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FCC White Paper

The Public Safety Nationwide Interoperable Broadband Network: A New Model for Capacity, Performance and Cost

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The Federal Communications Commission ("FCC") has performed a technical analysis of the capacity and performance of the public safety broadband network assuming that the National Broadband Plan recommendations concerning this network are implemented. This analysis includes examining different emergency situations based on actual experiences and as submitted in the record of the National Broadband Plan. This analysis shows:

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 set forth below.
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, 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).

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I. Introduction

In March 2010, the FCC released the National Broadband Plan (NBP), which makes significant recommendations for improving access to broadband communications across America. A critical issue the NBP addressed was how to ensure the availability of broadband communications for public safety and emergency response on a cost-effective and technically feasible basis. For many years this issue has gone unresolved; today the goals of mission critical broadband networks for public safety use and nationwide interoperability for public safety communications have not yet been achieved.

The NBP proposes a cost-effective and technically viable strategy for the creation and deployment of a nationwide interoperable public safety broadband wireless network for first responders and other public safety personnel. The recommendations in the NBP comprise a comprehensive plan to provide the public safety community with the capacity, performance, nationwide coverage, interoperability, technological growth and affordability required for reliable, nationwide, interoperable broadband communications.

The cornerstone of the NBP's public safety recommendations is the utilization of 10 megahertz of dedicated 700 MHz spectrum, currently designated by Congress for public safety use. In order to exploit this asset, the NBP recommends that this spectrum be utilized by public safety agencies through the creation of incentive-based partnerships with commercial entities, such as 700 MHz broadband service providers, to construct the public safety broadband network in a cost-efficient manner by leveraging commercial technologies and infrastructure, with the support of public funding. The NBP also recognizes the importance of commercial use of the D block because it shares the same LTE band class as the public safety broadband spectrum. As the D block is developed and deployed for commercial use, public safety will be able to leverage the commercial economies of scale associated with that band in its own frequency allocation, something the other 700 MHz bands do not offer as affordably.

While 10 megahertz of dedicated spectrum will support the core of the public safety broadband network, the NBP also recognizes that it is critical that the public safety community have access to additional capacity in the worst emergencies. Accordingly, the NBP recommends that the FCC adopt rules to ensure that public safety users are able to roam and obtain priority access on commercial broadband wireless networks— across the 700 MHz band commercial spectrum. The NBP also envisions that coverage and capacity of the public safety broadband network will be supplemented through in-building systems and through provision of deployable cell sites and vehicular relays.

This paper provides the FCC's analysis of why the NBP recommendations will provide public safety users across the country with required broadband wireless network capacity and performance, both on a day-to-day basis and during emergencies, while ensuring that the approach is cost-effective and technically feasible.[2]

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[2] In a separate paper, the Omnibus Broadband Initiative explained in detail the NBP's cost model for the nationwide public safety broadband network. *See* Omnibus Broadband Initiative, A Broadband Network

II. Why the Plan Meets Public Safety Capacity Requirements: Baseline Capacity

In accordance with the Budget Act of 1997, FCC rules allocate 24 megahertz of dedicated spectrum to public safety in the 700 MHz band, bringing public safety's total spectrum allocation to 97 megahertz. This 24 MHz allocation makes public safety among the largest holders of spectrum in the 700 MHz band. The FCC designated 10 megahertz of this 24 megahertz for broadband use.[3] Even if one only considers this 10 megahertz of spectrum allocated for broadband use, public safety would have 200 thousand users per megahertz.[4] This is considerably fewer users than the estimated number of users that commercial broadband providers will support in an equivalent amount of similar spectrum. Accordingly, 10 megahertz of spectrum is a relatively large allocation for public safety's routine communications traffic. Furthermore, our analysis demonstrates that 10 megahertz of spectrum will provide significant capacity for the public safety broadband network on a day to day and emergency basis.

> Public safety has a total of 97 MHz of spectrum allocated for use across the RF spectrum with 60 MHz of that total available for broadband use. Overall, the allocation of spectrum per user for public safety is now 25 times that of commercial providers.

Providing an additional 10 megahertz of spectrum to public safety would not guarantee public safety sufficient capacity for the worst emergencies. Priority access and roaming onto commercial bands can provide public safety with far more capacity during periods of greatest need. Further, reallocation of the D block would result in several severe detriments, including:

- The cost of the network and the associated mobile devices could increase significantly. The benefits associated with sharing an LTE band class (Band Class 14) with the commercial D block licensee would evaporate. Equipment vendors would not be able to rely on the broader commercial LTE market in Band Class 14. Accordingly, equipment costs could be much higher then estimated.

Cost Model: A Basis for Public Funding Essential to Bringing Nationwide Interoperable Communications to First Responders (rel. Apr. 2010) (*Cost Model Paper*), *available at* http://www.fcc.gov/pshs/docs/ps-bb-cost-model.pdf (last visited May 10, 2010).

[3] In the 1997 Budget Act, Congress specifically determined that public safety would be provided with 24 megahertz of spectrum from the 108 megahertz of spectrum recovered from the DTV transition and the remainder of the spectrum was to be auctioned. Of this 24 megahertz, 12 megahertz has been designated for dedicated voice systems using traditional trunked technology and 2 megahertz is used as an internal guard band.

[4] 170 megahertz: This includes the cellular and PCS bands; 547 megahertz: This includes the 700 MHz (formerly TV), AWS1, and EBS/BRS bands, a substantial portion of which is not currently in use; Public Safety: According to the Bureau of Labor Statistics, U.S. Department of Labor, there are 1.1 million police, fire and EMS professionals. This number excludes some first responders, such as volunteer firefighters. For this analysis, we assume 2 million public safety users. 97 megahertz: This includes the 700 MHz (formerly TV) and 4.9 GHz bands, a substantial portion of which is not currently in use.

- Technological evolution might be slowed. Without a Band Class 14 commercial partner, vendors may have less incentive to advance the technology envelope in this band class without significant cost imposed on public safety.
- In most cases, this spectrum would be severely underutilized.

A. Network Capacity Drivers

Many people equate capacity with spectrum. While spectrum is one of the resources being utilized, the amount of spectrum available to a network alone is not a meaningful measure of network performance and capacity. Network capacity and performance are dramatically improved through many factors in addition to the amount of spectrum. These factors include the type of architecture employed, the number of cell sites in operation, the number of sectors per cell, sound network and spectrum management, and the specific technology that the network utilizes. Accordingly, in order to analyze the capacity and performance of any given network, a multitude of factors must be evaluated in relation to one another. Relying solely on the amount of spectrum available to a network is a flawed way to evaluate the capacity of a network, and doing so could lead to seriously flawed and expensive decisions.

A significant driver of cellular network capacity is available infrastructure to support the network. In a cellular architecture, as recommended in the NBP, spectrum can be reused most efficiently, yielding greater network capacity, when a network utilizes an increased number of cell sites for a given geographic area because this technique enables greater spectrum reuse with minimal interference. To first approximation, the total capacity that a cellular architecture can provide to a given region can be described by the following equation.

$$\text{Total capacity} = \frac{(\#\text{ of sites}) * (\#\text{ of sectors per site}) * (\text{Capacity/MHz}) * (\#\text{ of MHz of spectrum})}{\text{Frequency Reuse Factor}}$$

Accordingly, two networks with the same amount of spectrum covering the same geographic area can have widely disparate capacity just by changing the number of cell sites available for network use in the relevant service area. It is for this reason that sound network engineering principles have dictated that commercial networks generally are built out using a dense number of cell sites. This enables these networks to be operated in a spectrally efficient manner by leveraging additional infrastructure, as opposed to spectrum, and to utilize a cost-effective means to increase network capacity.

Cellular networks also increase capacity through the deployment of spectrally-efficient advanced technologies. As commercial wireless carriers migrate to 4G standards such as LTE, it is estimated that the networks using this technology will provide more capacity (Mb/s) per megahertz of spectrum in any given cell than earlier technologies. As in the past, commercial cellular networks experience significant improvements in capacity per megahertz as technology advances, and further improvements are expected with LTE. In addition, advances in compression technology, particularly for video, means that new technologies hold the promise that the same piece of information (*e.g.* a video stream) can be carried using less capacity. The commercial marketplace has benefited greatly from such developments as new technologies are introduced.

In contrast, if technology is developed exclusively for a much smaller market, such as public safety, the pace of improvements is likely to be slower. This is one of many reasons that the NBP recommends an approach for public safety broadband communications that leverages the advantage of technologies and standards that are gaining commercial use whenever they are suitable for public safety purposes, including the use of LTE technology for the radio access network. This is also why the NBP recommends the commercial auction of the D block, to ensure a potential partner in the same LTE Band Class as public safety. This approach provides public safety with access to commercial technologies that have generally been shown to advance more quickly to increase spectral and other operating, as well as cost, efficiencies.

Another way to increase capacity is to provide supplemental infrastructure to expand available capacity. There are unique strategies for increasing capacity within buildings, where a substantial amount of cellular network traffic originates. Additional infrastructure, such as distributed antenna systems (DAS) and pico cells, can be installed inside buildings to improve coverage and offload traffic from external cell towers. These approaches decrease strains on the available cell site infrastructure. The NBP recommends that building codes be changed or enacted to enable greater use of these technologies and that FCC rules be developed that enable and facilitate their use. Further, additional outreach by the federal, state and local governments to building and facility owners can assist in ensuring that this technology is widely pervasive as 4G networks are deployed.

Capacity can be further expanded by utilizing deployable communications systems, such as next generation cell sites on wheels (a.k.a. "COWs" or "COLTs"[5]) and vehicular relays, as is frequently done with today's wireless technologies during disasters and major incidents or events. The NBP recommends deployment of these technologies for public safety broadband use, through a program that would help fund caches of equipment throughout the country that can be rapidly deployed to the site of any major disaster.

Further, sound spectrum management must also be considered. For example, to meet day-to-day fixed needs for applications like video monitoring, the public safety community should rely on other transmission technologies, such as fixed wireline and fixed wireless technologies, which will enable public safety to preserve its 700 MHz capacity for mobile broadband communications. By ensuring that the overall public safety communications network leverages all existing resources most suited to the intended purpose, public safety can have access to the most robust and reliable communications network possible, on a cost-effective basis.

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[5] "COW" and "COLT" are common industry terms for Cell On Wheels and Cell On Light Truck.

In addition, as discussed, supra, utilizing the communications networks of other network operators is another way to increase network capacity and provide a capability backstop to public safety. There may be times that 10, 20 or even 30 megahertz of capacity, even with sound network design and management principles might be insufficient to support demands during a major incident. In these cases, it is critical that public safety have access to additional broadband wireless networks, such as those operated by commercial network operators. Guaranteeing access to these networks will enable the public safety community to have access to substantially more capacity than a dedicated network can provide without vastly more dedicated spectrum than is under consideration. Roaming with priority access will also provide increased reliability and resiliency, especially if any roaming partner utilizes different cell tower sites for all or some of its network.

In conclusion, the amount of spectrum is only one of several interrelated factors in determining capacity and is influenced by other factors, such as increasing the number of sites, maximizing the sectors per site and using advanced technologies to achieve greater capacity per megahertz. As long as sound network management is adhered to, including the provision of adequate funding to construct sufficient cell sites in the network area, the deployment of cutting-edge technology in each cell site, and the use of supplemental tools to increase capacity, network capacity for public safety communications will be significant in 10 megahertz of dedicated capacity. As this paper will show, our analysis demonstrates that by deploying sufficient infrastructure and using sound spectrum management principles, the 10 megahertz of dedicated public safety spectrum can meet public safety capacity and performance requirements in circumstances that range from routine day to day use to serious emergencies.

B. Public Safety Communications Today

Unless we are able to get past the mindset that network capacity is synonymous with spectrum, it would be natural to expect that the capacity from this 10 megahertz block at 700 MHz will be comparable to what public safety has experienced in the past. This is not the case. The public safety LMR networks in use today consume a large amount of spectrum per user.[6] This occurs in part because of legacy network design and technical considerations: public safety networks utilize radio systems with a relatively small number of high site towers and very sensitive radios. This technology and design greatly increases the amount of spectrum needed per user when compared to cellular architectures, which are used for today's commercial communications networks. Further, unlike cellular commercial systems, public safety communications have generally been locally operated which necessarily results in spectrally inefficient overlapping, independent networks. The NBP recommends that the public safety broadband network utilize a cellular architecture with LTE technology[7] and be deployed in a coherent

[6] Not including spectrum allocations in the 4.9 GHz and 700 MHz bands, over 23 megahertz of spectrum have been allocated for public safety use. Public safety LMR networks use frequencies in the 25-50 MHz, 150-174 MHz, 220-222 MHz, 450-470 MHz and 806-824/851-869 MHz bands. In some metropolitan areas public safety also uses frequencies in the UHF T-Band (470-512 MHz).

[7] The Public Safety and Homeland Security Bureau (Bureau) sought comment on the Public Safety Spectrum Trust's (PSST) filing and the National Public Safety Telecommunications Council's Broadband

manner throughout larger non-overlapping geographies. This should result in dramatic increases in spectrum and cost efficiencies, while handling heavier traffic demands than currently exist.

Due to the spectrum efficiency of modern digital technologies and the movement towards larger network operation areas, analysis of the required capacity for the public safety broadband network must not rely on assumptions based on today's technology and LMR network designs. A coherent, nationwide public safety broadband network with a modern cellular architecture and the same 4G technology that is used commercially (LTE) will offer public safety users far more capacity on 10 megahertz of spectrum than would be the case if a traditional LMR-type network were deployed. For example, a recent study of public safety communications in the greater Los Angeles area showed that a shift from today's LMR technology to even a pre-LTE cellular technology could increase capacity per megahertz by a factor of 16. In other words, the study demonstrated that 10 megahertz of capacity on a cellular network would be the equivalent of 160 megahertz on an LMR-type network.[8]

It would be a mistake to design a network based upon the public safety's past experience in using spectrum. Public safety agencies do not have significant incentives to use spectrum efficiently, because, unlike commercial entities, public safety agencies in America do not pay for spectrum. Accordingly, using spectrum inefficiently is not a cost. However, constructing adequate infrastructure is a cost even when that cost would result in improved communications and reduced costs over the long term. Nevertheless, both spectrum and infrastructure are costly. Spectrum is a scarce public resource and receives a high price at auction for its exclusive use, because it is highly valued resource, especially in the bands below 3 GHz.[9] On the other hand, it can be expensive to acquire, engineer, build and operate additional cell sites (although establishing new cell sites on existing towers, as recommended in the NBP, can decrease these costs significantly). In general, cellular networks achieve sufficient capacity for their users by balancing the costs of acquiring spectrum with the costs of adding sites—not by minimizing one cost without serious consideration of the other.[10]

Task Force (NPSTC BBTF) recommendations. *See* Comment Sought on NPSTC Broadband Task Force and Public Safety Spectrum Trust Technical Recommendations for 700 MHz Public Safety Broadband Deployments, PS Docket. 06-229, *Public Notice,* DA 10-458 (rel. Mar. 17, 2010) (*NPSTC PN*). Commenters were generally supportive of the technical recommendations of the NPSTC BBTF, including the mandatory use of Long Term Evolution (LTE) as an air interface, while recognizing that this standard is not yet fully developed. *See, e.g.*, Motorola NPSTC PN Comments at 1-2; IP Wireless NPSTC PN Comments at 1; Harris Corp. NPSTC PN Comments at 3.

[8] J.M. Peha, "How America's Fragmented Approach to Public Safety Wastes Money and Spectrum," *Telecommunications Policy,* Vol. 31, No. 10-11, 2007, p. 605-618.

[9] At Auction 73 in 2008, for example, winning bids for the 700 MHz A, B, C and E blocks totaled approximately $19 billion. *See* Federal Communications Commission, Auction – Auction 73, http://wireless.fcc.gov/auctions/default.htm?job=auction_summary&id=73.

[10] In recognition that cell sites have significant capital costs associated with them, the NBP recommends public funding, based on a cost-effective incentive-based partnership approach, to ensure there are an adequate number of sites available for the nationwide public safety broadband network, whether in rural or urban parts of the country.

The NBP recommendations for the public safety broadband network include the deployment of 44 thousand sites nationwide,[11] and a cost effective approach for funding this network in a manner that enables an efficient use of the 10 megahertz of dedicated public safety spectrum to meet important public safety requirements. This would give the public safety network at 700 MHz a site density comparable to commercial providers, and a total site count greater than all but two of these providers, even though the commercial providers typically serve user densities that are greater by an order of magnitude or more. In addition to providing significant aggregate capacity, this high site density is necessary because public safety requires a level of signal reliability (i.e., the ability to get a strong signal when needed) that is more stringent than users of commercial systems demand. Regardless of the amount of capacity needed or the amount of spectrum available, high signal reliability requires a high cell site density.

To compensate for limitations in public safety narrowband communications systems in terms of capacity, public safety has been allocated significant amounts of spectrum. Even if we examine only the spectrum allocated to public safety use and commercial use before 2002, we find that public safety has been allocated more than 20 times as much spectrum per user as commercial providers. In recent years, allocations to both public safety and commercial providers have been greatly increased, including spectrum at 700 MHz (although not all of this spectrum is currently being utilized). Public safety has a total of 97 MHz allocated for its use across the RF spectrum with 60 MHz of spectrum which can be used for broadband. Using 2010 data, the allocation of spectrum per user for public safety is now 25 times that of commercial providers.

Cellular architecture, advanced technology, and the accompanying funding to deploy it mean that a more spectrally- and cost-efficient approach can be taken, and this huge gap in spectral efficiency can be reduced. Instead, public safety, using current technologies, larger geographic service areas, sufficient infrastructure, and sound spectrum management principles, should be able to operate more efficiently and support increased traffic demands within less spectrum than previously experienced. Further, because of the use of commercial technologies, public safety communications no longer has to operate in a silo. Instead, public safety can access additional networks for spikes in capacity demands, such as during particularly large emergencies.

[11] *See Cost Model Paper*.

III. How the Plan Meets Public Safety Capacity Needs; Capability Back-stop

As discussed above, capacity depends on factors such as architecture, technology, and the number of sites, as well as amount of spectrum. Under NBP recommendations, public safety would have architecture, technology, and a number of sites comparable to leading commercial providers. Moreover, by commercial standards, 10 megahertz would be a large allocation to serve this number of users. For example, even if we completely disregard the 87 megahertz of spectrum public safety has outside this band, and we include spectrum recently allocated to commercial providers that is not yet in use, commercial providers would serve 2.7 times as many users per megahertz as public safety. (If we exclude commercial allocations made since 2006, because infrastructure has not yet been fully deployed in many of these bands, commercial providers would serve 8.5 times as many users per megahertz.) Commercial providers would need their current allocation and 900 megahertz of new spectrum before the amounts of spectrum per user were the same. Thus, if the routine needs of public safety users are comparable to, or twice as great as, those of commercial users, this combination of infrastructure build-out and spectrum would meet those needs.[12]

Nevertheless, for public safety communications, we must look beyond routine communications use to ensure that there is sufficient capacity available when major emergencies occur. As shown in the Appendix, our analysis demonstrates that 10 megahertz of dedicated spectrum will likely provide a significant amount of capacity and the required performance when used with 4G technology and sufficient infrastructure. The Appendix presents a series of specific scenarios: a "dirty bomb" attack at Manhattan's Penn Station,[13] a projected 12 year growth model for routine use of broadband services in New York City, a bridge collapse in Minneapolis, and a hurricane in Houston. This analysis determines that a system deployed in 10 megahertz of spectrum with the number of sites proposed in the FCC Cost Model[14] would have sufficient capacity for estimated broadband communications in each of these scenarios.

As these scenarios demonstrate, and as supported by the record and past public safety broadband experience, the most demanding application with respect to capacity is likely to be high-data-rate applications such as mobile video. In order to support the potential

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[12] This is consistent with the 2008 FNPRM which concluded that all communications for public safety could be supported within these 10 megahertz except under unusual circumstances. Under the rules proposed, public safety could supplement its 10 megahertz by accessing a limited portion of the D block if and only if the President or a state governor declares a state of emergency, the President or a state governor issues an evacuation order impacting areas of significant scope, the national or airline sector threat level is set to red, the National Weather Service issues a hurricane or flood warning likely to impact a significant area, other major natural disasters occur, such as tornado strikes, tsunamis, earthquakes, or pandemics, manmade disasters or acts of terrorism of a substantial nature occur, power outages of significant duration and scope occur, or the national threat level is set to orange.

[13] *See* City of New York Ex Parte Filing, PS Docket No. 06-229, 700 MHz Public Safety Broadband Applications and Requirements at 34-40 (Feb. 23, 2010) (*New York City Paper*).

[14] *See Cost Model Paper*.

for video demands during times of emergency, it is important to look first at sound spectrum management policies that ensure that capacity is properly allocated among users and available networks and technologies. Second, for the rare times when additional capacity is actually needed, such as when the public safety network is not available, the NBP recommends that public safety have roaming and priority access on commercial wireless broadband networks. This will provide a safeguard to ensure that public safety has access to multiple, redundant networks with significant additional capacity when it is needed. Further, the public safety community can enter into additional spectrum sharing arrangements with other commercial partners. In these scenarios, it is likely that in extreme emergencies with heavy video or other high-bandwidth requirements, far more capacity will be required.

A. Ensuring Capacity During Huge Demands or When the Network is Unavailable

Public safety communications capacity demands are generally modest (though support critical communications requirements), with occasional spikes during emergencies.[15] Public safety must have adequate capacity to accommodate large capacity requirement spikes if and when they do occur. However, allocating dedicated resources to public safety to support the largest spike imaginable would leave a great deal of capacity unused between spikes. It is impossible to anticipate the timing of spikes. Reserving dedicated spectrum for these extreme emergencies would be grossly inefficient and waste two scarce resources: money and spectrum.

Further, even with 20 megahertz of spectrum, it is extremely unlikely that in the most video-dependent or most high-bandwidth response situations that public safety would have adequate capacity. The most cost-effective and spectrally efficient way to meet the emergency communications needs of the public safety community is through providing adequate infrastructure and spectrum sharing – ensuring a backstop capability for times when the public safety network is unavailable or there is a huge surge in demand. This

[15] For example, as was observed based on usage data from Denver's public safety communications systems, "[m]odern public safety wireless communications systems are generally designed for the worst-case scenario: a large-scale event which requires communication between large numbers of first responders, potentially from diverse agencies. . . . Most of the time, these systems operate at the low end of their designed-for capacity." Joshua Marsh, "Secondary Markets in Non-Federal Public Safety Spectrum," *Telecommunications Policy Research Conference* (2004). In addition, at its peak, the Minneapolis system handled over two times the number of calls during the I-35W bridge collapse that it would typically expect. During the busy-hour of September 17, 2008, the Harris County Regional Radio System handled almost twice as many PTTs than it would handle on a typical day. *See* Federal Communications Commission, Emergency Communications during the Minneapolis Bridge Disaster: A Technical Case Study of the Federal Communications Commission's Public Safety and Homeland Security Bureau's Communications Systems Analysis Division at 16-17 (2008) (*Minneapolis Bridge Case Study*), *available at* http://www.fcc.gov/pshs/docs/clearinghouse/references/minneapolis-bridge-report.pdf; *see also* Federal Communications Commission, Emergency Communications During Hurricane Ike: Harris County Regional Radio System: A Technical Case Study by the Federal Communications Commission's Public Safety and Homeland Security Bureau's Communications Systems Analysis Division at 12-13 (2009) (*Hurricane Ike Case Study*), *available at* http://www.fcc.gov/pshs/docs/clearinghouse/case-studies/Hurricane-Ike-Harris%20County-120109.pdf.

can be best achieved through the implementation of the NBP's recommended priority access and roaming regime.[16] The FCC has plans to begin a rulemaking that will result in the implementation of this priority access and roaming regime in the near term.

LTE technology is particularly promising with regard to priority access and roaming. As part of its current standard it allows network operators to assign different priority levels to different users or services, such that low-priority users have restricted use of network resources. Moreover, with IP (Internet Protocol) and LTE technology, it is possible to prioritize traffic in a way by which capacity is transferred to the highest and best use. Such prioritization schemes have been used successfully in military systems. The LTE standard is bringing these capabilities to wireless cellular systems.

B. Possible Future Capacity Expansions

In analyzing network capacity, it is also important to ensure that there is room for expansion and growth. Generally, a simple way to increase capacity is to increase the number of cell sites in a network. This can be done at a relatively low cost by exploiting commercial and other existing infrastructure wherever it is appropriate.[17] Accordingly, by using a constant amount of spectrum and expanding infrastructure deployment, network capacity can be increased.

Furthermore, LTE is at an early stage of technology development, and it will continue to progress. The NBP recommendation to leverage this commercial technology provides an opportunity for public safety communications to benefit from commercial technology advances, including increases in spectrum efficiency. Commercial operators are constantly upgrading their network capabilities to take advantage of greater spectrum and operational efficiencies. The NBP's incentive-based partnership applies this approach to the public safety broadband network.

C. Efficient Use of Public Safety Spectrum

Finally, public safety users can ensure adequate capacity through good stewardship of the broadband spectrum that is allocated to them. The 700 MHz public safety broadband spectrum has excellent propagation characteristics for mobile wireless broadband services and the public safety community should manage it as efficiently as possible. This includes ensuring that the public safety broadband spectrum is used for its best use: mobile use. Public safety should look to utilize fixed wireline and fixed wireless systems for some applications that are better supported by these technologies. A good example of this is video surveillance. For example, in addition to its allocations under 1 GHz, public safety has exclusive use of 50 megahertz of the 4.9 GHz band on a flexible basis which is well-suited for fixed uses, such as video surveillance.

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[16] This commercial spectrum would be used for commercial purposes when not required for public safety use.

[17] *See Cost Model Paper*.

Governance procedures are also an important component of sound spectrum management practices. For example, public safety needs to prioritize particular applications among incident commanders. This is an area on which the Emergency Response Interoperability Center (ERIC) and its federal partners can work with the public safety community. It is particularly important that public safety has access to capacity across its network; whether its dedicated 10 megahertz of public safety broadband capacity or the capacity of its roaming partners, in a manner that best supports the pubic safety community's needs at any one time.

D. The Role of Video and Future Bandwidth Intensive Applications

As previously discussed, mobile video is an example of one bandwidth-intensive application where capacity constraints may be experienced no matter the total amount (*e.g.*, 10, 20 or even 25 megahertz) of dedicated spectrum available to pubic safety for broadband communications. First, no matter how much capacity public safety has available to it, public safety network engineers must consider the appropriate data rate for mobile video. Not only must there be sufficient aggregate capacity to support all of the video devices in operation, but the system must be designed such that a single video device can operate even when it is at the edge of a cell. The data rate and performance available to a device in a cellular broadband network is a function of how far it is from a transmission tower. This is particularly important for video uplinks. The received power levels from an end-user device, not the amount of spectrum, are the limiting factor that determines the maximum video uplink data rate. A network that must be capable of supporting a video device or other device that supports a high-data-rate application must therefore have smaller cell radii, even if very few such devices will be used. Since smaller cells means more cells for a given area, requiring a network to support higher-data-rate video increases costs.

Leading organizations representing public safety, represented by the National Public Safety Telecommunications Council (NPSTC), have stated that a system that supports 256 kb/s per video device throughout the coverage area, including edge of cell, is sufficient for public safety in urban areas (and lower data rates are acceptable in suburban and rural areas).[18] This does not limit fixed devices located near a transmit tower, but typical mobile hand-held video devices must be capable of operating at 256 kb/s or less. The Department of Homeland Security's SAFECOM Program has stated that the preferred data rate for video depends on its use and purpose. 256 kb/s is acceptable for tactical and live surveillance of large targets, but for small targets, 512 kb/s may be needed.[19] Under these recommendations, average video rates would fall somewhere between 256 and 512 kb/s. A great deal of tactical capability – currently unavailable to public safety users – can be made available through a mobile network that supports these data rates.

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[18] *See* National Public Safety Telecommunications Council, Public Safety 700 MHz Broadband Statement of Requirements at 39 (2007).

[19] *See* Department of Homeland Security, SAFECOM Program, Public Safety Statement of Requirements for Communications & Interoperability Volume I (2006) and Volume II (2008).

However, a few vendors of high-data-rate video equipment have argued that the public safety broadband network must support 1.2 Mb/s or even 3.5 Mb/s for each video device, which is enough to carry standard-definition television (SDTV) and high-definition television (HDTV), respectively. While, of course, any public policy must strive to maximize public safety's tactical capabilities, the policy must also be grounded in practical assumptions. Because of the uplink power limitations of video devices, high speed uplink from the cell edge can only be supported at a limited distance from the cell site. Hence, video uplink speeds of greater than 1 Mbps from the cell edge, as suggested by a few vendors, will require vastly more cell sites than would otherwise be necessary.
This cell limitation is independent of the amount of spectrum. Consider the cost of a coverage-limited network that can support a single 1.2 Mb/s device at the edge of a cell and that is otherwise built to the same standards as recommended in the NBP.[20] A coverage-limited network requires fewer cell sites than capacity-limited networks, and therefore costs less, so we can use this coverage-limited network to get a reasonable lower bound on the cost of a network that can support 1.2 Mb/s. We estimate that a coverage-limited network supporting 1.2 Mb/s would require 2.85 times as many cell sites, and both capital expenditures (CAPEX) to construct the network and operating expenditures (OPEX) to operate, maintain and upgrade the network are roughly proportional to the number of cell sites. Thus, by increasing the required data-rate-per-device to 1.2 Mb/s, a nationwide network that would have cost only $14 billion would instead cost $40 billion.

Of course, increasing the number of cell sites nationwide by a factor of 2.85 to support a single 1.2 Mb/s stream at edge of cell would have the effect of dramatically increasing aggregate capacity. This unavoidable expansion in aggregate capacity means a much larger number of video streams can be supported, without increasing the spectrum allocation beyond 10 megahertz. Indeed, a system operating in 10 megahertz of spectrum and designed to support 1.2 Mb/s video devices by deploying 2.85 times more sites than was proposed in the NBP would have more aggregate capacity than a system operating in 20 megahertz that has the amount of infrastructure proposed in the NBP.[21]

As noted above, we are not denying the value of mobile video capability to public safety. Indeed, we recognize that use of mobile video is likely to be a key tactical capability provided by the public safety broadband network. However, we emphasize that a significant degree of capability can be provided at bitrates that are much more reasonable from a cost-benefit standpoint over a mobile 700 megahertz system. To the extent that

[20] *See Cost Model Paper*.

[21] There is one way to overcome the problems highlighted above and provide much higher data rates for video anywhere in a cell: one can use higher-gain antennas than is typical for commercial handsets, and perhaps higher-power transmitters. Users of commercial cell phones typically prefer smaller form factors rather than superior antennas, but this is presumably not an issue for a public safety command center. In effect, a device with a high-gain antenna at the edge of the cell can communicate as if it were much closer to the center of the cell. While this technology makes it possible to transmit at higher rate, it also reduces the effective consumption of network capacity, so high-data-rate video provided in this way does not create a problem for the network operating at 700 MHz.

public safety agencies require high-definition, full frame video capabilities, some of these services are more cost effectively accommodated using other spectrum.[22]

E. The Effect of Interference

Adjacent cell interference can also impact the capacity of a wireless network. In the past, there have been instances in which public safety's LMR networks experienced levels of interference from commercial operations in adjacent spectrum that created problems for public safety users.[23] However, the use of advanced RF engineering techniques in combination with LTE technology can greatly reduce potential interference problems.

A nationwide broadband LTE cellular network based is far less likely then LMR networks to be susceptible to interference may potentially to reduce capacity. Cellular broadband networks are generally interference limited rather than noise limited, so they can tolerate more interference than LMR. Indeed, today's broadband cellular networks are designed to operate at an interference threshold so high that adjacent cells can reuse the same frequencies without causing harmful interference.

Moreover, while significant differences in cell site density also can increase the probability of near-far problems, site density will be more similar for two cellular networks using comparable technology (*e.g.,* LTE) than for a cellular network and LMR system. Furthermore, the number of public safety cell sites recommended in the NBP is roughly consistent with the number of sites currently operated by commercial nationwide wireless providers using spectrum comparable to the 700 MHz band. Thus, if these recommendations are realized and sufficient cell sites are deployed, the anticipated site density of the broadband public safety network will be very similar to that of a 700 MHz commercial network, substantially reducing the risk of near-far problems.

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[22] We note, for example, that commercial broadcasters utilize higher frequency spectrum for mobile Electronic News Gathering operations, which involve different network topologies optimized for high data rate video feeds suitable for HDTV broadcast.

[23] One important reason that adjacent channel interference can more easily become harmful to LMR systems is that LMR systems are noise limited, meaning that radios must operate well even when they receive very weak signal levels. In contrast to LMR networks, commercial cellular networks are designed to operate despite significant interference. Accordingly, LMR-based networks are inherently more vulnerable to interference, including adjacent-channel interference, than commercial networks.

The problem is compounded by differences in the number of cell sites deployed in a given region. The site density of commercial wireless networks is typically much higher than that of public safety LMR networks, as discussed infra. Thus, it is common for an LMR public safety radio to be far from an LMR cell site, receiving a weak signal that is close to the noise floor and close to a commercial cell site that is transmitting in adjacent spectrum. In this case, interference in the public safety spectrum allocation may be raised in the area directly around the commercial cell site, due to a) the presence of high levels of radiated power in out-of-band emissions; and/or b) intermodulation products that fall within the public safety channel; and/or c) in-band emissions that are too strong to be adequately filtered out by the public safety receiver. Thus, a commercial site using adjacent spectrum can create a coverage hole for LMR radios. This is called a "near-far" interference scenario. The larger the difference in site density between the commercial network and the adjacent public safety network, the greater the probability that this form of harmful interference will occur.

As public safety leverages commercial infrastructure and commercial broadband technology, and a sufficient number of sites, near-far issues for public safety will be essentially the same as near-far issues for commercial networks. This means that commercial standards for interference between networks operating in adjacent spectrum will apply to public safety. For example, 3GPP specifications for LTE assume that two adjacent channel LTE networks operated by different wireless providers (i.e., in which sites are not necessarily co-located) would not require an additional guard band, assuming they are each deployed using similar site densities.[24] As a result, spectrum allocations for LTE around the world (*e.g.*, digital dividend allocations in the United Kingdom[25] and Germany[26]) do not include guard bands between adjacent operators.

III. Cost as a Driver for Network Capability

In addition to providing sufficient capacity, the NBP recommendations are designed to provide public safety nationwide interoperable broadband communications in a cost-effective manner. One important way to reduce cost is to maximize the use of commercial technology. If public safety uses commercial-scale components in its devices, they will benefit from commercial economies of scale. This is achieved in part by requiring the D Block licensee, and perhaps other 700 MHz licensees, to offer some devices that are also capable of operating in the public safety band. However, if there is no D Block commercial operator, then there will be no ecosystem of D Block commercial devices. In this situation, the market for Band Class 14 LTE devices*, i.e.* the devices that use either the D Block or PS broadband spectrum, would be far smaller and the costs of public safety devices would be far larger. This same phenomenon would negatively impact the radio access network equipment market. Without one or more commercial operators utilizing equipment that can operate in Band Class 14, it is likely that public safety will not be able to benefit from the commercial economies of scale that are available in the rest of the 700 MHz band.

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[24] Section 5.7.1 of the 3GPP standards on channel spacing provides:

The spacing between carriers will depend on the deployment scenario, the size of the frequency block available and the channel bandwidths. The nominal channel spacing between two adjacent E-UTRA carriers is defined as following:

$$\text{Nominal Channel spacing} = (BW_{Channel(1)} + BW_{Channel(2)})/2$$

where $BW_{Channel(1)}$ and $BW_{Channel(2)}$ are the channel bandwidths of the two respective E-UTRA carriers. The channel spacing can be adjusted to optimize performance in a particular deployment scenario.

[25] *See* http://www.bis.gov.uk/assets/biscore/corporate/docs/migrated-consultations/digital%20britain%20report-%20a%20consultation%20on%20a%20direction%20to%20ofcom%20to%20implement%20the%20wireless%20radio%20spectrum%20modernisation%20programme.pdf (paragraph 3.33 on page 17 which states that the 800 MHz digital dividend spectrum will be auctioned "in six lots of 2 x 5megahertz").

[26] *See* http://www.cesifo-group.de/pls/guestci/download/CESifo%20DICE%20Report%202010/CESifo%20DICE%20Report%201/2010/dicereport110-db4.pdf (Germany allocated digital dividend spectrum into six 2x5 megahertz blocks).

Another significant cost-saving element of the NBP is the incentive-based partnership approach. Although not required, NBP deployment costs were calculated using this approach, and the savings were considerable when compared to a stand-alone network dedicated to public safety and does not leverage commercial infrastructure. Under the NBP, a $6.5 billion investment could provide coverage to 99% of Americans by enabling construction of a public safety "overlay" network on 41,600 existing commercial sites; hardening of commercial towers; the addition of over 3,000 sites in rural areas; and the development of a fleet of public safety deployables. This is far less expensive than a stand-alone public safety network, which would likely cost at least $15 billion to construct.[27] Moreover, failing to leverage commercial infrastructure would mean that existing commercial networks would not be hardened, making them less reliable for carrying critical infrastructure traffic. The NBP also noted that this hardened infrastructure will better support utilities and facilitate the deployment of energy-efficient smart grid technology.

In sum, incentive based partnerships, where public safety holds full rights to its spectrum but where infrastructure is shared between public safety and commercial systems, provide a more cost effective mechanism for this necessary evolution path. A stand alone system dedicated to public safety would require all evolution costs to be borne by the vastly smaller public safety user base. Moreover, because of the higher cost of the stand-alone approach, the resulting network would probably have fewer cells with much larger cell radii, and the capacity and performance of public safety communications would suffer as a result.

IV. Conclusion

The NBP's recommendations for the deployment of a nationwide interoperable public safety broadband wireless network were developed over the course of almost a year of intense study, inquiry, analysis and meetings with and input from public safety leaders, communications engineers and industry experts. The result is a plan that will provide public safety with a nationwide, interoperable network that has the capacity for all day-to-day operations and with the innovation of public safety roaming and priority access across the 700 MHz cellular spectrum, surge capacity for emergencies, and even extraordinary contingencies.

The network is based on the availability of 10 megahertz of spectrum dedicated to public safety use by Congress, which provides public safety with substantially more spectrum per user than major commercial networks, providing them with the required capacity and performance for critical communications needs. Roaming and priority access will provide additional capacity on up to 70 megahertz or more of spectrum. The NBP recommendations makes full use of the additional capacity that can be gained from use of LTE and IP technology, and public funding to build out a sufficient number of cell sites to support the network.

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[27] *See Cost Model Paper* at Section E.

Appendix

INTRODUCTION

In this Appendix, we analyze public safety use of broadband wireless communications employing a network built in accordance with the FCC Cost Model in 10 megahertz of spectrum in four scenarios depicting various types of emergencies. For each scenario, we calculate the expected value of utilization[28] of the network.[29] We assume for purposes of this analysis an LTE network whose capacity averaged over each sector[30] is 7.5 Mb/s (downlink) and 3.25 Mb/s (uplink). These figures represent average throughput and are in-line with current industry benchmarks.

In addition, while studies of voice communications among present day emergency responders during disaster events have shown that the command and control communication structure used by public safety results in a sparse, highly compact process of communication,[31] our analysis departs from this model to yield a more conservative result. For purposes of analysis we assume that video and data communications are generated by individual responders, mobile vehicles and command centers. Activity levels assumed per device category are greater than or equal to those typically found in the commercial environment. These assumptions produce a rich, video intensive environment in which large amounts of data are continually transmitted by emergency responders.

Our analysis yields the following observations/conclusions:

- LTE networks deployed in accordance with engineering assumptions in the FCC Cost Model, which are themselves consistent with commercial engineering assumptions, provide sufficient capacity to meet the communication needs of public safety utilizing the 10 megahertz of spectrum that has been allocated to public safety for broadband over a broad range of scenarios and assumptions.

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[28] Utilization is the fraction of capacity in use. Utilization must be below 1 to be feasible, and not too close to 1 to avoid congestion problems.

[29] *See* Omnibus Broadband Initiative, A Broadband Network Cost Model: A Basis for Public Funding Essential to Bringing Nationwide Interoperable Communications to First Responders (rel. Apr. 2010) (*Cost Model Paper*), *available at* http://www.fcc.gov/pshs/docs/ps-bb-cost-model.pdf (last visited May 10, 2010).

[30] Each cell site is typically divided into 3 sectors.

[31] *See* Federal Communications Commission, Emergency Communications during the Minneapolis Bridge Disaster: A Technical Case Study of the Federal Communications Commission's Public Safety and Homeland Security Bureau's Communications Systems Analysis Division at 16-17 (2008) (*Minneapolis Bridge Case Study*), *available at* http://www.fcc.gov/pshs/docs/clearinghouse/references/minneapolis-bridge-report.pdf (last visited Apr. 28, 2010).

- Deploying greater numbers of cell sites achieves a greater aggregate capacity and higher overall level of spectral efficiency, consistent with Commission goals to achieve highest use for this scarce resource.

Scenario I and II have been extracted from the New York City Department of Information and Technology's recent filing in FCC Docket 07-114 (*New York City Filing*).[32] Scenario III and IV are based on actual events and empirical data that was collected and analyzed by FCC staff, to include data extracted from FCC reports on these disasters.

Scenario I: Dirty Bomb in New York City

The *New York City Filing* provides one of the few discussions in the record developed for the NBP of the public safety response to a specific emergency scenario, in this case a hypothetical "dirty bomb" attack at Manhattan's Penn Station in the middle of a busy work day.[33] In this scenario, the attack has left 900 people injured, some of whom are in critical condition. With support from the New York City Transit Authority, EMS has been mobilized to assist the injured. In addition, the New York City Police Department has initiated a Level 4 mobilization to deal with the security threat. To contain the broader dangers of the nuclear contaminants unleashed by the dirty bomb attack, the New York City Fire Department has set up a hazardous material (HazMat) detoxification / wash-down.

For purposes of analysis we employed the following assumptions, all of which are taken directly from the *New York City Filing*.[34] In the downlink direction, there are 38 video links active at a time, and 16 Mb/s of non-video traffic, which includes database access, file downloads, telemetry, computer aided dispatch, and VoIP. In the uplink direction, there are 12 simultaneous video links, and 7 Mb/s of non-video traffic which includes 2 Mb/s of triage images from EMS. The locations of emergency responders are uniformly distributed across an area surrounding the incident. (In the *New York City Filing*, this area consists of three sectors.[35])

In addition, we have employed three traffic assumptions in our analysis that differ from those in the analysis reflected in the *New York City Filing*. The first concerns video data rate. As discussed in great depth previously, NPSTC and SAFECOM have indicated that the needs of public safety can be met with per-device data rates of 256 Kb/s and 384 Kb/s respectively.[36] Notwithstanding these assessments, the analysis reflected in the *New York*

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[32] *See* Comments of NYC Department of Information and Technology, FCC Docket 07-114 (received Nov. 17, 2009) (*New York City Filing*).

[33] *See id*.

[34] *See id.* We take no position on the appropriateness of the assumptions reflected therein.

[35] *See id*. at 14.

[36] *See* Public Safety Spectrum Trust, Public/Private Partnership Bidder Information Document at 8 (2007); National Public Safety Telecommunications Council, Public Safety 700 MHz Broadband Statement of Requirements at 39 (2007), *See* Public Safety Statement of Requirements, Vol II, Ver 1.2, Tables 6 and 7 at

City Filing is based on the assumption that public safety will require downlink video at 1.15 Mb/s (essentially standard broadcast quality video) and 647 Kb/s quality uplink video[37]. For the reasons stated, we have rejected this assertion.[38] We do, however, include the non-video traffic assumption reflected in the *New York City Filing* analysis of this scenario.[39]

Second, the sector downlink capacity assumption of 7.5Mb/s (for 10 megahertz), which is the limiting factor in this scenario, is more conservative than that employed in the analysis reflected in the *New York City Filing*. The *New York City Filing* analysis assumes a downlink capacity of 10 Mb/s for 10 megahertz bandwidth and 21 Mb/s for 20 megahertz bandwidth.[40]

Thirdly, our assumptions differ from the analysis reflected in the *New York City Filing* with regard to the number of cell cites deployed. We assume that an appropriate number of cell sites have been deployed, as would be the case under the NBP recommendations. The NBP recommends and the FCC Cost Model assumes that to meet public safety requirements either for capacity or in-door signal-reliability, the number of sites should be significantly increased from the 200 reflected in the *New York City Filing*.[41] Increasing the number of cells would allow each cell to cover a smaller area, increasing overall capacity and spectral efficiency. As a result, where the analysis reflected in the *New York City Filing* assumes that the activities associated with disaster response would be distributed over 3 sectors, we conservatively assume the activities would be distributed over 6 sectors. The FCC Cost Model would result in the deployment of considerably more than 3 times as many cell sites than that reflected in the *New York City Filing* scenario. Therefore 9 or more sectors would cover the area of operation for the dirty bomb as assumed in the *New York City Filing*. As **Exhibit 1** below shows, this emergency would produce a mean utilization of 58% (downlink) of the capacity available in 10 megahertz for a video rate of 256Kb/s.

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http://www.safecomprogram.gov/NR/rdonlyres/2ADCC02F-4665-4D4C-B512-63CE59BD58DB/0/PS_SoR2_v12.pdf (last visited May 10, 2010).

[37] *See New York City Filing* at 23.

[38] *See supra* at Section I(G).

[39] *See New York City Filing* at 24.

[40] See *id*. at 23.

[41] *See id*. at 14.

Public Safety Spectrum Utilization During "Dirty Bomb" Scenario
256 Kb/s video

	Downlink utilization	Uplink utilization
Video	.22	.16
All other applications combined[42]	.36	.36
Total	.58	.52

Exhibit 1

Even with higher-quality video, there is still more than enough capacity in 10 megahertz of spectrum to respond to the dirty bomb attack in Penn Station described in the scenario. **Exhibit 2** shows network utilization below 68% (downlink) for 384 Kb/s video. We also show in **Exhibit 3** the case for 512 Kb/s video with network utilization (downlink) of 79%.[43]

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Exhibit 2

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Public Safety Spectrum Utilization During "Dirty Bomb" Scenario
384 Kb/s video

	Downlink utilization	Uplink utilization
Video	.32	.24
All other applications combined	.36	.36
Total	.68	.60

Exhibit 2

Public Safety Spectrum Utilization During "Dirty Bomb" Scenario
512 Kb/s video

	Downlink utilization	Uplink utilization
Video	.43	.32
All other applications combined	.36	.36
Total	.79	.68

Exhibit 3

[42] Including VoIP, database access, file transfers, telemetry, computer aided dispatch, images transfers, sensors, incident management, and more. *See New York City Paper* at 34-40.

[43] In the *New York City Filing*, downlink utilization for the 200 cell site, 20 megahertz network under this scenario was 95%.

These Exhibits show that deploying a sufficient number of cell sites, in-line with commercial design strategies and the NBP recommendations, increases overall network capacity, improves spectral efficiency and provides sufficient capacity to meet public safety needs for this serious emergency in 10 megahertz of dedicated spectrum utilizing adequate infrastructure and sound spectrum management principles.

Scenario 2: New York City Network Growth needs for Major Urban Environment

In addition to the emergency dirty bomb scenario reflected in the *New York City Filing*, the New York City Department of Information and Technology's ("NYCDIT") estimate of the 12-year operational growth needs for a citywide wireless network provides a second scenario for analysis.[44] This estimate includes communications associated with a variety of municipal functions including public safety and many applications such as video and non-mission critical voice. As described below, we assess the ability of a system built out in 10 megahertz of dedicated spectrum to support this traffic using these projections. For simplicity of comparison, we will use all traffic load assumptions used by NYCDIT in their filing, although the FCC takes no position on the appropriateness of these assumptions.

NYCDIT estimates a network aggregate traffic load of approximately 7.3 Gb/s (downlink) and 3.6 Gb/s (uplink) in Year 12. **Exhibit 4** (Figure 5 from the *New York City Filing*) shows the growth of network traffic plotted against capacity for a 200 site network deployed in 10 megahertz of dedicated spectrum. NYCDIT's figures indicate when aggregate load would reach 75% of capacity.[45]

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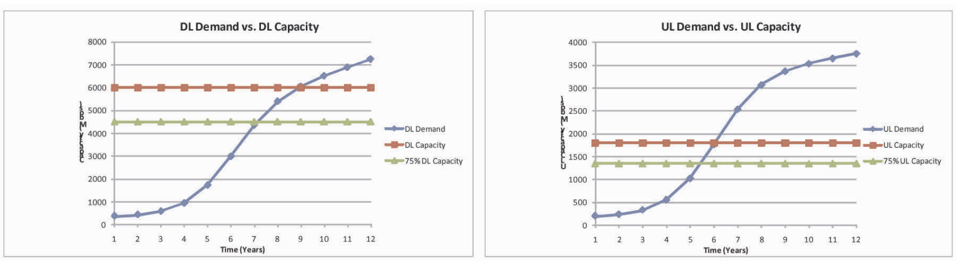

Exhibit 4

Exhibit 5 (Figure 6 from the filing) shows the same growth projection for a 200-site network deployed in 20 megahertz of spectrum:

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[44] *See New York City Filing* at 10.

[45] NYC uses a 75% capacity threshold here as a conservative estimate of effective maximum capacity or a trigger point for capacity expansion.

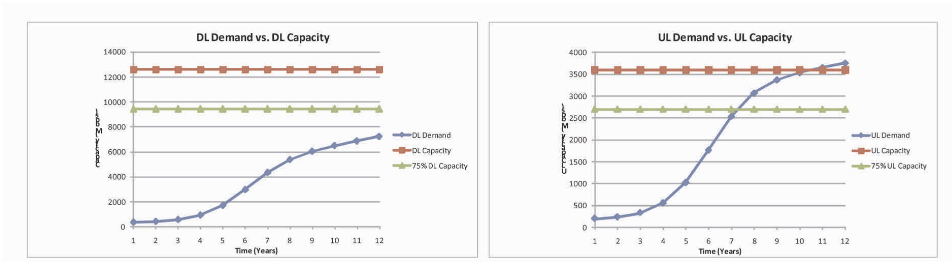

Exhibit 5

NYCDIT summarizes these results in **Exhibit 6** (Tables 2 and 3 from the *New York City Filing*).[46] A review of these tables demonstrates that the uplink channel will be the first to run out of capacity, reaching 75% of capacity in 5.5 years with a 10megahertz allocation, and 7.1 years with a 20 megahertz allocation. Even with 20 megahertz of spectrum proposed by NYCIDT in its estimation, NYCDIT will need to expand the network by year 7 or 8 under these assumptions.

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75% Capacity Exceeded	With Voice	Without Voice
Downlink	7 years	7.5 years
Uplink	5.5 years	5.8 years

Table 2 - Capacity with and without Voice with 10 MHz LTE Bandwidth

75% Capacity Exceeded	With Voice	Without Voice
Downlink	> 12 years	>12 years
Uplink	7.1 years	8 years

Table 3 - Capacity with and without Voice with 20 MHz LTE Bandwidth

Exhibit 6

As explained earlier, these network capacity exhaust time intervals are not intrinsic to the spectrum allocated; they depend on many factors, including the number of cell sites deployed. The number of cell sites assumed when deriving the above table is considerably less than would be recommended in the NBP. Indeed, it is just over half the number of sites that NYC has in use today, implying that New York would choose to greatly reduce its infrastructure at a time when the NBP would support expansion.

Based on NYCDIT's growth model, we establish a target network capacity such that at Year 12, network capacity is 75% of total network capacity. As shown in **Exhibit 7**, NYDITC's projected growth to reach 75% network capacity over the next 12 years can be supported within 10 megahertz of spectrum as long as at least approximately 492 cells are deployed, even using the more conservative FCC assumption of 7.5 Mb/s downlink capacity, which is still well below the number of sites that would be provided for based

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46 *New York City Filing* at 15.

on the methodology employed within the FCC Cost Model. If, for example, NYCDIT were to deploy 750 sites (which is consistent with the NBP and the FCC's cost model planning assumptions), then utilization would not reach 50% within 12 years, as shown in **Exhibit 8**.

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In sum, by building out sufficient cell sites, even these 12-year traffic projections from NYCDIT can be supported within 10 megahertz of dedicated spectrum with excess capacity to spare. To be more specific, the FCC funding proposal derived from the FCC Cost Model would provide for significantly more capacity within a 10 megahertz allocation of spectrum than the NYCDIT proposed design which minimizes cell site deployment at the expense of spectral efficiency of NYCDIT's proposed 20 megahertz spectrum allocation. This approach of deploying more cell sites to increase capacity and spectral efficiency is consistent with the FCC Cost Model and funding recommendations for a public safety broadband network developed by the FCC.

New York City 12 Year Growth Requirements

	75% Capacity Uplink Cell Sites Required Year 12	75% Capacity Downlink Cell Sites Required Year 12
Capacity Required in NYC projection	4.8 Gb/s	9.7 Gb/s
No. Cell Sites Needed with FCC Plan	492	433

Exhibit 7

New York City Utilization after 12 Years with 750 cells

Uplink utilization after 12 years	Downlink utilization after 12 years
.49	.43

Exhibit 8

Scenario III: Collapse of the Minneapolis Bridge

The third scenario is based on an actual disaster. At 6:00pm on August 1st, 2007, the Interstate 35 West Bridge collapsed in Minneapolis killing 13 people and injuring 145. Emergency responders reacted quickly. In a little over 2 hours, all survivors from the affected area had been removed. The FCC, with the cooperation of public safety communication officials from Minnesota studied this disaster and issued a report.[47]

As a result of the study certain facts are known which allow us to make certain approximations for purposes of analysis. Nearly all emergency responders in this area shared a common LMR system. This allows us to approximate the number of responders at the scene. We also know that as emergency responders rushed to the incident, the two LMR sites immediately adjacent to the disaster showed a combined increase of approximately 600 unique radio IDs in hour 2 of the disaster, over the baseline of 994 unique radio IDs that were present in the hour preceding the collapse.

We assume that each radio ID represents a single first responder. We assume that a majority of the 994 personnel on duty before the disaster continued their normal function and were randomly scattered throughout the two LMR serving areas, comprising an approximate serving area of 254 square miles. Thus, 600 additional personnel flooded a small area around the site of the disaster, participating in the rescue efforts. We also apportion an additional 40 emergency responders within the emergency area to represent the approximate number of emergency responders that might normally have been within a 10 square mile area of the disaster site and allocated this number to the rescue effort as well. Thus, a total of 640 emergency responders are used to represent the number of responders within the incident area. We vary the area constituting the affected rescue area, first assuming an approximate 10 square mile box that encompassed major highways surrounding the bridge and progressively shrinking the box to 5 sq. miles and then 1 sq. mile. This increases the density of emergency responders in the incident area and increases the traffic load per sector.

In addition to the individual first responders, we consider a scenario in which mobile command centers are on the scene, and are receiving and generating a significant amount of video traffic. The actual amount of video required at the incident scene is, of course, an estimate. As a figure of merit, we take the estimate employed by the NYCDIT in its analysis of the dirty bomb incident of 38 videos down and 12 videos up and apportion this video estimate over a conservative 6 sector[48] area. Thus, within the affected area, each sector supports 6 video links down and 2 video links up.

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[47] *See Minneapolis Bridge Case Study*.

[48] As noted earlier, we estimated a minimum of 9 sectors would cover the equivalent area in the NYC dirty bomb scenario (Scenario I). We assume 6 sectors over which the video traffic will be distributed, rounding the result.

This traffic is designated as Command Unit Uplink and Downlink Video in the traffic model, as shown in **Exhibit 9**.[49] For the command unit video only, we vary the quality of the video from 256 Kb/s to 512 Kb/s. As the model shows, we also assume that some percentage of video, at 256 Kb/s, is generated by emergency responders.

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For these scenarios we assume the following traffic model:

Type of application or device	% of responders carrying device	% of time devices transmit	Up Link data rate (Kb/s)	% of time devices receive	Down Link data rate (Kb/s)
Mobile Video Camera	25%	10%	256	5%	12
Data File Transfer CAD/GIS	87%	15%	50	5%	300
VoIP	100%	5%	27	15%	27
Secure File Transfer	12%	5%	93	5%	93
EMS Patient Tracking	6%	10%	30	5%	50
EMS Data Transfer	6%	25%	20	5%	25
EMS Internet Access	6%	10%	10	5%	90
Command Unit Downlink Video	NA	NA	NA	100%	256, 384, 512
Command Unit Uplink Video	NA	100%	256, 384, 512	100%	256, 384, 512

Exhibit 9

The amount of VoIP traffic in the model is a conservative estimate based on prior analysis of public safety communications.[50]As noted, Command Unit video is derived from the example presented in the *New York City Filing*.[51] The remaining functions are approximations of public safety functions on a broadband network chosen to ensure that each emergency responder will present a network load. In this model, emergency responders are assumed to contribute to the overall video traffic. Assumptions about data rates are taken directly from the *New York City Filing*, PSST Bidder Information Document and the SAFECOM Statement of Requirements (SoR). [52]

[49] Command Units are specialized vehicles used by emergency responder command staff for incident management and generally equipped with extensive communications equipment.

[50] Data developed during the FCC Report on the Minneapolis Bridge Disaster demonstrated that voice utilization by public safety is very low for LMR radio, less than 3%. To remain conservative, we assume higher utilization rates for this analysis.

[51] *See New York City Filing* at 24 (Nov. 17, 2009).

[52] *See* Public Safety Statement of Requirements, Tables 6 and 7 at http://www.safecomprogram.gov/SAFECOM/library/technology/1258_statementof.htm

See also Public Safety Spectrum Trust Public/Private Partnership Bidder Information Document, Version 2.0, November 30, 2007.

See also New York City Filing at. 7.

Exhibit 10 shows the area of the bridge disaster with a 10 square mile area that encompasses major highways surrounding the bridge. Traffic is modeled in the following manner. As shown in **Exhibit 9**, the average number of responders within a sector is calculated and the traffic load generated by emergency responders under the model is calculated. This is combined with the Command Unit video traffic to provide the traffic per sector to be supported. Finally, the traffic utilization for sector is calculated.

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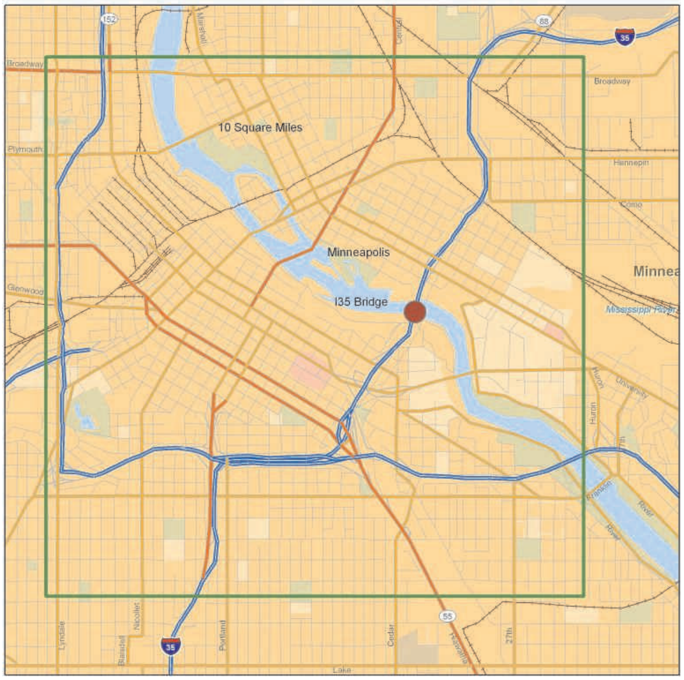

Exhibit 10

Case 1: Responders Operate in 10 Square Mile Area

Responder Area: 10 Square Miles - Sector Utilization

Responders At Scene: 640	**Sectors: 60**	**Responders/Sector: 11**
Type of application or device	**Up Link Load**	**Down Link Load**
Mobile Video Camera	2%	0%
Data File Transfer CAD/GIS	2%	2%
VoIP	1%	1%
Secure File Transfer	0%	0%
EMS Patient Tracking	0%	0%
EMS Data Transfer	0%	0%
EMS Internet Access	0%	0%
Total	5%	3%

Exhibit 11

As can be seen from **Exhibit 11**, with a 10 square mile operating area, the Non-Command Unit traffic has a utilization of only 5% up and 3% down.

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	Video Links	**Up Link Load 256 Kb/s**	**Down Link Load 256 Kb/s**	**Up Link Load 384 Kb/s**	**Down Link Load 384 Kb/s**	**Up Link Load 512 Kb/s**	**Down Link Load 512 Kb/s**
Command Unit Downlink	6	0%	20%	0%	31%	0%	41%
Command Unit Uplink	2	16%	0%	24%	0%	32%	0%
	Total	16%	20%	24%	31%	32%	41%
Total Traffic	**Total All**	21%	23%	29%	34%	37%	44%

Exhibit 12

As shown in **Exhibit 12**, a single sector can support 6 downlink video channels and 2 uplink channels and still support a range of other activities with low utilization levels even at video quality as high as 512 Kb/s for Command Unit traffic. The total utilization with 512 Kb/s Command Unit video is 37% (uplink) and 44% (downlink). Thus, this traffic can easily be supported.

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Case 2: Responders Operate in 5 Square Mile Area

We next look at the same bridge scenario but with emergency responders operating within a 5 mile area, effectively doubling the density of the population as well as the traffic they generate within the served area, as shown in **Exhibit 13**. We again focus on the traffic utilization for a single sector.

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Responder Area: 5 Square Miles - Sector Utilization

Responders At Scene: 640	Sectors: 31	Responders/Sector: 21
Type of application or device	**Up Link Load**	**Down Link Load**
Mobile Video Camera	4%	0%
Data File Transfer CAD/GIS	4%	4%
VoIP	1%	1%
Secure File Transfer	.5%	0%
EMS Patient Tracking	.25%	0%
EMS Data Transfer	.25%	0%
EMS Internet Access	0%	0%
Total	10%	5%

Exhibit 13

	Video Links	**Up Link Load 256 Kb/s**	**Down Link Load 256 Kb/s**	**Up Link Load 384 Kb/s**	**Down Link Load 384 Kb/s**	**Up Link Load 512 Kb/s**	**Down Link Load 512 Kb/s**
Command Unit Downlink	6	0%	20%	0%	31%	0%	41%
Command Unit Uplink	2	16%	0%	24%	0%	32%	0%
	Total	16%	20%	24%	31%	32%	41%
Total Traffic	**Total All**	26%	25%	34%	36%	42%	46%

Exhibit 14

As can be seen from the results in **Exhibit 14**, compressing the incident area provides more traffic per sector. For example, uplink utilization non-command unit traffic has doubled from 5% to 10%. Total traffic utilization per sector however, even for 512 Kb/s video, remains relatively low at 46% (Down Link). Again, this traffic can be supported.

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Case 3: Responders Operate in 1 Square Mile Area

Finally, we examine the scenario where all responders are working within a 1 square mile area. **Exhibit 15** shows this area overlaid on the bridge location. This represents one of the more serious communication scenarios faced by public safety since such a concentration of resources places a greater burden on any communications system.

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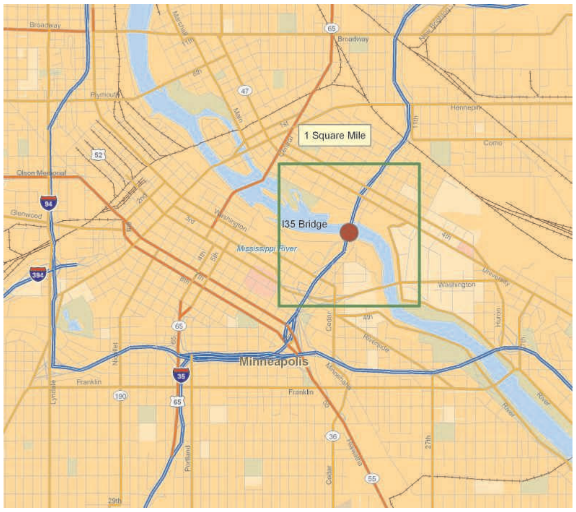

Exhibit 15

Responder Area: 1 Square Mile - Sector Utilization

Responders At Scene: 640	Sectors: 6	Responders/Sector: 107
Type of application or device	**Up Link Load**	**Down Link Load**
Mobile Video Camera	21%	0%
Data File Transfer CAD/GIS	22%	19%
VoIP	4%	6%
Secure File Transfer	2%	1%
EMS Patient Tracking	1%	0%
EMS Data Transfer	1%	0%
EMS Internet Access	0%	0%
Total	51%	26%

Exhibit 16

	Video Links	Up Link Load 256 Kb/s	Down Link Load 256 Kb/s	Up Link Load 384 Kb/s	Down Link Load 384 Kb/s	Up Link Load 512 Kb/s	Down Link Load 512 Kb/s
Command Unit Downlink	6	0%	20%	0%	31%	0%	41%
Command Unit Uplink	2	16%	0%	24%	0%	32%	0%
	Total:	16%	20%	24%	31%	32%	41%
Total Traffic	**Total All**	67%	46%	75%	57%	83%	67%

Exhibit 17

Exhibit 16 and **Exhibit 17** show that with 107 responders within a sector, full video is maintained, even at a video rate of 512 Kb/s for Command Unit Video. Total uplink utilization is at 83% with command unit video of 512 Kb/s. While this is approaching the practical limits of operation, all video assumed in the scenario is still fully supported. With command unit video at 256Kb/s video, uplink utilization is only 67% and the network has excess capacity. All applications are still supported within the sector.

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Local incidents are likely to represent the most extreme communications scenario for a public safety network since responders concentrate within a small area proportionately increasing traffic for that portion of the network. Nevertheless, this analysis demonstrates that there are serious emergencies concentrated within one square mile that can be accommodated with an appropriately built-out network operating in 10 megahertz of dedicated spectrum.

Scenario 4: Hurricane Ike Hits Houston

The fourth scenario is also based on an actual disaster. On Saturday, September 13, 2008, Hurricane Ike struck Texas as a Category 2 hurricane with winds up to 110 mph. Immediately prior to Hurricane Ike's arrival, Galveston Island and other coastal areas were devastated by twenty foot storm surges. Hurricane Ike was extremely large and powerful. At almost 900 miles wide it rolled across the Gulf of Mexico and eventually passed 100 miles to the east of Dallas, Texas. The massive Category 2 hurricane, with winds up to 110 mph at landfall, hit Texas on Saturday, September 13, and became the third hurricane to hit or affect Texas in less than two months. 20-foot storm surges swallowed Galveston Island and other coastal areas just before Ike's arrival and prompted the National Weather Service to later upgrade Ike to a Category 4 hurricane.

The results of our analysis show that in the worst case, the average number of responders per cell site will be 27 and sector utilization will be 18.67% Up Link and 12.9% Down Link. As shown in **Exhibit 18** if 4 times the responders (324 responders) arrived at each cell site, 75% of the Up Link and 51% of the Down Link capacity is utilized – Public Safety communications is still supported.

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This analysis, which is based on empirical data that was collected and analyzed by FCC staff, considers the ability of a public safety broadband network to meet average capacity needs in the 14 sites affected in the aftermath of the hurricane, assuming that emergency responders make full use of a variety of broadband applications, including voice and video.[53] At peak of this event, 14,991 unique radios were active throughout these 14 sites. As this analysis shows, if emergency responders were unformally distributed across the county with the most public safety activity, they would consume a mere 18.67% of uplink capacity and 12.9% of downlink on average at the peak of the response. Moreover, even in the extreme case in which the density of Public Safety responders reached four times that level, a cell site would still have a utilization of 75% in the Up Link and 51% in the Down Link direction, which means there would be more than enough capacity available in 10 megahertz.

Capacity Summary - Equivalent PSBB Network to Support Hurricane Ike				
	PS Radios at Peak per Cell	PS Radios at Peak per sector	Total Up Stream load	Total Down Stream Load
Uniformly Distributed across Typical PSBB network	81	27	18.67%	12.90%
2x PS Responders at scene	162	54	37.34%	25.46%
4x PS Responders at scene	324	108	74.69%	50.59%

Exhibit 18

[53] *See Emergency Communications during Hurricane Ike at, http://www.fcc.gov/pshs/docs/clearinghouse/case-studies/Hurricane-Ike-Harris%20County-120109.pdf.*

Exhibit 19 shows the locations of the Harris County Regional Radio System (RRS) tower sites, in relation to the path of Hurricane Ike. The Harris County RRS with 24 sites, presently covers nine counties and supports more than 44,320 users in 243 agencies and 641 departments. Currently, the system covers 9,581 square miles supporting a population of 5,879,458. The Grade of Service (GoS) objective for this system is 2%, meaning that no more than 2% of calls should experience delays exceeding 3 seconds. However, on September 17th, that objective could not be achieved, as traffic levels reached double those that occur in the busiest hour of a typical day. 95% of all the users were served by the 14 LMR sites along or near the path of Hurricane Ike.

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Exhibit 19

Of the 14,991 Public Safety responders dispersed across these 14 Harris County LMR sites during Hurricane Ike, the major radio users were 58% Law Enforcement, 12% Fire Departments, 10% Public Works, 7% Transportation Departments and 6% Emergency Medical Services. The distribution is shown in **Exhibit 20**.

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Radio Usage during Hurricane Event - Busiest Day	
Type of Radio User	**Total % of Radio Usage**
Law Enforcement	57.79%
Fire Department	12.26%
Public Works	9.82%
Transportation Departments	7.39%
Emergency Medical Service	6.49%
Communications/Dispatching	2.94%
Security Companies	1.53%
Engineering Departments	0.73%
Elected Officials	0.43%
Parks Departments	0.34%
Probation Departments	0.17%
Legal Departments	0.05%
Admin Administrative	0.03%
Environmental Monitoring and Services	0.02%
Independent School Districts	0.01%
Humane Services	0.01%
Utility	0.00%
Grand Total	**100.00%**

Exhibit 20

As discussed in Section II, a broadband system that reaches 99% of the population with approximately 44,000 cell sites, as recommended in the NBP, would have many more cell sites serving the same area. Cell size depends on many factors, and the FCC model [which one] considers both population density and terrain.[54] **Exhibit 21** shows the number of cells estimated in each county. In the roughly 7,265 square-mile area severely affected by the hurricane, we estimate that 529 sites would be deployed, for a total of 1,278 sectors. As a result, the number of active radios per cell at the peak of the response ranges from 5 in Montgomery County to 81 in hard-hit Brazoria County.

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[54] *See Cost Model Paper*.

	HARRIS County Regional Radio System (RRS)						PSBB Network Cell Site Count and PS Users - During Hurricane Ike -		
COUNTY	POPs	Square Miles	Harris RRS All Sites	Sites exceeding Grade of Service (GoS) objective during Hurricane Ike	PS Radio at Peak	PS Radios at Peak per sector	Total Cells Sites	PS Radios at Peak per Cell	PS Radios at Peak per sector
BRAZORIA	309,208	1,773	5	3	6307	701	78	81	27
CHAMBERS	31,431	723	1	0					
FORT BEND	556,870	1,375	3	3	2056	228	104	20	7
GALVESTON	286,814	456	3	1	942	314	18	53	18
HARRIS	4,070,989	2,070	6	5	5291	353	246	21	7
LIBERTY	75,779	1,253	1	0					
MONTGOMERY	447,718	1,591	2	2	395	66	83	5	2
WALKER	64,119	817	2	0					
WALLER	36,530	575	1	0					
	Incident Total :	7,265		14	14,991		Total Cell Sites:		
	Harris RRS Total:	9,581	24				529		

Exhibit 21

For this comprehensive analysis, we considered the applications shown in **Exhibit 22**. Assumptions about data rates are taken directly from the *New York City Filing*, PSST Bidder Information Document and the SAFECOM Statement of Requirements (SoR).[55] We assume that Public Safety responders of various types (*e.g.* police, firefighters, and EMS) are distributed evenly across the disaster area, such that the percentages in each region correspond to the overall percentages from the actual event, presented in **Exhibit 20**. Given that the average number of radios per cell was 81 in the worst case discussed above, we consider the case of 81 radios per cell or 27 per sector.

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Exhibit 22 is based on the county that was most severely affected by the hurricane, and assumes that responders are uniformly distributed across that county. In reality, the density of responders may be greater in some parts of the county and worse in others. Thus, a busy cell may have two or more times the density of responders. Nevertheless, as shown in the table below, there is ample capacity even if density reaches four times the country-wide average of the busiest county and the busiest time in the aftermath of Hurricane Ike.

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The results show a mean utilization of, only 18.67% in the Up Link and 12.9% in the Down Link direction. Therefore, during this extreme disaster in September 2008, when the Harris County RRS encountered an exceedingly high demand for resources, which

[55] *See id.* The FCC takes no position on the appropriateness of New York City's assumptions.

See also; Public Safety Statement of Requirements, Tables 6 and 7 at http://www.safecomprogram.gov/SAFECOM/library/technology/1258_statementof.htm.

See also; Public Safety Spectrum Trust Public/Private Partnership Bidder Information Document, Version 2.0, November 30, 2007.

resulted in a doubling of busy-hour traffic, a public safety broadband network with 10 megahertz of dedicated spectrum could have supported this mission critical event.

Hurricane Ike Incident Scenario

PS Responders at scene- Uniformly Distributed across 426 PSBB sites:	14,991	# of PSBB sectors serving:	1278	PS Responders per sector:	27				
Type of application or device	**% of responders carrying device**	**% of time devices transmit**	**Up Stream data rate (Kb/s)**	**Up Stream Capacity (Kb)**	**% of time devices receive**	**Down Stream data rate (Kb/s)**	**Down Stream Capacity (Kb)**	**Up Stream load**	**Down Stream Load**
Law Enforcement Mobile Video Cameras	58%	10%	256	3,250	5%	12	7,500	12.34%	0.25%
Law Enforcement Data file transfer CAD/GIS	58%	10%	50	3,250	5%	300	7,500	2.41%	6.26%
Law Enforcement Mobile Handheld Users (VoIP)	58%	5%	27	3,250	15%	27	7,500	0.65%	0.28%
Fire Department Data file transfer CAD/GIS	12%	15%	50	3,250	5%	300	7,500	0.75%	1.94%
Fire Department Secure File Transfer Program (SFTP)	12%	5%	93	3,250	5%	92	7,500	0.46%	0.20%
Fire Department Mobile Handheld Users (VoIP)	12%	5%	27	3,250	15%	27	7,500	0.13%	0.06%
Public Works Data file transfer CAD/GIS	10%	15%	50	3,250	5%	300	7,500	0.62%	1.62%
Public Works Mobile Handheld Users (VoIP)	10%	5%	27	3,250	15%	27	7,500	0.11%	0.05%
Transportation Departments Mobile Handheld Users (VoIP)	7%	5%	27	3,250	15%	27	7,500	0.08%	0.03%
Transportation Departments Data file transfer CAD/GIS	7%	18%	50	3,250	5%	300	7,500	0.52%	1.36%
Other Mobile Handheld Users (VoIP)	7%	5%	27	3,250	15%	27	7,500	0.08%	0.03%
Emergency Medical Service Patient Tracking	6%	10%	30	3,250	5%	50	7,500	0.15%	0.11%
Emergency Medical Service Data Transfer	6%	25%	20	3,250	5%	25	7,500	0.25%	0.14%
Emergency Medical Service Internet Access	6%	10%	10	3,250	5%	90	7,500	0.05%	0.19%
Emergency Medical Service Mobile Handheld Users (VoIP)	6%	5%	27	3,250	15%	27	7,500	0.07%	0.03%
							Total:	18.67%	12.56%

	Number	Video Streams	% of time devices transmit	Up Stream data rate (Kb/s)	Up Stream Capacity (Kb)	% of time devices receive	Down Stream data rate (Kb/s)	Down Stream Capacity (Kb)	Up Stream load	Down Stream Load
Broadcast Video Channel	1	1	0	0	0	10%	256	7,500	0.00%	0.34%
Command Units	0	1	100%	256	3,250	100%	1,000	7,500	0.00%	0.00%

	Up Stream load	Down Stream Load
Total All	18.67%	12.90%

Exhibit 22