Discussion of 700 MHz Spectrum Policy Issues for Public Safety in King County

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Introduction

This policy white paper evaluates the potential policy and technical impacts of the FCC's proposed nationwide interoperable public safety broadband network in the 700 MHz band of spectrum reserved for public safety and focuses on related potential implications of the proposed “Flexible Use” of the 700 MHz band for both broadband and narrowband operations. The first part of this paper provides a historic context to the band allocation to public safety. The next section explains the broadband policy debate over providing more spectrum in the 700 MHz band to public safety. Then the paper discusses the Flexible Use Notice and comments on its implications for narrowband users. We conclude with an observation on the future direction of technology toward an all broadband, all IP network architecture and how public safety could begin to prepare. We provide a detailed technical analysis (Attachment A) of the impacts of shared broadband and narrowband uses in the 700 MHz band.

History of the 700 MHz Allocation to Public Safety

In the late 1990's the FCC set aside spectrum in the 700 MHz band, re-assigning television channels 63 and 64 and 68 and 69 to public safety licensing. The new spectrum was meant to provide an “expansion band” which would be contiguous with the previously allocated 800 MHz band for public safety. The allocation included 24 MHz of spectrum, divided into narrowband and wide band channels, intended for voice and data traffic respectively. These channels were to be made available for licensing after they were vacated by the television stations using them until the digital television conversion was completed. The television stations took much longer than originally anticipated to vacate these channels, so that in most states the 700 MHz allocation for public safety came available for use in approximately 2008. Because of this decade-long delay, equipment development for public safety’s use was also delayed. Dual 700/800 MHz radios were introduced to “future proof” 800 MHz systems around 2004, but base stations and other core equipment simply were not developed or marketed until later. When the FCC wrote rules for public safety use of this spectrum in 1997, it required that, like the previous allocation in 800 MHz, the regional users form a Regional Planning Committee (RPC) and submit a plan to coordinate with one another prior to requesting licenses, to avoid interference, and to encourage the most spectrally efficient use of radio spectrum region-wide. In the northwest, regions are divided by State. Washington is Region 43. Washington was one of the first states to adopt a regional plan for the 700 MHz PS allocation; it was completed and approved by the FCC in 2005, and it was revised in 2008 to reflect revisions to the 700 MHz band plan initiated by the FCC in 2007, which are described below.

In 2007, the FCC rules were rewritten for the public safety 700 MHz spectrum. The important changes included a re-banding of the channels; carving off 10 MHz for broadband use, eliminating the wide-band channels, and a re-shuffling of the channelization, causing the band edges to differ substantially from the Canadian and Mexican allocations. As Washington is a border state to Canada, this difference is significant, in that it introduced yet another delay in the utility of the band to allow for coordination of band plans with Canada to avoid interference at the borders between systems operated by Washington users and Canadian users, and an effective reduction of useable channels at the borders [1]

1 Use of the 700 MHz Public Safety band in the border zone between the U.S. and Canada is governed by *Arrangement G – Sharing Arrangement Between the Department of Industry Canada and the Federal Communications Commission of the United States of America Concerning the use of the Frequency Bands 764 to 776 MHz and 794 to 806 MHz by the*

Even more significantly, the FCC removed the 10 MHz of broadband spectrum from local user licensing, and awarded it to a "Public Safety Spectrum Trust" (PSST), composed of representatives from most major public safety associations. This PSST was to be the sole licensee of broadband spectrum in the public safety 700 MHz band, and was directed in the regulations to work with a commercial licensee, who would be awarded 10 MHz in contiguous blocks (known as the "D Block") to build a nationwide public-private network in partnership with the PSST. The auction for the D Block took place in 2008, but failed to produce a commercial bid to buy the license.

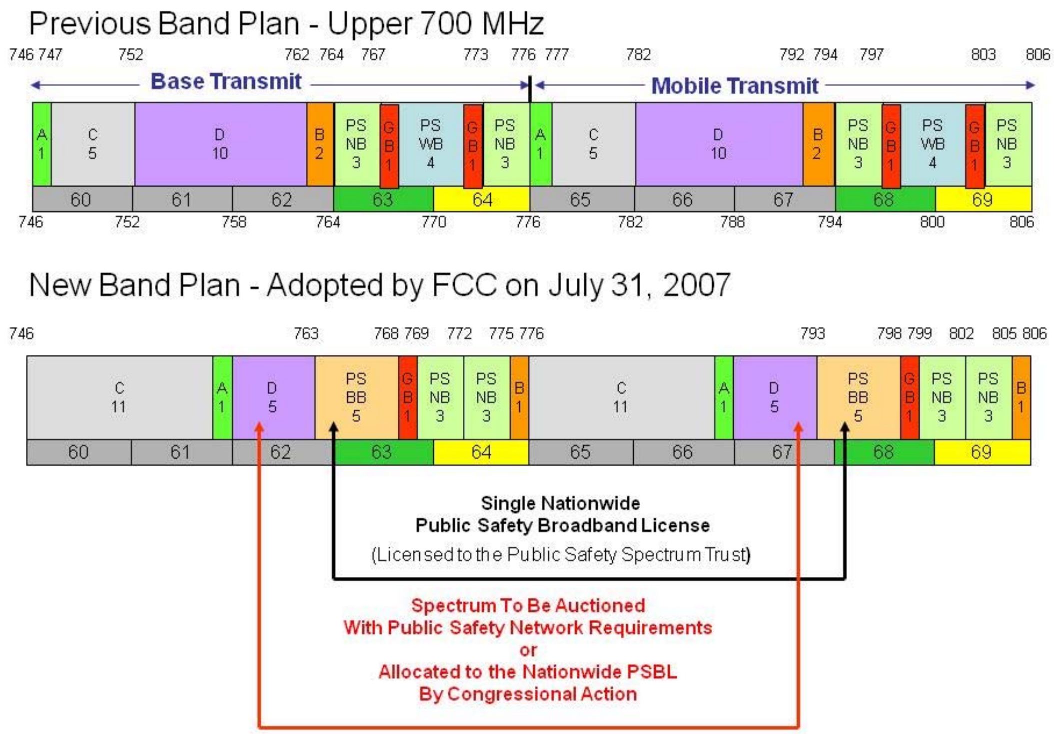

Figure 1: 700 MHz Band Plan (from PSST)

There was, however, enough certainty in the new rules concerning narrowband uses by late 2006, that several states, major cities and counties proceeded with planning and implementing 700 MHz regional or statewide Land Mobile Radio (LMR) systems. In 2006, the Department of Homeland Security (DHS) began requiring that public safety radio systems funded with DHS grant funds build a P-25 compatible digital trunked network. This requirement was meant to encourage adoption of the P-25 radio suite of standards developed by the International Association of Public Safety Communications Officers (APCO). As of October, 2010, there are several P-25 "compliant" narrowband systems

Land Mobile Service along the Canada-United States Border; June 2005. This treaty document establishes rules for the use of the 700 MHz public safety band in Sharing Zone II (which extends 140 kilometers into each country along each side of the U.S. Canada border, and which encompasses much of the Puget Sound Region), and divides the 700 MHz narrowband spectrum in the PSNB band into two sets of channels: one set has Primary status in the U.S. and Secondary status in Canada, while the other set has Primary status in Canada and Secondary status in the U.S.

licensed and constructed, or under construction throughout the country[2]. P-25 systems are very expensive to build, but once pervasive, will provide a higher level of voice interoperability for first responders as well as higher spectrum efficiency and more options to purchase equipment from multiple vendors (this was intended to spur competition among equipment vendors, leading to lower prices eventually).

By 2004, and with growing clarity since, it became clear that public safety organizations would adopt broadband and internet-based applications in their communications systems. The dramatic growth of the Internet and cellular wireless services and coverage has accelerated even as the regulatory uncertainty for public safety has their broadband development stalled. The growth on the commercial side has meant rapid dissemination of new and more powerful digital applications, including mobile video and data, voice over IP (VOIP) and the development of netbooks, smart phones and all manner of end-user devices. WiFi and 3G (and now 4-G) wireless systems mean that even as public safety users have no broadband radio systems, their kids and families do, and most urban and suburban communities are blanketed with pervasive, powerful and inexpensive commercial wireless broadband services.

In 2010, several major cities, impatient to gain access to the 700 MHz broadband spectrum awarded to the PSST, petitioned the FCC to grant them waivers to use the 700 MHz PSST broadband spectrum to build broadband networks for public safety. Several more waiver requests followed. The waivers were granted, but the networks were not federally funded. Simultaneously, the public safety lobbying community began a full press political effort to convince the FCC and Congress to abandon the plans to re-auction the 10 MHz of spectrum reserved for D Block auction to a commercial provider, and instead allocate it to public safety. This effort has bloomed into a serious political battle between associations representing public safety on one side, and the FCC and commercial entities on the other side (planning to auction the spectrum for commercial networks). In 2010, the FCC released its National Broadband Plan, including a section on its plan for a nationwide interoperable public safety broadband network. The 2010 plan includes proposed federal grant funding for a nationwide public safety broadband network, a requirement that both the D Block winner and the public safety community build LTE standard networks, and that roaming and prioritization for public safety be supported across all commercial networks in the 700 MHz band, not just the D-Block. Immediately, the public safety associations criticized the broadband plan for failing to adequately address public safety's need for dedicated broadband spectrum. The details of this political battle, the policy issues it raises and the likely outcomes and consequences for King County are the topics of the following sections of this paper.

The Issue in the 700 MHz Band – Does Public Safety Have Enough Spectrum Already to Future Proof Its Networks?

The overarching issue under debate is whether public safety has enough spectrum available under the current allocations for both broadband and narrowband uses. This question is important to wireless providers ***because the issue has been framed in such a way as to suggest that allocations to the public safety community are at the expense of commercial wireless providers***. The debate over the D-Block illustrates this dichotomy. The D-Block is composed of the 10 MHz of spectrum intended for a

2 According to the FCC ULS, 445 licenses have been issued to Public Safety in the 700 MHz band including licenses for 126 SG or conventional systems, 53 SL or statewide systems and 266 SY trunked radio systems. RPCs have more than double that number in the frequency coordination process. (Seybold, Ex Parte Filing, September 10, 2010).

commercial broadband provider[3]. However, it is immediately contiguous to the public safety allocation of 10 MHz of broadband spectrum. Since contiguous spectrum is more economical to develop than non-contiguous spectrum (because the same equipment can use it with no modification to radios), and because there is no other 10 MHz band immediately identifiable that would be available to public safety, public safety hopes to succeed in lobbying Congress and the FCC to turn over the D-Block to them.

In the case of narrowband public safety 700 MHz spectrum, this band was created specifically to address the shortage of spectrum for voice communications in the other public safety bands. The history of public safety narrowband allocations has been one of small slices of spectrum interleaved with other services, across a wide set of frequencies, all incapable of inter-operating. Expansion of demand always meant populating a new band, and creating networks that could not interoperate. The identification of the 700 MHz band was specifically an answer to this problem. It created spectrum resources contiguous to the existing 800 MHz band (the narrowband mobile transmit side of the band is immediately adjacent to the mobile transmit side of the 800 MHz band), which allowed development of standards-based interoperable equipment capable of operating over multiple bands for the first time in history.

The FCC Position on Public Safety Spectrum Needs for Broadband

The FCC released a position paper[4] in August 2010, in response to public safety arguments that it needs the D-Block to be reallocated from commercial use to public safety use. In this white paper, the Commission claims that its technical analysis shows that a nationwide broadband public safety network constructed with just the 10 MHz of broadband spectrum currently held in reserve for the PSST ***will be adequate, and that the D-Block auctions should proceed***. The paper concludes that:

1. "The 10 megahertz of dedicated spectrum allocated to public safety in the 700 MHz band for broadband communications provides more than the required capacity for day to day communications and for each of the serious emergency scenarios (analyzed within the paper).
2. For the worst emergencies for which public safety must prepare, even access to another 10 megahertz of spectrum would be insufficient. Accordingly, priority access and roaming on the 700 MHz commercial networks is critical to providing adequate capacity in these extreme situations. Moreover, priority roaming is a cost-effective way to improve the resilience of public safety communications, along with its capacity, in a way that a single network cannot provide.
3. The capacity and efficiency of a public safety broadband network will far exceed the expectations of someone who has only experienced narrowband land mobile radio (LMR). This is because of the system architecture, density of cell sites, the density of cell sectors per site,

3 The D-Block auction winner, under the previous auction, was supposed to contract with the PSST to build its network using both the PSST spectrum and the D-Block, and to provide priority services to public safety in exchange for having access to the PSST allocation. Fees for both sides were to be negotiated. It is unknown whether a new auction would contain similar requirements. The Broadband Plan suggests that the D-Block auction proceeds would be used to build out the PSST network at the same time as the D-Block network, taking advantage of economies of scale and sharing cell sites. However the feasibility of this approach is under fierce debate.

4 **The Public Safety Nationwide Interoperable Broadband Network: A New Model for Capacity, Performance and Cost**, Federal Communications Commission, June 2010.The authors of this paper are Jon M. Peha, Walter Johnston, Pat Amodio and Tom Peters.

network and spectrum management, and the use of new and emerging technologies.

4. Public safety can make more capacity available when and where it is needed by using all of its spectrum resources appropriately and effectively, no matter how much spectrum is available (*e.g.*, use the 700 MHz band for mobile devices and other frequency bands for fixed devices)."

The Industry Position on Public Safety Spectrum Needs for Broadband

In general the Carrier Community has supported the FCC's intent to auction the D-Block for commercial use and is not backing the public safety position that they need exclusive access to the D-Block spectrum. The position of the Industry in general, is that there is an ever growing need for spectrum for commercial users of next generation wireless networks, and that the *US needs more commercial broadband network capacity to remain competitive globally.* However, there is some splintering in the carrier world on the public safety broadband spectrum issue. This divergence of views is mainly driven by competitive advantage issues between incumbent spectrum holders vs. non-incumbent spectrum holders, and can be essentially seen as strategic regulatory positions that erect barriers to entry for competitors that are not already licensed for next generation spectrum slots. In short:

- Carriers that already hold 700 MHz spectrum licenses in the C-Block (including Verizon and AT&T) support public safety getting the D-Block presumably so that they won't have to make their networks available for priority roaming for public safety in the future, and to erect a barrier to entry to another provider.
- Carriers that do not already hold 700 MHz spectrum licenses (such as the Coalition for 4G, made up of T-Mobile, Sprint-Nextel, The Rural Cellular Association, and other companies opposed to the reallocation of the 700-MHz D Block to Public Safety which is now known as "Connect Public Safety Now" (CPSN)) want a chance to win the D-Block auction and compete for commercial broadband customers. These carriers claim that public safety has enough spectrum, and in the Katrina or 9-11 type event when they don't, public safety should rely on priority roaming on all commercial networks for emergency expansion capacity when the public safety network becomes overloaded as an alternative to awarding the D-Block to public safety. Further they support the FCC's assertion that public safety is an inefficient user of its existing spectrum allocations, and thus should not be "rewarded" with additional spectrum.
- Equipment vendors that provide public safety network equipment (notably Motorola) support providing the D-Block to public safety and dispute the technical analysis of both the FCC and the Commercial Carriers that public safety will have sufficient spectrum without the D-Block.

Public Safety Position on Public Safety Spectrum Needs for Broadband

Public safety organizations including the Public Safety Alliance (PSA), the Association of Public Safety Communications Officials (APCO), and the National Public Safety Telecommunications council (NPSTC) take the position that public safety has demonstrable demand for broadband spectrum that eclipses the allocation of 10 MHz in the 700 MHz band to the PSST for public safety. They support the allocation of the D-Block spectrum to public safety and assert that federal funding is critical to building a nationwide wireless broadband network that provides the capacity needed to transmit mission critical real-time high-resolution video, voice and data.

These organizations have lobbied Congress and the FCC relentlessly for the past year in an attempt to prevail over FCC Staff and Industry positions supporting an auction of the D-Block. These groups convinced many legislators in both the House and Senate to support re-allocation of the D-Block to public safety. Senator John (Jay) Rockefeller, IV (D – WV), Chairman of the Senate Commerce, Science, and Transportation Committee introduced S. 3756, the Public Safety Spectrum and Wireless Innovation Act of 2010. This legislation builds on the growing support in Congress from Senators Joe Lieberman (I – Conn.) and John McCain (R – Ariz.) who introduced S. 3625; Representatives Peter King (3rd Dist., NY) and Yvette Clarke (11th Dist., NY), who introduced H.R. 5081, which had more than 68 cosponsors; and Representative Henry Waxman (30th Dist., CA), whose draft language was the catalyst to identifying the necessary funding to build out and maintain a nationwide interoperable public safety broadband network. The senate bills would have provided public safety with up to $5.5B for capital expenditures and $5.5B for operating expenses, depending upon the auction results, to deploy public safety broadband through an auction of spectrum other than the D Block (1.7 and 2.1 GHz). However, all of these bills in both houses of Congress calling for the 700 MHz D Block spectrum to be reallocated for public-safety broadband use *failed to pass the committee level*, meaning the legislative effort to re-allocate the D Block to Public Safety will likely will have to be restarted with a new Congress in 2011[5]. Speculation on how that might go, given the new make-up of the Congress is beyond the scope of this paper, but it is assured that public safety groups will re-institute their efforts.

Analysis of the Public Safety Broadband Debate

The FCC and Congress, the public safety community, and even the commercial wireless industry clearly support the development of a nationwide public safety broadband network, which would allow first responder priority over other users, which would be based on industry standards, and which would cover nearly the entire land mass and population of the United States. The policy arguments are coalescing and polarizing around the issues of control, financing (cost), and most importantly, spectrum (public safety vs. carrier need for additional spectrum). Of these, the spectrum debate is drawing the most lobbying effort, for good reason. Spectrum is a scarce resource, and the 700 MHz spectrum is particularly desirable. Its characteristics allow for very good coverage (in buildings and outdoors); it is contiguous to both the commercial spectrum already deployed for wireless broadband, cellular service and the public safety broadband allocation; and it is currently available (incumbents have moved out). In short, it is worth a lot of money.

In contrast to wireless telecoms, public safety has always acquired its spectrum allocations for free. In prior decades, when small allocations (under 5 MHz) in any band would last for decades, and when narrowband voice was the only application, this approach worked well. It supplied expansion capacity in most markets for many years, and generally didn't conflict with the expansion intentions of commercial wireless carriers. The world has changed since the 1990's however, when the last major public safety set-asides were made. Today public safety's interest in a free set-aside (the D-Block), would displace a growth band from the very powerful cellular industry which could generate billions of dollars in revenue for that industry and for the federal general fund.

Public safety is a higher priority than commercial use in theory. The litmus test for public safety is to prove that despite efficiencies to be gained by new technologies, it cannot protect the public adequately

[5] Urgent Communications Magazine, Donny Jackson, October 18, 2010 at http://urgentcomm.com/policy_and_law/news/recess-hold-dblock-action-20101018/

using the spectrum resources provided to date. Unfortunately for all the reasons discussed in the first part of this paper, public safety has been unable to build out broadband networks, and demonstrate[6] that there is enough immediate demand to necessitate expanding public safety's 700 MHz broadband allocation. Instead, the public safety community has had to focus on a stewardship argument – that the additional D-Block spectrum should be reserved for public safety because they ***anticipate*** a high demand, and thus a ***high spectrum need in the future***. The wireless carriers have a much more demonstrable case for immediate demand and economic benefit for expansion right now. Analysts expect the number of wireless broadband customers to exceed two billion by 2015. This should produce a revenue growth of more than $780 billion, which is an increase of 2400% compared to the revenue this industry brings in today. The customer base for LTE technologies alone should exceed half a billion people by that time and is expected to contribute nearly $2 billion to the total wireless broadband revenue[7]. The Public safety community has not been able to either refute the glowing economic predictions, nor to project the public value in economic terms of providing the spectrum to them instead. The public safety argument is severely diluted when the Industry points to large swaths of public spectrum that is "unused" that has already been granted to public safety, including the 700 MHz broadband band, 4.9 GHz broadband band, and in most places in the country, the narrowband portions of 700 and 800 MHz.[8] Narrowbanding in the public safety VHF and UHF bands is also pointed to as a source of more "available" spectrum for public safety.

Moreover, on the issues of control and cost, the Industry has effectively lobbied the FCC that the public safety user community has neither the financial means nor the technical depth to finance, manage and maintain a nationwide LTE broadband network, and build it out to the entire nation. Their argument is that public safety would be better served to use a commercially controlled next generation broadband network, with prioritization and preemption allowing for head-of-the-queue public safety traffic. The details of how this prioritization and preemption would work are still sketchy, but have been the subject of several white papers.[9]

Meanwhile, the current 10 MHz of 700 MHz spectrum already available to public safety for a nationwide broadband network is ***effectively embargoed by FCC policy actions***, except in the areas where waivers have been granted to use the spectrum temporarily[10]. Even in these areas, neither federal funds nor local funds have not been forthcoming to fund the construction of these networks[11], and the standards to which the networks must conform are still to be developed by the FCC.[12] The waiver holders are required to build LTE networks however, and the cost of entry of LTE networks is

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[6] Except for a few pilot projects such as those in NYC and Washington DC

7 Broadband DSL Reports, http://www.dslreports.com/shownews/Wireless-Broadband-Revenue-To-Increase-2400-By-2015-96764, accessed 10-26-10

8 Both the T-Mobile and FCC whitepapers on Public Safety spectrum issues build this case, although the assumptions they use about public safety use and occupancy of these bands are faulty. See Attachment A of this paper.

9 See **The Public Safety Nationwide Interoperable Broadband Network: A New Model for Capacity, Performance and Cost**, Federal Communications Commission, June 2010.The authors of this paper are Jon M. Peha, Walter Johnston, Pat Amodio and Tom Peters, and **Technical Analysis of the Proposed 700 MHz D-Block Auction**, Roberson and Associates, LLC, for T-Mobile, August 23, 2010

[10] Additional waiver requests are pending

11 The FCC worked with the NTIA BTOP program to allow waiver holders a special window to apply for federal BTOP funding for network construction. Then, inexplicably, all of the grant applications were denied, except for one in the Bay Area, which is currently contested locally, and may be in trouble.

12 The FCC has required that these networks use the LTE air interface, but prioritization and roaming, among other standards are left to the FCC to oversee, and no progress has been made on these issues. In 2010 the FCC formed the Emergency Response Interoperability Center (ERIC), but it has not been staffed and has not begun operations.

extensive – much more expensive than other broadband data technologies. LTE technologies are designed to serve hundreds of thousands of users, not hundreds or thousands. Therefore, the waiver cities are going to have a great cost hurdle to actually finance network build-outs, and may end up sitting on that spectrum for lack of financial resources until their waivers are revoked, playing directly into the Carriers' arguments that public safety will only waste broadband spectrum.

In 2011, in the new Congress, we can expect to see a resurgence of efforts on both sides of the debate to resolve the D-Block argument. Public safety needs to re-frame and restate its arguments for broadband spectrum allocations and federal funding for public safety broadband build-outs. They have another chance to win the D Block with arguments that show that, in an era of spectrum scarcity, public safety use of spectrum is a higher national priority for its allocation than commercial use, and that they can identify and commit the funding to build the networks regionally and nationally.

The Next Round – Broadband from Flexible Use and New Technologies

T-Mobile recently (August 2010) submitted a white paper to the FCC (Roberson and Associates) providing "***additional technical analyses of the effects of auctioning the 700 MHz D-Block***." According to the summary of their paper, the analysis conducted shows that "the capacity and throughput provided by a 5+5 MHz LTE network in the 700 MHz public safety broadband spectrum is sufficient...to meet immediate public safety broadband spectrum needs" as long as the network is designed to use both the 700 MHz and 4.9 GHz public safety allocations. Further, "consideration of the total amount of narrowband voice spectrum available to public safety, taking into account the significant increases in voice capacity that will be realized in the future due to narrowbanding in the VHF and UHF bands, and the reconfiguration of the 800 MHz band, prompt the discussion of a future ***re-purposing of a portion of the 700 MHz public safety narrowband spectrum for broadband use."*** (emphasis added)

Just a month later, the FCC released a Notice of Inquiry (NOI)[13] asking for comment on "the feasibility of allowing for flexible use of the 700 MHz public safety narrowband spectrum". Specifically the FCC seeks "to explore whether allowing public safety the option of using 700 MHz narrowband spectrum for broadband services would be operationally feasible and technically compatible with existing and future public safety narrowband operations." The FCC notes "as a procedural matter" that this Public Notice does not propose any change to the current rules governing the 700 MHz narrowband spectrum; its purpose is to gather information in order to develop a better understanding of ***options for future evolution of the 700 MHz narrowband spectrum*** that the Commission could make available for the public safety community."

The FCC specifically invited comment from the States and Regional Planning Committees (RPCs)[14] of

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13 **Public Safety and Homeland Security Bureau Seeks Comment on the Technical and Operational Feasibility of Enabling Flexible Use of the 700 MHz Public Safety Narrowband Allocation and Guard Band for Broadband Services**, PS Docket No. 06-229, DA 10-1877, Released: September 28, 2010.

14 RPCs are an invention of the FCC. They were first formed when the rules for public safety spectrum in the 800 MHz band were written, and were also written into the 700 MHz band rules. RPCs are composed of "all eligible license holders in a region" who must reach consensus on the processes for application for allocation of spectrum licenses in a particular region including showing how spectrum will be distributed among licensees, how interference protections will be implemented, and how interoperability will be accomplished. Each RPC must write a "band plan" for the region which must be submitted to the FCC and approved by them prior to any licenses being granted in the region.

each region on a series of questions posed in the Notice, on planned usage of the narrowband 700 MHz spectrum. The FCC asks for comment on whether there are funds committed to planned deployments of 700 MHz narrowband systems, whether public safety jurisdictions are planning to deploy both 700 MHz broadband and narrowband systems in the same geographic area, and whether these systems will combine infrastructure, network operations or other resources. The Commission also asks whether flexibility to "shift spectrum from narrowband to broadband use over time" would benefit jurisdictions. They ask what impact allowing flexible use of all or a portion of narrowband spectrum have on the continued ability to support nationwide narrowband interoperability, how much, if any, of the narrowband allocation and guard band should be made available for broadband operations, and what role should the 700 MHz RPCs and the states play in implementing flexibility in the narrowband spectrum. They ask whether allowing flexible use "prior to widespread deployment in the public safety broadband allocation" will create incentives for the development of broadband devices and equipment capable of operating in both narrowband and broadband spectrum, and whether there is potential for development of dual-use equipment that might be software-defined and programmable to allow for ease of transition.

Finally, the Commission asks whether, if it were to permit flexible use of the narrowband spectrum, it should also reconsider and possibly rescind the requirement to move to 6.25 kHz narrowband channels (or to devices with "6.25 kHz equivalent spectrum efficiency", such as two-slot TDMA P25 Phase 2 radios) in the 700 MHz narrowband band segment by December 2016.

Comments on Issues Raised in the Flexible Use Notice

The FCC is looking for methods to promote spectrum efficiency across all bands, not just the public safety allocations. The Commission has identified a need for 500 MHz of **newly available** for broadband within 10 years, of which 300 megahertz should be made available for mobile use within five years.[15] The question behind the questions in the Flexible Use Notice appears to be: "If public safety users need more broadband spectrum, can the FCC introduce rule changes and spur technology advances to "push" a broadband transition of public safety's narrowband allocation, and thereby identify the extra broadband spectrum public safety needs within its existing allocation?" The FCC may be thinking that there are only a limited number of areas where investment has already occurred in P25 700 MHz narrowband LMR radio system deployments, and only these few will require a transition strategy (dual use radios, interference protection, or a re-location and compensation strategy).

In addition, the Commission may believe that *narrowband and broadband requirements are slow-growing enough* that a regional or national migration strategy for narrowband to broadband channels coupled with new technology advances could meet growing demand as it comes, and *negate the public safety argument that it needs the D-Block added to its spectrum set-aside right now.*

The Commission may anticipate that, in many areas of the Country, where public safety agencies do not have 700 MHz build plans, they will prefer to leap-frog past the current incentives and requirements to build narrowband P-25 air interface standard LMR networks and instead migrate narrowband uses directly to the anticipated nationwide broadband LTE network.

Since the release of the FCC's Report of the Spectrum Policy Task Force in 2002[16], the Commission

[15] National Broadband Plan Executive Summary at http://www.broadband.gov/plan/executive-summary/
[16] Report of the Spectrum Policy Task Force, to the Federal Communications Commission, Washington DC, November 14, 2002 accessed at http://www.fcc.gov/sptf/reports.html

has been looking into new types of spectrum rights; new forms of spectrum licensing that include both primary and secondary users, new sharing principles and the development of "all IP networks" and software-defined **cognitive radios**[17] as potential solutions to spectrum scarcity. **Cognitive radios** are being developed that can bond non-contiguous channels into a larger channel, use multiple bands at once (such as VHF and UHF) and change air interfaces (from P-25 to LTE, for instance).

In 2009, two major efforts have moved this technology closer toward commercialization. First, the TV Whitespaces rule-making (completed in 2010) has opened up spectrum licensed to broadcasters to "non-interfering" devices on an unlicensed, secondary basis. These devices will be allowed to use spectrum without a license for a variety of broadband transmissions, on a non-interfering basis. Secondly, the FCC and NTIA jointly created a "test-bed" for cognitive radios based on spectrally adaptive technologies, which is currently underway with several vendors, and which is proving the ability of these new classes of radios to use spectrum without interfering with primary uses. There is an expectation that Advanced LTE standards will include cognitive radio capability. Even if cognitive radios are beyond the commercialization time-frame and thus irrelevant to this inquiry, the FCC may be interested in promoting "all-IP" networks to replace LMR P-25 licensing. Certainly, all carrier-grade networks are moving from a circuit switched to IP cores, and are driving IP to the network edges. Digital LMR networks, like Harris' VIDA network equipment, are also all-IP in the core. Since networks are moving to all-IP, the development of voice applications over IP, commonly known as Radio over IP (ROIP) are expected to make it possible in the reasonably near future for voice to reside as a priority application over a broadband network. Taken to the next step—the FCC may be thinking that there is little need for the 700 MHz narrowband channels.

Analysis of the Spectrum Issues for Public Safety in Light of Both the Flexible Use Notice and the D-Block Issues

LTE is not a substitute for LMR

An analysis of the record on both the "Flexible Use" notice and the public safety broadband policy arguments suggests that the FCC may be positioning, along with the carrier industry, to promote an all-IP, all LTE future for public safety ***in advance of technology*** being available to deliver. Commercial LTE networks are only now being rolled out in a few markets, and there is no real experience with them yet. To consider LTE to be a potential "perfect substitute" for LMR today is a repudiation of priority for interoperable public safety communications systems now and in the near future. The LTE standard does not support voice communications, push-to-talk, one-to-many communications, talk-around, dispatch, multi-band uses, or interoperability with P25 radios or any LMR technology. Cognitive radios that would allow narrowband push-to-talk traffic to be relocated to other bands such as VHF and UHF on a shared, dynamic basis don't exist today. Their development and commercialization cycle is unknown. Radio over IP is possible in the core backbone of networks, but not at the scene on the ground. Public safety's need for reliable voice coverage in all areas where they operate, including wilderness search and rescue missions, wild fires, inside high rises, in underground tunnels and garages, and a multitude of other harsh environments necessitates network operability in all

17 A cognitive radio is defined as one which can sense its environment, and adapt to changes in spacial, temporal and frequency conditions. In theory, a cognitive radio can learn whether to operate as a broadband or narrowband radio based on its location, and available frequencies for use, at any given time. A cognitive radio senses whether a channel is in use, and if it is available, will transmit in the "white space."

these situations. Today, the only communications technology that is reliable for this type of operation is LMR, and there is a shortage of channels for its use.

Public safety hopes to develop robust broadband networks using LTE technology alongside and in many cases in tandem with its digital LTE networks. However, it is not feasible, with today's LTE technology to migrate LMR radio uses to LTE networks.

More, Not Less Narrowband Need is Evident

Statewide 700 MHz allocations and General Use 700 MHz allocations will be fully licensed and fully used, at least in the most populated areas. RPC Band Plans that have been approved by the Commission in almost every region, and a check of their licensing data base shows hundreds of licenses granted or in process. These include both statewide and regional narrowband systems. Clearly the delays to date in fully licensing the band in populated areas of the Country has been directly caused by the delay in clearing the band and making it available (as we have stated, licensing was not possible until the band was cleared of broadcasters and P25 equipment was available on the market, and this has been only within the last three years). In the King County area, the 700 MHz band is the only band available for expansion and new systems requiring multiple channels for simulcast narrowband systems. The VHF, UHF and 800 MHz bands are for all practical purposes, congested and unavailable for large-scale system development. Most urban areas have allocated all available channels in the VHF, UHF and 800 MHz bands as well as most 700 MHz general use channels in a pre-coordination strategy. Often, the demand for 700 MHz channels is from both license holders in 800 MHz who need to expand their systems, and from entities who find the all other bands completely allocated who must move into the 700 MHz band for availability of channels.

New Narrowband Capacity is Overstated

Narrowbanding in the VHF, UHF and 800 MHz bands will increase the number of available expansion channels in the future but far less than the quadrupling that some companies are predicting. New 12.5 kHz channels (and eventually new 6.25 KHz channels) will be created in theory, once the narrowbanding process is complete in the VHF and UHF bands, but very few of them will actually be usable to create new capacity for narrowband voice operations. The assumption that the narrowbanding process in the VHF and UHF bands will produce a 4:1 increase in voice channels once the transition is made to 6.25 kHz channels does not take into account the realities of frequency coordination, shared spectrum, and prohibited contour overlap in the UHF and VHF bands. Nor does it consider the situation in the U.S.-Canada Border Zone, where half the spectrum is licensed in Canada and it is therefore very difficult, it not impossible, to license those channels at elevated sites that can provide wide area coverage. A very optimistic guess is that maybe 20-25% of the VHF and UHF channels that now have prohibited channel overlap at 25 kHz will become clear (in terms of being able to be licensed at usable sites) when adjacent channel users have narrowed their channel bandwidth to 12.5 kHz. The circumstances are not likely to improve significantly with the transition to 6.25 kHz channels, especially since the likely transition in public safety systems will be to P25 Phase 2, which will continue to operate on 12.5 kHz channels with "6.25 kHz equivalent spectrum efficiency". This is not necessarily a simple flash upgrade or even a straightforward equipment replacement process. Therefore it is not correct to assume that migration to Phase 2 operation will provide a straight doubling of voice channel capacity on existing systems. Some system redesign and reallocation of channels may be required to maintain UHF and VHF coverage, and this may limit the total number of working channels available to particular user groups relative to the current circumstances.

Since Canada is not narrowbanding its VHF and UHF channels across the board in the same fashion as the U.S., and because many Canadian UHF channels are, and will remain, licensed for 16K0F3E operation, it is almost never possible to "split" a 25 kHz channel into two adjacent 12.5 kHz channels and license both channels if there are adjacent channel users in Canada. The new 12.5 kHz channel has to remain on the original 25 kHz channel center; it just reduces its bandwidth from 25 kHz to 12.5 kHz, which does not produce any new "spectrum" or any new voice channels (unless it operates in TDMA mode).

The claim that there will be an additional 3.6 MHz of 800 MHz spectrum resulting from 800 MHz rebanding is certainly not true in the U.S.-Canada Border Zone. It may be that the result of 800 MHz rebanding in the Border Zone *is a net reduction in available spectrum,* not an increase, because the systems operating in the 3 MHz of spectrum that comprises the pre-rebanding NPSPAC band (866-869 MHz) have to be moved down into the portion of the band between 851 and 854.75 MHz. This portion of the band is already used by existing Public Safety and Industrial Business systems in the Puget Sound Region, so there is no "spare" spectrum in this part of the band. The frequencies above 854.75 MHz and below 862.25 MHz are allocated to Canada as Primary spectrum, so even though this portion of the 800 MHz band is being vacated by Sprint-Nextel, there are significant restrictions on the use of frequencies in this part of the band in the Puget Sound Region. T-Mobile's claim[18] of large spectrum gains from rebanding is even incorrect outside the border zone, especially in urban areas. For example, the number of additional 800 MHz channels available after rebanding in the San Francisco Bay is difficult to determine at present, but it may ultimately amount to a few dozen or even a handful of channels—not 3.6 MHz of additional spectrum.

Flexible Use Creates Financial Uncertainty

The Flexible Use Notice potentially introduces substantial loss of certainty about the future of the narrowband allocation, which will lead to a "chilling effect" on investment, and further paralysis for network development. The concept of creating some undefined future option for "flexibility to "shift" spectrum from narrowband to broadband use over time" might be an attractive idea in a future where the narrowband channels have become a fallow wasteland with no reasonable expectation that they would be needed. But this simply isn't a true representation of the band's status.

There *are* needs to use narrowband spectrum for statewide LMR networks *now*, as well as for dozens of working networks licensed by counties and cities across the Country. Uncertainty about the status of the band, and its forward path for upgrades and expansions simply chills investment. It does not benefit jurisdictions. Loss of certainty concerning the size of the narrowband allocation creates a number of financial and technical difficulties for system owners. Expansion opportunities could be limited to further narrowbanding from 12.5 to 6.25 kHz channels. However, the standards-based technologies to create these types of systems are currently unavailable (though there are manufacturer-specific proprietary solutions available), and the price points and potential technical issues related to system design and coverage are not well defined. Standards for these systems are in development under the P-25 project, but the notice on Flexible Use suggests that the requirement to narrowband to this level may be changed or rescinded. This might mean another delay in the Industry's ability to respond with marketable products to accomplish further narrowbanding. Moreover, implications

[18] From the Robeson and Associates white paper

within the Notice and the proceedings on the Broadband 700 MHz future suggest that P-25 may be abandoned by the Federal government as a standard for public safety, in favor of LTE. Current LTE standards do not support push-to-talk voice or the other group- and fleet-oriented voice communication functions supported by LMR. These factors roll up into the potential to **paralyze public safety's ability to invest in any new technology** for narrowband systems because the expansion, replacement and end-of-life calculations one might have used only months ago are completely uncertain in this new environment. Moreover, public safety is also inhibited from investing in LTE technologies because they are broadband only, don't support push-to-talk and other operational requirements of public safety and transit, and the broadband standards for public safety interoperability have not been developed. The failure of the FCC to move forward with a viable plan to develop a nationwide public safety broadband network has effectively ended (for now) the development of any nationwide broadband network for public safety. The ability of waiver holders to finance individual broadband systems in discrete population centers using LTE technology is unknown. Their ability to provide local funding or create partnerships is also still unknown.

Flexible Use Cuts Off System Expansion Options

If the number of narrowband channels is decreased in the band, existing and planned systems may not be able to simply add channels when demand grows—an entire re-investment strategy may be necessary to create additional capacity. If some or all of the narrowband allocation is re-purposed to broadband, present system owners face a completely revised future path for upgrades and expansion. Expansion for narrowband traffic is likely to be relegated to other bands, where 6.25 kHz channel spacings can be expected eventually, perhaps the 800 MHz band—though this is not possible in many areas of the U.S., especially the urbanized areas; in some areas it may be necessary to move to a dual band strategy using the UHF and or VHF bands.. (This assumes that significant VHF or UHF spectrum is generally available, which is not the case in the Puget Sound Region, even after the first phase of narrowbanding is completed in 2013). Because the frequency coordination policies for 6.25 kHz systems are not yet clearly defined, prediction of how much additional spectrum might become available after the second phase of narrowbanding is difficult. Also, the proximity of Canada (which is not following the same narrowbanding process as the U.S.) has a significant impact on the availability of VHF and UHF spectrum in the Puget Sound Region. For most 700 MHz system owners this would require significant re-investment in core network technology and radio base stations, combiners and antennas (assuming that sufficient spectrum could be obtained to move into the lower frequency bands). This is likely to also require new end-user equipment. Multi-band radios (VHF-700-800) are only just being introduced into the marketplace. Currently they are extremely expensive. ($5-8000 per unit). It is impossible to know, given the uncertainty of the technology development path, whether the price for equipment will come down, whether LMR R&D investment will be abandoned in favor of LTE investment, or whether cognitive radios, or some other type of dual purpose, dual air-interface, or dual band radios will be available. No planning cycle is obvious, and it is not even clear whether the vendors actually have new products in the pipeline, or are waiting for these regulatory questions to shake out before making their development investments. Uncertainty now exists on the end-of-life calculations for existing investments in this band. Where equipment could be depreciated for 14 years or more in reasonable financial plans up until now for LMR systems, we may be looking at technology obsolescence due to regulatory changes that provides a system life-span with a hard end at 2016. However, given the uncertainties described above, it is not at all clear whether any viable alternate products will be available by 2016.

Flexible Use Threatens Interoperability in the Band

The negative impact of allowing flexible use of all or a portion of narrowband spectrum on nationwide narrowband interoperability could be substantial. Flexible use of the public safety narrowband spectrum can have a negative effect on regional, statewide, and nationwide interoperability. If there are agencies or municipalities in different parts of the country, or even in different parts of a state or 700 MHz Region, that opt for a broadband network while other agencies continue to operate on narrowband networks, there will be problems when these agencies or municipalities need to provide mutual aid assistance during emergencies. Given the current state of broadband technology, maintaining interoperability in this case would require multiple radios—which is precisely the scenario that all of the efforts to establish interoperability to date are striving to eliminate. Also, the interoperability channels in the public safety narrowband allocation are interleaved with other types of channels throughout the band. Any rearrangement of the channels in the band to accommodate flexible use would likely to require the elimination of some of these channels. If different 700 MHz Regions adopt different approaches to "Flexible Use" and end up with different sets of700 MHz narrowband interoperability channels, then any possibility of interoperability between or among different Regions would be either eliminated or seriously limited.

Flexible Use Creates Certain Interference

Broadband cannot coexist with narrowband uses within the 700 MHz narrowband band segment because interference and degradation of narrowband radio performance is certain. Direct interference to public safety narrowband subscriber unit receivers from an LTE broadband downlink signal operating on "co-channel" spectrum would appear as noise, effectively reducing the sensitivity of the narrowband receiver. Even in cases where the LTE system and the narrowband public safety systems operate in adjacent segments of spectrum (e.g. the PSTT and/or D Block broadband spectrum and the PSNB narrowband spectrum, or two different segments of the PSNB spectrum) interference to narrowband subscriber units will also occur in the vicinity of broadband base station sites. This interference would present itself in two forms: out of band emissions which would cause direct interference to the desired narrowband signal and indirect interference to the subscriber unit receiver in the form of intermodulation and/or receiver desensitization (caused by strong undesired LTE signals affecting the RF stages of the narrowband subscriber unit). These are the same mechanisms that are the basis for the well-established interference to public safety systems by Sprint-Nextel systems in the 800 MHz band. Because an LTE system might operate in an adjacent frequency band, as opposed to having cell sites operating on frequencies interleaved with public safety frequencies as is the case with Sprint-Nextel, and because an LTE "channel" occupies more bandwidth than a Sprint-Nextel channel (even at the lowest bandwidth versions of LTE), the interference circumstances are not identical for the two cases. However, it should be noted that that the basic interference mechanisms are the same in both cases and that the received signal power threshold at which intermodulation interference will be produced in the victim narrowband receiver it likely to be similar for both cases. For geographically separated LTE and public safety narrowband system operating in the same segment of spectrum, which might occur in the case of "Flexible Use" in the public safety narrow band —the interference mechanism would be direct co-channel interference[19].

19 Attachment A contains a much more detailed technical discussion of interference issues and impacts of flexible use.

Conclusions

1 *It remains unknown if public safety will prevail in both the D-Block argument and federal funding for public safety broadband networks.*

The FCC is unlikely to back down on its position that public safety has enough spectrum, and instead needs more efficient network architectures and equipment. Congress' ability to push forward law to mandate the allocation and federal funding seems more unlikely with the new Congress. It may be likely that a delay in policy on this issue will continue, while a push will be made by the FCC to address and define roaming and prioritization standards for public safety on LTE networks. This policy push will be useful to public safety regardless of how the D-Block argument resolves, because prioritization and roaming standards for LTE will be extremely important for public safety anyway. Waiver recipients building LTE networks in the PSST spectrum need prioritization and roaming standards defined for the operation of their own networks. While these might only address prioritization and pre-emption issues between and among public safety agencies, the standardization of an approach is essential to interoperability and efficiency on LTE networks[20]. Whether the network includes D-Block spectrum or not, the definition of prioritization and pre-emption should not be left to individual network providers, and will define the efficacy of the networks in emergency operations mode, when contention for spectrum can be expected.

Moreover, however the D-Block issue is resolved, public safety can expect to benefit from defined roaming and priority rights on commercial networks. It is very likely that end user equipment purchased for LTE networks will be software-definable to allow operation across both the D-Block and PSST block, and likely that they will be capable of operating on the A and C Blocks as well. In order to benefit fully from the ability to roam, prioritization and pre-emption standards should be uniform across all commercial networks, and among all public safety services and entities. Efforts to define these standards, which appear to be all but non-existent today, are perhaps as important to address as the acquisition of the D-Block.

Public safety has generally taken the position that, to build LTE networks with the coverage and capacity needed in rural and wilderness areas, the PSST 10 MHz will not be sufficient. They claim a need for the D-Block to allow high-power, high-site placements, rather than low-site, dense cell architectures generally used in the cellular industry. This system design would allow more coverage more economically, but it also requires more spectrum. One possible policy outcome is a partnership between public safety and a commercial D-Block licensee that pools spectrum from both blocks, and shares infrastructure to allow the development of these types of architectures in more rural areas. Such an outcome would rely heavily on defined roaming, prioritization and pre-emption agreements between public safety and commercial network owners.

2 *In the short term, Flexible Use is at best a premature discussion, and at worst a full assault on public safety's ability to develop standards-*

[20] LTE networks have 15 levels of Allocation and Retention Priority, and 9 Quality Class Identifyers (QCIs). The assignment of these attributes to packet traffic is managed by a Policy Charging and Rules Function (PCRF) within the network's Evolved Packet Core (EPC). However, the PCRF function in the network is optional, and controlled by the network owner. Thus, without standards on policy management and the architecture of the EPC, each LTE network could treat the same types of public safety uses differently.

based interoperable push-to-talk networks.

It is certain the record created in the Flexible Use inquiry will establish the fact that public safety is using the 700 MHz public safety narrowband allocation, and actively involved in building networks all across the nation. This spectrum is no longer a "greenfield" with potential for re-purposing. In many regions, including Region 43, and King County in specific, millions have been invested to create interoperable, standards-based public safety networks, under a regulatory regime that seemed certain, and with owner confidence that these networks could be upgraded, expanded and maintained for the next 20 years. The actions by the FCC to suggest that the 700 MHz band be re-apportioned for a third time, and that narrowband channels be curtailed or eliminated reveal a misinformed Public Safety and Homeland Security Bureau staff, and a full-press lobbying effort by wireless carriers to knock public safety radio users aside in favor of their commercial interest in developing scarce spectrum resources for other, more profitable uses.

3 In the Long-Term Voice over Broadband may become the standard, and public safety and transit should begin preparing for this.

Looking **at least a decade into the future**, it is likely that narrowband LMR will become a niche market of private networks rather than a system of systems for emergency response as was envisioned by DHS and APCO only five years ago. LMR is simply not as spectrally efficient as emerging cellular technologies, nor do manufacturers see enough of a future market, based on national spectrum policy for continued development of more affordable and more capable network systems. Those with investments in today's LMR technologies are facing a possible wholesale technology change in the next generation of systems. Loss of federal support for the development and mandate of P-25 systems in favor of adaptation of cellular network design and air-interfaces, and all-IP functionality is pretty clearly the direction suggested by this Commission's leadership and the carrier industry. LTE Advanced standards are currently being developed, and these will include voice applications. It is unknown whether they will also include the one-to-many, dispatch and other types of operations that public safety and transit need, but these are likely in the next decade. There is a high demand for these types of applications, not only from public safety, but from other user communities including health, construction, energy and transit. Though public safety is fighting on a number of fronts to retain narrowband LMR configurations while also fighting for licenses and funding on the broadband front, its message is getting diluted and dichotomized. We believe that LMR is likely to go the way of analog broadcast TV (which was "retired" in 2008) within 15-20 years, or perhaps sooner. There is so much evidence that applications can be developed for digital, IP networks, and as markets address these needs, LMR will become less and less pervasive. As the market shrinks, development of new products for LMR will cease. This could leave existing LMR system owners with a risk of a "gap" where newer all-IP architectures do not contain the same operability that they are accustomed to in current operational modes. There may be a risk of needing to migrate narrowband applications to LTE "as-is."

A smart strategy long term will be to continue to pressure for local control through RPCs of frequency planning and allocation in all public safety LMR bands [NOTE: the RPCs now only function in the 700 MHz and 800 MHz bands, not in the VHF and UHF bands], and continuous protection for "incumbent" 700 MHz narrowband networks, while understanding that *the new world in the broadband allocations is about prioritization, preemption and public-private partnerships, and less about stand-alone overbuilding of public safety infrastructure*. In the broadband arena, successful networks will be partnerships, serving multiple communities of interest (public safety, government, education, health, transit, energy) on a priority basis, with commercial consumer traffic mixed in the backbone network. Future network architecture for public safety users is all about applications; those that control priority and preemption; those that control security and authentication; and those that control roaming and push-to-talk voice. To make progress in these areas, public safety needs to invest heavily in standards development, with industry partners and government, that govern the operation of all broadband networks in this country, much like the standards that govern 911 efforts on voice networks.

Next Steps

It is certain that policy for the use and future allocation of public safety spectrum will change. Vigilance on both spectrum policy and technology development is highly recommended. The current public safety and transit advocacy groups' efforts are not effective enough or unified enough in standards and technology assessment areas. Their approach relies too heavily on anecdotal justifications for a blanket spectrum preference. Public safety advocates should rely more heavily on expert technology and research and development advisors and less on vendors and practitioner organizations than they have in the past. The landscape for public safety and transit communications will change rapidly, moving toward all-IP based networks, with digital voice applications. These users should:

1. Continue to develop expert information and technology assessment sources to monitor the technical and policy landscape and advise them more accurately on emerging technologies. Academic institutions, the Institute of Electrical and Electronics Engineers (IEEE), and policy organizations such as the Silicon Flatirons Center and the Aspen Institute are all informed institutions that public safety and transit organizations could benefit from.
2. Begin authoring a set of needs/requirements documents that address functionality and operability requirements of public safety and transit for IP based technologies such as LTE. Gain wide national acceptance and participation in such standards efforts.
3. Suggest revisions to the National Broadband Plan (NBP), the Intelligent Transportation System (ITS) plans, and participate actively and thoughtfully in FCC Notices of Inquiry to insure that the record on needs and standardized requirements is thorough, technically sound and not anecdotal.
4. Put local resources into contingency planning, strategic planning and needs assessments now, so that the options and opportunities are clear.

Attachment A
Public Safety Broadband Systems and "Flexible Use" – Technical and Operational Issues

ATTACHMENT A – PUBLIC SAFETY BROADBAND SYSTEMS AND “FLEXIBLE USE” – TECHNICAL AND OPERATIONAL ISSUES

Introduction

This report contains a detailed evaluation of operational and technical issues related to the implementation of public safety broadband systems, both in the Public Safety Broadband (“PSBB”) segment of the 700 MHz Band licensed to the Public Safety Spectrum Trust (“PSST”) and in the D-Block; and to the FCC’s request for comments[21] on the technical and operational feasibility “Flexible Use” of the 700 MHz narrowband (“PSNB”) spectrum. The report addresses the potential for future use of broadband systems for public safety voice communications and shared use of commercial broadband networks by public safety users; licensing issues related to the FCC’s “Flexible Use” proposal (especially with respect to the U.S.-Canada Border Zone) and the availability of “alternate” narrowband spectrum outside the 700 MHz band; and interference issues between broadband and existing narrowband public safety systems.

Potential for Future Use of Broadband Systems for Public Safety Voice Communications

Compatibility Issues

The discussion of compatibility issues that follows centers on LTE broadband systems. However, the same issues exist for other broadband technologies, such as WiMax. LTE and narrowband integrated voice and data systems, such as P25 systems, use different modulation and access schemes. LTE uses OFDMA and the narrowband P25 systems use a combination of FDMA and (with the adoption of a P25 Phase 2 Standard) TDMA. These technologies are not compatible with each other and a single radio has not been developed to operate on both types of systems. Currently commercial implementations of LTE will be used for data only services and radios, or modems, for this service are connected or integrated into MDTs, laptop, PDAs and other types of mobile broadband devices. Voice operation on LTE is still a number of years away and will be IP based. In the initial implementation of LTE by service providers in the U.S. will still use existing circuit switched 3G networks for voice communications.

There are companies that are in the process of forming joint ventures that are proposing to provide the public safety community with equipment for operation on P25 networks overlaid with broadband LTE networks. Although this will provide a combined voice and high-speed data network with some integration in the 700 MHz spectrum the narrowband and broadband systems will be operating in separate frequency bands and there will still be the need for separate user equipment for each service, as there are no radios currently being manufactured to provide dual operation on these different infrastructures.

Priority Access

Although this is not an issue for broadband systems owned and operated by public safety or local

[21] DA 10-1877 - *Public Safety and Homeland Security Bureau Seeks Comment on the Technical and Operational Feasibility of Enabling Flexible Use of the 700 MHz Public Safety Narrowband Allocation and Guard Band for Broadband Services*; Released: September 28, 2010.

government agencies, such as those that might be implemented under a "Flexible Use" policy, priority will certainly be an issue for networks that carry both commercial and public safety traffic (as the D Block systems may if the D Block is auctioned to a commercial carrier). The discussion of the use of commercial broadband networks by public safety agencies includes the assertion that modern broadband networks include traffic management features that allow public safety traffic to have priority when it is needed. Priority certainly needs to be given to Public Safety (PS) both during normal day-to-day operations and a much higher level of priority is needed during disasters and/or major incidents, which means carriers may have to severely restrict or cut off commercial traffic completely in order not to overload the network when a significant amount of capacity is needed by public safety users. A guarantee of priority access is not enough to meet the needs of public safety users in the case of a major incident. What is required is preemption, which would drop all traffic except the highest priority traffic (i.e. public safety traffic). It is extremely unlikely that a commercial operator would allow outright preemption on its network.

Existing cellular networks can be brought to their knees by events as simple as a snowstorm during which large numbers of users are stuck in fixed locations and their calls overload a single cell site or multiple cell sites. Natural disasters (e.g. Hurricane Katrina) also lead to system overload and system outage, especially since commercial cellular systems are not built to the "survivability" standards of public safety narrowband networks. If PS and commercial users are on the same network it may not matter what kind of priority is given to public safety if the network is overloaded and no one can get through.

During a natural disaster such as a flood the dense low elevation sites of an LTE network could be completely knocked out, in the case of a flood, hurricane or earthquake. This not only leaves the commercial users with out service but would also leave the PS community without service in a time when it's needed most.

There is much discussion of QOS and other mechanisms available in LTE to provide priority access, but the discussion is largely theoretical, since there are no operational LTE systems in the U.S. on which to test how well these priority systems actually work in practice, nor is there a shared public safety/commercial LTE system operating anywhere today. It has often been the case with commercial cellular technologies that the practical reality of capacity, throughput, and access schemes in real systems falls short of the theoretical promise.

"Flexible Use" and Interoperability

Flexible use of the PS narrowband spectrum can have a negative effect on regional, statewide, and nationwide interoperability. If there are agencies or municipalities in different parts of the country, or even in different parts of a state or 700 MHz Region, that opt for a broadband network while other agencies continue to operate on narrowband networks, there will be problems when these agencies or municipalities respond to help out during emergencies. Given the current state of broadband technology, maintaining interoperability in this case would require multiple radios—which is precisely the scenario that all of the efforts to establish interoperability to date are striving to eliminate.

Also, the interoperability channels in the PSNB band are interleaved with other types of channels throughout the band. Any rearrangement of the channels in the PSNB to accommodate flexible use would likely to require the elimination of some of these channels (or the elimination of some other channels, such as general use or statewide channels). If different 700 MHz Regions adopt different approaches to "Flexible Use" and end up with different sets of 700 MHz narrowband interoperability channels, then any possibility of interoperability between or among different Regions would be either eliminated or seriously limited.

Deployment costs

King County covers a total land area of 2,134 square miles, with much of the eastern half of the County heavily forested and mountainous. Throughout the County, the terrain is irregular and relatively rough, such that providing narrowband coverage of the entire County is challenging. The County's public safety operations require coverage of the entire County, including the unpopulated portions, to support search and rescue and wild land fire operations. If the existing narrowband 700 and 800 MHz radio systems were to be replaced by broadband systems, the number of base station sites that would be required to provide broadband voice and data service would be significantly larger than the number of sites now required to provide narrowband voice coverage.

The existing King County Metro voice and data radio system has a total of 8 sites, while the existing King County Regional 800 MHz Radio System has a total of 27 sites. An LTE system intended to provide coverage similar to the coverage provided by these existing systems would be likely to require 150 or more sites. The existing Nextel cellular system uses more than 90 sites to provide coverage in the urbanized area of King County, and even with that many sites, some of the rural portions of the County do not have adequate coverage; an LTE system would require even higher site density than the existing Nextel system.

Transit's requirements for voice communications differ significantly from those of Public Safety, such that Transit and Public Safety have two separate narrowband voice radio systems (for reasons that have been well documented in a number of previous King County reports). However, Transit's requirements for County-wide coverage are similar to those of Public Safety. Any broadband system intended to replace the existing narrowband voice radio systems would need to meet the needs of both Public Safety and Transit in King County, in terms of both functionality and coverage, so such a system would need to "duplicate" the operational features, capacity and coverage of both existing radio systems.

Transit could conceivably port its vehicle location and other data functions over to LTE, but this still would not address the core voice applications of one-to-many dispatch communications that are needed to effectively manage large fleets and widely dispersed maintenance, supervisory and support staff.

The County has invested more than 15years and nearly $100M in the development and implementation of its existing narrowband voice and data radio systems. Replacing these systems with a broadband system or systems which will be much more expensive than the existing systems does not make good fiscal sense, even if these systems could provide the voice and data communications needs of both Public Safety and Transit in King County—and currently these systems do not provide the required functionality for either Public Safety or Transit.

The time and budget required to develop and maintain broadband systems intended to replace those systems is likely to require more time and significantly more money than the existing systems, such that it may be beyond the capability of County to implement these systems.

Implementation of shared-use broadband systems by commercial providers has been part of the ongoing discussion of broadband system implementation between the public safety community and the FCC. Based on the track record of existing commercial cellular systems, a commercial broadband system is extremely unlikely to provide coverage over the entire area of King County. There are significant portions of the County that do not now have 3G, 2G, or even basic voice coverage from commercial cellular systems.

Given the kinds of site density required for LTE broadband systems, the cost involved in providing the level of coverage required by King County's public safety operations, which is now provided by narrowband systems, will be prohibitive even for a commercial provider with funding support from the federal government. For example, the LTE systems now being implemented by Verizon use site spacing of less than one mile in densely populated urban areas in order to provide adequate coverage and capacity in these areas. Site spacing will be larger in less densely populated areas than in rural areas, but the total number of sites required to provide coverage equivalent to existing narrowband coverage will be much larger than the number of sites used in typical narrowband systems such as those employed in King County, as described above

The assumption underlying the concept of a Public Safety broadband network operating on infrastructure provided by one or more commercial carriers (which is the model for the kind of "public-private" nationwide broadband network proposed in the FCC's broadband planning documents) is that commercial broadband networks will expand to meet the coverage and capacity needs of Public Safety users. There is little or no historical evidence to support this assumption. Commercial networks provide service only where there is a sufficient number of subscribers to justify the cost of building out the required infrastructure. This means that sparsely populated or unpopulated areas seldom receive adequate coverage from commercial wireless systems unless they happen to be adjacent to a major highway.

Also, the high elevation sites used in narrowband systems to provide wide area coverage are not likely to be suitable for LTE networks, since they will be likely to produce excessive co-channel interference in the lower elevation portions of the network.

The backhaul systems for LTE networks require a much larger number of links than those used in a typical public safety narrowband system, and they require significantly more bandwidth. Backhaul requirements for a typical public safety narrowband system repeater site might be one or two T1 circuits, while links to each site in an LTE network would typically be Gigabit Ethernet. Public safety systems typically employ licensed microwave systems for backhaul for reliability and cost reasons, while commercial cellular systems usually employ leased circuits—primarily landlines (microwave links are usually employed on cellular systems only when leased landlines are not available). There are significant issues of cost, reliability, and microwave system spectrum availability related to the provision of backhaul to a large number of broadband cell sites.

Dispatch Functionality and Talk Around

In a broadband network used for voice communications (once that application becomes available over broadband networks, whether the network is operated by a public safety entity or by a commercial carrier, there will need to be a connection between public safety dispatch centers and the broadband network if the broadband network is going to be used for voice communications in day-to-day operations or in tactical and emergency situations. Broadband networks currently do not have the capability to carry voice communications, and the voice application that is likely to be developed first (for commercial reasons) is one-to-one voice communications. One-to-many, or multicast voice communication is much more typical of dispatch operations and for normal "push-to-talk" communications among users in a given workgroup. This type on communication is vital to public safety and transit agencies and allows for the quick dissemination of information to persons in the field and for efficient command and control during major incidents. It is not clear when this type of functionality will be available on broadband systems, but it is certainly not available today.

Simplex or "talk around" operation of radios is also very vital to public safety to ensure communication when radios are not able to connect to the network, or to move traffic off of the backbone network in situations where large number of users need to communicate over a small area (such as a fire ground scene), or when fire fighters or other first responders need to enter buildings where coverage from the network is inadequate, or when the network is inoperable due to a natural disaster or other large scale incident. Broadband networks do not provide any provision for "talk-around" functionality, nor does such functionality appear to be on the development roadmap for these systems. "Off-network" features, such as talk around, are not likely to ever be incorporated into broadband systems standards because these standards are driven the requirement of the largest global commercial cellular carriers, and not by Public Safety. The U.S. Public Safety market is 4.1 Million[22] units of a total of 323 Million units (comprising 1.3% of the U.S. Market share). The North American market as a whole is only 6%[23] of the worldwide market. Therefore Public Safety would represent only a tiny fraction of a percent of the global market for services from these providers; hence they are very unlikely to modify their standards based on "odd" system features required by the Public Safety market.

Broadband Data Rates

LTE touts theoretical data rates of 100Mbps or more, but this is for a bandwidth of 20MHz and using up to 4X4 MIMO antenna systems. These data rates will be reduced drastically when using 1.4 or 3 MHz bandwidth without MIMO which would be a much more likely system configuration for "Flexible Use" broadband systems in the PSNB band. These data rates would be reduced even more when there are many users on the network and in an area where there is an emergency when there are firefighters, police and EMS using the system simultaneously; in some circumstances, this kind of scenario might even cripple the network. In a shared commercial system, these capacity issues would be exacerbated by the commercial users that would be accessing the system at the same time as public safety users.

T-Mobile ex parte Presentation

The ex parte presentation submitted to the FCC by T-Mobile[24] contains a number of assertions in support of its arguments that public safety agencies already have more than enough narrowband spectrum and that the 700 MHz PSNB band should be converted to broadband spectrum which are at

[22] Informa Telecoms & Media, WCIS+, September 2010

[23] Public Safety Communications Research Winter 2010 Meeting, Boulder CO.

[24] *Ex Parte* Letter from Thomas J. Sugrue, Vice President Government Affairs, T-Mobile USA, Inc. to Marlene H. Dortch, Secretary, Federal Communications Commission, August 24, 2010; (and attached *Whitepaper: Technical Analysis of the Proposed 700 MHz D-Block Auction*, dated August 23, 2010)

best wild exaggerations, and at worst simply untrue.

The assumption that the narrowbanding process in the UHF band will produce a 4:1 increase in voice channels once the transition is made to 6.25 kHz channels assumes a perfect world, and does not take into account the realities of frequency coordination, shared spectrum, and prohibited contour overlap in the UHF and VHF bands. Nor does it consider the situation in the U.S.-Canada Border Zone, where half the spectrum is licensed in Canada and it is therefore very difficult, it not impossible, to license those channels--especially in the northern portion of the Border Zone north of Line A, but also at some elevated sites further south (and even south of Line A) because operation at these sites has the potential to cause interference to Canadian systems.

Based on Hatfield & Dawson's experience in the Puget Sound region (which is extensive), a very optimistic guess is that maybe 20-25% of the VHF and UHF channels that now have prohibited channel overlap at 25 kHz will become clear (in terms of being able to be licensed at usable sites) when adjacent channel users have narrowed their channel bandwidth to 12.5 kHz. This is because nearly all of the "interstitial" 12. 5 kHz channels created by the move to a 12.5 kHz channel bandwidth are already licensed at 12.5 kHz bandwidth close enough to the existing 25 kHz channels that a new 12.5 kHz channel on the channel adjacent to the existing 25 kHz channel in the same location would have prohibited overlap. The circumstances are not likely to improve significantly with the transition to 6.25 kHz channels, especially since the likely transition in public safety systems will be to P25 Phase 2, which will continue to operate on 12. 5 kHz channels with "6.25 kHz equivalent spectrum efficiency". This is not necessarily a simple flash upgrade or even a straightforward equipment replacement process; there may be coverage issues related to the transition from analog or P25 Phase 1 operation to Phase 2 operation. Therefore it is not necessarily correct to assume that migration to Phase 2 operation will provide a straight doubling of voice channel capacity on existing systems. Some system redesign and reallocation of channels may be required to maintain UHF coverage, and this may limit the total number of working channels available to particular user groups relative to the current circumstances.

These circumstances are similar in the more rural portion of Washington east of the Cascade mountain range, so the assumption that there is a significant amount of new UHF spectrum available in rural areas is also incorrect. Other urbanized areas (such as the San Francisco Bay area and the Los Angeles area) and rural areas on the West coast have similar licensing circumstances in the UHF and VHF bands, and we have no doubt the a significant portion of the eastern U.S. has comparable licensing issues.

Since Canada is not narrowbanding its VHF and UHF channels across the board, and because many Canadian UHF channels are licensed for 16 kHz bandwidth (16K0F3E) operation, it is almost never possible to "split" a 25 kHz channel into two adjacent 12.5 kHz channels and license both channels if there are adjacent channel users in Canada because there is spectral overlap between the proposed U.S. channel and the existing Canadian channel. The new 12.5 kHz channel has to remain on the original 25 kHz channel center; it just reduces its bandwidth from 25 kHz to 12.5 kHz, which does not produce any new "spectrum" or any new voice channels (unless it operates in TDMA mode).

The claim that there will be an additional 3.6 MHz of 800 MHz spectrum resulting from 800 MHz rebanding is certainly not true in the U.S.-Canada Border Zone. Because any "new" spectrum that might become available above 854 MHz is Primary to Canada, it has serious licensing restrictions. Also, the band segment from 854-860 MHz is already heavily used in the Puget Sound region (secondary to Canada). It may be that the result of 800 MHz rebanding in the Border Zone is a net reduction in available spectrum, not an increase, because the systems operating in the 3 MHz of spectrum that comprises the pre-rebanding NPSPAC band (866-869 MHz) have to be moved down into the portion of the band between 851 and 854.75 MHz. This portion of the band is already used by existing Public Safety and Industrial Business systems in the Puget Sound Region, so there is no "spare" spectrum in this part of the band. The frequencies above 854.75 MHz and below 862.25 MHz are allocated to Canada as Primary spectrum, so even though this portion of the 800 MHz band is being vacated by Sprint-Nextel, there are significant restrictions on the use of frequencies in this part of the band in the Puget Sound Region. T-Mobile's claim of large spectrum gains from rebanding is even incorrect outside the border zone, especially in urban areas. For example, the number of additional 800 MHz channels available after rebanding in the San Francisco Bay is difficult to determine at present, but it may ultimately amount to a few dozen or even a handful of channels—not 3.6 MHz of additional spectrum.

The T-mobile paper also makes claims about public safety broadband subscriber units doing VOIP over an LTE system being able to take advantage of higher antenna efficiencies typical of public safety equipment to improve coverage. The antennas used on public safety mobile radios may be somewhat more efficient than the antennas used on cell phones, but they are not particularly high efficiency devices. A ¼-wave whip antenna on a 700/800 MHz portable radio (which is the typical antenna used on these radios because users will not tolerate longer antennas) has a gain of -8.6 dBd when used at head level and a gain of -15.4 dBd when used at belt level with a swivel case[25].

The assumption that existing public safety narrowband systems can simply pick up and move to 800 MHz or UHF, when those in the Puget Sound region (and many other areas) already have enormous investments in narrowband infrastructure and portable/mobile equipment is completely unrealistic. The only realistic source of new narrowband voice channels for these systems is the current set of narrowband channels in 700 MHz—especially in Puget Sound where the UHF band is already full to overflowing, and suffers from extremely limited licensing opportunities on both the domestic and Canadian fronts. T-Mobile's assumption that narrowbanding in the UHF band will result in a 4:1 increase in the number of available channels does not take into account the complexity of frequency coordination, licensing, and treaty issues in an area like the Puget Sound region. Even after the initial transition to 12.5 kHz operation is completed at the end of 2012, it will still be difficult to find UHF channel suitable for use in wide-area county-wide or regional narrowband radio systems because existing channels in the region already operate with extensive contour overlap and because the shared use of the UHF spectrum with Canada makes many potential UHF channels unusable at elevated sites in the region.

Licensing and U.S.-Canada Border Zone Issues

U.S.-Canada Border Zone Issues

Currently, King County has 700 MHz frequencies licensed throughout the PSNB band, in part because of coordination requirements with other 700 MHz systems in the region, and in part because of the requirement to use U.S. Primary 700 MHz channels to implement systems with wide area coverage in

[25] "*Portable Radio Antenna Performance in the 150, 450, 800, and 900 MHz Bands 'Outside' and In-Vehicle*", Casey Hill and Tom Kneisel, IEEE Transactions on Vehicular Technology, Vol. No. 40, No. 4, November 1991

the Puget Sound Region. (This is also true with respect to other 700 MHz systems licensed in the Puget Sound Region). The lowest base station transmit frequency used in the King County 700 MHz system (licensed under call signs WQHJ934 and WQHJ935) is 769.51875 MHz, while the highest base station transmit frequency is 774.64375 MHz.

The 700 MHz Working Arrangement[26] which governs the use of the 700 MHz public safety band in Sharing Zone II (which extends 140 kilometers into each country along each side of the U.S. Canada border, and which encompasses much of the Puget Sound Region), divides the 700 MHz narrowband spectrum in the PSNB band into two sets of channels: one set has Primary status in the U.S. and Secondary status in Canada, while the other set has Primary status in Canada and Secondary status in the U.S. The blocks of channels which are Primary in Canada and those which are Primary in the U.S. are interleaved within the narrowband segment of the 700 MHz public safety band. Channels which are Primary in one country may be used in the other country, but they are subject to rather severe restrictions on allowable RF power flux density levels at the border of the Primary country.

The nature of the topography in the Puget Sound Region, the close proximity of major urbanized areas on both sides of the U.S.-Canada border, and the location of the border itself in the northern portion of the Puget Sound region all make the engineering of 700 MHz systems in this region a formidable challenge. It is especially difficult to make use of Canadian Primary 700 MHz narrowband channels at elevated sites that provide wide-area coverage in the Puget Sound Region, while simultaneously meeting the power flux density limits at the Canadian border.

All of the factors described above severely limit the ability of agencies implementing 700 MHz narrowband systems either entirely or partially within Sharing Zone II to select appropriate 700 MHz channels for new systems in the region, and to find alternate channels for existing systems if these systems needed to be reconfigured to accommodate potential broadband systems operating in the PSNB band in the Puget Sound Region. The existing 700 MHz narrowband voice radio systems in the Puget Sound region are simulcast systems which use the same channel set at each base station repeater site in a simulcast “cell” (which consists of multiple sites). Therefore, any limitations on channel use imposed by Sharing Zone II requirements typically also extend to simulcast sites outside the Sharing Zone, since the same channels are used at all of the simulcast sites.

Any attempt to reassign existing licensed 700 MHz narrowband channels now used in licensed systems in the Puget Sound region in order to provide enough clear spectrum to implement a broadband system within the narrowband spectrum block within the Puget Sound Region would be an extremely difficult and time-consuming undertaking, not unlike the ongoing 800 MHz Rebanding process. It would also be expensive, since it would require a significant level of engineering effort to produce a frequency reallocation plan for multiple existing systems and it would be costly to reconfigure the existing systems to operate on new frequencies. Unlike 800 MHz Rebanding, where Sprint/Nextel covered the nominal costs of system reconfiguration, there is no obvious funding source for this work.

An additional consideration that affects the ability to implement broadband systems in the narrowband segment of the 700 MHz public safety band within Sharing Zone II is that the channel plan shown in

[26] Arrangement G – Sharing Arrangement Between the Department of Industry Canada and the Federal Communications Commission of the United States of America Concerning the use of the Frequency Bands 764 to 776 MHz and 794 to 806 MHz by the Land Mobile Service along the Canada-United States Border; June 2005

Arrangement G does not contemplate the use of broadband channels within the PSNB band segment. Presumably, this would require additional “harmonization” of Arrangement G beyond the changes now under consideration in Canada (these changes would realign the 700 MHz narrowband spectrum blocks in Canada so that they match those already implemented in the U.S. by the FCC).

LTE systems can operate in 1.4, 3, 5, 10, 15 and 20 MHz channels. The largest LTE channel bandwidth that could be used in the 700 MHz PSBB band or in the PSNB band would be 5 MHz. If LTE and narrowband operations were to be intermingled in the same spectrum in the PSNB band and in the same geographical area, the LTE system would need to operate in a 3 MHz channel or a 1.4 MHz channel in order to allow the remaining portion of the band (2 MHz or 3.6 MHz, respectively) to be used for narrowband operations. Because a portion of the PSNB band in the Puget Sound Region is assigned to Canada as primary spectrum and has limitations imposed by border protection requirements, it cannot be assumed that all of the PSNB spectrum that is not used for broadband system operation can be used by existing (or future) narrowband systems. “Flexible Use” of the PSNB spectrum for both broadband and narrowband systems in the same geographical area in the Puget Sound Region would severely limit the ability to operate or expand existing narrowband system or to implement new narrowband systems in the Region. Such use is probably not even possible, given the current configurations of existing systems and the limitations imposed by operation in the U.S.-Canada Border Zone.

Statewide Licensing in the 700 MHz Narrowband

The existing bandplan for the 700 MHz narrowband band segment includes a block of frequencies that are licensed to each state for use in statewide networks. These frequencies can also be integrated into regional networks to provide capacity for both state and local public safety agencies. These channels are interleaved with the other types of channels (general use, low power, interoperability) in the 700 MHz narrowband bandplan. A number of states have plans to implement statewide narrowband systems using these channels (Oregon [Region 35] is in the process of implementing such a system, and Washington [Region 43] has extensive planning documents that contemplate such a system). Because a statewide system would cover an entire state (as its name implies), allocating a section of the 700 MHz narrowband allocation for “Flexible Use” broadband operation would require moving the state licensed channels to a different portion of the PSNB band, which would also require a similar “reshuffling” of the general use channels used in local and regional systems. All of the Border Zone issues, implementation, and cost issues described above for the systems in the Puget Sound region would also apply to the state license channels and to statewide systems in the State of Washington. The interference issues described below would also apply statewide in the case of a statewide narrowband 700 MHz system, and because these channels would be used statewide, the potential for any geographic separation (which is required to prevent interference between broadband and narrowband systems) in the PSNB band would be effectively eliminated.

Interference Issues

The interference mechanisms described below are essentially the same for any form of digital broadband system. The two technologies that have the potential for implementation in frequency bands adjacent to 700 MHz public safety spectrum are WiMax and LTE. These two system technologies use very similar channel access and modulation schemes and operate in similar bandwidths. Therefore, the descriptions of potential interference mechanisms shown below apply equally to WiMax and LTE systems. In the case of recent waivers granted to state and local government entities to construct broadband systems in the 700 MHz PSST public safety broadband segment ("PSBB"), the FCC has mandated the use of LTE for these systems. It is also likely that any systems that might eventually be implemented in the 700 MHz public safety narrowband ("PSNB") segment under the "Flexible Use" policy will also use LTE technology.

Broadband to Narrowband Interference

There are two distinct interference mechanisms that have the potential to degrade the performance of 700 MHz narrowband systems operating in proximity to broadband systems in the 700 MHz band (especially those systems operating in the D Block, the public safety broadband 700 MHz band now licensed to the PSST ("PSBB"), and any systems that might operate in the public safety narrowband segment ("PSNB") under the FCC's proposed "Flexible Use" policy).

The first mechanism is direct interference to public safety narrowband subscriber units by downlink signals broadcast from the broadband system's cell sites. In the case of a broadband system operating in the D Block, there is enough frequency separation between the D block frequencies and the PSNB frequencies that any out-of-band emissions from the broadband system will sufficiently attenuated that they will not be a source of interference within the PSNB band. In the case of a broadband system operating in the 700 MHz PSBB band adjacent to the 700 MHz PSNB band, interference may be an issue in the lower segment of the PSNB band due to "out-of-band" emissions generated by the broadband system's transmitters. In the case of a broadband system operating in the 700 MHz PSNB band (under the proposed "Flexible Use" policy), there is potential for interference both from the desired "in-band" signals of the broadband system (if public safety narrowband subscriber units in the same block of spectrum as the broadband system) and from "out-of-band" emissions from the broadband system if the broadband and narrowband systems operate in different segments of the PSNB band. The discussions of interference mechanisms that follow refer to LTE broadband systems; however, they apply equally to other broadband technologies, such as WiMax.

Direct interference to public safety narrowband subscriber unit receivers from an LTE broadband downlink signal would appear as noise. This LTE "noise" would add directly to the thermal noise already present in a subscribe unit receiver raise the noise floor of the narrowband subscriber unit's receiver, effectively reducing the sensitivity of the receiver, essentially by the amount the noise floor is raised by the LTE signal.

For co-channel interference (where the LTE system and the narrowband public safety system operate in the same segment of spectrum) the narrowband subscriber unit's receiver noise floor would be raised by the power of the portion of the LTE signal falling within the passband of the subscriber unit's preselector filter. How much impact this would have would depend upon the relative physical locations of the LTE site (or sites, since the noise from multiple sites would be cumulative) and the narrowband subscriber unit.

Interference in cases where the LTE system and the narrowband public safety systems operate in adjacent segments of spectrum would present itself in two forms: out of band emissions (which would cause direct interference to the desired narrowband signal) and subscriber unit receiver intermodulation and/or receiver desensitization (which are indirect effects caused by strong undesired LTE signals affecting the RF stages of the narrowband subscriber unit) These are the same mechanisms that are the basis for the well-established interference to public safety systems by Nextel systems in the 800 MHz band. Because an LTE system would operate in an adjacent frequency band, as opposed to having cell sites operating on frequencies interleaved with public safety frequencies, and because an LTE "channel" occupies more bandwidth than a Nextel channel (even at the lowest bandwidth versions of LTE), the interference circumstances are not identical for the two cases; however, it should be noted that that the basic interference mechanisms are the same in both cases and that the received signal power threshold at which intermodulation interference will be produced in the victim narrowband receiver it likely to be similar for both cases. For geographically separated LTE and PSNB systems operating in the same segment of spectrum, which might occur in the case of "Flexible Use" in the PSNB band—the interference mechanism would be direct co-channel interference (described above).

Out of Band Emissions

Out of band emissions are the undesired spurious signals or "noise" that fall outside a transmitter's channel bandwidth. This sideband noise will appear on the adjacent channel and will raise the noise floor of a receiver on that channel.

With respect to out-of-band emissions, the FCC's Rules specify the current OOBE (Out of Band Emission) power limit for public safety broadband systems operating in the 763-768/793-798 MHz public safety broadband (PSBB) band segments as -46 dBm in any 6.25 kHz channel within the PSNB base station and mobile transmit bands (769-775 MHz and 799-805 MHz)[27]. This is equivalent to a spectral power density of -84 dBm/Hz at the antenna terminals of the broadband base station. Assuming a transmitter output power of 40 Watts for the broadband base station, it is possible to calculate the spectral power density (in dBm/Hz) of the OOBE "noise" at the antenna terminals of a typical narrowband public safety subscriber unit operating in the vicinity of a typical broadband "cell" site as shown below in Table 1:

Broadband Base Station TPO	+46 dBm (40 Watts)
OOBE Spectral Power Density at BB TX Output	-84 dBm/Hz
Broadband Base Station Antenna System Net Gain	+14 dBd
Free Space Path Loss @ 769 MHz	-75 dB @ 950 feet from base station antenna
Narrowband Subscriber Unit Antenna Gain	-9 dBd (Portable radio at head level)
OOBE Spectral Power Density at NB Subscriber Unit RX Input	-154 dBm/Hz

Table 1- Broadband OOBE Spectral Power Density at Narrowband Subscriber Unit

Assuming that the narrowband subscriber unit has a Noise Figure (NF) of 8 dB, its thermal noise floor will be (-174 +8) = -166 dBm/Hz. As shown in Table 1, the OOBE "noise" has a power level 12 dB higher than the thermal noise floor. The composite sum of the thermal noise floor of the radio and the broadband OOBE noise power is 153.7 dBm, which degrades the effective receive sensitivity of the narrowband subscriber unit by 12.3 dB.

As demonstrated above the existing OOBE power limit for broadband systems is not adequate to protect narrowband subscriber units operating in the vicinity of a broadband system cell site when the broadband system operates in the 700 MHz PSBB band (763-768/793-798 MHz), which will be the band used by broadband systems implemented under the various waivers currently granted to local jurisdictions for use of the PSST 700 MHz spectrum. In order to protect narrowband systems, these systems will need to suppress their OOBE levels significantly below the level specified in §90.543(e)(1) of the Commission's Rules.

The circumstances with respect to broadband systems operating in 700 MHz narrowband spectrum adjacent to existing 700 MHz narrowband systems will be comparable to those shown above (assuming

[27] §90.543(e)(1) of the Commission's Rules specifies that emission from PSBB base and fixed stations must be attenuated below the transmitter power (P) within the licensed band(s) of operation, measured in Watts, by a factor not less than 76 + 10 * log (P) in a 6.25 kHz band segment on all frequencies between 769-775 MHz and 799-805 MHz. This is equivalent to an absolute spectral power density of -46 dBm in a 6.25 kHz bandwidth, or -84 dBm/Hz.

that a guard band of at least 1 MHz is provided between the frequencies used by the broadband system and the frequencies used by the narrowband system, as is the case for broadband systems operating in the PSBB band segment).

In order to protect narrowband subscriber units operating in the vicinity of broadband base station sites, the OOBE spectral power density limit should be increased by at least 12 dB, to -58 dBm in a 6.25 kHz band segment. This will result in a 3 dB degradation of the sensitivity of a narrowband subscriber unit at a distance of 950 feet from the base station site. This is likely to be a reasonable compromise between the goal of completely eliminating the effects of broadband system out of band emissions and the tighter transmitter filter requirements imposed on broadband systems by the stricter OOBE limit.

Receiver Intermodulation

Operation of broadband systems and narrowband systems in the same geographical area in adjacent blocks of spectrum has the potential to cause interference to narrowband subscribe units operating in the vicinity of the broadband system's base station sites. Because broadband systems require relatively high signal strengths within their intended service area, these systems will have a large number of sites distributed throughout the service area, with a site density similar to that employed by existing commercial cellular systems. The interference mechanism in this case is receiver desensitization and the production of intermodulation products in the front end of victim narrowband subscriber unit receivers in the presence of broadband signals with high power levels (typically greater than -50 dBm).

The analysis in Table 2 below shows the received signal power levels at a distance of 950 feet from a typical broadband base station site.

Broadband Base Station TPO	+46 dBm (40 Watts)
Broadband Base Station Antenna System Net Gain	+14 dBd
Free Space Path Loss @ 769 MHz	-75 dB @ 950 feet from base station antenna
Narrowband Subscriber Unit Antenna Gain	-9 dBd (Portable radio at head level)
Broadband Signal Power at Narrowband Subscriber Unit Antenna Input	-24 dBm

Table 2 - Broadband Signal Power Levels in the Vicinity of a Broadband Base Station Site

Experience with 800 MHz interference to public safety subscriber units from Sprint/Nextel has shown that this power level (-24 dBm) for the undesired interfering signal will produce significant receiver intermodulation in public safety narrowband subscriber units.

Narrowband receiver intermodulation in the vicinity of broadband base station sites is likely to be an issue even for broadband systems operating in the D Block and the PSBB band; it will be an even more serious issue for broadband systems operating in the PSNB band under a "Flexible Use" policy.

The intermodulation mechanism in receivers is usually thought of as two or more separate signals mixing together; however, in the case of LTE (or WiMax) the signal consists of many sub-carriers and is broad enough that IM can be created by mixing of the subcarrier signals. This intermodulation appears as spectral regrowth at the edges of the signal normal occupied bandwidth and extends out several megahertz from the LTE channel edge. This intermodulation process produces OOBE noise in the LTE transmitter and produces spectral regrowth intermodulation products that appear as noise in the front ends of narrowband subscriber unit receivers. In addition to the intermodulation products produced by each broadband signal itself, there are mix products between and/or among the individual broadband carriers that produce higher levels of intermodulation interference than that produced by a single broadband system by itself.

At the received signal power levels shown above, the desensitization of the receiver created by these intermodulation products can be significant—on the order of 25 dB of degradation is possible if the subscriber unit is operating in the vicinity of a cell site with multiple broadband systems (e.g. a 5 MHz D Block system and a 5 MHz PSBB system—a C Block system will have negligible impact because its signals will be attenuated by the narrowband unit's RF preselector). The addition of a third system within a segment of the PSNB band segment at the same site would increase the severity of the existing two system intermodulation by an additional 5 dB (assuming a 3dB increase in the level of the intermodulation products for each 1 dB increase in the primary interfering signal power).

The potential for this type of interference is increased by the typical design of 700 MHz narrowband subscriber units, which have RF preselectors which do not significantly attenuate signals in the frequency range occupied by the D Block and the PSBB band segment. Because these radios are designed to cover the entire PSNB band segment, their receiver preselectors will have no affect whatsoever on signals from a broadband system operating in the PSNB band.

If a D Block system and a system operating in the PSBB band segment at the same cell site operate at two separate 5 MHz systems (rather than as a single 10 MHz system), the total interfering power at the narrowband subscriber unit's antenna terminal will be 3 dB higher than it would be for a single 10 MHz system. This will produce intermodulation products 9 dB higher than those produced by a single 10 MHz system. Therefore, purely from the standpoint of the potential for interference to narrowband public safety systems, a single 10 MHz system operating over the combined D Block and PSBB frequency range would be preferable to two independent 5 MHz systems in the D Block and PSBB band segment.

To the extent that narrowband base station sites are co-located with broadband base station sites, the effects of both out-of-band emissions and receiver intermodulation could be reduced because the desired signals from the narrowband base stations will have a high enough received signal level to overcome the "noise" produced by the broadband base stations. However, since a broadband system will by definition have a much larger number of base station sites than a narrowband system, the use of co-location will only provide a limited reduction in the potential for interference to narrowband subscriber units.

The other potential issue with co-location is the generation of intermodulation products throughout the narrowband band segment which contain broadband signal components. These mix products could occur both in subscriber units as receiver intermodulation or as passive intermodulation products produced in non-linear junctions (dissimilar metal junctions, "rusty joints", etc.) at the base station site.

Narrowband to Broadband (LTE) Interference

LTE is much more robust and less susceptible to interference than narrowband digital or analog systems, especially when the interference appears in the form of a narrowband signal. LTE employs OFDMA and adaptive modulation and coding to mitigate interference. OFDMA uses OFDM, which splits the signal bandwidth into many sub-carries spaced 15 kHz apart and modulates the individual sub-carriers using QPSK, 16-QAM or 64-QAM. LTE groups these sub-carriers into groups of 12 called resource blocks. OFDMA assigns each user a resource block or group of resource block as needed for their transmission. The LTE user equipment is able to report back to the base sites on the condition of the RF channel and the base site is able to respond accordingly by changing to a slower modulation scheme or by reassigning resource blocks. If portions of an LTE signal have their SNR (Signal-to-Noise Ratio) reduced by interfering narrowband signals the system can change to a more robust modulation so that data can get through. If portions of the LTE signal that are assigned to a user are knocked out altogether by a narrowband signal, the LTE system can reassign that user to different resource blocks.

Since public safety narrowband sites tend to be much more widely distributed than broadband sites, and are often located at elevated sites away from more densely populated lowland areas, interference created by out of band emissions or strong signals in the vicinity of the site from a narrowband base station facility will probably have only minimal impact on broadband subscriber units. However, if narrowband base station sites and broadband base station sites are co-located, strong signals from the narrowband base stations could affect the performance of broadband subscriber units. The impact of strong narrowband signals on broadband subscriber units depends upon the IM rejection and third order intercept specifications for these receivers. Since these receivers have significantly wide receiver bandwidths than narrowband receivers, their IM rejection and third order intercept specifications will be lower that those for a typical narrowband receiver. Without specific subscriber unit specifications, it is not possible to model the potential for this mode of interference. However, since public safety narrowband base station sites will always be significantly fewer than broadband base station sites, the overall impact of this kind of interference will be lower than the broadband to narrowband case.

There might be circumstances in which a large number of public safety narrowband mobiles operate close to an LTE cell site and produce strong signals at the LTE base station receiver on multiple narrowband uplink frequencies. Without specific information about the LTE receiver our-of band rejection specifications and base station filtering characteristics, it is not possible to model what might happen in this circumstance. With 30 or 35 Watt public safety narrowband radios, it is conceivable that receiver intermodulation could be produced in the LTE base station receiver, and that there could be a significant impact on the uplink data throughput at the LTE cell

Narrowband vs. Broadband System Architecture

The way that broadband and narrowband systems are deployed also contributes to interference between the two systems, especially if these systems are operating in the same block of spectrum, as would be the case in the “Flexible Use” of the public safety narrowband block in the 700 MHz band. Public safety LMR sites are usually are high elevation, high powered sites designed to cover a large geographic area. Broadband systems (especially LTE systems) will be built out in cells, or even micro-cells less than a mile apart in densely populated urban areas, in order to accommodate user traffic and data throughput; these systems will operate with relatively low power at each cell compared to LMR sites. Although LTE may operate with lower power than narrowband systems the density of the sites and the closer proximity of these sites to narrowband remotes contributes significantly to the interference problems mentioned above, especially at the edges of the narrowband system coverage area or in shadowed areas, where the narrowband signal is weak. This broadband system architecture also reduces the likelihood of interference from narrowband base station to broadband subscriber units, since these narrowband signals will typically have lower power levels at a broadband subscriber unit than the desired broadband signals.

Potential Mitigation Strategies for OOBE Intermodulation, and Co-Channel Interference

Out of band emission interference my be mitigated by high performance filtering installed at the LTE base station, but if these two systems are operating in the same 6 MHz of spectrum without a guard band the filtering employed in the LTE base stations will not be capable of significantly reducing the level of these emissions at the edge of the channel occupied by the broadband system. A guard band of at least 1 MHz is required to allow for frequency "space" for transmit filters in the broadband transmitters to attenuate the out of band noise produced by the broadband transmitter. It should be noted that a guard band only provides space for filtering of out of band emissions; it does not reduce the potential for other forms of interference, such as receiver intermodulation.

If LTE or other broadband systems and narrowband systems are allowed to operate in the same spectrum block receiver intermodulation (IM) is very likely to occur, since the receiver frontend of these radios will pass the entire block. Receiver intermodulation is of even greater concern than out of band emissions, since this form of interference is the primary source of interference now experienced by public safety narrowband subscriber units from Sprint/Nextel in the 800 MHz band, and it is the form of interference that is likely to affect a significant portion of the PSNB band, not just the portions of the band immediately adjacent to the broadband channel.   It may be possible to limit the impact of this type of interference by providing narrower preselector filters and higher levels of intermodulation rejection in narrowband subscriber receivers, but this would require redesign and replacement of the narrowband subscriber units. New radios with high performance filtering and higher performance receiver front ends would be certain to come at increased cost to public safety agencies who already have limited budgets or who have already spent a large portion of their existing budgets on current narrowband radio infrastructure and subscriber equipment.

Mitigation of Co-Channel Interference (Narrowband and Broadband Systems in the Same Spectrum)

The only way to avoid interference in the case of co-channel interference between narrowband and broadband systems operating in the same spectrum is by using geographic separation. Before any broadband systems are deployed in the PSNB band under the "Flexible Use" policy, specific standards need to be established with respect to the geographic separation required between broadband and narrowband systems to prevent destructive interference to either system. There will be some variation in the required separation between these co-channel systems due to factors such as base station location and operating power (for both narrowband and broadband systems), and differences among regions in the U.S. due to variations in terrain and topography. Although the 700 MHz RPCs should make the ultimate determination of compatibility and potential interference risks with respect to proposed broadband systems and their impact on narrowband systems in a particular region, overall guidelines need to be established to assure that there is consistency across RPC boundaries. In Region 43, for example, it would be possible for Region 43 (Washington) and Region 35 (Oregon) to adopt different criteria with respect to "Flexible Use", which might result in potential interference issues for narrowband systems in the Vancouver, Washington area, from broadband systems in the Portland, Oregon area, which is directly across the Columbia River from Vancouver.

Mitigation will be tedious and time consuming, especially if there are no defined spectrum segments or channels for broadband and narrowband operations in the proposed flexible use of the PSNB spectrum. RPCs will not only need to oversee coordination of the narrowband channels for public safety entities but will have to work with the agencies developing LTE systems on frequency and site coordination to assure that the potential for interference is minimized.

Interference Modeling

Modeling co-channel and adjacent channel interference between a narrowband IV&D system and an LTE system is a difficult task because LTE is a new technology that has an evolving standard. Systems currently deployed in the U.S. are under test and not in use commercially, and equipment is still being developed. Since LTE systems are not fully operational and equipment is in development or non-existent, obtaining information on site locations and system configuration details such as frequency reuse and transmitter power levels is difficult to impossible. Modeling how these systems will work, let alone modeling the likelihood and extent of interference from broadband systems to narrowband systems, will require a detailed understanding of broadband systems and equipment. Even current computer programs used for modeling these systems have limited capabilities, due to the fact that LTE is a new and the standard is evolving.