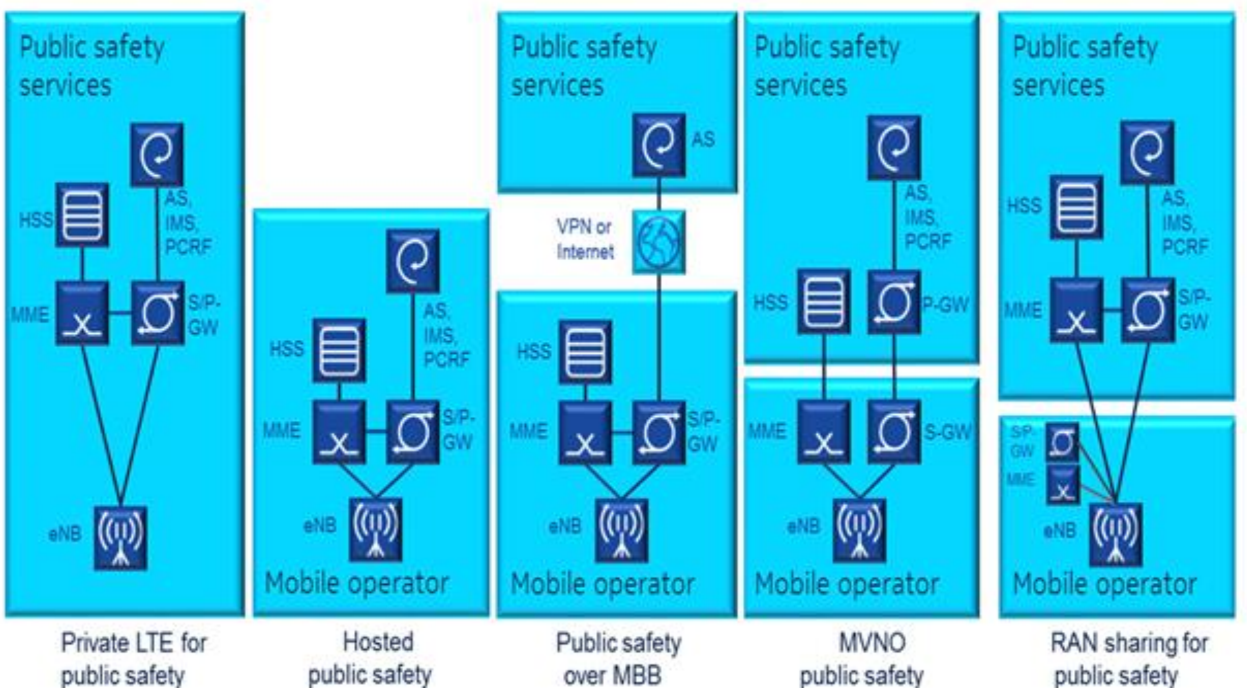
2.13 Public safety mobile broadband can be delivered through a dedicated network, commercial network or a combination of both dedicated and commercial network (hybrid network).

- **Dedicated:** In this approach, dedicated spectrum is allocated for PPDR network. Dedicated spectrum can offer availability, control and security. For economic reasons, dedicated spectrum is shared by a number of PPDR agencies (police, fire, emergency medical services etc) and other critical communication user organizations.
- **Commercial:** In this approach, no spectrum is allocated to PPDR network. The spectrum is shared with the commercial networks throughout the country.
- **Hybrid:** In this model, the spectrum can be shared with the commercial network operator in some areas and dedicated spectrum in some areas. Spectrum can be shared with the commercial network operators to provide enhanced coverage by leveraging the already existing networks in the less populated area (rural areas) at lower cost. However for densely populated area (urban areas) dedicated spectrum can be allocated to PPDR.

2.14 United Kingdom (UK) is using commercial network to provide mobile broadband to public safety agencies. EE (mobile network operator) has won the contract to provide mobile (access) services to public safety agencies using its existing commercial 4G network. South Korea, US, Australia, Qatar, Thailand, France have allocated dedicated spectrum for Public Safety-LTE (PS-LTE). US government authority (FirstNet) is exploring ways to monetize the capacity of dedicated spectrum while it is not needed by PPDR agencies. This is the hybrid model, which includes typically dedicated coverage in urban areas while the rural coverage cost can be reduced by sharing radio access with mobile operators.

ii. <u>Network deployment strategy based models</u>

2.15 Based upon network deployment strategy[14] PPDR network can be classified as dedicated network infrastructure, commercial network infrastructure and hybrid network infrastructure.



AS	Access Service	PCRF	Policy and Charging Rule Function
VPN	Virtual Private Network	IMS	IP Multimedia System
HSS	Home Subscriber Server	eNB	eNode B
MME	Mobility Management Entity	P –GW	Packet Data Network Gateway
S –GW	Serving Gateway	MBB	Mobile Broadband

Figure 2.1: PPDR network based upon network deployment strategy

[14] http://resources.alcatel-lucent.com/asset/200168

a) **Dedicated Network(s) Infrastructure:** The Mobile Broadband Network is planned, build, and operated by the PPDR/PS-LTE Agency themselves. These networks provide the mobile broadband services through service offering tenders. In Figure 2.1 above, (i) Private LTE for Public Safety comes under this category.

b) **Commercial Network(s) Infrastructure:** This model is based on the common network infrastructure that is shared between PPDR/Public Safety and Commercial network subscribers. In this type of model the mobile broadband services to PPDR agencies are differentiated using user access barring, special QoS, on demand resource reservation, dedicated applications etc. In Figure 2.1 above, (ii) Hosted Public Safety model will belong to this category.

c) **Hybrid Network(s) Infrastructure:** This model is based on partly Dedicated and partly Shared Network Infrastructure between PPDR /Public Safety and Commercial Networks. There may be geographical split between PPDR and Commercial network(s). Also this model can be based on various type of Mobile Virtual Network Operator (MVNO) architecture. The MVNO models may be of the following three types:

- Over-The-Top services: PPDR/PS services in LTE can be implemented as applications over MBB. Here the business logics are located outside of the network and connected to the networks using VPN or Internet. In Figure 2.1 above, (iii) Public Safety over MBB uses this model.
- MVNO Model: In this model, the public safety service provider role is separated from the network provider. In the Figure 2.1 above, (iv) MVNO Public Safety belongs to this category.
- RAN Sharing Model: In this model, Common RAN will be shared across both commercial and PS Services. In this model the Core and App Servers hosting the PS services are not shared. In the Figure 2.1 above, (v) RAN sharing for Public Safety belongs to this category.

2.16 In order to make better utilization of spectrum resource, utilize attendant benefits of technology and also unlock its economic value to certain extent, a possibility for above discussed commercial model approach and hybrid model approach can also be explored in India too. There are several reasons why many counties across the world are moving towards adoption of commercial based or hybrid solutions to attain maximum benefit from the spectrum resource.

2.17 The Government has statutory obligations for the provision of national mission critical communications (especially for PPDR). Dedicated spectrum could be required for such services. Therefore, one of the key issues that need to be deliberated is whether there should be exclusive dedicated spectrum earmarked in the country for mission critical services. Choosing to build dedicated mission critical networks, dedicated spectrum may be necessary – which is an additional financial burden, if the opportunity costs are factored into. While making such choices the trade-offs like loss accruing from non-commercial deployment of valuable spectrum viz-à-viz; socio-economic benefits from effective PPDR operation needs to be deliberated to arrive at the right balance.

2.18 The market value of the spectrum and economic circumstances may force a rethink of the affordability of a dedicated network over the next few years. Dedicated network if deployed exclusively by PPDR agencies will require huge capital investment. Further technological advancements will require periodic investments in future. It is appropriate and better to discuss and adopt affirm futuristic approach which may not become economic constraint to PPDR agencies as well as can yield commercial value.

2.19 In a shared commercial network, mission critical users can act only as clients or as priority users with others sharing the network. Such PPDR networks can be built, owned and operated by government-owned-and-operated networks efficiently. Re-use of the available spectrum is an inherent part of the commercial offering.

2.20 Commercial or hybrid model as discussed above can be built by inviting bids from the existing TSPs or it can be given on nomination basis to State owned TSPs viz. BSNL and MTNL since these PSUs have vast infrastructure and presence across the length and breadth of the nation which could help in minimize time to market and reduce overall deployment, operation and maintenance cost by leveraging the existing infrastructure and assets. Both, TSP and various PPDR agencies may enter into stringent SLAs for operation and maintenance of such networks. The optical fiber network of Bharat Net can play a vital role in national broadband PPDR network. In United States, a government authority (FirstNet)[15] was created by Congress to build, operate and maintain the first high-speed, nationwide wireless broadband network dedicated to public safety which will provide a single interoperable platform for emergency and daily public safety communications. This type of a model could also be deliberated upon.

2.21 Few countries have adopted MNO-MVNO model to leverage MNO`s network to fulfill capacity and coverage (specially indoors/rural) requirements of Public safety networks while keeping the budget under control. The goal[16] of MVNO model in PPDR communication is to leverage the existing commercial mobile broadband radio infrastructure to create and operate dedicated services for the critical users. Dedicated services can deliver added value including better availability, security, quality control and better customer care than can be delivered by the

[15] http://www.firstnet.gov/about

[16] Book-Mobile Broadband Communications for Public Safety: The Road Ahead Through LTE technology **By Ramon Ferrus, Oriol Sallent**

commercial MNO individually. This model is already in place in Europe (Belgium). ASTRID, a TETRA network operator for Belgium[17] emergency and security services, launched Blue Light Mobile, a mobile broadband data service that uses three Belgian commercial networks. Blue Light Mobile enables the emergency and security services in Belgium to use the commercial 3G networks. A single subscriber identity module (SIM) card gives priority access within a secure environment to three Belgian operators, as well as 11 operators in four neighbouring countries. With Blue Light Mobile, ASTRID becomes a mobile virtual network operator (MVNO), supplying services via third-party networks. ASTRID first announced the plan in 2012. Several other TETRA operators, including Airwave in the United Kingdom, have announced similar MVNO-based broadband services since then. Such arrangements can also be explored in the regime of UL (VNO) licensing.

H. Prevailing PPDR communication network in India

2.22 As mentioned earlier, primary PPDR communications systems in India are designed and run by many independent state agencies. All the mission-critical organizations operate their own voice oriented networks on a variety of frequency bands and technologies. The PPDR communication networks in India use narrowband radios[18]. The narrowband nature of these radios limits them to 2-way voice communications with no inherent support for high-bandwidth transmission requirements.

2.23 According to the National Frequency Allocation Plan (NFAP 2011) released by DoT[19], "*public protection and disaster relief (PPDR) communications including Broadband Wireless Access may be considered,*

[17] http://www.mvnodynamics.com/2014/04/30/belgium-operator-astrid-adds-3g-mvno-public-services/
[18] http://wpc.dot.gov.in/DocFiles/IITB_proposal_Spectrum-for_Public_Safety.pdf
[19] http://www.wpc.dot.gov.in/Docfiles/National%20Frequency%20Allocation%20Plan-2011.pdf

as far as possible, in the Frequency band 380-400 MHz, 406.1-430 MHz, 440-470 MHz, 746-806 MHz, 806-824/851-869 MHz, 4940-4990 MHz and 5850-5925 MHz on a case-by-case basis depending on specific need and equipments availability".

Channel assignment criteria

2.24 Trunking operators (PMRTS and CMRTS) in India are assigned 814-819 MHz/859-864 MHz band for Analog and 811-814/856-859 MHz band for Digital networks. License conditions for PMRTS/CMRTS provides that initially, not more than five channels (frequency pairs) will be assigned for Analogue system and for Digital system upto 30 frequency channels (25KHz each) depending on the availability, justification and the actual usage of the same. Further additional channels will be considered subject to availability of frequency spectrum in the designated frequency bands in the particular service area and after taking into account growth of service. This includes the control channels also.

2.25 PPDR agencies in India are issued license by DoT under CMRTS category, accordingly spectrum is allocated by WPC Wing of DoT in the 300 MHz or 400 MHz or 800 MHz bands as mentioned in the Table 2.4 & 2.5 below. These frequencies have adjacent channel spacing of 12.5 KHz in 300 MHz/400 MHz band and 25 KHz in 800 MHz frequency bands. Duplex spacing in 300/400 MHz band is 10 MHz and same for 800 MHz is 45 MHz. Allocation of the frequencies is made on case to case basis and depending on technology used and availability of frequency spots.

Table 2.4: Frequency band: 300 MHz or 400 MHz

Frequency band (MHz)	**Block size of spectrum allocated**	**Uses**	**IND Footnote**
338-340, 348-350	2x2 MHz	Mobile Trunk Radio for Captive networks. PMRTS on case to case basis.	IND 27

336-338, 346-348	2x2 MHz	PMRTS	
351-356, 361-366	2x5 MHz	Digital CMRTS	IND 28
356-358, 366-368	2x2 MHz		
380-389.9, 390-399.9	2x9.9 MHz	Digital PMRTS	IND 29
410-430	20 MHz		

Table 2.5: Frequency band: 800 MHz

Frequency band (MHz)	Block size of spectrum allocated	Uses	IND Footnote
806-811, 851-856	2x5 MHz	Mobile Trunk Radio for captive networks. PMRTS on case to case basis.	IND 40
811-814, 856-859	2x3 MHz	Digital PMRTS	IND 41
814-819, 859-864	2x5 MHz	PMRTS	IND 42
819-824, 864-869	2x5 MHz	PMRTS	IND 43

I. 3GPP Standards and features on Public Safety

2.26 Cellular mobile provides the mass market with one-to-one communications whereby a mobile unit can call another mobile unit or a fixed line through interconnection with public switched telephone network (PSTN). The persons handling PPDR operations are generally using trunked radio services such as CMRTS.

2.27 With technological developments in trunked radio in recent years, the ability to interconnect to PSTN is also available. Additionally, coupled with the ability to send short messages directly to a handset, there is now some overlap with the mobile cellular services. However, in terms of equipment design, the mobile cellular is not designed to the extent of robustness that trunked radios offer which is an important factor for end users who are operating in challenging work environment.

2.28 By leveraging the strengths of LTE and adding a comprehensive set of features needed for public safety communications, Mission Critical Push to Talk brings technical unity to commercial and public safety PTT communications. 3GPP has defined requirements for Mission Critical Push to Talk (MCPTT) application in LTE Release 13. The functionality from TETRA and P25 standards has also been included in LTE Release 13. Through its Technnical Specifications (TS) document 3GPP TS 24.380 version 13.0.2 Release 13 and ETSI TS 124 380 V13.0.2 (2016-05) on Mission Critical Push To Talk (MCPTT) media plan; protocol specification, 3GPP and ETSI has specified the media plane control protocols and interactions with the media needed to support Mission Critical Push To Talk (MCPTT).

2.29 Presently various vendors providing LTE technology are also able to provide critical enterprise communication services such as broadband trunking, video surveillance, data acquisition, broadband data access, emergency communications, and other broadband services on a single network. Thus technological innovations has enabled and made it feasible for PPDR trunking service roaming on public network, Trunking service on common carrier smartphone, Interoperation between LTE and TETRA network and interconnection to 2G/3G/PSTN /IP PBX through gateway.

2.30 It is possible that a captive PPDR user in addition to using its own network can also use public networks as well, thus making much better utilization of resources. Captive PPDR networks can be integrated with public networks so when users move out of the private area to the public area, the basic trunking service (unicast) is continuously available through the public sites. This feature can extend the PTT service nationwide over the public mobile network. The VPN channel between the PTT server and handset in the public network is established, and the encrypted data is transmitted through the public network. Therefore, issue of security of the PTT service over the public network is eliminated.

2.31 Push-to-Talk over Cellular (PTToC) uses IP technology to connect to the Captive PPDR network, thereby achieving trunking group calls. With this feature, commercial handsets with PTToC clients can access the LTE network or public networks for group call services. The PTToC service enables the handsets to implement group call services using other networks in the absence of the private network.

2.32 In view of foregoing discussion, it is debatable whether advantage of the technology can be better leveraged by looking into feasibility of intergrating cellular networks having desired functionality so that natural resource particulaly spectrum can be utilised efficiently in the interest of nation and its citizens.

2.33 In view of the above, following issues are put for the comments of stakeholder:

Q1. Do you consider the existing fragmented model of PPDR communication network in the country adequate to meet the present day challenges? If not, what are the deficiencies in the existing model of PPDR?

Q2. In the various models described in para 2.11-2.15, in your opinion which of the model (dedicated, commercial, hybrid) will be more suitable for Indian conditions? or Is there any other alternate model which would be more suitable for Indian telecom environment? Please provide rationale for the suggested model.

Q3. Should PSUs be earmarked for providing nationwide broadband PPDR communication network? Please justify your answer.

Q4. Will it be technically feasible and beneficial to permit PPDR trunking service roaming on public telecom networks? If yes, what challenges do you foresee in implementation of such an arrangement? Please justify your answer.

CHAPTER III: SPECTRUM AVAILABILITY AND FUTURE REQUIREMENTS FOR BROADBAND PPDR

3.1 Spectrum allocation is the most important component to adopt LTE as the future technology of choice for broadband PPDR in India. An appropriate spectrum allocation can help provide greater capacity for overloaded network and dynamic reconfiguration capability to better manage load and connectivity.

A. International identification and allocation of broadband PPDR bands

3.2 The Resolution 646 (WRC-03)[20] states that for the purposes of achieving regionally harmonized frequency bands/ranges for advanced public protection and disaster relief solutions, consider following identified frequency bands/ranges or parts thereof when undertaking their national planning: 406.1-430 MHz, 440-470 MHz, 806-824/851-869 MHz, 4940-4990 MHz and 5850-5925 MHz. Additionally, it is noted in the Resolution 646 (rev.WRC-12)[21] that some countries in Region 3 (Region 3 includes India too) have also identified the bands 380-400MHz and 746-806MHz for PPDR applications.

3.3 As stated in the resolution 646 (WRC-03), the public protection and disaster relief applications at that time were mostly narrow-band supporting voice and low data-rate applications, typically in channel bandwidths of 25 kHz or less; many future applications will be wideband (indicative data rates in the order to 384-500 kbit/s) and/or broadband (indicative data rates in the order of 1-100 Mbit/s) with channel bandwidths depending on the use of spectrally efficient technologies. In times of disasters, if most terrestrial-based networks are destroyed or impaired, amateur, satellite and other non-ground-based networks may

[20] https://www.itu.int/dms_pub/itu-r/oth/0A/0E/R0A0E00006A0001MSWE.doc
[21] www.cept.org/files/9421/Resolution%20646%20(Rev.%20WRC-12).docx

be available to provide communication services to assist in public protection and disaster relief efforts.

3.4 According to ITU, the benefits of spectrum harmonization[22], even though restricted to a regional rather than a global level, include increased potential for interoperability in PPDR activities. It is also expected to create a broader manufacturing base, leading to economies of scale and cheaper, more readily available equipment. This, in turn, will give PPDR agencies better access to enhanced system capabilities built on uniform types of equipment.

3.5 Rec. ITU-R M.1826 [23] recommended Regions 2 and 3 to consider the band 4940-4990 MHz, or parts thereof, when undertaking their national planning for broadband PPDR applications for the purposes of achieving harmonized frequency bands/ranges for PPDR.

3.6 WRC-12 approved agenda 1.3 for WRC-15 with the objective to update Resolution 646 for Broadband PPDR systems:

- *to review and revise Resolution 646 (Rev. WRC-12) for broadband public protection and disaster relief (PPDR), in accordance with Resolution 648 (WRC-12)*
- Resolution 648 (WRC-12):[24] Studies to support broadband public protection and disaster relief

3.7 The Resolution 646 (REV. WRC-15)[25] encourages administrations to consider parts of the frequency range 694-894 MHz, when undertaking their national planning for their PPDR applications, in particular broadband, in order to achieve harmonization. It further encourages

[22] www.cept.org/files/9421/Resolution%20646%20(Rev.%20WRC-12).docx
[23] https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.1826-0-200710-I!!PDF-E.pdf
[24] http://www.cept.org/files/9421/ITU-R%20Resolution%20648.pdf
[25] https://www.itu.int/en/ITU-R/information/Documents/Res.646(WRC-15).pdf

administrations to also consider parts of the following regionally harmonized frequency ranges, for their PPDR applications: –

- *In Region 1:* 380-470 MHz
- *In Region 3:* 406.1-430 MHz, 440-470 MHz and 4 940-4 990 MHz

The other frequency previously indicated as harmonized for PPDR in the Asia-Pacific Region remain in the agreement.

3.8 Table 3.1 gives the summary of recommendations given by ITU so far for Region 3 for PPDR.

Table 3.1: Harmonized band for PPDR recommended by ITU for Region 3

Source	***Harmonized band for PPDR***	***Technology***
Resolution 646 WRC 03 , rev.WRC 12	406.1-430 MHz 440-470 MHz 806-824/851-869 MHz 4940-4990 MHz 5850-5925 MHz **For Region 3**	Narrowband
ITU-R recommendation M.1826	4940-4990 MHz **For Region3**	Broadband
Resolution 646 rev. WRC 15	694-894 MHz **Globally**	Broadband

3.9 In 2012, the 13th Meeting of the South Asian Telecommunications Regulator's Council adopted SATRC[26] guidelines on harmonized use of frequency bands for public protection and disaster relief (PPDR). The guidelines recommended the members to adopt the following harmonised frequency bands for PPDR applications:

- Narrowband: 406.1-430 MHz and 440-470 MHz
- Wideband: 806-824/851-869 MHz
- Broadband: 4940-4990 MHz (to be reviewed in future)

[26] http://www.apt.int/SATRC-SAPIII

3.10 April 2017, Asia-Pacific Telecommunity (APT) issued a report[27] on "Harmonization of frequency ranges for use by wireless PPDR applications in Asia-Pacific region" suggesting APT administrations to consider using parts of the following frequency ranges for PPDR when undertaking their national planning for PPDR operations:

a) 694-894 MHz, as described in table 3.2

b) 406.1-430 MHz and 440-470 MHz, as described in table 3.3

c) 4940-4990 MHz, as described in table 3.4

Table 3.2: Arrangements in parts of frequency range 694-894 MHz

Regional Organisation	**Frequency Arrangement Number**	**Paired arrangements**				**Example of frequency arrangement**
		Mobile station transmitter (MHz)	**Base station transmitter (MHz)**	**Duplex separation (MHz)**	**Usage type**	
APT	G3-1-1	703-748	758-803	55	Broadband	Any one or two 5+5 MHz channels or any one 10+10 MHz channel can be used for Broadband PS LTE system
APT	G3-1-2	806-824	851-869	45	Narrowband -25kHz	In this arrangement the band can be used for various narrowband and wideband fixed and mobile systems
APT	G3-1-3	806-824	851-869	45	Narrowband - 25kH; 12.5 kHz & 6.25 kHz	806-811/851-856MHz (channel bandwidth 25 kHz) 811-813.5/856- 858.5MHz (the channel bandwidth 12.5 kHz) 813.5-816/858-861MHz (the channel bandwidth 6.25 kHz)
APT	G3-1-4	806-824	851-869	45	Broadband & Narrowband	The sub-band 806-813/ 851-858 MHz is used for narrowband systems with a channel bandwidth of 25 kHz; the sub-band 814-824/ 859-869 MHz is used for broadband (LTE) systems using carrier bandwidths of 5 to 10

[27] http://www.aptsec.org/sites/default/files/Upload-files/AWG/APT-AWG-REP-73_APT_Report_PPDR_Spectrum_Harmonization.docx

						MHz. The sub-band 813-814/ 858-859 MHz acts as guard band between narrowband and broadband systems.
APT	G3-1-5	806-824	851-869	45	Broadband & Narrowband	In this frequency arrangement shows channel arrangement in the band for a wider broadband tuning range.
APT	G3-1-6	806-834	851-879	45	Broadband & Narrowband	The sub-band 806-823/ 851-868 MHz is used for narrowband systems with a channel bandwidth of 25 kHz; the sub-band 824-834/ 859-879 MHz is used for broadband PPDR (LTE) systems using carrier bandwidths of 5 or 10 MHz. The sub-band 821/823-824/ 866/868-869 MHz acts as guard band between narrowband and broadband systems or is used for legacy SRD devices such as RFID

Table 3.3: Arrangements in parts of frequency range 406.1-430 & 440-470 MHz

Regional Organ-isation	Frequency Arrangement Number	Paired arrangements			Usage type
		Mobile station transmitter (MHz)	Base station transmitter (MHz)	Duplex separation (MHz)	
APT	R3-2-1	414.0125-414.1000	414.0125-414.1000	N/A	Narrowband
APT	R3-2-2	406.1125-411.5875	414.1125-419.5875	8	Narrowband
APT	R3-2-3	410-420	420-430	10	Narrowband
APT	R3-2-4	408.6375–410.5375	418.0875–420.0000	9.45	Narrowband 12.5 kHz
APT	R3-2-5	420.0000–430.0000	-	-	-
APT	R3-2-6	457.50625–459.9875	467.50625–469.9875	10 MHz	Narrowband 12.5 kHz

Table 3.4: Arrangements in parts of frequency range 4940-4990 MHz

Regional Organ-isation	Frequency Arrangement Number	Paired arrangements				Example of frequency arrangement
		Mobile station transmitter (MHz)	Base station transmitter (MHz)	Duplex separation (MHz)	Usage type	
APT	R3-3-1	4940-4990	4940-4990	N/A	Broadband	Channel width of 5MHz, 10Mhz, 20MHz

3.11 UHF band spectrum is essential to fulfill the coverage requirements. Being a lower frequency band, it has better propagation characteristics. Lower frequency band provides best range and penetration. Normally frequencies >1GHz are needed for capacity. Experience from the early adopters across the globe suggest that a mixture of lower frequencies for wide area coverage together with higher frequencies for hot-spots of activity might provide a more balanced portfolio for PPDR users.

3.12 Table 3.5 shows plan for broadband PPDR in various countries.

Table 3.5: International Practices

Country	***Amount of Spectrum***	***Band[28]***	***Frequencies***
South Korea	2x10 MHz	700 MHz band 28	718-728/773-783
United States	2x10 MHz	700 MHz band14	788-798/758-768
Australia	10 MHz	800 MHz	-
	50 MHz	4.9 GHz	4940-4990[29]
Qatar	2x10 MHz	800 MHz band 20	791-801/832-842[30]
UAE	2x10 MHz (for PPDR application) + 5MHz	700 MHz band 28	-

[28] **The detail of the 3GPP LTE bands are given in Annexure II**
[29] http://www.acma.gov.au/Industry/Spectrum/Spectrum-projects/Mobile-broadband/~/media/F7DA9B92820A4148980D28B395A88718.ashx
[30] https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2015-1-201502-I!!PDF-E.pdf

	(for direct mode operation)		
Thailand	2x10 MHz	800 MHz band 26 (research going on to evaluate if 4.4-5 GHz band is suitable for BB-PPDR)	814-824/859-869
Canada	2x5 MHz (going to consult on allocating an additional 10 MHz of spectrum known as the D block)	700 MHz band 14 (before this, Canada was using 4.9 GHz for public safety mobile broadband)	763-768/793-798
France	2x5 MHz	700 MHz band 68	698-703/753-758
	2x3 MHz	700 MHz band 28	733-736/788-791

B. PPDR Spectrum requirement calculation

3.13 In order to evaluate the amount of required spectrum and to plan efficient use of spectrum, assessments are usually made by PPDR agencies and organizations on the operational and tactical requirements of PPDR operations in the different scenarios.

3.14 ITU in its report ITU-R M.2377-0[31] on "Radio-communication objectives and requirement for Public Protection and Disaster Relief" provides broad objectives and requirements of PPDR applications, ranging from narrowband through wideband and broadband. Report ITU-R M.2291[32] provides the capabilities of IMT technologies to meet the requirements of applications supporting broadband PPDR operations.

3.15 Many studies have substantiated the spectrum needs for mobile broadband PPDR applications in different countries across the world. The United Arab Emirates' telecommunication regulatory authority (TRA)

[31] http://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-M.2377-2015-PDF-E.pdf
[32] https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-M.2291-2013-PDF-E.pdf

also conducted a PPDR spectrum study[33] that concluded that using LTE technology together with the potential availability of higher power user equipment, PPDR use could in theory be supported in as little as 2x5 MHz of spectrum, an allowance of 2x10 MHz would allow for reasonable future growth. However, this has to be in the same band and a mixture of lower frequencies (e.g. 700 MHz or 800 MHz) for wide area coverage together with higher frequencies (e.g. 2300 or 2600 MHz) for hot-spots of activity might provide a more balanced portfolio for PPDR users.

3.16 According to ECC Report 199[34] titled User requirements and spectrum needs for future European broadband PPDR systems,[35]

- At least 10 MHz is required for the terrestrial network uplink. With 10 MHz made available, many but not all of the scenarios can be accommodated.
- At least 10 MHz will also be required for the terrestrial network downlink. With 10 MHz made available, most of the scenarios which utilized individual calls can be accommodated. All scenarios can be accommodated in a 10 MHz downlink where group calls are optimally used.

3.17 A study released in June 2013[36] considered eight Asian countries, namely, Australia, China, Indonesia, Malaysia, New Zealand, Singapore, South Korea and Thailand. The study supports that a minimum of 10 MHz for broadband PPDR is required on the basis of the opportunity cost argument.

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[33] http://www.lstelcom.com/fileadmin/content/marketing/spectrum/LS_Spectrum_2014-1_CriticalCommunications_en.pdf

[34] http://www.erodocdb.dk/docs/doc98/official/pdf/ECCRep199.pdf

[35] **This analysis does not incorporate the demands for voice call, air to ground (except some limited uplink included in some scenarios), or Direct Mode Operation. These will require additional or separate spectrum.**

[36] http://trpc.biz/wp-content/uploads/PPDR-_Report_16-May-2013_FINAL-2.pdf

3.18 Despite the differences across some of these estimates, reserving a minimum of 2x10 MHz for mobile broadband PPDR is becoming the prevailing option, though excluding additional country allocations to meet specific needs.

3.19 For broadband PPDR, South Korea and United States have allocated 2x10 MHz in 700 MHz band. Thailand has allocated 2x10 MHz in 800 MHz. UAE has allocated 2x10 MHz (for PPDR application) and 5 MHz (for direct mode operation) in 700 MHz band. Australia has allocated 10 MHz in 800 MHz band and 50 MHz in 4.9 GHz band. France has allocated 2x5 MHz and 2x3 MHz in 700 MHz band.

C. Spectrum options and candidate bands for LTE based Broadband PPDR in India

3.20 It is pertinent to mention that India has so far not allocated a dedicated spectrum for broadband PPDR. In general, lower frequencies give better performance, so the lowest common commercial frequency, around the 700 MHz/800 MHz band, is most suitable.

3.21 There are few potential 3GPP bands[37] those could also be considered for adoption. One of them is 450 MHz existing 3GPP Band 31 and potential new 3GPP Band 68. There can be a common pool of spectrum for National Disaster Management planning, consider globally harmonized LTE bands (B14/26/27/28/31/68) for Disaster Management (DM) broadband services on PAN India basis. During severe incidents all agencies can switch to DM frequencies.

3.22 There is a need to clearly identify the bands as well as the quantum of spectrum for broadband PPDR communication keeping in mind the global ecosystem development for PPDR communication in those bands.

[37] The detail of the 3GPP LTE bands are given in Annexure II

3.23 In view of the above, following issues are put for the comments of stakeholders:

Q5. Can frequency bands be identified exclusively for public protection and disaster relief? What are the candidate bands for PPDR operations in India?

Q6. If wideband/broadband PPDR is to be implemented in India, what quantum of spectrum will be needed for such solution for PPDR?

Q7. What is the cost and benefits tradeoff envisaged for public protection and disaster relief viz-a-viz commercial value of spectrum?

Q8. Do you suggest any other workable option that can be adopted?

Q9. Please give your comments on any related matter not covered in this consultation paper.

CHAPTER IV: INTERNATIONAL PRACTICES

United Kingdom

4.1 UK Home Office led Emergency Services Mobile Communications Programme (ESMCP)[38], a cross-departmental programme set up to provide a more affordable, more capable and more flexible next generation communication system, to be known as emergency services network (ESN)[39], for the 3 emergency services (police, fire and rescue, and ambulance) and other public safety users. ESN will provide the next generation integrated critical voice and broadband data services for the 3 emergency services and over 300 other organizations who are active users of the current emergency communication service. Offering more flexibility than the old system, the new services will replace the existing system from mid-2017 as the current contracts expire. The ESMCP is now in the mobilisation phase before the start of transition.

4.2 The main contracts for ESN have been awarded in December 2015. UK Home Office separated user services and mobile services.[40] The mobile services operator will provide broadband data service with full coverage in the defined area, along with extension services to offer coverage beyond the network. The user services provider will provide end-to-end systems integration for the ESN, public-safety application development and operation, and other services.[41] Motorola was the winner to provide user services. EE was the winner to provide mobile (access) services. In addition to user services, Motorola will provide system integration and critical functionality for the new public safety LTE network.

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

[39] https://www.gov.uk/government/publications/the-emergency-services-mobile-communications-programme/emergency-services-network

[40] **user services: is a service integrator to provide end-to-end systems' integration, manage user accounts, provide user services including public safety functionality ; mobile services: is a network operator to provide a resilient national mobile network**

[41] http://www.mccmag.com/Features/FeaturesDetails/FID/589

4.3 EE will host the new Emergency Services Network (ESN) on its existing 4G network,[42] which is already used to deliver mobile services to general public. EE would serve both ESN customers and EE's commercial customers in the same network using EE bands. Prioritization of public safety users and services will be done over regular subscribers and service. EE said that it will improve its network to provide nationwide coverage for critical communication.[43]

4.4 According to Ofcom's Cellular Frequency Chart January 2016[44], the bands allocated to EE are shown in table 4.1. EE has a total bandwidth of 10 MHz in <1 GHz spectrum and 160 MHz in >1 GHz spectrum that can be used to provide LTE mobile (access) services.

Table 4.1: Bands allocated to EE

Frequency band	**Bandwidth (MHz)**		**LTE band[45]**
800 MHz	2x5	796-801/837-842	band 20
1800 MHz (1.8 GHz)	2x45	1831.7-1876.7/1736.7-1781.7	band 3
1900 MHz	10	1899.9-1909.9	-
2100 MHz	2x20	2149.7-2169.7/1959.7-1979.7	-
2600 MHz (2.6 GHz)	2x35	2655-2690/2535-2570	band 7

South Korea

4.5 The South Korean government plans to build a broadband network dedicated to public safety using Long Term Evolution (LTE) technology to

[42] http://www.telegraph.co.uk/finance/newsbysector/mediatechnologyandtelecoms/telecoms/11958367/EE-wins-landmark-contract-in-controversial-1.2bn-police-radio-replacement.html
[43] http://mccmag.com/Features/FeaturesDetails/FID/623/
[44] http://licensing.ofcom.org.uk/binaries/spectrum/mobile-wireless-broadband/cellular/licensee-frequency-technical-info/Cellular_Frequency_Chart_Jan_2016.pdf
[45] http://www.pcadvisor.co.uk/how-to/mobile-phone/how-tell-whether-phone-is-supported-by-your-network-3597426/

be deployed nationwide by 2017.[46] The network will be used by about 200,000 users from 324 mandatory agencies including police, fire, EMS, Coast Guard, military, provincial administrative offices, electricity, gas and the forest service.

4.6 Earlier, the mission-critical organizations were operating their own voice-oriented networks on a variety of frequency bands and a variety of technologies including TETRA, iDEN, VHF, UHF and AM/FM and hence were not interoperable with each other. That's why the South Korean government wants to deploy a unified/integrated nationwide public-safety network so that every mandatory agency can communicate with each other. The network will be always operational, rather than just during emergencies and will be designed to provide full coverage to the nation.

4.7 A dedicated spectrum 2x10 MHz of 700 MHz band 28 (718-728/773-783)[47] was allocated for PS-LTE in 2014. The Ministry of Public Safety and Security (MPSS) is the supervising entity for South Korea's PS-LTE network. MPSS planned to introduce PS-LTE nationally in phases focusing on the rural provinces first. The phase one is to be established in the Gangwon Province, which is where the 2018 Winter Olympics, Pyeongchang, is located. The network will then be extended from rural to urban. Phase two covers other provinces, and phase three covers metropolitan cities.

4.8 A pilot[48] PS-LTE network was launched in three South Korean cities-Gangneung, Pyeongchang and Jungsun with 205 base stations and 2,496 handsets. The pilot was expected to offer testing and validation of the country's planned nationwide public-safety LTE network. Users on

[46] http://www.radioresourcemag.com/Features/FeaturesDetails/FID/482
[47] http://www.rrmediagroup.com/News/NewsDetails/NewsID/11430
[48] http://www.rrmediagroup.com/News/NewsDetails/NewsID/11912/

the pilot network include four organizations — police, fire, coast guard and the local administration office. In October 2015, two commercial carriers (KT, SKT)[49] were selected for PS-LTE pilot in three areas of the country. KT is South Korea's second-largest commercial wireless operator by subscriber numbers, and SKT has the largest number of wireless subscribers in the country.

4.9 In June 2016, KT Corp announced the establishment and demonstration of what it claims is 'the world's first trial public safety long term evolution (PS-LTE) network'.[50] In the trial phase KT had built wireless base stations in the PyeongChang area, established operation centres to take control in possible disasters and provided special handsets designed for communication in the PS-LTE network. Further, during the pilot KT undertook verification tests for over 550 qualification items such as synchronisation between control centres and base stations and compatibility with 37 telecom functions in disasters under the supervision of the Telecommunications Technology Association and the Ministry of Public Safety and Security and passed all of them. A full-scale nationwide PS-LTE network is expected to start soon.

United States

4.10 In 2012, FirstNet[51] (a government entity) was created to build, operate and maintain the first high-speed, nationwide wireless broadband network dedicated to public safety which will provide a single interoperable platform for emergency and daily public safety communications.

[49] http://www.rrmediagroup.com/Features/FeaturesDetails/FID/607/

[50] https://www.telegeography.com/products/commsupdate/articles/2016/06/15/kt-completes-trial-operation-of-ps-lte-infrastructure/

[51] http://www.firstnet.gov/about

4.11 Initially FirstNet will provide mission-critical, high-speed data services to supplement the voice capabilities of today's LMR networks. In future it is planning to provide voice over LTE (VoLTE). FirstNet users will be able to send and receive data, video, images, text, as well as use voice applications. FirstNet will bring latest tools to tens of thousands of organizations and individuals that respond to emergencies at the local, state, tribal and federal levels.

4.12 All 56 U.S. states and territories must have a radio access network that is connected to the FirstNet core network to create a nationwide network. To contain costs, FirstNet is tasked with leveraging existing telecommunications infrastructure and assets.

4.13 When FirstNet was established, [52]Congress provided $7 billion for costs related to planning and deploying the broadband network, and a $135 million grant program to assist states with plans to connect to FirstNet's broadband network. The anticipated cost of building and operating a nationwide core broadband network— and the interoperable radio networks that connect to it—is significantly in excess of the amount appropriated. The Spectrum Act provides for public-private partnerships with FirstNet or with states, and for fees (charged to states and other users) to ensure that FirstNet becomes self-sustaining.

4.14 FirstNet will provide public safety users with true priority access to the network. During incidents where multiple agencies converge in a small area, first responders must be able to leverage access priorities.

4.15 A dedicated spectrum band 14 (700 MHz), which is 2x10 MHz FDD band (788-798/758-768)[53] have been allocated for this project.

[52] https://www.fas.org/sgp/crs/homesec/R42543.pdf

[53] https://www.fcc.gov/general/700-mhz-public-safety-spectrum-0

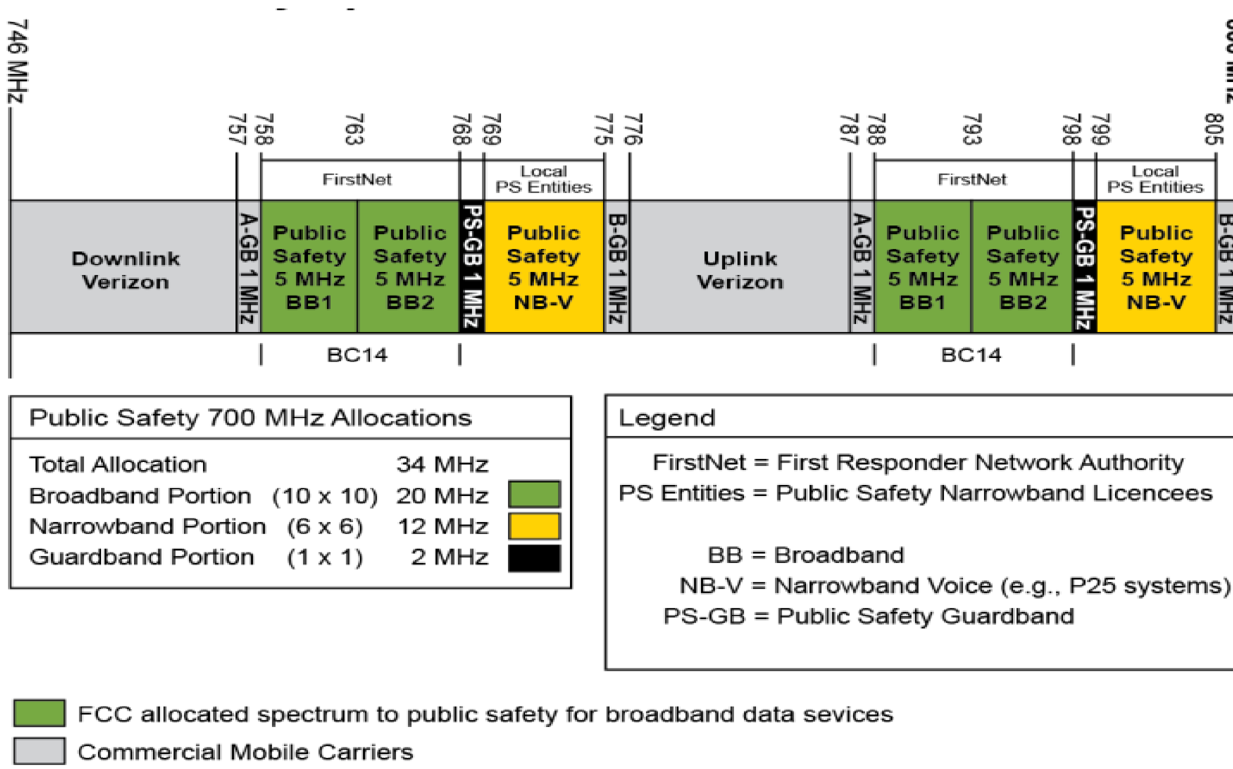

Figure 4.1: 700 MHz Band Plan for Public Safety Services in US

4.16 FirstNet anticipates that the amount of available contiguous spectrum will provide capacity for public safety needs.[54] FirstNet also anticipates there may be times when there is excess capacity. FirstNet is exploring ways to make this valuable resource available to other users while preserving priority access to first responders. According to Spectrum Act, FirstNet can offer access to its assets, including radio frequency spectrum capacity, in return for financial payment or other support.

Australia

4.17 In October 2012,[55] the Australian regulator ACMA allocated an additional 60 megahertz of spectrum for use by Australia's Public Safety Agencies

[54] http://www.firstnet.gov/about/guiding-principles
[55] http://www.acma.gov.au/webwr/radcomm/frequency_planning/radiofrequency_planning_topics/docs/spectrum_for_public_safety.pdf

(PSAs) across a number of bands to facilitate the deployment of high-speed, nationally interoperable mobile broadband networks and overhaul existing mission-critical narrowband radio networks.

4.18 The ACMA has worked closely with Public Safety Mobile Broadband Steering Committee (PSMBSC), which was established in May 2011[56] to identify public-safety agency requirements and demands. It focused on the costs associated with a range of models for consideration and technical aspects and radio spectrum calculation, which all make provision for backhaul infrastructure that may include use of the National Broadband Network.

4.19 The ACMA announcement advised that it was undertaking a number of initiatives to improve spectrum provisions for public safety, the most important being:

- Making available 10 megahertz of 800 MHz spectrum to realize a dedicated nationally interoperable public-safety mobile broadband 4G data capability, which supports the 4G LTE system and is considered to be “beach front” spectrum by carriers and PSAs.
- Providing 50 megahertz from the 4.9 GHz band for use nationwide by PSAs. The 4.9 GHz spectrum is recognized internationally as a PPDR band and is capable of high capacity, short range, deployable data and video communications including supplementary capacity for the public-safety broadband network in areas of very high demand. This frequency is suitable for several wireless technologies, including Wi-Fi and air-to-ground communication[57]. The ACMA released a consultation paper on the issue. Based on which, in June 2013,[58] the

[56] http://www.rrmediagroup.com/News/NewsDetails/NewsID/8085/
[57] http://www.pc.gov.au/inquiries/completed/public-safety-mobile-broadband/report/public-safety-mobile-broadband.pdf
[58] http://www.acma.gov.au/theACMA/new-spectrum-for-emergency-services

ACMA developed a class licence[59] that provides nationwide access to 50 MHz of spectrum in the 4.9 GHz band on a shared, non-exclusive basis. The class licence regime means that none of the PPDR applications will need individual licences.

- The continuation of implementing critical reforms in the 400 MHz band, where spectrum has been identified for the exclusive use of government, primarily to support national security, law enforcement and emergency services.

Qatar

4.20 The Ministry of Interior (MoI) in Qatar made the decision to go for dedicated PS-LTE network in 2010[60]. It was one of the first public-safety entities in the Middle East to commercially award a public-safety LTE network contract (awarded to Nokia Solutions and Networks (NSN)) to complement its existing TETRA network with broadband applications. It uses 800 MHz band for PS-LTE.

4.21 The first phase of the network went live in 2012 with 24 sites in Doha. The network is primarily used for multimedia and video transmissions from incident locations to the Ministry's command center. Today, the public safety LTE network in Qatar has practically reached nation-wide coverage and emergency service workers are seeing clear benefits of high-speed data in their daily work.

4.22 In Qatar, MoI's telecom department provides different agencies like fire brigades, medical emergency services and internal security forces with broadband LTE services. In addition to mission-critical data services, MoI is also adopting Voice over LTE (VoLTE). When new, standardized public safety-specific features become available, such as the recent addition of

[59] https://www.legislation.gov.au/Details/F2013L00827
[60] https://blog.networks.nokia.com/public-safety/2016/05/26/qatars-ministry-interior-implements-nation-wide-lte-public-safety/

push-to-talk, they can be introduced with software upgrades to the existing network.

United Arab Emirates

4.23 In 2013, UAE regulator TRA set aside 2x10 MHz for PPDR application in 700 MHz with additional 5 MHz for direct mode operation.[61]

Thailand

4.24 Thai regulator NBTC has reserved 2x10 MHz of 800 MHz band 26 (814-824/859-869 MHz)[62] for public protection and disaster relief (PPDR) application. NBTC will continue to monitor international development in 4.4-5 GHz and work with PPDR agencies to evaluate if this band is suitable for broadband PPDR in Thailand.

Canada

4.25 In 2012, Industry Canada allocated 10 MHz in the upper 700 MHz band for public-safety broadband use and said it was going to consult on allocating an additional 10 MHz of spectrum known as the D block for public-safety broadband.

4.26 Figure 4.2 shows the Canadian Band Plan[63] in the Band 746-806 MHz. The Upper 700 MHz band includes the paired commercial block C1 that consists of the 746-751 MHz and 776-781 MHz bands, the paired commercial block C2 that consists of the 751- 756 MHz and 781-786 MHz bands, the paired PSBB block that consists of the 763-768 MHz and 793-798 MHz bands, the paired D block that consists of the 758- 763

[61] https://twitter.com/theuaetra/status/337176368209084418

[62] https://www.nbtc.go.th/wps/wcm/connect/NBTC/4a77f14a-9f7b-4b52-8ef5-d82e229f4081/Spectrum+Master+Plan+Thailand+by+ITU+16062559.pdf?MOD=AJPERES&CACHEID=4a77f14a-9f7b-4b52-8ef5-d82e229f4081

[63] http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf10459.html

MHz and 788-793 MHz bands, and the paired NB/WB PS block that consists of the 768-776 MHz and 798-806 MHz bands. The Upper 700 MHz band also includes two 1 MHz guard bands at 756-757 MHz and 776-777 MHz that are held in reserve for future consideration.

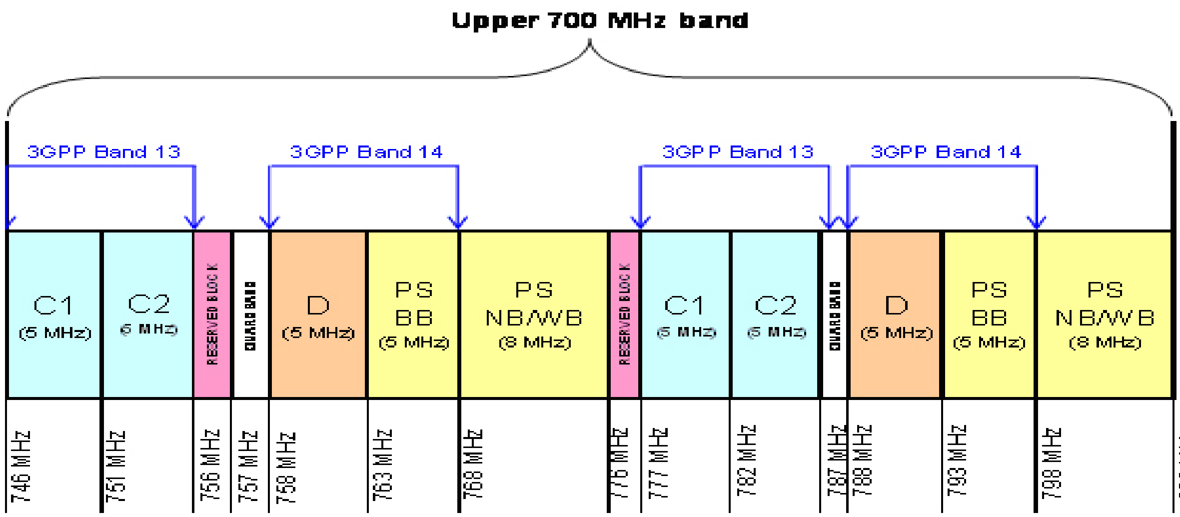

Figure 4.2: Canadian Band Plan in the Band 746-806 MHz

4.27 If the proposed D block is allocated for public-safety broadband, Canada's public-safety users will have the same spectrum dedicated for a broadband network as the U.S. has allocated[64].

4.28 The public-safety hierarchy was defined in 2009, when Industry Canada released a policy document, Radio Systems Policy RP-25 [65] Policy Principles for Public Safety Radio Interoperability. The following categories of users or agencies that may be eligible for access to spectrum designated for public safety:

- Category 1 -police, fire and emergency medical services

[64] http://www.rrmediagroup.com/Features/FeaturesDetails/FID/451/
[65] http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf09554.html

- Category 2 -forestry, public works, public transit, hazardous material clean-up, border protection and other agencies contributing to public safety
- Category 3 -other government agencies and certain non-governmental organizations or entities.

The hierarchy of agencies, as described by the categories above, is applied in the radio licensing process to outline priority access to spectrum designated or made available for public safety use.

4.29 In the 700 MHz and 800 MHz bands, the spectrum designated for public safety narrowband use can be accessed by Category 1 and Category 2 users as long as Category 1 users are the main users of the system. Category 3 users (e.g. hydro and gas utilities) are allowed on these systems only during emergencies, and their access is controlled by the main users of those systems.

4.30 The 4.9 GHz band was designated for public safety mobile broadband in 2006[66]. It can be accessed by an entity exclusively serving Category 1 agencies or by an entity also serving Category 2 and Category 3 users as long as it does not hinder the development and use of systems dedicated to the higher priority categories.

France

4.31 French regulator allocated 2x5 MHz (698-703/753-758) and 2x3 MHz (733-736/788-791) in the 700 MHz band for a broadband public protection and disaster relief (PPDR) dedicated network[67]. The French government considers that the 700 MHz allocation will not be sufficient to cover all the country's broadband PPDR needs. They are planning to

[66] http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf08671.html#c2
[67] http://www.rrmediagroup.com/Features/FeaturesDetails/FID/642

add 400 MHz spectrum for broadband PPDR in future. The PPDR spectrum in France is one of harmonization options identified for CEPT countries.[68]

[68] http://www.erodocdb.dk/Docs/doc98/official/pdf/ECCREP218.PDF

CHAPTER V: ISSUES FOR CONSULTATION

Q1. Do you consider the existing fragmented model of PPDR communication network in the country adequate to meet the present day challenges? If not, what are the deficiencies in the existing model of PPDR?

Q2. In the various models described in para 2.11-2.15, in your opinion which of the model (dedicated, commercial, hybrid) will be more suitable for Indian conditions? or Is there any other alternate model which would be more suitable for Indian telecom environment? Please provide rationale for the suggested model.

Q3. Should PSUs be earmarked for providing nationwide broadband PPDR communication network? Please justify your answer.

Q4. Will it be technically feasible and beneficial to permit PPDR trunking service roaming on public telecom networks? If yes, what challenges do you foresee in implementation of such an arrangement? Please justify your answer.

Q5. Can frequency bands be identified exclusively for public protection and disaster relief? What are the candidate bands for PPDR operations in India?

Q6. If wideband/broadband PPDR is to be implemented in India, what quantum of spectrum will be needed for such solution for PPDR?

Q7. What is the cost and benefits tradeoff envisaged for public protection and disaster relief viz-a-viz commercial value of spectrum?

Q8. Do you suggest any other workable option that can be adopted?

Q9. Please give your comments on any related matter not covered in this consultation paper.

LIST OF ACRONYMS

ACRONYMS	DESCRIPTION
3GPP	3rd Generation Partnership Project
4G	4th Generation of Wireless Access Technology
ACMA	Australian Communications and Media Authorithy
AM	Amplitude Modulation
APT	Asia Pacific Telecommunity
AS	Access Service
BSNL	Bharat Sanchar Nigam Limited
CEPT	Conference Of European Postal And Telecommunications
CMRTS	Captive Mobile Radio Trunked Systems
CP	Consultation Paper
DM	Disaster Management
DoT	Department Of Telecommunication
DR	Disaster Relief
ECC	Electronic Communication Committee
EKG	Electrocardiograph
EMS	Emergency Medical Service
eNB	eNode B
ESMCP	Emergency Services Mobile Communications Programme
ESN	Emergency Services Network
FDD	Frequency Division Duplexing
FDMA	Frequency Division Multiple Access
FM	Frequency Modulation
GIS	Geographic Information Systems
HSS	Home Subscriber Server
ID	Identity Document
IECRS	Integrated Emergency Communication and Response System
IMS	IP Multimedia System
IMT	International Mobile Telecommunications
IoT	Internet of Things
IP	Internet Protocol
ITU	International Telecommunication Union
LF	License Fee
LMR	Land Mobile Radio
LTE	Long Term Evolution
M2M	Machine to Machine
MBB	Mobile Broadband
MME	Mobility Management Entity
MNO	Mobile Network Operator
MoI	Ministry of Interior
MPSS	Ministry of Public Safety And Security
MTNL	Mahanagar Telephone Nigam Limited

MVNO	Mobile Virtual Network Operator
NBTC	National Broadcasting and Telecommunications Commission
NFAP	National Frequency Allocation Plan
NSN	Nokia Solutions and Networks
OFDMA	Orthogonal Frequency Division Multiple Access
PAN	Presence Across Nation
PCRP	Policy and Charging Rule Function
P-GW	Packet Data Network Gateway
PMRTS	Public Mobile Radio Trunking Service
PP	Public Protection
PPDR	Public Protection Disaster Relief
PS	Public Safety
PSA	Public Safety Agencies
PS-LTE	Public Safety-Long Term Evolution
PSMBSC	Public Safety Mobile Broadband Steering Committee
PSU	Public Sector Undertaking
PTT	Push To Talk
QoS	Quality of Service
RAN	Radio Access Network
SATRC	South Asian Telecommunications Regulator's Council
S-GW	Serving Gateway
SLA	Service Level Agreement
SUC	Spectrum Usage Charges
TDD	Time Division Duplexing
TDMA	Time Division Multiple Access
TEDS	Tetra Enhanced Data Services
TETRA	Terrestrial Trunked Radio
TRA	Telecommunication Regulatory Authority
TSP	Telecom Service Provider
UAE	United Arab Emirates
UHF	Ultra High Frequency
UK	United Kingdom
UL (VNO)	Unified Licence (Virtual Network Operator)
US	United States Of America
VHF	Very High Frequency
VoLTE	Voice over LTE
VPN	Virtual Private Network
WPC	Wireless Planning Coordination
WRC	World Radio Communication Conferences
YOY	Year-on-Year

ANNEXURE 1

Standards used for mobile PPDR communication

1. TETRA

- It has higher data throughput than other standards such as DMR (Digital Mobile Radio), Project 25
    - Bit Rate 36000bps (18000 symbols/sec)
    - 4-slot TDMA (Time division multiple access)
- π/4 DQPSK (Differential Quadrature Phase Shift Keying) modulation
    - Requires linear transmitter in base station and terminals, which is more expensive, requires a higher current and is physically larger
- Requires wideband 25kHz channel
    - Few areas of spectrum where wideband channels licensed, e.g. only 380-430MHz in Europe.
    - Needs minimum transmit/receive frequency separation.
    - Cannot operate next to narrowband channels.
- No upgrade path from analog
- Poorer coverage
    - Coverage roughly half that of DMR (Digital Mobile Radio) for same frequency and transmit power, thus need 4 times amount of sites.

Advantages

- Open standard
- High level of interoperability between TETRA products from different vendors
- TDMA (Time Division Multiple Access) gives 6.25kHz channel efficiency (four timeslots in 25kHz channels)
- Radios have a lower transmit power and therefore can be smaller, less expensive, and similar to cell phones
- Encryption

Disadvantages

- TETRA systems require clean blocks of contiguous spectrum, which may not be available from the relevant regulatory authority. This is in part because TETRA channels cause interference on existing analog channels and in part because the standard requires that transmit and receive frequencies of a channel is 10MHz apart. A "clean" block of spectrum is needed, so that no currently licensed frequencies interfere with the TETRA channel plan. TETRA requires 25 kHz channels, which may conflict with narrow banding plans. Many countries are considering plans to reform their spectrum into 12.5 kHz channels, to increase the number of available channels.
- TETRA is not designed for backwards compatibility or migration from legacy analog networks. Organizations that decide on a TETRA system will need to completely replace their radios because TETRA radios will not interoperate with analog FM radios. Moreover, TETRA infrastructure cannot operate in an analog FM mode to provide services to legacy radios.
- TETRA coverage is significantly less than for other PMR/LMR (Professional Mobile Radio/Land Mobile Radio) standards, which means that many more radio sites are required for a given service area. This is an important consideration for networks in areas with a low population density. It may also mean that more channel licenses are required.
- TETRA is not available as a conventional network.
- The lower power of TETRA radios (1W) restricts the range between peer-to-peer (direct mode) users to as little as three kilometers (two miles).
- TETRA base stations/repeaters must be linear, which adds to their cost.
- The TETRA vocoder is older than and probably not as effective as the new half-rate vocoders.

2. TETRAPOL

- It is a trunking technology that was developed by EADS (European Aeronautic Defence and Space) formerly MATRA (Mécanique Aviation Traction) and is mainly in use by police and military in Europe.
- It pre-dates TETRA, as its first implementation was for the French National Gendarmerie in 1988.
- The core design criteria have been trunking, encryption, and wide area coverage. It is well-proven having enjoyed a successful rollout over some years, and although it is a proprietary system, the system interfaces are publicly available.
- It uses FDMA (Frequency Division Multiple Access) 10 or 12.5 kHz channels. Future third generation TETRAPOL is expected to make provision for two 6.25kHz channels in a single 12.5kHz channel

Advantages

- It has been well planned from the outset, with initial consensus from the users, and with all specifications available and stable for vendors to use in their product designs. Consequently there has been no uncertainty for vendors about features or operation.
- In the TETRAPOL trunking systems, a range of services are available. These include status messaging, and call types such as individual, group and emergency calls.
- TETRAPOL systems also provide a “direct” or simplex mode.
- Approximately 4.8kbit/s data speed is achieved to the limit of radio coverage.
- The available data speed does not deteriorate as the signal weakens.

Disadvantages

- TETRAPOL radios themselves offer no conventional mode operation, and it is necessary to use a SCC (Single Channel Converter) to communicate with analog radios. (This interface can also provide an interface with other types of radio networks.)

- Very limited vendor support.
- Aging design with older vocoder.

3. Project 25 (P25)

Phase 1

- Lower data throughput than TETRA
- 9600bps (Symbol rate of 4800 symbols/sec)
- C4FM Modulation (Continuous 4 level Frequency Modulation)
- No need for linear transmitters
    - Cost and size about same as analog FM transmitter
- Transmitter output spectrum fits in to existing 12.5kHz narrowband FM Analog channel
    - No need for re-banding or re-licensing
    - Thus can choose best frequency for application
- Designed to make analog to digital upgrade easy
- Coverage designed to be the same as Analog FM (Frequency Modulation)
    - Can use existing Infrastructure sites

Phase 2

- Lower data throughput than TETRA
    - 12000bps (Symbol Rate of 4800 symbols/sec)
    - 2-slot TDMA (Time Division Multiple Access)
- Modulation choices made to optimize performance and simplify terminal design
    - HDQPSK (Harmonized Differential Quadrature Phase Shift Keying) Modulation in downlink (base station to terminals)
        - Requires linear transmitter in base station - more expensive, needs a higher current and is physically larger
    - HCPM modulation in uplink (terminals to base station)
        - No need for linear transmitters in terminals

        - Cost and size about same as Analog FM (Frequency Modulation) Transmitter
- Transmitter output spectrum fits into existing 12.5kHz narrowband FM Analog channel
    - No need for re-banding or re-licensing
    - Thus can choose best frequency for application.
- Designed to make analog to digital upgrade easy
- Coverage designed to be the same as analog FM (Frequency Modulation)
    - Can use existing infrastructure sites

Advantages

- Non-proprietary open standard.
- Conventional, trunked, and simulcast options. Combinations of these options can be optimized to reflect customer requirements. For example, trunked in high-density urban areas and conventional in rural areas.
- Designed for gradual, phased migration from analog FM (Frequency Modulation). Equipment can operate in Analog FM (Frequency Modulation) mode, in digital P25 mode, or in dual mode.
- Supports simplex mode (repeater talkaround) for direct communications outside network coverage.
- Very secure end-to-end encryption.

Disadvantages

- Only 12.5 kHz channel efficiency (FDMA). However, Phase 2 of the P25 standard provides an upgrade path to 6.25 kHz channel equivalence, but only for voice.
- While P25 radios can be dual mode (analog FM or digital P25), trunked P25 networks cannot offer analog FM (Frequency Modulation) services.
- High cost of systems

ANNEXURE II

3GPP FDD LTE Bands & Frequencies[69]

LTE band number	*Frequencies (uplink/ downlink) MHz*
band 3	1710-1785 / 1805-1880
band 5	824-849 / 869-894
band 7	2500-2570 / 2620-2690
band 8	880-915 / 925-960
band 12	699-716 / 729-746
band 13	777-787 / 746-756
band 14	788-798 / 758-768
band 17	704-716 / 734-746
band 18	815-830 / 860-875
band 19	830-845 / 875-890
band 20	832-862 / 791-821
band 26	814-849 / 859-869
band 27	807-824 / 852-869
band 28	703-748 / 758-803
band 31	452.5-457.5 / 462.5-467.5
band 68	698-728 / 753-783

[69] SOURCE:

1. http://www.radio-electronics.com/info/cellulartelecomms/lte-long-term-evolution/lte-frequency-spectrum.php
2. http://www.awt-global.com/resources/lte-e-utran-bands/
3. http://www.simpletechpost.com/p/lte-frequency-bands.html
4. https://www.google.co.in/url?sa=t&rct=j&q=&esrc=s&source=web&cd=11&cad=rja&uact=8&ved=0ahUKEwjipOf4oo7QAhULto8KHZioBccQFghSMAo&url=https%3A%2F%2Fwww.qualcomm.com%2Fmedia%2Fdocuments%2Ffiles%2Fthe-lte-standard.pdf&usg=AFQjCNGnKtHHFFksbP7wJDaHNtnqr9Kb4Q
5. https://en.wikipedia.org/wiki/LTE_frequency_bands
6. http://www.3gpp.org/DynaReport/36124-CRs.htm