T-Mobile

December 22, 2009

<u>Written Ex Parte Presentation</u> - via Electronic Filing

Ms. Marlene H. Dortch
Secretary
Federal Communications Commission
445 12th Street, S.W.
Washington, D.C. 20554

RE: *700 MHz Interoperable Broadband Public Safety Network*
<u>WT Docket No. 06-150, PS Docket No. 06-229,</u>
<u>GN Docket Nos. 09-47, 09-51, 09-137</u>

Dear Ms. Dortch:

T-Mobile USA, Inc. ("T-Mobile") submits for inclusion in the above-captioned dockets the enclosed white paper, *Public Safety Wireless Broadband Spectrum Requirements* ("*Public Safety Broadband Spectrum Requirements*"), prepared by Dr. Kostas Liopiros of the Sun Fire Group LLC.

In *Public Safety Broadband Spectrum Requirements*, Dr. Liopiros concludes that the approach that best serves consumers and the public safety community with regard to the 700 MHz D Block[1] would be to auction the D Block for commercial use. As summarized below, *Public Safety Broadband Spectrum Requirements* analyzes today's public safety spectrum allocations, projected broadband spectrum needs for public safety uses, the adequacy for public safety uses of the allocations in the 700 MHz band, the best uses of the D block, and the benefits of a converged 700 MHz broadband network for public safety purposes.

***Present Spectrum Allocations for Public Safety*:** In *Public Safety Broadband Spectrum Requirements*, Dr. Liopiros tabulates the spectrum allocations, totaling 99.7 MHz, now designated for the exclusive use of state and local public service organizations. 60 MHz of this spectrum is designated for public safety wireless broadband, including the 10 MHz allocated in the 700 MHz band to be used for a national broadband network, and 50 MHz allocated in the 4.9 GHz band to be used for local-area broadband communications at the scene of an incident, where spectrum needs are greatest.

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1 The 758-763/788-793 MHz band is commonly referred to as the "700 MHz D Block" or "D Block."

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Spectrum Requirements for Public Safety Broadband Networks: Although there frequently are claims of a public safety "spectrum shortage," *Public Safety Broadband Spectrum Requirements* shows that these claims rely on a report by the Public Safety Wireless Advisory Committee ("PSWAC") in 1996 (the "1996 report") that attempted to forecast spectrum requirements in 2010.[2] The 1996 report used a model based on public safety radio technologies and spectrum usage and reuse practices dating before 1996.[3]

Adequacy of Current 10 MHz Allocation for Public Safety Broadband: Based on the use of modern spectrum-efficient technologies such as Long Term Evolution ("LTE"), *Public Safety Broadband Spectrum Requirements* demonstrates that the 10 MHz already allocated for public safety should be adequate to meet peak public safety requirements for a wireless broadband network while still keeping substantial spectrum in reserve for future requirements.[4] Indeed, multiple state and local public safety agencies are seeking Commission approval to deploy broadband systems in the current 10 MHz allocation, with many of these agencies proposing to use LTE technology.[5]

Best Use of the D Block for Public Safety and Other Purposes: *Public Safety Broadband Spectrum Requirements* finds that additional spectrum is not needed to build a public safety broadband network that will accommodate future growth.[6] Reserving the D Block for future public safety use is not the most efficient use of the spectrum and involves a considerable opportunity cost.[7]

*Public Safety Broadband Spectrum Requirement*s concludes that preserving the D Block for commercial use, without inflexible public safety requirements, is the best way to maximize its value and utility. The best way to use the D Block for the benefit of public safety would be to use the revenue gained from auctioning the D Block to jumpstart the construction of the public safety wireless broadband networks.[8]

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[2] *See Public Safety Broadband Spectrum Requirements* at 6-7.

[3] *See id.* at 1, 8-9.

[4] *See id.* at 9-12, 18.

[5] *See id.* at 13-14. New York City, Washington, DC, Hawaii, New York State, Boston, and Flow Mobile, among others, plan to implement their public safety broadband system with LTE technology.

[6] *See id.* at 15, 18.

[7] *See id*. at 15-16.

[8] *See id.* at 16, 18.

Potential Use of Converged Public Safety Networks: Dr. Liopiros also discusses an important additional benefit of combining separate voice and data networks into one converged broadband network. According to *Public Safety Broadband Spectrum Requirements*, this would provide increased capacity for voice communications while eliminating the need to operate and maintain two separate wireless networks. This could result in significant spectrum efficiencies and cost savings for public safety organizations and the public.[9]

Pursuant to Section 1.1206(b) of the Commission's rules, an electronic copy of this letter and *Public Safety Broadband Spectrum Requirements* is being filed with the office of the Secretary. If you have any questions regarding this filing, please contact the undersigned.

Very truly yours,

/s/ Kathleen O'Brien Ham
Kathleen O'Brien Ham
Vice President, Federal Regulatory Affairs

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9 *See id.* at 16-18.

Public Safety Wireless Broadband Spectrum Requirements

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22 December 2009

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I. INTRODUCTION AND OVERVIEW

From the beginning of mobile radio, public safety radio services have been limited primarily to voice and low-speed data delivered over narrowband radio channels. As data communications became increasingly important, public safety agencies began to supplement their dedicated narrowband communication capabilities with commercial wireless broadband data communications. Today, commercial wireless broadband data systems are used in support of mission critical voice communications in local and state public safety agencies across the U.S. Accordingly, spectrum has been allocated to bring public safety's wireless broadband capabilities up to date with what's commonly available in the commercial market.

The Federal Communications Commission (FCC) has been responsive to the need to allocate spectrum for public safety broadband communications. In addition to the 10 MHz allocated for this purpose in the 700 MHz band – for a national wireless broadband network – there is 50 MHz in the 4.9 GHz band – for incident local-area broadband communications where spectrum needs are often the greatest. Yet it is stated frequently that there is a public safety "spectrum shortage" and that more spectrum, specifically the 10 MHz D block, is needed for a nationwide 700 MHz broadband network.[1]

The forecast of a public safety "spectrum shortage" dates back to an assessment in 1996 of the spectrum needs of public safety agencies.[2] The forecast of spectrum needs was based on an extrapolation of how traditional public safety radio technologies and spectrum usage in years prior to 1996 could support *peak* public safety communication requirements in 2010. Recently, however, the public safety community has endorsed the use of a modern spectrum-efficient technology to build public safety wireless broadband systems.[3] As a result, public safety wireless broadband communications requirements

[1] Indeed, public safety has stated that the current 10 MHz allocation in the 700 MHz band will not be sufficient to support disaster operations. This statement, however, has not been supported with any up-to-date requirements analysis. See *NPSTC 700 MHz Public Safety Broadband Task Force Report and Recommendations, National Public Safety Telecommunications Council,* September 4, 2009 pp 11-12.

[2] Public safety defined an aggressive set of communication requirements representative of public safety agencies in a large, expansive urban area, specifically the five county area encompassing Los Angeles. The communication requirements assumed extensive use of data and video to support first responders (i.e. police, fire and emergency medical teams) and an almost equal number of general government personnel. The broadband spectrum requirements represent over 70 percent of the total spectrum required by public safety agencies. *Infra* pp 6-7.

[3] The Association of Public-Safety Communications Officials (APCO), the National Emergency Number Association (NENA), the National Public Safety Telecommunications Council (NPSTC) and the Public Safety Spectrum Trust (PSST) have endorsed long term evolution (LTE) for the development of a nationwide interoperable public safety broadband network in the 700 MHz public safety band. See *APCO & NENA Endorse LTE as Technology Standard for the Development of Nationwide Broadband Network*, (June 9, 2009) at http://www.apcointl.org/new/news/nena_endorse_lte.php; *NPSTC Votes To Endorse LTE Technology for Broadband Network* (June 10, 2009) at http://www.npstc.org/documents/Press_Release_NPSTC_Endorses_LTE_Standard_090610.pdf; and *The PSST Endorses LTE as the Preferred Technology Standard for the Nationwide 700 MHz Safety Wireless Broadband Network* (July 24, 2009) at http://www.psst.org/documents/PSSTPress072409.pdf. Also, the NPSTC has convened a task force to develop recommendations for LTE-based technical, governance, and

can now be met readily with the spectrum the FCC has already allocated for broadband.

Specifically, the 10 MHz allocated in the 700 MHz band should be sufficient for public safety agencies to build a dedicated wireless broadband network. A properly designed cellular network, using a modern spectrum efficient technology, can meet peak public safety communication requirements, while still providing a substantial reserve of capacity for future growth in requirements. A number of state and local public safety agencies have sought waivers to use the existing 10 MHz public safety allocation in the 700 MHz band to build out their wireless broadband systems.[4]

Additional spectrum is not needed to build a dedicated public safety wireless broadband network in the 700 MHz band. Thus, reserving the D block (or any other spectrum) for future public safety use is not the most efficient use of the spectrum. It also incurs a considerable opportunity cost.

The best way to maximize the value of the D block would be to preserve it for commercial use – without inflexible public safety requirements. Accordingly, the best way to use the D block for the benefit of public safety would be to use the revenue gained from an unrestricted auction of the D block to jump-start the construction of the public safety wireless broadband network.

A public safety communications architecture that separates voice communications from broadband data communications will produce an infrastructure that is more expensive than necessary and requires more spectrum than necessary. The current public safety allocations in the 700 MHz band pair a high capacity broadband data network with a low-capacity voice network. Additional and significant spectrum efficiencies and cost savings can be gained, over the longer term, by converging the separate voice and data services over one 700 MHz broadband network, thus increasing the capacity for voice while also negating the need to operate and maintain two separate wireless networks.[5]

II. PUBLIC SAFETY SPECTRUM ALLOCATIONS

A. Total Spectrum Allocated

Currently, almost 100 MHz of spectrum -- in frequency bands ranging from 25

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operations standards to support interoperability. See *NPSTC to Develop Requirements for 700 MHz Broadband Network* (June 12, 2009), at http://www.npstc.org/documents/Press_Release_Task_Force_090612.pdf.

[4] Fourteen state and local public safety agencies (and one commercial provider) have sought waivers to use the 10 MHz allocation in the 700 MHz band to construct wireless broadband systems. *Infra* note 41 and accompanying text.

[5] New York City, which has applied for a waiver to use the 10 MHz public safety broadband spectrum, plans to adopt voice over-IP (VoIP) technology for mission-critical voice applications. They plan to conduct a proof-of-concept demonstration of mission critical voice capability. If successful, the city plans to migrate its mission-critical voice capability into the 700 MHz broadband band. *Infra* note 45 and accompanying text.

MHz to almost 5 GHz -- is allocated for the exclusive use of state and local public safety organizations (see Table 1 below).[6]

Table 1. Grand Total of Public Safety Spectrum Available

Band (MHz)	Available MHz (estimated)	Primary Use
Narrowband (NB) Voice		
25-50	6.3	Conventional dispatch voice communications
138-144/148-174	3.6	Conventional dispatch voice communications
220-222	0.1	Conventional dispatch voice communications
450-470	3.7	Conventional dispatch voice communications
806-824/851-869	9.5	Conventional and trunked voice communications
806-824/851-869	4.5 *	Conventional and trunked voice communications
769-775/799-805	12	Conventional and trunked voice communications
Total NB	**39.7 ** **	
768-769/798-799	2	Guard bands between 700 MHz NB and BB spectrum.
Broadband (BB) Data		
763-768/793-798	10	Broadband data communications
4940-4990	50	Broadband data communications
Total BB	**60**	
Grand Total	**99.7 *** **	

* The 4.5 MHz is available as a result of the reconfiguration of the 800 MHz band.
** Not included in the total are locally vacant 6 MHz TV channels (470-512 MHz band) available in 11 metropolitan areas for public safety use.[7]
*** The grand total does not include 2 MHz of guard band spectrum since it is unused spectrum.

As shown in the Table above, approximately 40 MHz is available to support

[6] The "inventory" of spectrum available for public safety spectrum was complied from several sources: See *Public Safety Wireless Advisory Committee (PSWAC), Final Report*, September 1996. Available at (http://ntiacsd.ntia.doc.gov/pubsafe/publications/PSWAC_AL.PDF). (*PSWAC Final Report*); and *Emergency Communications: Meeting Public Safety Spectrum Needs*, Congressional Research Service (CRS), July 1, 2003. Available at http://digital.library.unt.edu/govdocs/crs/permalink/meta-crs-5390:1. (*CRS Report*).

[7] Spectrum in the 470-512 MHz band (i.e. TV channels 14 to 20) is available for land mobile users in 11 areas, defined as a 50-mile radius around center-city co-ordinates. The cities are Boston, Chicago, Dallas, Detroit, Houston, Los Angles, Miami, New York, Philadelphia, Pittsburgh, San Francisco and Washington. One or two 6 MHz spectrum blocks (TV channels) are available in most of these markets for common carrier and private land mobile radio use. New York and Los Angeles have three 6 MHz spectrum blocks available – one of which is reserved exclusively for public safety use.

public safety voice communications. However not all voice allocations have equivalent value or can support the same services, primarily because of differences in propagation due to frequency. Similarly, although 60 MHz is available for public safety broadband data communications, the broadband allocation in the 700 MHz band, because of its superior propagation characteristics can support certain requirements of public safety that the spectrum in 4.9 GHz cannot. Nevertheless, the 4.9 GHz band can also satisfy certain public safety needs.

B. Spectrum In Use

Public safety radio services today are limited primarily to voice and low-speed data delivered over narrowband communication systems. About 23.2 MHz of VHF and UHF spectrum is used currently for public safety voice and low-speed data communications.[8] (The 12 MHz in the 700 MHz band and 4.5 MHz of additional 800 MHz spectrum are just now becoming available).

Public safety radio communications services started with the introduction of commercial mobile radio services in the low VHF band (30-50 MHz). As radio technology improved and usage of radio increased, public safety communications migrated up in frequency to the high VHF band (138-144/148-174 MHz) and the UHF bands (450 and 800 MHz).

The VHF band is the primary spectrum resource for local public safety agencies. It is used especially by state highway patrols for conventional dispatch radio (usually half-duplex push-to-talk (PTT) communications). VHF communications, because of favorable propagation characteristics, are more practical and economical than UHF communications for large area coverage of low-density population areas.[9] 800 MHz UHF systems, in contrast, are used to provide both conventional and trunked communications to multiple agencies and departments because of their greater capacity.[10]

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[8] The International Telecommunications Union (ITU) Radio Regulations divides the radio spectrum into nine general bands. The classifications of interest for public safety include: the high-frequency (HF) band from 3-30 MHz; the very-high (VHF) frequency band from 30-300 MHz; the ultra-high frequency (UHF) band from 300 MHz to 3 GHz; and the super-high frequency (SHF) band from 3-30 GHz.

[9] The low VHF band at 25-50 MHz, because of propagation anomalies and other reasons, is not used heavily. It was used primarily by state highway patrols for wide-area coverage since signals at this frequency bounce off the ionosphere and travel great distances. However, because of this type of propagation, there are frequent dead spots (or "skips") and the band has the highest noise level of any public safety band. As of 2003, no public safety quality radios were being produced for this band. See *Why Can't We Talk?* National Task Force on Interoperability, February 2003, p. 51. Available at http://www.safecomprogram.gov/NR/rdonlyres/322B4367-265C-45FB-8EEA-BD0FEBDA95A8/0/Why_cant_we_talk_NTFI_Guide.pdf.

[10] Trunking technology was deployed in the 800 MHz band in order to use the available channels more efficiently. Instead of assigning a channel to each user, a trunk group allows users to share a group of channels by dynamically assigning channels to a user when requested and reassigning channels when no longer needed.

Although a variety of spectrum bands and communications systems are employed currently, public safety communications share one common characteristic. For historical and financial reasons, public safety communication systems are designed to maximize radio coverage from a centrally located base station throughout a relatively large and specified area of responsibility or jurisdiction. For this purpose, repeaters are used to extend the coverage area as necessary. Public safety communication systems are designed to provide one-to-one and one-to-many voice communications for a comparatively small group of users in the operating area. This type of architecture, which results in little geographic reuse of frequencies, is not very efficient in terms of spectrum usage.[11]

C. 800 MHz Band Reconfiguration

Public safety agencies currently have available 9.5 MHz of spectrum in the 800 MHz UHF band Additional 800 MHz spectrum is becoming available for public safety use as a result of the reconfiguration of the band to eliminate interference between public safety and land mobile communication systems.[12] The FCC estimates that a "running average" of 4.5 MHz of additional 800 MHz spectrum -- sufficient for an additional 90 channels -- will be available as Sprint Nextel relocates from the interleaved portion of the 800 MHz band.[13] The availability of the de-interleaved spectrum will increase the amount of available 800 MHz spectrum to 14 MHz.

D. Spectrum Now Being Deployed

The last group of spectrum to be made available for public safety includes 24 MHz in the 700 MHz band[14] and 50 MHz in the 4.9 GHz band.[15] The 24 MHz in the 700 MHz band is divided into a 10 MHz block (5 MHz pair) designated for broadband

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[11] Geographic frequency reuse is the number of times that a frequency or channel may be used in a specific geographic area. *Infra* note 29.

[12] See *Improving Public Safety Communications in the 800 MHz Band*, Report and Order, Fifth Report and Order, Fourth Memorandum Opinion and Order, and Order, WT Docket 02-55 (rel. August 6, 2004).

[13] Eligibility for the vacated 800 MHz channels will be limited to public safety entities for the first three years and to public safety and critical infrastructure industries (CII) entities for the following two years. After five years, any remaining vacated channels will be available for licensing to any eligible applicant. See *Public Safety and Homeland Security Bureau Announces Application and Licensing Procedures for Certain Channels Relinquished by Sprint Nextel Corporation in the 80-809.5/854-854.5 MHz Band*, Public Notice DA-08-2810 (rel. December 29, 2008); and *Public Safety and Homeland Security Bureau Announces Application and Licensing Procedures for Certain Channels Relinquished by Sprint Nextel Corporation in the 809.5-815/854.5-860 MHz Band*, Public Notice DA-09-2301 (rel. October 28, 2009).

[14] The 24 MHz was reallocated in 1997 from the television broadcast spectrum for public safety use as part of the digital TV transition. See *Reallocation of Television Channels 60-69, the 746-806 MHz Band*, Report and Order, ET Docket No. 97-157, (rel. January 6, 1998) and *Service Rules for the 698-746, 747-762 and 777-792 MHz Bands*, Second Report and Order, WT Docket No. 06-150 (rel August 10, 2007) (*700 MHz Second Report and Order*).

[15] The 50 MHz was transferred in 2003 from the Federal government for public safety use. See *In the Matter of the 4.9 GHz Band Transferred From Federal Government Use*, WT Docket No. 00-32, Second Report and Order and Further Notice of Proposed Rulemaking, (rel. February 27, 2002).

communications and a 12 MHz block (6 MHz pair) designated for narrowband voice communications (See Figure 1 below). Two 1 MHz internal guard bands separate the narrowband from the broadband segments. In addition, two 1 MHz external guard bands are required to isolate the narrowband segments from adjacent commercial services.

Figure 1. Public Safety 700 MHz Spectrum Bands

The 12 MHz of narrowband spectrum is being used to augment the 800 MHz narrowband voice systems. Since the 700 MHz and 800 MHz bands display similar characteristics, the same base stations and antennas structures can be used for the 700 MHz systems. Thus it is expected that 700 MHz narrowband voice systems would exhibit similar frequency usage and reuse patterns as the 800 MHz systems.

The 50 MHz of 4.9 GHz spectrum is divided into ten 1 MHz wide channels and eight 5 MHz wide channels, which can be aggregated as (up to a maximum of 20 MHz bandwidth) to provide higher data rates. The 4.9 GHz band is intended to provide high capacity local-area communications at the scene of an emergency, to include fixed hotspots in critical areas as the capability to deploy communications to the scene of an incident. This includes the ability to establish wireless local-area networks (LANs) among the diverse public service agency units as the scene of an incident.

The 700 MHz and 4.9 GHz spectrum allocations are complementary and do not support the same needs. The 700 MHz band would best be used to provide longer distance, wide-area communications (because of propagation) while the 4.9 GHz band would provide high-capacity, local-area communications at the incident scene where spectrum needs are greatest. The availability of 4.9 GHz local-area broadband communications at the scene of an incident would reduce need for 700 MHz broadband communications.

III. PUBLIC SAFETY SPECTRUM REQUIREMENTS

A. Public Safety Spectrum Requirements (2010)

Public safety's spectrum "requirements" are based on a widely cited report by the Public Safety Wireless Advisory Committee (PSWAC) in 1996.[16] More than 13 years

[16] See *PSWAC Final Report.*

later this estimate of spectrum needs has not been revised or updated and remains the basis for the public safety "spectrum shortage." A total of 129.3 MHz of spectrum is forecast to be required nationwide by 2010 to support the public safety communication needs of first responders (i.e. police, fire, emergency medical services) plus a number of general government personnel(see Table 2 below).[17] Of that total requirement, 91.5 MHz (over 70%) -- is forecast to be needed for broadband data.[18]

Table 2. Projected Total Public Safety Spectrum Needs (2010)

Service	Police	Fire	EMS	General Government	Total
Narrowband (NB) Voice					
Voice	9.2	11.9	3.7	7.5	32.3
Narrowband Data	1.6	2.3	1.3	0.1	5.3
Status/Message	0.0	0.1	0.0	0.1	0.2
Total NB Spectrum					**37.8**
Broadband (BB) Data					
Wideband Data	9.7	21.7	8.1	1.3	40.8
Video	10.1	26.5	7.6	6.5	50.7
Total BB Spectrum					**91.5**
Total Spectrum Needs	30.6	62.5	20.7	15.5	**129.3**

Comparing Tables 1 (spectrum available) with Table 2 (spectrum needed), we see that spectrum availability and spectrum needs for narrowband voice and low speed data are closely matched. The "spectrum shortage" is for broadband spectrum, where public safety projects a need for 91.5 MHz and the FCC has allocated 60 MHz.

[17] The PSWAC report estimated in 1996 that an *additional* 95.3 MHz of spectrum would be needed *nationwide* to meet public safety spectrum requirements in the year 2010, after accounting for current spectrum in use and the use of commercial spectrum (assumed to be 10% of total spectrum needs). The PSWAC estimate is updated here by accounting for new allocations since 1996 and compensating for non-productive guard bands. See *PSWAC Final Report*.

[18] The PSWAC report did not define broadband data but addressed the need for wideband data and video, which we take to be the equivalent of broadband data.

B. Public Safety Spectrum Model

The projected spectrum needs were developed with the use of a simple model with nine parameters (see Appendix). The model and choice of parameters are based on the technologies, architectures and operational concepts used for public safety radio communications in the period prior to the report (i.e. pre 1996).

The model was used to estimate the *peak* spectrum demands of public safety agencies in the Los Angeles area assuming a dedicated pubic safety system. (i.e. peak usage in a large urban area). The Los Angeles area was defined to be the five county region including Los Angeles, Orange, Ventura, Riverside, and San Bernardino Counties, which has an area of 34,000 square miles and (in 1996) a total population of about 580,000 public safety users.[19] Assumptions about the use and reuse of spectrum were derived from patterns of equipment and spectrum usage in 1995 in the five-county region. The input parameters to the model were adjusted to account for anticipated changes between 1995 and 2010.[20] Spectrum required to support each service for each user segment (police, fire, emergency medical teams (EMT) and general government) was then estimated for year 2010.

Broadband Data Usage. The projected usage for narrowband voice and data were based on past usage and experience (prior to 1996). However, no such data and experience was available for estimating average broadband data usage since wireless broadband services were not available at that time.[21] A wide and significant usage of data, images and video was assumed *a priori*.[22] Peak broadband data usage (wideband data and video) in 2010 was defined to be an average 0.0380 erlangs per broadband user (with source rates of 384 kbps).[23] This translates into an average data usage of more than 1 GB per month per broadband user.[24] The projected usage is considerably greater than the typical commercial wireless data usage (estimated at 40 MB) or even smart phone

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[19] The first responders number 89,400 police, 164,700 fire and 55,800 EMT for a total of 309,900 __ but they are only 53% of the total. In addition, 269,800 general government personnel are users of public safety communication systems in the Los Angeles area. See Tables extracted from the PSWAC Report in the Appendix.

[20] See *PSWAC Final Report,* (Appendix D) Spectrum Requirements Subcommittee Final Report.

[21] A number of public safety agencies were using the cellular digital packet data (CDPD) system in the early 1990s for mobile terminals. CDPD operated over the analog AMPS system and was limited to a maximum speed of 19.2 kbps.

[22] For example, the broadband communication requirements include the use of steaming video, still images, alerts, data files and data base queries. Streaming live video is the most bandwidth intensive service. This includes, among many other applications, applications such as police helicopters transmitting video feeds at the scene of a fire or other incident to police and fire chiefs on the ground and fire helmets equipped with video cameras to transmit video feeds from the scene of a fire. See PSWAC Final Report.

[23] This is the sum of the average erlangs per user for wideband data (0.0140) and video (0.0240). An erlang is a dimensionless unit used to measure offered telecommunications traffic. Traffic of one erlang refers to a single resource (e.g. a communications channel) being in continuous use.

[24] We estimate the average broadband usage, assuming 20 eight-hour workdays per month – which translates into 576,000 seconds of usage per month. Noting that there are 8 bits per byte (B), the per user broadband data usage can be calculated as 0.0380 X 576,000 X 382 kb/s /8 = 1,050 MB per month.

usage (estimated at up to 350 MB) in 2009.[25]

The projected public safety broadband data usage also appears at odds with the perceived data requirements of many public safety users. In a recent FCC workshop on public safety broadband, for example, there was little agreement on the need for broadband or exactly what are public safety's needs.[26]

Frequency Reuse. The reuse assumptions were based on the number of assignments per frequency channel in the Los Angeles area. In the typical public safety system with a large service area, the number of simultaneous users is limited to the number of channels available. To ensure a high availability, the number of assignments per channel (channel or frequency reuse) is kept small. It was also assumed that there will be little change in frequency reuse in the future and it was also assumed that broadband video systems would follow the implementation and reuse history of mobile data systems. A frequency reuse factor of 2.5 (assignments per channel) was used for voice, narrowband data and status/messaging and a factor of 4.0 (assignments per channel) was used for wide-band data and video. These reuse assumptions are orders of magnitude less than what is achievable in commercial cellular systems.

C. Public Safety Broadband Spectrum Requirements -- Revised

The public safety spectrum model estimates that 91.5 MHz of spectrum is required for public safety broadband in 2010. This very high estimate is driven by the low frequency reuse of the traditional large cell public safety communications architecture. Much higher reuse can be obtained with a cellular architecture.

The traditional public safety approach is contrasted with the cellular approach in Figure 2. The contour of a "typical" public safety communication system is represented by a circle that covers the entire operating area or jurisdiction of a public safety agency or agencies. (The actual coverage would be irregular due to terrain and other variations). A cellular system would provide coverage of the same operating area by the combination of many small overlapping cells, rather than one large one.[27]

To estimate the spectrum required by a cellular-based public safety system, we need to consider the impact of frequency reuse and one-to-many communications. We

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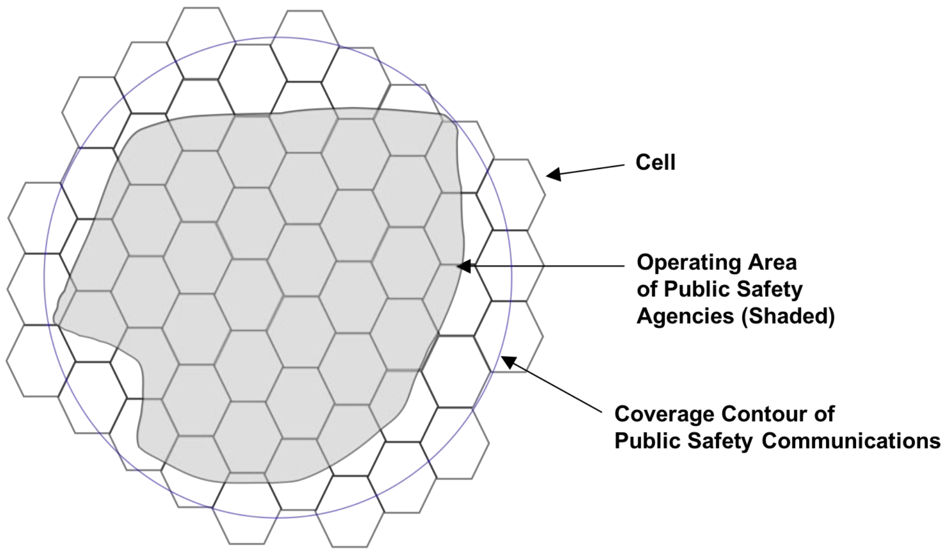
[25] For example, the average commercial wireless data usage is the equivalent of about 40 MB per month. It is estimated that iPhone (AT&T Wireless) users consume an average of about 300 - 350 MB per month. See *Apple and AT&T: The iHog Dilemma*, Bernstein Research, December 2, 2009.

[26] These comments were made by several of the public safety agency participants at the FCC National Broadband Plan Workshop on Public Safety and Homeland Security on August 25, 2009. The feelings were summarized by a representative of the National Public Safety Telecommunications Council (NPSTC): "It's going to be evolutionary and the network is going to grow and expand in its capabilities with time." See p. 59 of the transcript at http://www.broadband.gov/docs/ws_14_public_safety.pdf.

[27] The cells in Figure 2 are represented notionally as hexagons -- to account for the minimum cell overlap required to ensure contiguous coverage of an area. The area of a inscribed hexagon can be shown to be $3R^2\sin(\pi/3)$, where R is the cell radius.

examine both issues for a cellular system using Long Term Evolution technology (LTE).[28]

Figure 2. Public Safety vs. Cellular Reuse



Geographic Frequency Reuse. A traditional public safety system will typically transmit every message to every user. A cellular system transmits a message only in the cell or cells that may contain intended recipients. At any given time, different messages can be transmitted in many different cells using the same frequency that is reused throughout the systems coverage. Thus cellular frequency reuse reduces the amount of spectrum needed throughout the coverage region.[29]

The geographic frequency reuse is proportional to the number of cells required to cover the public safety operational area. Since individual cells are relatively small compared to the coverage of a traditional single cell public safety system, fairly large frequency reuse factors can be achieved. For example, the five-county Los Angeles area

[28] Long Term Evolution (LTE) is the next-generation follow-on to the Universal Mobile Telecommunications System (UMTS). AT&T and Verizon plan to start deploying LTE in their 700 MHz spectrum in 2010. See *AT&T and Verizon have announced plans to deploy LTE networks in the 700 MHz band*. Available at http://www.dslreports.com/shownews/700Mhz-Auction-Winners-Finally-Talking-93295. T-Mobile USA also plans to deploy LTE in the future, although they have not yet announced a timeline. See *T-Mobile's Ray promises national HSPA+ deployment by mid-2010*, available at http://www.fiercewireless.com/story/t-mobiles-ray-promises-national-hspa-deployment-mid-2010/2009-09-18. Other carriers are also expected to adopt LTE or a solution that can evolve to LTE (such as HSPA).

[29] Cellular frequency reuse is the rate at which the same frequencies can be used in a cellular network. It is typically written as 1/k, where k is the number of cells that cannot use the same frequency for transmission. (Cellular reuse can also be designated by the cluster size k). The geographic frequency reuse is the product of the cellular frequency reuse and the total number of cells in the coverage area.

(34,000 mi^2) can be covered with approximately 1,400 5 km radius cells.[30] With a cellular frequency reuse of 1/3, the geographic frequency reuse would be about 450 X -- a considerable improvement over the 4.0 X factor used in the spectrum needs model for broadband data.

One-to-Many Communications. Public safety frequently employs one-to-many communications for voice communications, and to a much lesser extent for data communications.[31] Compared to one-to-one communications, one-to-many communications will increase the traffic in a cellular system for the same number of users. Thus, increased capacity will be required to support one-to-many broadband data communications. Studies, using simulations of public safety traffic in LTE networks, have shown that the increase in traffic in an LTE cellular system can range up to a factor of two times -- thus requiring a two-fold increase in capacity.[32] The worst case is that of one-to-many communications to a single group -- as the number of separate one-to-many groups increases, the additional capacity required to support the same number of users will decrease.

Revised Spectrum Needs. The amount of spectrum required by a cellular system can be determined by substituting the cellular geographic reuse factor in the spectrum model (for wideband data and video) and multiplying the resultant value by a factor of two (to account for one-to-many traffic). The revised spectrum estimate is shown parametrically in Figure 4 as a function of the average cell radius and for two values of cellular frequency reuse (reuse of 1 and of 1/3).

Public safety communication requirements can be met by a range of cellular deployments with varying cell sizes as shown in Figure 3.[33] With a 5 km cell radius and a 1/3 frequency reuse, about 1.6 MHz of spectrum would be required to support the stated public safety requirements. With a cellular frequency reuse of 1 and/or smaller cell sizes, the spectrum required would be reduced even further.

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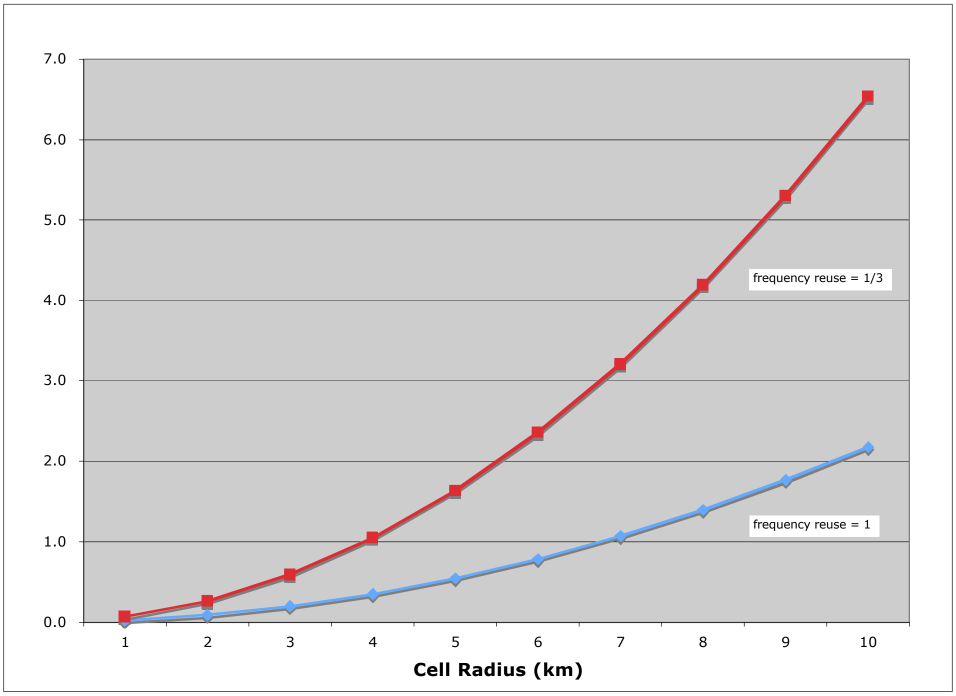
[30] The area of a hexagonal cell circumscribed by a circle of radius 5.0 km is about 65 km^2 (23.4 mi^2); 34,000 divided by 23.4 equals approximately 1,453.

[31] The pattern of video and broadband data usage will differ considerably from the one-to-many aspect of public safety voice communications. While public safety voice communications makes a great use of one-to-many communications, video, for example, is more likely to be one-to-one or one-to-few.

[32] See *Public Safety Communications Over 3GPP LTE*, Stefan Sundkvist, Lulea University of Technology, February 7, 2008.

[33] The cell size in an LTE deployment can vary over a fairly large range. Commercial LTE cell sizes will likely be commensurate with those of 3G and 3.5G UMTS deployments (LTE is the follow-on technology). The optimal cell size for UMTS and LTE is 5 kms -- shorter ranges (i.e. one km or less) would be used in dense, high demand urban areas and longer ranges would be used in less dense, lower demand rural areas. LTE can support a 30 km cell with reasonable performance and a 100 km cell with acceptable performance. See *UTRA-UTRAN Long Term Evolution (LTE) and 3GPP System Architecture Evolution (SAE)*, 3rd Generation Partnership Project (3GPP), available at ftp://ftp.3gpp.org/Inbox/2008_web_files/LTA_Paper.pdf.

Figure 3. Spectrum Required by a Public Safety Cellular Broadband System



A cellular deployment could have sufficient excess capacity to accommodate significant future growth in requirements. With a 5 km cell radius, for example, only 18% of the allocated 10 MHz of spectrum is required to support the stated public safety broadband requirements. This could support over five times the stated requirements -- a potential growth of over 400 percent.

Network Design. A characteristic of public safety communications is low average demand and high peak demand, often concentrated in a small geographic area. Thus, the design for a public safety wireless network must balance the need for basic coverage over a large area with the need to support high capacity in any single area – such as dense urban areas. Large cell sizes could be used in an initial deployment of a network to provide basic coverage of the operating area of public safety agencies. However, smaller high capacity cells should be deployed in high demand areas and other potential trouble spots. Later, as the demand grows, additional capacity can be added by reducing the cell sizes in selected areas (i.e. by splitting cells). Such scalability is not possible with the architecture of existing public safety systems.

IV. WAIVERS TO USE THE 10 MHz ALLOCATION

A. Current Public Safety Broadband Systems

Several existing operational public safety broadband networks utilize 10 MHz or less of spectrum.

New York City currently operates a public safety wireless broadband data network – the New York City Wireless Network (NYCWiN) - on 10 MHz of leased spectrum in the 2.5 GHz Educational Broadcast Service (EBS) band.[34] The NYCWiN uses TD-UMTS[35] time-division duplex technology and comprises approximately 400 sites throughout the five boroughs of the city. The NYCWiN is designed to support the "in-street" requirements of the City's public safety first responder and public safety organizations. New York is also interested in deploying a 700 MHz broadband network for in building coverage. They have applied for a waiver to use the current 10 MHz public safety allocation.[36]

Washington D.C. operates a regional public safety broadband network – the Regional Wireless Broadband Network (RWBN) -- using 2.5 MHz of spectrum in the 700 MHz public safety band designated for narrowband voice.[37] The RWBN uses CDMA 200 EV-DO Revision A technology with twelve base stations, providing 80-95 percent coverage of the outdoors in the District of Columbia. (Five additional base stations are in storage, pending funding for installation). The RWBN can also support roaming onto commercial networks in the 1.9 GHz band.

The RWBN has been operating under a series of 180 day special temporary authorizations (STAs) from the FCC and may have to be shut down to avoid interference when neighboring municipalities begin implementing voice systems in the 700 MHz narrowband spectrum.[38]

B. Waivers to use 10 MHz

Fourteen cities and/or states (including one commercial provider) have requested FCC approval[39] to begin construction of public safety broadband networks on the existing 10

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[34] *Infra* note 44.
[35] TD-UMTS is the time-division duplex version of the universal mobile telecommunications system (UMTS) third generation (3 G) technology.
[36] *Infra* note 44 and accompanying text.
[37] The RWBN was constructed using 700 MHz public safety narrowband spectrum under an experimental license and special temporary authority (STA) waiver from the FCC. See *District of Columbia Request for Waiver*, PS Docket No. 06-229 (filed June 26, 2009) (*DC Petition*).
[38] Washington, D.C. plans to migrate the RBWN to the 700 MHz public safety broadband band. It has applied for a waiver to use the current 10 MHz public safety allocation. See *DC Petition*.
[39] The Commission's current 700 MHz rules give the 700 MHz D block licensee the exclusive right to build and operate the public safety wireless broadband network. Absent a successful D block auction, the current rules do not allow for the individual deployment of public safety networks. Hence the need to request a

megahertz of 700 MHz public safety broadband spectrum.[40] North Dakota subsequently withdrew their petition, which was essentially a duplicate of Flow Mobile's (the commercial provider) petition.

Twelve of the cities and/or states propose to build an interoperable public safety network on the 10 MHz of spectrum already allocated to public safety. Many propose to use LTE technology to build out their networks.[41] Flow Mobile plans to also use a six MHz block of the public safety narrowband allocation to build a broadband network with 16 MHz of spectrum.[42]

Several cities and states that applied for a waiver propose to use their broadband networks for VoIP services.[43] New York City, in particular, proposes to conduct a proof-of-concept demonstration of mission critical voice capability on the 700MHz broadband network and to migrate such voice communications to the 700MHz broadband network rather than support two wireless public safety networks – one for voice and one for data. They plan to operate their 700 MHz broadband network alongside the current 2.5 GHz broadband network. They have no plan to use the 700 MHz narrowband spectrum for voice services. They note, however, that additional broadband spectrum may be required in the future to support both broadband and voice requirements.[44]

V. ROLE OF THE D BLOCK

The Federal Government provided public safety the spectrum but not the funds necessary to build and operate a broadband network. In an effort to provide funding, the

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waiver of the rules. See *47 C.F.R.* §§ 27.1330 & 90.1430(a).

[40] These include: (1) the City of Boston (Boston); (2) the City and County of San Francisco, the City of Oakland, and the City of San Jose (Bay Area); (3) the State of New Jersey (New Jersey); (4) the City of New York (New York City); (5) the District of Columbia (DC); (6) the State of New York (NYS); (7) the City of Chesapeake, Virginia (Chesapeake); (8) the City of San Antonio, Bexar County, and Comal County, Texas (San Antonio); (9) the State of New Mexico (New Mexico); (10) the State of North Dakota; (11) the City of Charlotte, North Carolina (Charlotte); (12) several counties and the City of Cedar Rapids, Iowa (Iowa Coalition); (13) the County of Maui, County of Hawaii, County of Kauai, City and County of Honolulu and State of Hawaii; and (14) New EA, Inc. dba Flow Mobile (Flow Mobile). The waiver requests were filed in PS Docket No. 06-229.

[41] New York City, Washington DC, Hawaii, New York State, Boston and Flow Mobile, among others plan to implement their public safety broadband system with LTE technology.

[42] The North Dakota Department of Emergency Services granted Flow Mobile permission to use the 769-775 MHz narrowband spectrum block, which is designated for base station (downstream) operations and licensed to the State. This is adjacent to the 763-768 MHz block assigned for public safety broadband base station transmissions. The combination of the two would provide 11 MHz of spectrum capacity for downstream transmissions – coupled with 5 MHz for upstream. See *Flow Mobile Petition for Waiver*, PS Docket No. 06-229 (filed July 7, 2009) (*Flow Mobile Petition*); and *State of North Dakota Petition for Waiver*, PS Docket No. 06-229 (filed July 17, 2009) (*North Dakota Petition*).

[43] This includes New York City and Boston. See *New York City Petition*; and *City of Boston Amended Request for Waiver*, PS Docket No. 06-229 (filed May 28, 2009) (*Boston Amended Petition*). New Jersey plans to provide the "full spectrum of multi-media" applications, which would include VoIP capability. See *State of New Jersey Petition*, PS Docket No. 06-229 (filed Apr. 3, 2009) (*New Jersey Petition*).

[44] See *City of New York Petition for Waiver*, PS Docket No. 06-229 (filed June 8, 2009) (*New York City Petition*).

FCC proposed establishment of a public/private partnership to build and operate a shared public safety - commercial wireless broadband network pairing the 10 MHz of public safety broadband spectrum with the adjacent 10 MHz of commercial D block spectrum.[45] In addition to building and operating the network, the public/private partnership would also provide public safety with additional sources of funding and priority access to the D block spectrum in times of large-scale emergencies.[46]

The effort to build and operate the public safety wireless broadband network via a public/private partnership failed when the D block license could not attract a winning bid in the 700 MHz auction (Auction 73).[47] The high cost of building and operating a shared network that meets public safety requirements deterred companies from bidding for the D block, despite the inducement of less expensive spectrum (the reserve price for the D block was discounted relative to other spectrum in the 700 MHz band).[48] Public safety agencies and others have concluded that there is no viable business case for a commercial wireless network operator to build a nationwide network that will meet public safety coverage and survivability standards.[49] Thus the mandated public/private partnership, which was to be a commercial approach to funding the public safety network, "failed the market test."

As we have demonstrated, there is little value in reserving the D block for a public safety use. Additional spectrum is not needed since 10 MHz of spectrum should be sufficient to build a dedicated wireless broadband network that meets public safety peak requirements – while still providing room for growth. A substantial opportunity cost is incurred however, by restricting the use of the D block.

The opportunity cost of reserving the D block for public safety is the revenue lost

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[45] The FCC plan would pair the public safety broadband spectrum with the commercially auctioned D block of 700 MHz spectrum to create a shared public-private national network. The 700 MHz D block licensee would have the exclusive right to build and operate the shared network on 20 MHz of contiguous spectrum and to provide commercial services as well as services to public safety entities. See *Service Rules for the 698-746, 747-762 and 777-792 MHz Bands*, Second Report and Order, WT Docket No. 06-150, (rel. August 10, 2007) ¶ 13 *recon. Pending.*

[46] The public safety licensee would lease access to its 10 MHz spectrum block exclusively to the D block licensee, on a secondary basis subject to preemption. In return for allowing commercial usage of its spectrum, public safety would have access, on an emergency basis, to the D block spectrum.

[47] The D-block attracted only one bid of $472 million, well below the reserve price of $1.33 billion. See *Auction of 700 MHz Band Licenses Closes*, Public Notice DA 08-595, March 20, 2008. The FCC decided not to reauction the D block immediately, in order to provide additional time to consider other options. This kept intact rules regarding the public/private partnership and the role of the D block. See *Auction of the D Block License in the 758-763 and 788-793 MHz Bands*, Order, AU Docket No. 07-157 (rel. March 20, 2008).

[48] The extensive list of public safety requirements made construction and operation of a shared network more expensive (and thus riskier) – when compared to competitive commercial systems in the 700 MHz band. These included, among others, very stringent build out requirements, the need for backup power and hardening of sites such as base stations. Commercial wireless providers generally do not provide such extensive requirements.

[49] An FCC audit of the D block failure concluded that the plan had been burdened with too many expectations and uncertainties including a growing list of requirements. See *D Block Investigation*, Office of Inspector General Report, Federal Communications Commission, April 25, 2008.

from not auctioning the 700 MHz D Block for commercial purposes.[50] In the 700 MHz auction (Auction 73) the average price of spectrum was $1.28 per MHz-pop. (The average price of paired 700 MHz spectrum was slightly more at $1.35 per MHz-pop).[51] A recent study, taking into account the current economic recession and financial crisis on the spectrum market, estimates that the generic value of licensed 700 MHz spectrum would currently be roughly $1.00 per MHz-pop (about a 20% discount).[52] At that price, the D block would be valued at about $2.9 billion.

However, the revenue from an auction of the 10 MHz D block would vary depending upon the conditions placed on the spectrum and on the eligibility of the bidders.[53] The 22 MHz C block, which had open access conditions placed upon it, brought in $0.76 per MHz-pop.[54] At that price, the D block would be valued at less than $2.2 billion.

Preserving the D block for commercial use – without inflexible public safety requirements – would be the best way to maximize the value of the spectrum. Based on the above, the auction of the D block could provide revenues of about $2 to $3 billion, depending upon the conditions placed on the auction and the spectrum and the general economic conditions at the time of the auction.

The best way to use the D block for the benefit of public safety would be to use the revenue gained from an unrestricted auction of the D block to jump-start the construction of the public safety broadband network in the already allocated 10 MHz.

VI. CONVERGED 700 PUBLIC SAFETY MHZ NETWORK

In the longer term, additional and significant efficiencies and cost savings can be gained by converging voice communications and data services over one public safety wireless broadband network.

Public safety's estimate for narrowband voice spectrum (see Table 2) is driven by the low frequency reuse of the traditional large cell public safety communications architecture. Public safety agencies have begun to implement 700 MHz narrowband

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[50] It may be beneficial to combine the D block with the two adjacent one MHz guard bands to create a 12 MHz of paired spectrum, which would make it consistent with most of the other allocations on the 700 MHz band.

[51] According to the FCC, $18,957,582,150 was bid (net bids) for 52 MHz of spectrum and $17,690,737,650 was bid for 46 MHz of paired spectrum (excluding the D block bid). The FCC uses a U.S. population of 285 million people (the population of the latest decennial census) to calculate $/MHz-pop spectrum values. *Auction of 700 MHz Band Licenses Closes*, Public Notice DA 08-595, March 20, 2008.

[52] See *The Need for Additional Spectrum for Wireless Broadband: The Economic Benefits and Costs of Reallocations*, The Brattle Group, October 23, 2009. Available at http://www.brattle.com/_documents/uploadlibrary/upload809.pdf.

[53] Due to concerns about the growing consolidation in the wireless marketplace and gains by Verizon Wireless and AT&T in the 700 megahertz band auction, spectrum aggregation limits might be imposed on bidders in future auctions of broadband spectrum to prevent carriers from amassing too much spectrum.

[54] The 22 MHz C block sold for $4,746,691,000.

systems in a similar manner.[55] As in the case for broadband, much higher reuse and capacity can be obtained with a cellular architecture resulting in a reduced demand for spectrum.

By using VoIP technology, public safety voice communications can be provided over the public safety broadband network, if that network is implemented, as planned, with an IP-based wireless technology (such as LTE).[56] By using the same network to provide voice and broadband data, public safety can leverage the increased capacity available by the high reuse of a cellular system. New York City in particular plans to conduct a proof-of-concept demonstration of the capability of a 700 MHz public safety broadband network to support mission-critical voice capability.[57]

The bandwidth required to transmit a call with VoIP is greater because of the overhead required of IP transmissions. Additional overhead may also be required to ensure adequate quality-of service (QoS).[58] Additional bandwidth will also be required to support the one-to-many voice communications prevalent in public safety operations.[59] However, any additional overhead required for VoIP can be more than compensated for by the increased capacity of a cellular system to handle voice calls.[60]

A cellular-based public safety broadband network on 10 MHz of spectrum would have enough surplus capacity for public safety agencies to begin to use LTE with VoIP communications. In the future, some part of the 12 MHz of 700 MHz narrowband spectrum could be transitioned into a larger broadband network supporting voice and broadband data services. Eventually, the entire 12 MHz narrowband spectrum plus the 2 MHz of internal guard band spectrum could be transitioned into a single 24 MHz broadband block to provide converged interoperable voice and broadband data services.

Converging voice and data services can provide efficiencies and cost savings in

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[55] *Supra* p. 6.

[56] The Commission has proposed previously that VoIP and push-to-talk (PTT) voice capabilities be required elements of the proposed broadband pubic safety network. See *Third Further Notice of Proposed Rulemaking*, WT Docket 06-150, PS Docket 06-229; ¶¶ 106. 110, 115; Appendix C, p 189, §27.305(a) (4); Appendix C, p. 203, § 90.1405 (rel. September 25, 2008).

[57] See *New York City Petition*.

[58] Typically, VoIP over a wireless system requires more bandwidth than native voice over wireless, since native voice does not have IP overhead. The advantage of VoIP over wireless is not increased capacity over native voce but simpler integration with other IP applications like broadband data.

[59] *Supra* note 31 and accompanying text.

[60] To illustrate this point, consider the following. A 50 kbps VoIP data rate is considered sufficient for adequate voice quality. The public safety spectrum model assumed that voice is transmitted at a native rate of 6 kbps. So VoIP increases bandwidth by a factor of about 8.4. We assume an additional factor of 2.0 (i.e. 100% additional bandwidth) to ensure quality-of-service (QoS). A factor of 2.0 is also assumed to support one-to-many calls. In the example on p. 10, an average cell radius of 5 km, with a cellular frequency reuse of 1/3, will provide a geographic frequency reuse of 450. The public safety spectrum model assumed a reuse factor of 2.5 for voice. So a cellular system would increase the geographic frequency reuse by an overall factor of 180 (450/2.5). Thus, the narrowband voice requirements (24 MHz of 700 MHz spectrum) could be supported instead with about 4.6 MHz of broadband spectrum (a reduction by a factor of about 10). This can be determined by the ratio: (24 MHz x 8.7 x 2.0 x 2.0)/180 = 2.32.

several other ways:

- The elimination of the two one MHz guard bands between the narrowband and broadband segments. These can be integrated into the broadband band to provide a total of 24 MHz of usable spectrum.

- The savings in building, operating and maintaining one combined network – instead of two separate and disparate systems for voice communications and data communications.

VII. CONCLUSION

The 10 MHz of spectrum in the 700 MHz band that is already allocated to public safety should be sufficient to build a dedicated wireless broadband network. A properly designed cellular network, using a modern spectrum efficient technology, can meet peak public safety communication requirements, while providing a substantial reserve of capacity for future growth in requirements.

The additional 10 MHz of D block spectrum is not needed to build a dedicated public safety broadband network in the 700 MHz band. Reserving the D block (or any other spectrum) for future public safety use is not the most efficient use of the spectrum and incurs a considerable opportunity cost.

Preserving the D block for commercial use – without inflexible public safety requirements – is the best way to maximize the value of the D block. The best way to use the D block to benefit public safety would be to use the proceeds from an unrestricted auction of the D block to jump-start the construction of a public safety wireless broadband network.

In the longer term, public safety agencies can extract even more efficiencies and cost savings from their spectrum by converging the separate voice and data services over one contiguous broadband network.

APPENDIX

Public Safety Spectrum Demand Model

The spectrum demand in MHz is given by the following equation:

MHz=(10000*ERL*POP*PEN*SRC)/(COD*RATE*LOAD*REUS*(100-ERR)),

where

ERL = Offered load per user (erlangs);

POP = Population of users (i.e. police, fire, EMS and general government);

PEN = Penetration (of services);

SRC = Source loading (data rate);

COD = Coding improvement factor (i.e. compression);

RATE = Transmitted rate (modulation efficiency);

LOAD = Channel loading;

REUS = Channel reuse factor; and

ERR = Error coding and overhead (percent).

The assumed input values of the nine parameters and the computed spectrum required is shown in the following four tables, which have been extracted from the PSWAC Final Report.

APPENDIX G

SPECTRUM COMPUTATION FOR NON-FEDERAL PUBLIC SAFETY

FREQ. MHz = ERL*(10000*POP*PEN*SRC)/(COD*RATE*LOAD*REUS*[100-ERR])

SPECTRUM COMPUTATION FOR POLICE THROUGH THE YEAR 2010

	Avg ERL/User	POP in thou.	PEN,%	Computed Net Pop, thous.	SRC,kb/s	COD	RATE b/s/Hz	LOAD,%	REUS	ERR,%	Computed MHz in 2010
Voice	0.0538	89.4	65	58.11	6	2	1.5	54.5	2.5	50	9.2
Data	0.0087	89.4	35	31.29	6	1	1.5	54.5	2.5	50	1.6
Stat/Messg	0.0004	89.4	31	27.71	6	2	1.5	54.5	2.5	50	0.0
W.B. Data	0.0140	89.4	23	20.56	384	3	3.5	54.5	4	50	9.7
Video	0.0240	89.4	14	12.52	384	3	3.5	54.5	4	50	10.1

SPECTRUM COMPUTATION FOR FIRE THROUGH THE YEAR 2010

	Avg ERL/User	POP in thou.	PEN,%	Computed Net Pop,thous.	SRC,kb/s	COD	RATE b/s/Hz	LOAD,%	REUS	ERR,%	Computed MHz in 2010
Voice	0.0484	164.7	51	84.00	6	2	1.5	54.5	2.5	50	11.9
Data	0.0087	164.7	27	44.47	6	1	1.5	54.5	2.5	50	2.3
Stat/Messg	0.0004	164.7	31	51.06	6	2	1.5	54.5	2.5	50	0.1
W.B. Data	0.0140	164.7	28	46.12	384	3	3.5	54.5	4	50	21.7
Video	0.0240	164.7	20	32.94	384	3	3.5	54.5	4	50	26.5

SPECTRUM COMPUTATION FOR EMS THROUGH THE YEAR 2010

	Avg ERL/User	POP in thou.	PEN,%	Computed Net Pop,thous.	SRC,kb/s	COD	RATE b/s/Hz	LOAD,%	REUS	ERR,%	Computed MHz in 2010
Voice	0.0484	55.8	47	26.23	6	2	1.5	54.5	2.5	50	3.7
Data	0.0087	55.8	45	25.11	6	1	1.5	54.5	2.5	50	1.3
Stat/Messg	0.0004	55.8	34	18.97	6	2	1.5	54.5	2.5	50	0.0
W.B. Data	0.0140	55.8	31	17.30	384	3	3.5	54.5	4	50	8.1
Video	0.0240	55.8	17	9.49	384	3	3.5	54.5	4	50	7.6

SPECTRUM COMPUTATION FOR GENERAL GOVERNMENT THROUGH THE YEAR 2010

	Avg ERL/User	POP in thou.	PEN,%	Computed Net Pop,thous.	SRC,kb/s	COD	RATE b/s/Hz	LOAD,%	REUS	ERR,%	Computed MHz in 2010
Voice	0.0430	269.8	22	59.36	6	2	1.5	54.5	2.5	50	7.5
Data	0.0087	269.8	1	2.70	6	1	1.5	54.5	2.5	50	0.1
Stat/Messg	0.0004	269.8	16	43.17	6	2	1.5	54.5	2.5	50	0.1
W.B. Data	0.0140	269.8	1	2.70	384	3	3.5	54.5	4	50	1.3
Video	0.0240	269.8	3	8.09	384	3	3.5	54.5	4	50	6.5

PUBLIC SAFETY WIRELESS ADVISORY COMMITTEE
September 11, 1996