Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	)	
	)	
The Development of Operational, Technical	)	
and Spectrum Requirements for Meeting	)	WT Docket 96-86
Federal, State and Local Public Safety	)	
Communications Requirements Through the	)	
Year 2010	)	
	)	

COMMENTS OF LUCENT TECHNOLOGIES, INC.

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EXECUTIVE SUMMARY

As more fully set forth herein, Lucent Technologies, Inc. ("Lucent") requests the Federal Communications Commission ("Commission") to rechannelize the 700 MHz public safety band to replace the existing wideband channels with three 1.25 MHz broadband channels.

The Commission's objective in 1998 when it initially promulgated the 700 MHz public safety band plan was to meet vital current and future public safety communications needs and to accommodate new public safety applications based on newly-developed technologies. Both the communications needs of first responders and the state-of-the-art in wireless technologies have changed dramatically since then. As the demands on the public safety community continue to increase, the need for first responders to have access to advanced mobile data applications becomes more apparent. Currently, however, the data technologies taken for granted by U.S. consumers, including nationwide mobile access to email, the Internet, and, most recently, streaming video, simply are not available to our nation's first responders. By specifying public safety's use of commercial broadband technologies, the Commission can enable first responders to quickly deploy fully interoperable, economically and spectrally efficient data networks capable of supporting high data rate applications.

The Commission should allocate 700 MHz spectrum resources for public safety's broadband networks because, unlike the 800 MHz public safety allocation, the 700 MHZ allocation is greenfield spectrum and therefore can be rechannelized without disrupting existing public safety communications or stranding legacy equipment. In addition, unlike the 4.9 GHz public safety allocation, the 700 MHz band offers appropriate propagation characteristics for cost-effective wide-area coverage.

Commercial broadband technologies, such as EV-DO, pose several significant advantages over wideband technologies, such as Scalable Adoptive Modulation ("SAM"). First, commercial broadband is highly spectrally efficient due to the technology's ability to support a frequency reuse of one. As a result, a three-channel nationwide broadband network can carry roughly ten times more data than can be carried using SAM in the same aggregate amount of spectrum. Second, unlike SAM, broadband provides users with sufficient data throughput to run the most advanced mobile applications, such as high-quality, near-real-time video.

Third, broadband was designed to offer seamless interoperability. Fourth, for a comparable cell-edge data rate, the cell range achievable with EV-DO is greater than that of SAM. Finally, the use of commercial technologies for public safety data networks will enable first responders to leverage the commercial wireless market's research and development investments and economies of scale to reduce costs compared to a niche technology, such as SAM. In addition, next generation commercial broadband technologies always have offered backward compatibility, thereby ensuring that the public safety community will be able to upgrade networks without stranding legacy devices.

The Commission should not adopt a permissive, mixed-use wideband and broadband channelization of the 700 MHz public safety band. Although providing individual public safety entities with the option of adopting wideband or broadband channels (or some combination of both) appears on its face to offer maximum flexibility, such mixed-use would, in fact, undercut the interoperability of first responder data communications, which is directly inconsistent with the Commission's objectives with respect to this spectrum. Further, operation of wideband and broadband equipment in the band will result in higher costs in the near term and encumber first

responders' future deployment of next generation broadband systems by requiring them first to clear legacy wideband deployments.

Further, we propose the Commission mandate the use of a single, commercial broadband technology by all first responders in the public safety 700 MHz band—cdma2000 1x Evolution-Data Optimized ("EV-DO")—to best facilitate broadband interoperability in view of the limited bandwidth available in the wideband block.

Finally, as set forth in detail herein, use of paired 1.125 MHz guardbands will prevent broadband systems operating in the center of the 700 MHz public safety band from causing interference to 700 MHz narrowband operations, without compromising spectral efficiency. Even considering the spectrum occupied by the guardbands, EV-DO networks will have far more data capacity than SAM networks deployed using the same spectrum resources. Also, no modifications to the Commission's out-of-band emission limits are necessary to support EV-DO in this band.

For these reasons, Lucent respectfully requests the Commission to adopt the Lucent Plan as set forth in the Commission's notice of proposed rulemaking.

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The Development of Operational, Technical and Spectrum Requirements for Meeting Federal, State and Local Public Safety Communications Requirements Through the Year 2010	)	WT Docket 96-86
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COMMENTS OF LUCENT TECHNOLOGIES, INC.

Pursuant to Section 1.415 of the rules of the Federal Communications Commission ("Commission"),[1] Lucent Technologies, Inc. ("Lucent") respectfully submits the instant comments in the above-captioned proceeding. The Commission requested interested parties to comment on whether and how the public safety portion of the 700 MHz band plan should be modified to accommodate interoperable broadband communications.[2] In particular, the Commission requested comment on three proposals to rechannelize this spectrum band to include broadband channels, either exclusively or in addition to existing wideband channels—the Lucent Plan, the Motorola Plan, and the National Public Safety Telecommunications Council

[1] 47 C.F.R. § 1.415.

[2] Development of Operational, Technical and Spectrum Requirements for Meeting Federal, State and Local Public Safety Communications Requirements Through the Year 2010, WT Docket No. 96-86, *Eighth Notice of Proposed Rulemaking*, 21 FCC Rcd 3668 (2006) ("*Eighth NPRM*").

("NPSTC") Plan.[3] As set forth herein, Lucent urges the Commission to adopt the Lucent Plan by rechannelizing the wideband block of the 700 MHz public safety band for broadband use and specifying the use of a commercial broadband technology nationwide—cdma2000 1x Evolution-Data Optimized ("EV-DO"). The Lucent Plan best serves the spectrum needs of the public safety community by providing first responders with the most effective and interoperable high-bandwidth data communications in the short term while, unlike the Motorola Plan and NPTSC Plan, enabling the public safety community's communications systems to evolve over the long term as broadband data technologies continue to evolve.

I. THE COMMISSION SHOULD REFORM THE 700 MHZ PUBLIC SAFETY BAND PLAN TO FACILITATE THE DEPLOYMENT BY FIRST RESPONDERS OF STATE-OF-THE-ART BROADBAND COMMUNICATIONS SYSTEMS

A. The Commission Should Adopt a Revised 700 MHz Band Plan That Accommodates Improvements in Wireless Data Technologies Since the Development of the Existing Plan and Accommodates Future Improvements in Broadband Technologies

Wireless technologies and the role played by wireless data services in public safety operations have changed dramatically since 1998 when the Commission first established the 700 MHz public safety band plan. The band plan adopted by the Commission nearly a decade ago, consisting of 24 MHz of spectrum divided into 1,920 6.25 kHz narrowband channels and 240 50 kHz wideband channels,[4] is not capable of accommodating state-of-the-art, high-speed

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[3] *See Eighth NPRM*, at ¶¶ 14-23 (describing each of the proposals to rechannelize the existing 700 MHz public safety band).

[4] Development of Operational, Technical and Spectrum Requirements For Meeting Federal, State and Local Public Safety Agency Communication Requirements Through the Year 2010; Establishment of Rules and Requirements For Priority Access Service, *First Report and Order and Third Notice of Proposed Rulemaking*, WT Docket No. 96-86, 14 FCC Rcd 152, ¶ 2

interoperable data services required by first responders today—*i.e.*, broadband technologies. Our first responders deserve access to the best, most advanced mobile communications technologies available and must be able to use these technologies to communicate across jurisdictional boundaries. Consequently, the Commission should take this opportunity to update the 700 MHz band plan to accommodate today's most advanced technologies.

The Commission recognized in 1998 that "[i]n order to successfully perform their missions in the modern world, public safety entities must rely on a forward-looking spectrum policy that promotes beneficial technological advances into their communications systems."[5] Accordingly, recognizing that the public safety community was likely to require the use of "new applications based on newly-developed technologies,"[6] the Commission adopted a "building blocks" spectrum aggregation approach to channelization[7] to "make provision in the 700 MHz band for both current and evolving operational modes,"[8] such as high speed data, including

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(1998) (summarizing the Commission's initial adoption of the 700 MHz public safety band plan) ("*First R&O*"). These channels are divided into general use, nationwide interoperability, and reserve spectrum categories. However, the Commission has requested comment on the rechannelization of the entire 700 MHz public safety spectrum band without consideration of the respective categorization of the channels. *See Eighth NPRM*, at¶ 5.

[5] *First R&O*, at ¶ 22.

[6] *Id.* at ¶ 22 n53 (citing the Final Report of the Public Safety Wireless Advisory Committee to the Federal Communications Commission, 2 (Sept. 11, 1996) which discussed, *inter alia*, first responders' need for larger spectrum blocks for "broadband data systems to provide access to databases for police officers on patrol, the use of video systems for surveillance purposes, and control of toxic or hazardous environments by robotics").

[7] Specifically, narrowband channels may be combined into spectrum blocks up to 25 kHz and wideband channels may be aggregated into blocks up to 150 kHz. *Id.* at ¶¶ 39-41.

[8] *Id.* at ¶ 24.

multimedia applications, images, and video.[9] The Commission's objective of "meet[ing] vital current and future public safety communications needs"[10] through its 700 MHz public safety band plan is just as warranted today as it was in 1998. Moreover, the need for better, more sophisticated public safety wireless technologies has never been more apparent. Despite the clear lesson provided by the national tragedy on September 11, 2001,[11] public safety personnel nevertheless still were struggling with the inadequacy of their mobile communications resources during the natural disasters inflicted along the Gulf Coast in 2005 by hurricanes Katrina and Rita.[12]

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[9] *Id.* at ¶ 40 ("We also must provide for a wideband channel size sufficient to accommodate the principal wideband applications (image/[high speed data] and video) envisioned for public safety use."); *see also id.* at ¶ 24 ("There are also projected needs for additional spectrum to . . . support the use by the public safety community of data applications, which are expected to increase exponentially in the next decade. Public safety entities also seek additional spectrum to develop emerging technology applications, such as image/HSD, video, and perhaps multimedia applications, which will enable them to better and more efficiently serve the public.") (citations omitted).

[10] *Id.* at ¶ 1.

[11] *See* The 9/11 Commission Report: Final Report of the National Commission on Terrorist Attacks Upon the United States, 396 (2004) ("The inability to communicate was a critical element at the World Trade Center, Pentagon, and Somerset County, Pennsylvania crash sites, where multiple agencies and jurisdictions responded. The occurrence of this problem at three very different sites is strong evidence that compatible and adequate communications among public safety organizations at the local, state, and federal levels remain an important problem."). *See also* Arlington County, After-Action Report on the Response to the September 11, 2001 Terrorist Attack on the Pentagon, 12-13 (2002) ("Almost all aspects of communications continue to be problematic, from initial notification to tactical operations. . . . [I]nteroperability problems among jurisdictions and agencies persist."); McKinsey & Company, Increasing FDNY's Preparedness, at 95 (2002) ("The FDNY needs to ensure that it can effectively and rapidly communicate with other agencies.") ("*NYC 9/11 Report*").

[12] *See, e.g.*, State Improving Interoperability Among First Responders: Government Establishes Panel to Direct Creation of Statewide System, 1 (2006) ("What we experienced in Katrina was not a failure to communicate, but an inability to communicate."); Mike Haston, *Inability to Communicate Major Flaw in Storm Response*, THE SHREVEPORT TIMES, May 28,

At minimum, the Commission should afford first responders with access to the same communications capabilities taken for granted by American consumers. The advance of commercial wireless technologies has dramatically outpaced improvements in public safety wireless technologies over the past decade. Commercial wireless providers are rapidly deploying third generation wireless networks both to enable consumers to take advantage of innovative new mobile applications and to benefit from the spectral efficiencies commercial broadband technologies make possible.[13] As a result, consumers are quickly becoming accustomed to having nationwide access to email, the Internet, and, most recently, streaming video from their wireless handsets.[14] In contrast, first responders still struggle with the cross-jurisdictional interoperability of basic voice communications.

If spectrum resources capable of supporting mobile broadband are not made available to first responders, today's dramatic technological disparity between public safety mobile communications systems and commercial wireless networks only will increase. The widest

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2006 ("Immediately after hurricanes Katrina and Rita, one of the biggest problems was the inability of local, state and federal officials to talk to each other.").

[13] *See, e.g., Make Way for 3G: New Cellular Networks Offer Mobile Workers Ubiquitous Access to Enterprise Applications*, NETWORK WORLD, Jan. 30, 2006 (discussing deployment of third generation networks by Cingular, Sprint Nextel and Verizon); *Cingular Wireless Announces Plans for 3G Wireless Network*, WIRELESS NEWS, Dec. 1, 2004.

[14] *See, e.g., Sprint Eyes Media Options, Talks to Sling Media*, REUTERS, May 25, 2006 (discussing Sprint Nextel's plans with respect to mobile video); Seth Schiesel, *For Wireless, the Beginnings of a Breakout*, THE NEW YORK TIMES, Jan. 13 2005 (discussing the applications available to consumers and businesses using equipment based on third generation technologies); Stephen Lawson, *Verizon Wireless Expands 3G Service*, PC WORLD, Jan. 9, 2004 (reporting that Verizon's BroadbandAccess service, based on EV-DO, will enable data speeds up to 500 Mbps). By contrast, the wideband technology for which the 700 MHz public safety band currently is channelized may offer only 75-120 kbps throughput if multiple channels are aggregated. *See infra* at 20.

possible aggregated channel in the existing 700 MHz public safety band, 150 kHz, is too small to accommodate the existing capacity and data-rate requirements of the public safety community, much less their communications needs in the future. Unless the existing 700 MHz public safety band plan is modified to accommodate broadband technologies, on February 17, 2009, the date on which broadcasters are required to vacate the 700 MHz band as part of the digital television conversion,[15] the public safety community will be relegated to a wideband technology that was not state-of-the-art in 2006 while commercial wireless providers will be operating networks capable of supporting Megabit per second ("Mbps") user data rates.[16]

The greenfield spectrum available in the 700 MHz public safety band offers the Commission a unique opportunity to address and resolve the divergence in functionality between commercial and public safety communications systems. In keeping with Congress's stated goals of ensuring that public safety has access to "spectrum sufficient for public safety services to meet current and projected communications requirements, including innovative technical applications," [17] the Commission should reform the 700 MHz band plan to accommodate broadband technologies. By adopting the Lucent Plan, the Commission can provide first responders with access over the short term to today's most advanced communications

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[15] *See* Deficit Reduction Omnibus Reconciliation Act of 2005, Pub. L. No. 109-171, § 3002 (2005).

[16] *Sprint Plans $20-$40, 2-3 Mbps Mobile Service in Top 100 Markets Starting 2008*, COMMUNICATIONS DAILY, Jan. 20, 2006 (discussing Sprint's plans to begin deploying in 2008 a fourth generation mobile network capable of supporting user bandwidths of two to three Mbps).

[17] *First R&O*, at ¶ 4 (endorsing Congress's policy objectives expressed in the Budget Act of 1997, Balanced Budget Act of 1997, Pub. L. No. 105-33, 111 Stat. 251 (1997)).

capabilities, and, even more important, a means of evolving public safety mobile communications systems over the long term to keep pace with state-of-the art technologies.

B. The 700 MHz Spectrum Band is the Only Spectrum Currently Available that is Ideally Suited for Public Safety High-Speed Wide-Area Data Communications

The Commission repeatedly has concluded that 700 MHz spectrum is uniquely suited to support broadband communications.[18] This spectrum band possesses propagation characteristics that are consistent with public safety's needs and, more important, is not encumbered by legacy public safety networks. By comparison, other public safety spectrum allocations either offer technical characteristics that render them inadequate for deployment of broadband communications systems by the public safety community or are burdened by extensive existing public safety use.

700 MHz. Due to favorable propagation characteristics, 700 MHz spectrum offers enhanced coverage over large geographic areas. This results in lower deployment costs because substantially fewer antenna sites and backhaul links are needed for a particular geographic region

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[18] *See, e.g.*, Inquiry Concerning Deployment of Advanced Telecommunications Capability to All Americans in a Reasonable and Timely Fashion, and Possible Steps To Accelerate Such Deployment Pursuant to Section 706 of the Telecommunications Act of 1996, CC Docket No. 98-146, *Notice of Inquiry*, 15 FCC Rcd 16641 ¶ 14 (2000) ("There appears to be substantial technical potential for broadband services on the 700 MHz commercial bands."); Service Rules for the 746-764 and 776-794 MHz Bands, and Revisions to Part 27 of the Commission's Rules; Carriage of the Transmissions of Digital Television Broadcast Stations; Review of the Commission's Rules and Policies Affecting the Conversion to Digital Television, WT Docket No. 99-168, CS Docket No. 98-120, MM Docket No. 00-39, *Third Report and Order*, 16 FCC Rcd 2703, 2733 (2001) (dissenting statement of Gloria A. Tristani) ("700 MHz spectrum offers unlimited possibilities for advanced wireless services"). *See also* FCC Task Force Recommends Actions to Speed the Rollout of Wireless Broadband Services to Consumers Across America, 2005 LEXIS 845 (2005) (in which representatives of several Commission bureaus determined"spectrum in the 700 MHz band is ideal for mobile broadband applications").

compared to higher frequency spectrum allocations.[19] Radiofrequency ("RF") transmissions at higher frequencies experience higher levels of attenuation as they propagate from a transmitter to a receiver. As a result, higher mobile transmit powers are required at higher frequencies to combat these higher levels of attenuation. These higher power levels and the limited output power that is feasible with battery-powered devices conspire to limit the range of a radio cell as transmission frequencies increase.

The primary benefit of the 700 MHz spectrum band, however, is that the Commission can modify the band's channelization to support broadband technologies without disrupting existing users or stranding equipment that already has been deployed. Upon the surrender of the 700 MHz band by television broadcasters, it will be greenfield spectrum unencumbered by legacy public safety networks reliant on historic channelization plans.[20] No other spectrum with appropriate propagation characteristics possesses this attribute.

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[19] *See infra* at 10-13.

[20] Although 700 MHz regional planning committees are in the process of drafting plans for the 700 MHz public safety spectrum band under the assumption that the center of the band will be required to be used for wideband communications per the Commission's existing band plan, only eight such plans thus far have been submitted to the Commission for approval, and only four plans have in fact been approved by the Commission. *See Eighth NPRM*, at ¶ 25. *See also* Wireless Telecommunications Bureau Seeks Comments on Request By Hennepin County, Minnesota, for Temporary Waiver of Part 90 Rules to Allow Establishment of a Region-Wide 700 MHz Wideband Public Safety Data Communications System, *Public Notice*, DA 06-1182 (June 1, 2006) ("Hennepin County states that [its proposed 700 MHz wideband communications system] will be the first public safety wireless data system in the nation utilizing SAM technology.") Consequently, it is unlikely that state and local public safety agencies have spent significant amounts on communications equipment reliant on the existing 700 MHz wideband channelization. Moreover, any detriment to such public safety agencies from setting aside their 700 MHz wideband coordination efforts to date is easily outweighed by the benefits that will accrue to the agencies for years to come from having access to broadband communications.

800 MHz. Approximately 9.5 MHz of 800 MHz spectrum has been allocated for public safety use.[21] Although this allocation is used primarily to support voice and low speed data services (*i.e.*, data rates of less than 10 kilobits per second ("kbps")) using narrowband channelization,[22] the spectrum possesses similar propagation characteristics to the 700 MHz band and therefore would be capable of supporting public safety broadband communications if it were rechannelized. However, the allocation is heavily encumbered by existing public safety uses and equipment and currently is undergoing a band realignment to avoid future interference from high-power uses of adjacent 800 MHz commercial spectrum allocations.[23] Accordingly, by

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[21] *See* Federal Communications Commission, *Report to Congress On the Study to Assess the Short-Term and Long-Term Needs for Allocation of Additional Portions of the Electromagnetic Spectrum for Federal, State and Local Emergency Response Providers*, at ¶ 5 (Dec. 19, 2005) (summarizing public safety spectrum allocations) ("*Report to Congress*").

[22] *See generally* Amendment of Part 90 of the Commission's Rules to Designate Frequencies in the 806-821 and 851-866 MHz Bands for Slow-Growth Land Mobile Radio Systems of Utilities and Public Safety Agencies, PR Docket No. 79-191, *Report and Order*, 48 Rad. Reg. 2d (P&F) 837 (1980) (allocating fifty narrowband channels in the 800 MHz band to public safety); Amendment of Part 90 of the Commission's Rules to Release Spectrum in the 806-821/851-866 MHz Bands and to Adopt Rules and Regulations Which Govern Their Use, PR Docket 79-191, *Second Report and Order*, 90 FCC 2d 1281 (1982) (increasing the number of public safety 800 MHz channels from fifty to seventy narrowband channels); Amendments of Parts 2 and 22 of the Commission's Rules Relative to Cellular Communications Systems, GEN Docket No. 84-1231, *Report and Order*, 2 FCC Rcd 1825 (1986) (allocating 6 MHz of narrowband spectrum in the 821-824/866-869 MHz bands for public safety) ("*800 MHz R&O*").

The reconfiguration of the 800 MHz band ordered by the FCC will not cause the band to be rechannelized but rather will modify the existing 800 MHz band to reduce interference to public safety entities from commercial mobile wireless service providers. *See generally* Improving Public Safety in the 800 MHz Band, WT Docket 02-55, *Report and Order, Fifth Report and Order, Fourth Memorandum Opinion and Order*, 19 FCC Rcd 14969 (2004) ("*Nextel Order*") (discussing interference problems with current configuration of 800 MHz band and ordering reconfiguration to address these problems).

[23] *See generally Nextel Order* (discussing reorganization of the public safety portion of the 800 MHz band, which is now from 806-824/851-869 MHz); *Supplemental Order and Order*

comparison to the relatively minimal cost of rechannelizing the greenfield 700 MHz public safety band, the cost of accommodating broadband public safety systems in the 800 MHz band is prohibitive.

As an initial matter, any modification of the channelization in this band to support multiple, contiguous 1.25 MHz blocks of spectrum would require substantial disruption to existing public safety communications and strand previously deployed narrowband equipment. Moreover, the Commission, Sprint Nextel, and the public safety community already have expended substantial resources over the past six years on the ongoing 800 MHz band realignment[24]—far more than the 700 MHz regional planning committees have spent to date in reliance on the existing 700 MHz band plan. Accordingly, further disruption of existing public safety operations in this band does not seem warranted, especially given the availability of the greenfield 700 MHz band.

4.9 GHz. Approximately 50 MHz of 4.9 GHz spectrum has been allocated for public safety use.[25] This allocation is certain to play an important role in mobile broadband communications over short ranges and fixed, point-to-point broadband communications over

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on Reconsideration, 19 FCC Rcd 25120 (2004); *Memorandum Opinion and Order*, 20 FCC Rcd 16015 (2005).

[24] *See Nextel Order*, at ¶ 61 (outlining timeline major milestones in 800 MHz band rationalization proceeding); Howard Buskirk, *Most Public Safety Licensees Still Not Seeking Planning Reimbursement From Sprint Nextel*, COMMUNICATIONS DAILY, Jun. 2, 2006 (stating that, as of March 31, 2006, Sprint Nextel reported spending $376 million on rebanding costs). Of the $850 million committed by Sprint Nextel for the retuning and replacement expenses associated with reconfiguration of the 800 MHz band, $700 million is dedicated for public safety licensees. *See* Supplemental Comments of the Consensus Parties, WT Docket No. 02-55 (Dec. 24, 2002).

[25] *See Report to Congress*, at ¶ 5 (summarizing public safety spectrum allocations).

longer ranges.[26] However, as the Commission previously has recognized, the poor propagation characteristics of this band, *e.g.*, high pathloss, poor foliage penetration, and low transmission powers, make it unsuitable for the wide-area mobile broadband wireless communications required by public safety entities.[27]

The deployment of mesh-based 4.9 GHz networks does not alter this conclusion. In the 4.9 GHz band, mesh networks cannot economically be used for wide-area coverage for several reasons. First, 4.9 GHz point-to-multipoint base stations are limited in geographic reach to roughly 300 yards in an urban environment.[28] By contrast, relatively low-power (*i.e.*, 800 mW

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[26] Spectrum allocated to public safety entities in the 4.9 GHz band supports data rates far in excess of the rates required for support of full-motion near-real-time video. 802.11(a), for example, provides data rates of up to 54 Mbps utilizing only 20 of the 50 MHz available in the 4.9 GHz public safety band. However, due to range constraints, the spectrum only is likely to be used for very localized communications systems requiring very high data rates and/or capacities, such as mobile systems for critical infrastructure, such as hospitals and police, fire, and emergency medical stations. The 4.9 GHz spectrum band also can be used with directional antennas to provide longer range, point-to-point fixed communications links used for backhaul. Such links, however, are of limited use to first responders for operational communications and cannot replace mobile broadband communications.

[27] *See* 4.9 GHz Band Transferred from Federal Government Use, WT Docket No. 02-47, *Second Report and Order and Further Notice of Proposed Rulemaking*, 17 FCC Rcd 3955, ¶ 26 (2002) (recognizing that 4.9 GHz spectrum is appropriate for short-range communications, such as incident scenes, whereas 700 MHz spectrum is "better suited for longer-range communications over larger service areas") ("*4.9 GHz R&O*"). *See also* LA County Comments, at 4 ("The 4.9 GHz band is not appropriate for wide-area mobile broadband communication, especially in a jurisdiction as large and varied as LA County."); Exhibit A (Propagation Loss Estimates at 4.9 GHz), at 2 (noting that already low ranges of 4.9 GHz communications will be reduced further when obstructions, *e.g.*, vegetation or walls, are considered).

[28] These ranges assume the deployment of low-gain, omni-directional antennas that operate with low transmit powers. Such antennas would be necessary for a mobile network comprised of multiple antenna sites. Longer ranges can be achieved for point-to-point backhaul links using directional antennas and higher output powers, but such links are of limited to utility to first responders requiring mobile communications capabilities. *Se*e Exhibit E (Range Analysis of EV-DO Rev. A and TIA-902.SAM).

EIRP) commercial broadband user devices utilizing 1.25 MHz channels in the 700 MHz band are capable of reliably supporting data rates of roughly 500 kbps for a range of 4.2 miles in an urban environment, 7.9 miles in a suburban environment, and 25.6 miles in open areas. As a result, ubiquitous coverage of a significant geographic area using a 4.9 GHz mesh network would require a far higher number of antenna sites when compared to a 700 MHz broadband network.[29] For example, the District of Columbia estimates that citywide coverage using 4.9 GHz spectrum would require nearly 50 times the number of antenna sites than would be required using 700 MHz spectrum.[30] As a result, the financial and time expenditure that would be required to deploy a wide-area mesh network would simply be prohibitive.

Moreover, given the vast number of antenna sites that would be required by a 4.9 GHz mesh network, local zoning laws governing antenna siting would create another tremendous obstacle, which could lead to holes in network coverage. In addition, the large number of antenna sites would make it difficult and potentially cost-prohibitive to deploy back-up power to prevent the network from being incapacitated by a power outage. Because of the smaller number of antenna sites required by a 700 MHz broadband network, back-up power generation facilities can be deployed and kept fueled to enable the network to withstand even prolonged outages.

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[29] *See* Spectrum Coalition Comments, at 18-20 (describing coverage limitations of 4.9 GHz spectrum).

[30] *On Protecting Homeland Security: A Status Report on Interoperability Between Public Safety Communications Systems: Hearing Before the House Subcommittee on Telecommunications and the Internet* (2004) (statement of Robert LeGrande, Deputy Chief Technology Officer, District of Columbia) ("*Interoperability Testimony*") *available at* http://energycommerce.house.gov/108/Hearings/06232004hearing1310/Legrande2091.htm. *See also* Comments of the Los Angeles County Sheriff's Department, WT Docket No. 05-157, at 7 ("[C]omplete coverage of a county like LA would require significantly more sites in the 4.9 GHz band than the 700 MHz band.").

Second, other fundamental technical characteristics of mesh-based networks will pose obstacles to effective wide-area coverage using numerous antenna sites. For example, network delays are inherent to the transport of data packets across multiple antenna sites. Consequently, substantial latency will be introduced as a communication is transmitted among the vast number of antenna sites required by a mesh-based 4.9 GHz network.[31] Also, because of degradation in signal quality caused by RF signals reflecting off buildings, hills and other large obstacles, achievable data rates at the edge of each antenna site's range for WiFi-based deployments will be reduced substantially. In certain circumstances, this may make network connections impossible.

In sum, the economic and technical impediments to the deployment of an effective 4.9 GHz broadband network covering a substantial geographic area probably are insurmountable. At minimum, such a network would be far more expensive, pose greater technical challenges, and take much longer to deploy than a broadband public safety network using 700 MHz spectrum to cover the same area.

II. COMMERCIAL BROADBAND TECHNOLOGIES OFFER SUBSTANTIAL ADVANTAGES OVER WIDEBAND TECHNOLOGIES

There is broad consensus regarding the importance of broadband technology to the public safety community.[32] For example, all three of the 700 MHz public safety band proposals

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[31] Multiple backhaul links may be deployed to reduce such delays, but the additional backhaul links would increase operational costs significantly.

[32] *See, e.g.*, *NYC 9/11 Report*, at 88 ("[T]he portable radios used in the World Trade Center response lacked more advanced features available in the marketplace."); The Spectrum Coalition for Public Safety, *Public Safety Spectrum: How Much Do We Need for Data?*, WT Docket No. 05-157 (Oct. 25, 2005) ("Public Safety Spectrum Report"); Comments of The Association of Public-Safety Communications Officials-International, Inc. and NPSTC, WT Docket No. 05-157, 6 (Apr. 28, 2005) ("Public safety agencies are increasingly recognizing the

addressed by the Commission in its *Eighth NPRM*—the Lucent Plan, the Motorola Plan, and the NPSTC Plan—propose to modify the 700 MHz public safety band plan to accommodate broadband technologies. In addition, a variety of public safety entities have stated clearly that broadband applications are required to satisfy public safety's wireless communications needs effectively.[33] The Commission, in consultation with the Department of Homeland Security ("DHS") and the National Telecommunications and Information Administration, recognized this consensus in its December 2005 *Report to Congress*:

> Emergency response providers would benefit from the development of an integrated interoperable nationwide network capable of delivering broadband services throughout the country. A network that delivers real-time, high speed, highly secure broadband data to emergency response providers in the field would improve their ability to respond to emergencies.[34]

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need for mobile broadband capability.") ("APCO/NPSTC Joint Comments"); Comments of County of Los Angeles, Internal Services Department and Los Angeles County Sheriff's Department, WT Docket No. 05-157 (Apr. 28, 2005) (discussing the "pressing need for a new county-wide, broadband mobile communications system" to enable first responders to "transmit and receive high speed data and full-motion video") ("LA County Comments").

[33] For example, Los Angeles County requires the ability to transmit and receive high-speed data and full-motion video to and from vehicles, emergency scenes, and command centers. *See* LA County Comments, at 3. *See also* APCO/NPSTC Comments, at 6 ("Real time, full motion video from any location in an agency's area of jurisdiction to any other location could be an invaluable tool for all elements of public safety."); Comments of City of Seattle, WT Docket No. 05-157, at 1 (Apr. 28, 2005) ("Seattle needs wireless networking which supports propagation through buildings, real time video, large file transfers, enhanced mission-specific (police, fire, utility) applications, special geographical (map-based) presentations, simplified user interfaces, and use of voice over IP for interoperability and redundancy."); Comments of California Highway Patrol, WT Docket No. 05-157, at 1 (Apr. 28, 2005) ("CHP is specifically interested in the potential to enhance our video downlink, currently an extremely bandwidth-intensive spectrum.").

[34] *Report to Congress*, at ¶ 2.

Even if a single nationwide broadband public safety network is not deployed in the foreseeable future,[35] the Commission can enable the public safety community to realize much of the benefit that would accrue from such a network by rechannelizing the 700 MHz public safety spectrum band to support broadband applications and mandating the use of a single, interoperable commercial broadband technology nationwide.

The benefits include greater spectral efficiencies, higher user throughputs, and enhanced interoperability offered by broadband technologies—benefits that generally are unavailable from wideband technologies, including Scalable Adaptive Modulation ("SAM"). In addition, adoption of a commercial broadband technology, such as EV-DO, will enable first responders to benefit from both prior and future research and development funded by commercial markets, facilitate future technology upgrades by first responders by ensuring backward compatibility of next generation systems, and reduce overall deployment costs by leveraging mass market economies of scale.

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[35] Lucent has proposed such a network. *See* Comments of Lucent Technologies, WT Docket No. 05-157 (Apr. 28, 2005). *See also* Cyren Call Communications Corporation, Petition for Rulemaking (April 27, 2006) (requesting that 30 MHz of Upper 700 MHz spectrum be assigned to public safety to create a nationwide, interoperable broadband network); M2Z Networks, Inc., Application for License and Authority to Provide National Broadband Radio Service in the 2155-2175 MHz Band (May 12, 2006) (proposing to provide free, ubiquitous nationwide broadband services, including to public safety organizations).

A. Broadband Technologies Offer Significantly Greater Spectral Efficiency than SAM

Over the years, first responders consistently have requested more and more spectrum to accommodate their communications needs.[36] This is partly due to the increasing demands on the public safety community and the advancement of mobile communications technologies, but also is due in large part to the historically inefficient use of existing spectrum resources by public safety entities to date.[37] By allowing the use of broadband technologies in the 700 MHz public safety band, the Commission can enable first responders to make more efficient use of their spectrum resources.[38]

Broadband technologies allow more efficient use of spectrum resources than SAM and other wideband technologies by enabling all assigned channels to be used in every cell throughout a broadband network—*i.e.*, frequency reuse of one.[39] Such tight frequency reuse, which is not possible with SAM, enables a broadband network to carry higher total volumes of

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[36] *See, e.g.*, *4.9 GHz R&O*, at ¶ 7 (stating that the public safety community "assert[s] that the public safety community is in great need of additional spectrum"); *First R&O*, at ¶ 14 ("The PSWAC Final Report found that the spectrum allocated to public safety was insufficient to support . . . the public safety community . . . [and] concluded that . . . 25 megahertz of new public safety spectrum allocations would be needed."); *800 MHz R&O*, at ¶¶ 90-96 (discussing requests for additional spectrum by various public safety agencies).

[37] *See, e.g.*, Jon M. Pena, *How America's Fragmented Approach to Public Safety Wastes Money and Spectrum*, 33d Telecommunications Policy Research Conference, 6-10 (2005); Comments of Ericsson Inc., WT Docket No. 05-157, 6-8 (Apr. 28, 2005).

[38] *See* Exhibit B (System Spectral Efficiency Comparative Analysis) (concluding that EV-DO Rev. A deployments using 3 x 1.25 MHz broadband carriers in three-sectored cell site configurations with a spectral re-use factor of 1 will have an estimated downlink spectral efficiency of between 0.63 and 0.75 bps/Hz/cell for the inbound (reverse) link and between 1.6 and 1.75 bps/Hz/cell for the outbound (forward link) whereas SAM deployments using omni cell site configurations with a spectral re-use factor of 7 will have an estimated downlink spectral efficiency of 1.12 Mbps/6 MHz or 0.18 bps/Hz/cell).

[39] *See* Exhibit B, at 5.

data, thus allowing more simultaneous users to send and receive more data than is possible with technologies that cannot accommodate a frequency reuse of one. By contrast, in a SAM network, if a particular frequency is utilized in one cell, the same frequency cannot be used in nearby cells and sectors but instead must lie fallow in these cells and sectors.[40] As a result, three 1.25 MHz channels reused by broadband public safety networks nationwide can carry roughly 10 times more data than can be carried using by a nationwide patchwork of SAM networks using the same aggregate amount of spectrum.[41]

Further, support of a frequency reuse of one by broadband technologies eliminates the need for the type of detailed frequency coordination that is required with SAM and other wideband technologies.[42] The Commission licenses public safety spectrum on a statewide or regional basis and the licensed state and regional public safety supervisory organizations may further allot channels to local first responder organizations.[43] With SAM, to prevent the resulting numerous, effectively independent public safety networks from causing interference to each other, extensive regional, state, and or local frequency planning and coordination is required. By

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[40] *See* Exhibit B, at 4 and Figure 1.

[41] *See* Exhibit B.

[42] *See* Exhibit C (Broadband and Regional Planning), at 1 ("At the heart of broadband is the premise that spectrum is more effectively utilized when shared by multiple protective services within the smallest jurisdiction.").

[43] *See* Exhibit C, at 1 ("Under current wideband plans, given the number of wideband channels available and the potentially large re-use factor required, a typical wideband deployment would necessitate cooperative agreements between counties to allow sharing a single infrastructure.").

contrast, even when identical channels are used in every state and local broadband network, no frequency coordination or planning is necessary.[44]

B. Broadband Technologies Support Higher Data Rate Applications than is Possible with Wideband Technologies, Such as SAM

High user data throughputs are required to support the advanced, data-intensive applications required by today's first responders, including high-quality video streams; fast transmission of multiple, high-resolution images; and rich multimedia communications. Broadband technologies are capable of supporting such high data rates, whereas SAM cannot.

For example, in the Statement of Requirements for Public Safety Wireless Communications & Interoperability ("SAFECOM SOR") issued by DHS's SAFECOM Program,[45] DHS sets forth a number of real-time and non-real-time data applications and voice services that are required by first responders in light of predicted operational scenarios representative of day-to-day, planned and incident responses. These include support of instant messaging, session signaling, geo-location, voice paging, full-duplex voice communications, automatic database transactions, remote database access, device status/telemetry, web browsing, email, bulk file transfer, near-real-time video streaming, and full-duplex videoconferencing.[46]

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[44] *See* Exhibit C, at 2 and Figure 1 (describing most cost-effective approach to deployment of a broadband public safety network).

[45] *See* The SAFECOM Program, US Department of Homeland Security, Statement of Requirements for Public Safety Wireless Communications & Interoperability, version 1.1, January 26, 2006 ("SAFECOM SOR").

[46] *See* SAFECOM SOR; *see also* Exhibit D (SAFECOM SOR)

Other public safety entities have developed similar first responder wireless technology requirements that are broadly consistent with the SAFECOM SOR.[47]

Broadband technologies can support each of these applications. By contrast, single or aggregated wideband channels simply are not capable of supporting certain data-intensive applications. For example, full-motion video (*i.e.* 30 frames per second ("fps")) requires very high data rates, *e.g.*, 500 kbps or greater, to achieve the resolution quality typically found on Personal Digital Assistants ("PDAs").[48] Even lower quality, limited-motion video (*i.e.*, 15 fps), requires minimum data rates in the 100-300 kbps range. All current broadband technologies support air interface bandwidths in excess of 1.25 MHz, and therefore reliable data rates in

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[47] *See* Project 25/34 New Technology Standards Project, Statement of Requirements: Wideband Aeronautical and Terrestrial Mobile Digital Radio Technology Standards for the Wireless Transport of Rate Intensive Information, (1999) (outlining "the public safety community's technology needs for the transport and distribution of rate intensive data, digital video and digital voice for both service-specific and general applications"); Project MESA Statement of Requirements (2005) (describing the services and applications involving air interface user data rates up to 2 megabits per second or greater); Service Specification Group Services and Applications: Statement of Requirements, TS 70.001, v3.1.1 (2002); Radiocommunication Objectives and Requirements for Public Protection and Disaster Relief.

[48] Using a variety of compression and error resiliency techniques, state-of-the-art video codecs, such as MPEG-4, can achieve reasonable quality full-motion video over wireless links. The data rate required for transmission of a video stream is primarily a function of video frame rate (*i.e.*, the rate at which video frames are refreshed on a display) and screen resolution (*i.e.*, the number of pixels used to display the image). The lower limit for acceptable quality full-motion video is 30 fps, whereas a frame rate of 15 fps "loses the continuity or smoothness of motion, resulting in a jerky, old-time movie effect." *See* Final Report of the Public Safety Wireless Advisory Committee to the Federal Communications Commission, Appendix B, 223 (1996). In addition, the resolution of liquid crystal displays used in the current generation of laptops and PDAs typically ranges between 80 and 120 pixels per inch. Thus, a typical 3 inches x 2.5 inches PDA screen has a resolution of around 320 pixels x 240 pixels. Assuming a frame rate of 30 fps at this resolution and an additional 32 kbps for the associated audio stream, an MPEG-4-encoded video stream requires a data rate of 468 kbps and a 15 fps video stream requires a data rate of roughly half this rate.

excess of 500 kbps.[49] By contrast, SAM supports a maximum air interface bandwidth of 150 kHz and reliable user data rates of only 75-120 kbps—insufficient throughput to accommodate video.[50] Moreover, unlike broadband technologies, the limited data rates of wideband technologies are unlikely to be able to support applications that integrate multiple communications capabilities into a seamless multimedia platform as may be required by first responders in the future.

As important, broadband technologies are capable of supporting in a 1.25 MHz channel far higher aggregate throughputs than can be supported by wideband technologies in the same bandwidth. This aggregate throughput is available to all public safety users in a coverage area. As a result of these higher capacities, more data-intensive applications can be accessed by each user than is possible with SAM, or, equivalently, a larger number of users can be supported in a coverage area.

C. Broadband Technologies, Such as EV-DO, Can Offer Superior Range Compared to Wideband Technologies, Such as SAM

Broadband technologies, such as EV-DO, are capable of achieving equal or greater range than wideband technologies, such as SAM. As set forth in Exhibit E, due to the superior receiver sensitivity performance of EV-DO base stations, for a comparable cell-edge data rate the cell range achievable with EV-DO is greater than that of SAM.[51] These tentative conclusions are

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[49] *See* Exhibit B (System Spectral Efficiency Comparative Analysis).

[50] *See* Sean O'Hara, 700 MHz Wideband Data Loading Factors, at 10.

[51] *See* Exhibit E (Range Analysis of EV-DO Rev. A and TIA-902.SAM) (comparing EV-DO Rev. A to the minimum required performance criteria specified for SAM in TIA-902.CAAB, "Radio Communications Performance Recommendations – Public Safety Wideband Data Equipment – Scalable Adaptive Modulation (SAM)" (2003)).

applicable for current commercial power class EV-DO devices and are independent of whether SAM base stations use directional antennas. Because of these higher ranges, EV-DO deployments will require fewer cell sites to cover a given geographic area compared to SAM.

D. Broadband Technologies Offer a Higher Level of Interoperability than Currently Supported by SAM

To date, interoperability of public safety networks has been limited due, in part, to the large number of proprietary technologies developed for use on the different public safety bands. To provide interoperability, broadband technologies have developed a highly structured framework premised on the following:

- The network can distinguish among user devices to determine the air interfaces, services, and data rates supported by a particular device and deliver mobile services in the most efficient manner possible given the device. Such capability enables backward compatibility as networks evolve.
- Common sets of services (*e.g.*, user authentication, mobility management, encryption key exchange, over the air programming) are supported on all air interfaces.
- Complete definition of an open-standard network architecture with standard interfaces to provide cross-vendor interoperability.
- Support of legacy devices on the same air interface as that technology evolves.

Further, commercial broadband technologies, such as EV-DO, also enable interoperability through the use of IP Multimedia Subsystem ("IMS"). IMS provides a common open-standard architecture and consistent set of services to be provided over a network regardless of the air interface used by a particular device.[52] Importantly, IMS has been accepted

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[52] IMS has been adopted by the world's primary commercial broadband wireless technologies: cdma2000 (which includes EV-DO) and UMTS. IMS is a collection of logical entities with standard interfaces to manage session control, media resources, and applications.

by standards bodies for the two primary broadband technologies deployed today, EV-DO and UMTS. IMS supports seamless roaming across commercial wireless networks (including WiFi networks) and dedicated public safety networks employing commercial broadband technologies. Moreover, the common framework employed by IMS can be used to support future air interface technologies. In sum, IMS provides for full-featured interoperability of Internet protocol ("IP")-based applications, without requiring dedicated interoperability channels.

E. The Commission Should Adopt a Single, Commercial Broadband Technology Standard for the 700 MHz Public Safety Band

In its consideration of wideband technologies in this proceeding, the Commission has expressly determined that the adoption of a "technical standard is necessary and appropriate to ensure that the spectrum use within the 700 MHz band is efficient."[53] This conclusion is equally valid with respect to broadband technologies and, as the Commission previously has recognized, the public safety community can recognize substantial benefits from the use of commercial technologies. In its *Report to Congress*, the Commission acknowledged that

> [i]ncorporating commercial technologies into networks operated by public safety may provide numerous benefits to the public safety community in terms of cost, access to technological advances and efficient spectrum use. Commercially proven, high-speed mobile data technologies can enhance public safety capabilities in both a timely and cost-effective manner. As to timeliness, public safety would benefit because technologies are already widely available in the commercial marketplace. Given this wide availability, therefore, public safety entities would benefit from the associated economies of scale in purchasing equipment and facilities.[54]

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[53] *First R&O*, at ¶ 37.

[54] *Report to Congress*, at ¶ 46.

Moreover, Congress and numerous public safety agencies, including the Spectrum Coalition for Public Safety and the Association of Public-Safety Communications Officials-International, Inc., have recognized and endorsed the benefits and efficiencies gained from utilizing commercial technologies to improve first responder communications systems.[55]

The advantages of mandating the use by the public safety community of a single, commercial broadband technology are substantial.[56] In addition to enabling increased spectral efficiencies, higher user throughputs, and enhanced interoperability as discussed above, specifying a commercial broadband technology standard for the 700 MHz public safety band will ensure that first responders continually are able to access the best and most advanced communications capabilities available as communications technologies evolve. Further, because commercial broadband technologies place great emphasis on the backward compatibility of next generation technologies, the public safety community will be able to upgrade its mobile data networks without disrupting legacy users or stranding prior network investments. Moreover, Commission mandate of a broadband technology will enable the public safety community to

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[55] *See* National Intelligence Reform Act of 2004, Pub. L. No. 108-458, § 7303(a)(1)(E) (2004) (encouraging the development of open systems integrating commercial technologies where possible); Spectrum Coalition Comments, at 9 ("There are significant obvious benefits in reusing as much commercial technology as possible in the deployment of public safety networks–particularly in the areas of cost savings."); APCO/NPSTC Joint Comments, at 9 ("[T]here is no question that many of the [commercial] broadband technologies being deployed today could be adapted to public safety operations.").

[56] Unlike in the public safety sector, technology mandates are not warranted in the commercial sector. The vast size and highly competitive nature of the commercial wireless market forces commercial wireless providers to manage spectrum resources efficiently and provide cross-carrier interoperability. These market-disciplining characteristics of the commercial sector are not present in the public safety sector.

spend its scarce resources cost-effectively by enabling first responders to benefit from the massive economies of scale available in the commercial market.

To be clear, Lucent is not proposing that the Commission require the use of commercial *networks* but rather proposes the adoption of commercial *technologies*. The majority of public safety entities who have expressed reservations about the use of commercial networks, such as their lack of control over the operation of such networks, insufficient robustness and reliability, and other concerns, nevertheless have endorsed the adoption of commercial broadband technologies.[57] To optimize the coverage and performance of public safety wireless networks, first responders will deploy commercial broadband technologies in a different manner than they are commonly deployed by commercial wireless providers. For example, commercial wireless networks tend to have limited in-building coverage because the networks typically are designed for maximum capacity, rather than maximum in-building coverage. Public safety networks relying on commercial broadband technologies may balance capacity and coverage considerations differently than commercial carriers depending on their individual needs. First responders serving rural areas may opt to deploy networks focused on enhanced range, while jurisdictions serving urban areas may choose to focus on enhanced capacity. Furthermore, the use of flat-IP architectures for public safety wireless networks instead of the traditional hierarchical architectures employed by commercial service providers can be used to provide enhanced service reliability.

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[57] *See, e.g.*, APCO/NPSTC Joint Comments, at 8-11; Comments of The Spectrum Coalition for Public Safety, WT Docket No. 05-157, at 9-11 (Apr. 28, 2005) ("Spectrum Coalition Comments"); Comments to FCC Region 8 700 and 800 MHz Regional Planning Committees, WT Docket No. 05-157, at 9-11 (Apr. 28, 2005) ("Region 8 Comments").

Increased Innovation. Use of a commercial broadband technology will enable the public safety community to benefit from the decades of innovation funded by the commercial sector. Driven by the competitive need to deploy new, revenue-generating services, commercial wireless providers and their technology vendors continually push the cutting edge of wireless technology. The very existence of third generation broadband technologies, such as EV-DO, demonstrates the need for first responders to leverage the research and development of the commercial market. It is unlikely that the public safety community independently could have driven the development of this technology. Yet first responders now have the opportunity to benefit from it without having to shoulder the financial burden of the underlying research and development. Moreover, the tremendous benefits that can be realized by piggy-backing on commercial wireless innovation is demonstrated clearly by comparing the limited capabilities and functionality of current public safety communications systems with the far more advanced, more flexible, and less expensive commercial services that the vast majority of Americans have come to take for granted.

Backward Compatibility. The market-driven dynamic between equipment purchasers and a competitive pool of manufacturers and software developers ensures that future advances in broadband technology have a high degree of backward compatibility with previously deployed networks. New technologies are only attractive to commercial wireless providers if the new technologies do not strand the providers' substantial prior investment in legacy network infrastructure and user devices. As commercial network infrastructure is upgraded to support enhancements of the underlying standard, the new core network equipment must continue to support both the large embedded base of legacy user devices as well as devices operating using the next generation of the standard.

For example, cdma2000 has employed the same 1.25 MHz channel structure since its first deployment in the early 1990s. Although the capabilities and spectral efficiencies of cdma2000 have improved significantly over this time period, from supporting circuit-switched voice services and low-rate data services in the early 1990s to broadband, IP-based multimedia services today, evolutionary cdma200 standards have remained backward compatible and have continued to utilize the same 1.25 MHz channel.[58]

Further, the longstanding incentives requiring next generation services to be backward compatible are not likely to change in the future. Accordingly, deployment of commercial broadband technologies by the public safety community will ensure that first responders have the ability to upgrade their networks in the years to come without stranding their existing legacy communications systems.

Economies of Scale. By providing for the adoption of a single commercial broadband technology nationwide, the Commission can ensure that increased manufacturing volume and increased competition among manufacturers will drive down the costs to the public safety community of the technology.[59] The standardization required by commercial wireless providers

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[58] *See, e.g.*, Spectrum Coalition Comments, at 9 ("There are significant . . . benefits in reusing as much commercial technology as possible in the deployment of public safety networks."); Region 8 Comments ("Although commercial networks do not meet the requirements demanded by Public Safety, first responders could reap the benefits of commercial technologies.").

[59] For example, since the Commission adopted an order modifying the public safety 4.9 GHz emission mask to accommodate rebanded versions of commercial wireless technologies, including IEEE 802.11(a) and 802.11(j), at least nine vendors have introduced rebanded public-safety versions of commercial products in the 4.9 GHz band. *See* In the Matter of the 4.9 GHz Band Transferred from Federal Government Use, WT Docket No. 00-32, *Memorandum Opinion and Order*, 19 FCC Rcd 22325, ¶ 10 (2004). Vendors which have announced introduction of

results in massive economies of scale, which dramatically reduce the cost of network infrastructure and each of the individual components that comprise user devices. Such continually decreasing costs have transformed commercial wireless service from a luxury item affordable by very few in the 1980s to a commodity enjoyed by the majority of consumers today. A substantial portion of these economies of scale will benefit the public safety community if a commercial broadband technology is adopted by first responders, but will never be realized with respect to niche wideband technologies.[60] For example, the District of Columbia has estimated that construction of a wireless network using a commercial broadband technology would be one-sixth the cost of a wideband network providing similar coverage.[61]

The much higher costs of wideband technology compared to broadband technology are due, in part, to the fact that SAM currently is available only from a single vendor who has substantial control over the costs of devices and network infrastructure to deploy SAM. By contrast, over 48 terminal vendors and 13 infrastructure vendors compete in the market for cdma2000 broadband technologies alone.[62] Moreover, the intellectual property rights ("IPR") licensing fees associated with commercial standards are significantly lower on a per-device basis

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public safety products based on commercial technologies include 3ETI, Alvarion, Enterasys, Cisco, Firetide, Motorola, Proxim, RADWIN, and Skypilot.

[60] Deployment costs specific to public safety uses of commercial wireless technology, such as the development and manufacture of hardened mobile devices appropriate for public safety applications, also will be reduced if the Commission mandates a single wireless technology, although this cost reduction will be realized irrespective of whether the Commission mandates a wideband or a broadband technology.

[61] Request for Waiver by the National Capital Region from Three Sections of 47 C.F.R. 90.531 Bandplan (in Subpart R Regulations), at 13 (May 12, 2006).

[62] *See* Ex parte presentation of Lucent Technologies, Inc., 11 (presenting side-by-side comparison of competition between SAM and EV-DO) (Nov. 2005).

than fees associated with public safety technologies. Although essential IPR incorporated into any open standard is licensed by the owner "on fair, reasonable terms and conditions and on a non-discriminatory basis," [63] the costs to IPR holders of developing their IPR are distributed over a much larger volume of products in commercial markets and, as a result, account for a small fraction of the total cost of user devices. Holders of IPR used in niche markets, such as wideband technology, generally do not have this luxury.

F. The 1.25 MHz Channels Supported by EV-DO Make it the Most Suitable Commercial Broadband Technology For Use in the Wideband Block of the Public Safety 700 MHz Band

There are several commercial broadband technologies that potentially could fulfill the high-bandwidth data communications needs of first responders, including EV-DO, UMTS, and IEEE 802.16e.[64] However, of these commercial technologies, EV-DO, with its support of 1.25 MHz channels, is the most suitable to be specified as a nationwide public safety interoperability standard due to its technical characteristics and market maturity.

EV-DO. EV-DO is a high-volume, open-standard wireless technology supported by a broad base of manufacturers. EV-DO continues to be developed in a robust, competitive standardization environment actively supported by multiple network operators, equipment manufacturers, and software vendors. Further, due to the strong, active involvement of commercial network operators in the EV-DO standardization process, EV-DO employs open interfaces and standardized architectures, allowing commercial wireless service providers to

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[63] Third Generation Partnership Project 2, *Working Procedures*, at 41 (Mar. 10, 2004).

[64] Time-Division-Duplex ("TDD") standards are not appropriate for use in the paired spectrum of the 700 MHz public safety band, which is channelized to support Frequency Division Duplex ("FDD") systems. Accordingly, we have not discussed TDD standards herein.

select equipment from multiple vendors. Currently, over 184 different user devices supporting EV-DO are available, a number which will continue to grow as network operators continue to deploy EV-DO. As a result, deployment of interoperable multi-vendor networks is the norm in EV-DO network deployments. EV-DO also provides the following advantages:

- EV-DO employs a 1.25 MHz channel bandwidth, providing public safety with flexible deployment options. For example, two of the three broadband nationwide channels proposed by the Lucent Plan could be used for wide-area coverage, reserving one channel for use by deployable infrastructure for enhanced incident area network coverage or spot coverage of planned events. In addition, different pools of agencies could be assigned exclusive use of a 1.25 MHz channel, if desired.[65]

- EV-DO supports all broadband applications required by public safety on a common air interface and enables scalable delivery of video and audio streams.

- EV-DO currently supports peak data rates of 3.1 Mbps (downlink) and 1.8 Mbps (uplink) per 1.25 MHz channel.[66] Multi-carrier revisions support even higher rates and spectral efficiencies.

- EV-DO supports priorities to provide preferential service based on roles (*e.g.*, incident commanders can be assigned higher priority levels than other first responders) or the priority of the transaction (*e.g.*, a man-down alert can automatically be assigned higher priority).

- EV-DO offers backward compatible evolution to support of multiple 1.25 MHz channels (so-called multi-carrier support), multiple input-multiple output antenna technology, and other capacity/spectral efficiency enhancements.

- EV-DO enables the use of deployable network infrastructure to provide coverage in areas not covered by existing network infrastructure, or to provide supplemental coverage at the scene of an incident.

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[65] Strict partitioning of spectrum based on agency, such as is done with many narrowband deployments today, results in very inefficient use of precious spectrum resources. This partitioning of spectrum by agency for narrowband deployments, for example, has been one of the primary factors accounting for the exhaustion of narrowband spectrum allocations owing to the lower Erlang efficiencies of small channel pools.

[66] Such data rates are supported by EV-DO Rev A.

First responders may be able to take advantage seamlessly of the substantial existing commercial EV-DO networks for day-to-day non-tactical operations and to back up dedicated public safety systems.[67]

UMTS-FDD. UMTS-FDD is a high-volume, spectrally-efficient, open standard wireless technology developed in a robust, competitive standardization environment. It is actively supported by multiple network operators, equipment manufacturers, and software vendors. Further, it also offers an evolution path to support higher data rates and spectral efficiencies. Like EVDO, UMTS-FDD also offers a rich set of advanced IP-multimedia features. However, the 5 MHz bandwidth of a single UMTS-FDD channel[68] does not provide public safety with the operational flexibility provided by EV-DO's finer granularity 1.25 MHz channels. Use of a single 5 MHz broadband channel in the 700 MHz band does not allow spectrum to be reserved for deployment in standalone coverage to support the communications needs of incident areas or planned events. If a particular regional plan calls for segregating a state agencies' traffic through the dedication of a broadband channel, for example, the bandwidth of the UMTS channel will not provide this flexibility.

IEEE 802.16e. Like EV-DO, IEEE 802.16(e) ("802.16e") specifications include operation using 1.25 MHz wide channels. From a technical perspective, 802.16e presents many interesting features that would be worth considering. However, because it is a recently

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[67] For example, the nationwide networks of Sprint-Nextel and Verizon Wireless employ EV-DO.

[68] *See* 3GPP TS 25.101, Technical Specifications Group Radio Access Network; UE Radio Transmission and Reception (FDD); TS 25.104, Technical Specifications Group Radio Access Network; Base Station (BS) Radio Transmission and Reception (FDD).

standardized technology, a broad base of manufacturers and network operators has not yet developed and it is not possible at this time to predict whether 802.16e will be deployed in sufficient quantities to generate the type of innovation and economies of scale that already are available from EV-DO. Moreover, the lack of commercial deployment of 802.16e prevents the public safety community from piggy-backing on existing infrastructure on a priority basis for overflow capacity in times of crisis.

III. THE LUCENT PLAN BEST SERVES THE SPECTRUM NEEDS OF THE PUBLIC SAFETY COMMUNITY TODAY AND IN THE FUTURE

The inherent technical and economic benefits of commercial broadband technologies clearly warrant the addition of broadband channels to the 700 MHz band plan. Recognizing this, like the Lucent proposal, the Motorola and NPSTC Plans each propose rechanneling the 700 MHz band to add multiple broadband channels in the center of the band. Problematically, however, the Motorola and NPSTC Plans propose mixed-use (*i.e.*, wideband and broadband) channelization of the center of the 700 MHz public safety band. Although at first glance this proposed mixed-use channelization may seem to offer increased flexibility to first responders, in fact, the opposite is true. Such mixed use will hamper the evolution and upgrade of public safety communications systems and will dramatically reduce interoperability. Only the Lucent Plan will enable first responders to realize the full benefit of commercial broadband innovation without stranding prior public safety network deployment or disrupting existing operations. Moreover, only the Lucent Plan will ensure nationwide interoperability of public safety devices and networks—a primary Commission objective.

A. Mixed Deployment of Broadband and Wideband Networks in the 700 MHz Band Will Undermine the Ability of Public Safety to Leverage Future Innovations in Broadband Technologies

Broadband-only channelization of the 700 MHz public safety band will result in greater benefits over the long-term when compared to wideband-only or mixed-use channelization of the band. The benefits of future innovation in broadband technologies only can be realized if the Commission relies solely on broadband channelization of the 700 MHz public safety band—*i.e.*, multiple, contiguous 1.25 MHz channels capable of being aggregated as technology improvements warrant. If the Commission fragments the 700 MHz public safety band by permitting the coexistence of broadband and wideband technologies, the public safety community will be forced to clear spectrum of wideband uses before upgrading to advanced broadband technologies as they are developed, including, in particular, broadband technologies that aggregate multiple broadband channels. This will be a very costly and highly complex undertaking. As a result, by permitting wideband use of the 700 MHz band, the Commission will increase the likelihood that the public safety community will be relegated to outdated communications technologies—the very problem that the Commission currently is attempting to overcome.

B. Mixed-Use Networks Will Dramatically Reduce Interoperability

The NPSTC and Motorola Plans contend that retaining wideband and broadband channels in the 700 MHz bands provides maximum flexibility for each public safety entity to determine the appropriate configuration of its individual network given the needs of the public safety entity. However, such “flexibility” in spectrum management makes it more difficult for agencies to manage interoperability and increases the costs of providing ubiquitous, interoperable data communications.

Motorola proposes to resolve the interoperability difficulties associated with its plan by mandating that each public safety mobile device be capable of supporting wideband technology, specifically SAM. The additional cost of mandating dual-mode handsets and support of SAM in the network is unwarranted. Doing so needlessly introduces additional cost and complexity without any additional benefit given the superior technical capabilities of broadband technology.

The Lucent Plan enables first responders to roam seamlessly across multiple, independent public safety broadband networks coast-to-coast without losing any functionality—just as consumers today transparently roam across multiple wireless networks operated by independent companies. Moreover, due to the frequency reuse of one accommodated by commercial broadband technologies, this robust interoperability can be maintained while achieving superior spectral efficiencies.

IV. THE LUCENT PLAN WILL PREVENT INTERFERENCE TO AND FROM 700 MHZ PUBLIC SAFETY NARROWBAND OPERATIONS

The Lucent Plan to rechannelize the 700 MHz public safety band includes a 1.125 MHz paired guardband surrounding the broadband portions of the band. As set forth in Exhibit G, the guardband will protect against interference to the allocated narrowband channels resulting from out-of-band emissions, blocking, and inter/cross-modulation if first responders deploy broadband systems in conformance with existing out-of-band emissions restrictions.[69] EV-DO products can be developed which are compliant with these restrictions, although the restrictions appear to be more stringent than is necessary to prevent interference to narrowband 700 MHz public safety services.

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[69] *See* Exhibit G (Protection of Narrowband Operations).

Guardband. As a result of the high spectral efficiency of broadband technologies when compared to wideband systems, the net data carrying capacity of the 12 MHz of spectrum proposed to be rechannelized under the Lucent Plan (*i.e.*, two 1.125 MHz guardbands and three paired 1.25 MHz broadband channels) exceeds the data carrying capacity of the current wideband channelization by an order of magnitude.[70] Accordingly, Lucent's proposed guardbands should not be considered underutilized spectrum. To the contrary, the existence of the guardbands enables such highly spectrally efficient use of Lucent's proposed broadband channels that, even taking the guardbands into account, the Lucent Plan offers the highest spectral efficiency of any of the proposals on which the Commission requested comment.

Moreover, the Commission should consider rearranging the 700 MHz public safety band plan to mitigate the need for paired guard bands. Under the proposals currently under consideration by the Commission, broadband channels are sandwiched between two narrowband blocks, which requires paired guardbands to protect the narrowband operations from interference. By placing all narrowband 700 MHz channels in a contiguous block at the upper end of the band and all broadband channels in a contiguous block at the lower end of the band—*i.e.*, replace the current 3+6+3 band plan with 6+6 band plan—additional spectral efficiencies can be derived by the elimination of one of the guardbands. In fact, under this proposal, it may be possible to replace the eliminated guardband with an additional 1.25 MHz broadband channel if the Commission also relaxes its proposed unnecessarily stringent out-of-band emission rules. Alternatively, the use of channels wider than 1.25 MHz, for example the 5 MHz channel used by

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[70] *See* Exhibit B (EV-DO Spectral Efficiency Analysis).

UMTS-FDD, is possible in light of the single guardband required to protect narrowband services. Such a band restructuring also would mitigate potential interference due to intermodulation between narrowband and broadband operations. Because first responders have not yet deployed narrowband infrastructure in reliance on the current 700 MHz narrowband channelization, such a restructuring merits consideration by the Commission in the instant proceeding.

Out-of-Band Emissions. The Commission's existing rules governing out-of-band emissions are sufficient to ensure that, to the extent such emissions occur under the Lucent Plan, they will not disrupt narrowband communications. Specifically, the Commission's rules require that fixed station spurious emissions into narrowband channels cannot exceed -46 dBm/6.25 kHz.[71] These limits are more stringent than necessary to protect Project 25 ("P25") narrowband services in the 700 MHz public safety band, in particular when compared to rules protecting, for example, (analog) National Public Safety Planning Advisor Committee ("NPSPAC") services from cellular operations in adjacent spectrum. Nevertheless, current EV-DO base station equipment commercialized by Lucent can meet these emission guidelines. For mobile devices, rules that apply to various band classes in cdma2000 (*i.e.*, ref IS-98) are comparable to the narrowband mobile emissions requirement of less than -35 dBm/6.25 kHz in the public safety 700 MHz band, except for a 230 kHz that the emission measurement offset defined by IS-98 is 230 kHz larger than the Commission's existing rules. Therefore such requirements can be easily met through a tightening of the transmit chain specifications.

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[71] *See, e.g.*, Petitions for Reconsideration of the Second Memorandum Opinion and Order, Service Rules for the 746-764 and 776-794 MHz Bands and Revisions to Part 27 of the Commission's Rules, WT Docket No. 99-168, *Third Memorandum Opinion and Order*, 17 FCC Rcd 13985 (2002).

Blocking. Potential interference due to blocking caused by deployment of broadband technologies in the center of the 700 MHz public safety band will have minimal or no impact on narrowband services in the band. Although the Commission's current out-of-band emission rules protecting 700 MHz narrowband services are more stringent than similar rules protecting NPSPAC channels from cellular operation, fully compliant public safety products will nevertheless be designed in accordance with the rules. Specifically, it is possible to design broadband transmitters for the public safety 700 MHz band based on commercial broadband platforms.

Inter/Cross-Modulation. The risk of inter/cross-modulation interference is higher with wideband technologies than with broadband technologies due to the significantly higher transmit power densities of wideband technologies. Further, band plans which accommodate both wideband and broadband can lead to more severe inter/cross-modulation degradation than single technology band plans.[72] Intermodulation and cross-modulation products may result due to non-linearity in a P25 user device's RF front end. These inter/cross-modulation products are artifacts of the current structure of the public safety 700 MHz band plan, which does not allow mobile receivers to easily reject channels operating in the wideband block.[73] However, as alluded to in

[72] Exhibit G (Protection of Narrowband Operations).

[73] The design of a (wideband block) rejection filter in a P25 receiver is difficult to realize leading to P25 receivers being built with a wideband filter covering the band 764-776. This is reminiscent of the 800 MHz situation with Specialized Mobile Radio ("SMR") fixed transmitters creating interference in the NPSPAC mobile receive band.

Exhibit G, the impact of these inter/cross-modulation products can be mitigated through engineering rules including guidelines on antenna placement and characteristics.[74]

V. CONCLUSION

As demonstrated in these Comments and the attached exhibits, the Commission should rechannelize the 700 MHz public safety band in accordance with the Lucent Plan and specify the use of a commercial broadband technology. As an alternative to the Lucent Plan, the Commission should consider adopting a 6 + 6 band plan in which broadband and narrowband channels are placed in contiguous blocks, such that the broadband block is capable of supporting multiple commercial broadband technologies, including UMTS. Doing so will provide the public safety community with access to the same state-of-the-art mobile data communication applications that U.S. consumers have come to take for granted. Current commercial broadband technologies offer greater spectral efficiency, higher user throughput, enhanced application-layer interoperability, and significantly lower costs than wideband technologies.

Most important, however, the continuing innovation and backward compatibility characteristic of commercial broadband technologies ensures that broadband networks deployed by the public safety community will be capable of being upgraded as broadband technologies improve without disrupting existing operations or stranding previously deployed network infrastructure and devices. As a result, adoption of the Lucent Plan will not only ensure that the

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[74] As specified in the text, intermodulation concerns also can be easily mitigated by rearranging the 700 MHz public safety band so that all narrowband channels are in a contiguous block on one end of the band and all broadband channels are in a contiguous block on the other end of the band. Such a 6 + 6 band plan would also enable the Commission to specify other commercial broadband technologies, such as UMTS, which supports 5 MHz channels.

public safety community has access to the best mobile data communications available today, but will prevent first responders from being left behind as wireless technologies continue to advance in the future.

Respectfully Submitted,

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EXHIBIT A: PROPAGATION LOSS ESTIMATES AT 4.9 GHZ

SUMMARY

This exhibit demonstrates the poor propagation characteristics of the 4.9 GHz band and resulting limited geographic reach of point-to-multipoint base stations utilizing such spectrum.

PROPAGATION MODEL AND EMISSION CHARACTERISTICS AT 4.9 GHZ

The ITU-R P.1411 ("ITU-R") lists one of the few known propagation models applicable to 4.9 GHz systems.[1] In particular, the ITU-R lists recommended calculation practices for line-of-sight operation in environments such as an urban canyon. Table 1 illustrates some of the emission and reception characteristics of 4.9 GHz systems. Values and parameters are indicative of a bandwidth scaled version of IEEE 802.11a.

Bandwidth (MHz)	Maximum EIRP (dBm)	Minimum PHY Bit Rate (Mbps)	Corresponding RSSI (dBm)	Maximum PHY Bit Rate (Mbps)	Corresponding RSSI (dBm)
5	23	1.5	-88	13.5	-71
10	26	3	-85	27	-68
20	29	6	-82	54	-65

Table 1: 4.9 GHz Emission and Reception Characteristics

The values listed in Table 1 are indicative of what is permitted today for point-to-multipoint operation, *i.e.*, operation with non-highly directional antennas and using the low-power L mask with its maximum permissible effective isotropically-radiated power ("EIRP") values.[2] The RSSI values listed above represent typical values and do not reflect possible modem implementation gains, which may vary between 0 and 2 dB in general.

RADIUS OF COVERAGE IN LINE-OF-SIGHT CONDITIONS

Based on the tabulated metrics and the ITU-R model, a number of propagation ranges can be estimated assuming that (i) the access point is on the rooftop of an emergency

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[1] ITU-R P.1411-3, Propagation data and Prediction Methods for the planning of short-range outdoor radio communications systems and radio local area networks in the frequency range 300 MHz to 100 GHz (2005).

[2] 4.9 GHz Band Transferred from Federal Government Use, WT Docket 00-32, *Memorandum Opinion and Order*, 19 FCC Rcd 22325 (2004).

communications van, or about 3 meters above ground; (ii) the receiving end is a first responder, or about 1.8 meters high; and (iii) the first responder is holding a portable device with an antenna gain close to 0 dBi. Table 2 compares ranges—*i.e.*, propagation loss as a function of surroundings—using minimum and maximum bit rates over different channel bandwidths at 4.9 GHz. The ranges listed in Table 2 are similar for each data rate because the difference in RSSI is compensated by the same difference in EIRP. Table 2 also provides an average estimated range (in bold) for planning purposes.

	Line-of-Sight Cell Radius (in meters)	
Bandwidth (MHz)	For Minimum Bit Rate	For Maximum Bit Rate
5	270-860 or **~570**	70-320 or **~195**
10	270-860 or **~570**	70-320 or **~195**
20	270-860 or **~570**	70-320 or **~195**

Table 2: Downlink cell radii in line of sight conditions

In reality, the reverse link will become the limiting factor since it is unlikely that 4.9 GHz devices will transmit at such a high EIRP. Assuming an EIRP of 15 dBm from the users' device, the ranges noted in Table 2 change as follows:

	Line-of-Sight Cell Radius (in meters)	
Bandwidth (MHz)	For Minimum Bit Rate	For Maximum Bit Rate
5	150-540 or ~**345**	30-190 or ~**110**
10	110-450 or ~**280**	25-140 or ~**82**
20	90-380 or ~**235**	20-100 or ~**60**

Table 3: Reverse link cell radii in line of sight conditions

Further, if obstructions such as vegetation or walls (for in-building coverage) are taken into consideration, the ranges listed in Table 3 will need to be lowered further to account for additional propagation losses. While it is true that using the emission mask M will boost power considerably, by up to 13 dB, the reverse link will be the determinant factor, especially when using wearable battery-powered devices. Alternatively, when desired, ranges can be extended by means of radio frequency repeaters or bridges.

The tabulated values highlight the limited reach of point-to-multipoint systems expected for operation at 4.9 GHz and, hence, the interest in such systems for incident area networks, which, in general, are contained within a small area.

In conclusion, results shown in Tables 2 and 3 suggest that WiFi-based deployments in urban areas in 4.9 GHz are uplink limited, with a range of roughly 300 meters.

EXHIBIT B: SYSTEM SPECTRAL EFFICIENCY COMPARATIVE ANALYSIS

SUMMARY

This exhibit provides a comparison of the spectral efficiencies achieved by representative cdma2000 1x Evolution-Data Optimized Rev A ("EV-DO") and TIA-902.SAM ("SAM") network deployments. Both technologies employ different channel bandwidths, deployment rules (*e.g.*, guardbands, reuse factors), modulation techniques, interference mitigation methods and other features. We use an objective measure of spectral efficiency which takes into account these differences: the total amount of data that can be carried by each technology at a cell site for deployments using the full 2x6 MHz of the wideband block. This general evaluation framework has been universally adopted by the wireless technical community.

Estimates of EV-DO spectral efficiency derived during the standardization process are readily available in the open literature from a variety of independent sources. Spectral efficiency estimates for EV-DO presented in this exhibit are based on results obtained from Lucent's EV-DO performance simulation tool. The Lucent tool employs 3GPP2's—the cdma2000 standards body—standardized evaluation methodology.[1] By contrast, details on the quantitative performance of SAM in the open literature are scarce. We were able to find only one analysis that addresses SAM's downlink performance.[2] The limited information available on the performance of SAM was deemed adequate for a rough, first-order comparison of spectral efficiencies.

On the basis of this initial analysis, as set forth in more detail below, we conclude the following:

- For SAM deployments using omni cell site configurations and a spectral reuse factor of 7, we estimate a downlink system spectral efficiency of 1.12 Mbps / 6 MHz or 0.18 bps/Hz/cell.

- For EV-DO deployments using three 1.25 MHz broadband carriers in three-sectored cell site configurations (reuse factor of 1), we estimate a system spectral efficiency of between 0.63 and 0.75 bps/Hz/cell for the inbound (reverse) and between 1.6 and 1.75 bps/Hz/cell for the outbound (forward) link.

On the basis of this initial analysis, we expect the system spectral efficiency of EV-DO networks to be roughly an order of magnitude larger than SAM networks.

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[1] *See* Third Generation Partnership Project 2, cdma2000 Evaluation Methodology," document C.R1002, document C.R1002.

[2] *See* David Buchanan, Sean O'Hara, Broadband Technologies Wideband Technology Group Update, NPSTC Open Committee Meeting (Nov. 18, 2004) ("*WTG Update*").

EV-DO SIMULATION METHODOLOGY

For a proper capacity evaluation of distinct technologies, assumptions and other useful parameters must be comparable. For example, both technology simulations should use comparable channel models, propagation loss models, etc. The definition and quantification of simulation assumptions used for EV-DO were based on limited information on the engineering of a SAM network. The following tables show system-level parameters used in the simulations. Table 1 is informative only and shows typical assumptions for an EV-DO field deployment. Table 2 illustrates assumptions used for this specific comparative analysis.

Number of 3-Sector Cells	19
Frequency	770 MHz for base station Tx and 800 MHz for base station Rx
Propagation Path Loss Model	Okumura Hata Davidson model for large city and open areas
Log-Normal Shadow Fading	Standard Deviation = 7 dB
Base Station Antenna Gain	16.1 dBi
Base Station Cable Loss	2 dB
Base Station Noise Figure	4 dB
Access Terminal Antenna Gain	2 dBi
Access Terminal Noise Figure	10.1 dB
Access Terminal Max Transmit EIRP	25 dBm
Body Loss	0 dB
Building Penetration loss	0 dB
Target Packet Error Rate (“PER”)	1%
Base Station Antenna Height	164 feet for urban & 262 feet for open area
Mobile Antenna Height	7 feet for urban & 6.5 feet for open area
Number Of Active Users/Sector	Technology dependent
Multi-Path Channel Model	3GPP2 C.R1002 “cdma2000 Evaluation Methodology”
Cell Radius	6.2 miles (determined by 9.6 kbps reverse link budget) and 2.9 miles (determined by 460.8 kbps reverse link budget) for large city; 32 miles (determined by 9.6 kbps reverse link budget) and 20.4 miles (determined by 460.8 kbps reverse link budget) for open areas

Average Coverage Probability	95%

Table 1: Typical EV-DO Rev. A System Deployment Parameters

Technology	SAM	EV-DO Rev. A
Number Of Cells	An isolated cell	Embedded 3-sector cells
Propagation Loss Model	Okumura HATA Davidson Model for large city	Okumura HATA Davidson Model for large city
Log-Normal Shadow Fading	Standard Deviation = 7 dB	Standard Deviation = 7 dB
Base Station Antenna Gain	6 dBd (i.e., 8 dBi)	16.1 dBi
Base Station Cable Loss	2 dB	2 dB
Base Station Noise Figure	Technology specific	4 dB
Base Station Max Tx EIRP	47dBm ERP (49dBm EIRP)	43 dBm referenced to the antenna connector
Access Terminal Antenna Gain	Technology specific	2 dBi
Access Terminal Noise Figure	Technology specific	10.1 dB
Access Terminal Max Tx EIRP	Technology specific	25 dBm
Body Loss	0 dB	0 dB
Building Penetration Loss	0 dB	0 dB
Cell Radius	8 km	8 km
Multi-Path Profile	TU 50 kmph (the 2nd path with 5 microseconds delay and -22.3 dB relative to the 1st path)	TU 50 kmph (the 2nd path with 5 microseconds delay and -22.3 dB relative to the 1st path)
Area Coverage Probability	90%	90%

Table 2: Matching Systems Parameters to TIA.902-SAM

SAM SYSTEM CAPACITY

Because of their relatively narrow channel bandwidth (*i.e.*, 50 to 150 kHz) wideband technologies such as SAM must rely heavily on frequency planning and coordination to mitigate co-channel interference. The same principle applies to Project 25 ("P25"). In contrast to broadband, a reuse factor larger than 1 must be employed such that identical wideband channels are not reused in adjacent cells. By the same token, adjacent channels generally are not used in

the same cell. Per 6 MHz, ignoring eventual use of guardbands, a maximum 120 x 50 kHz channels will be distributed over a cluster of cells.

For a wideband system using omni-directional antennas, and based on the minimum co-channel rejection ratio for QPSK per TIA-902.CAAB specifications, the expected frequency reuse factor for TIA-902 is likely to range between 7 and 9. Using the most optimistic factor of 7, up to 17 x 50 kHz wide channels, out of 120, are likely to be deployed at each wideband base station site. While this observation is based on QPSK only, allowing for overlap between coverage footprints, engineering rules to support SAM's higher order modulation (64QAM) over larger portions of the cell would lead to the likely use of a cluster size larger than 7.

Figure 1 illustrates the difference between a frequency reuse factor of one (or cluster size of 1) and of 7 (or cluster of size 7). Reliance on frequency reuse to mitigate co-channel interference has a significant drawback: a lower supported total capacity per cell site, and correspondingly lower capacity support per cluster of cell sites. For example, assuming SAM has an estimated outbound base capacity of 66 kbps[3] per 50 kHz channel per cell site, the achievable outbound capacity per cell site is 66x17 or about 1,120 kbps.

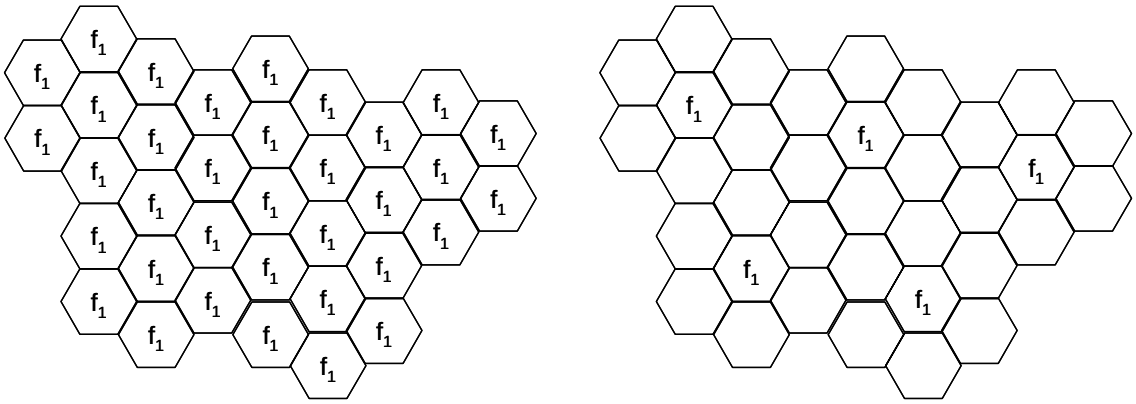

Figure 1: Examples of Frequency Re-use

EV-DO SYSTEM CAPACITY

In contrast, broadband systems such as those based on EV-DO have a number of features that provide significant spectral efficiency advantages over wideband systems. The use of short transmission intervals (1.67 ms), incremental redundancy, adaptive modulation, and fast cell-site selection allow EV-DO to take advantage of fast fluctuations in channel quality, increasing user data rates and capacity. Fast link feedback and scheduling result in increased multi-user

[3] *See WTG Update.*

diversity, providing further improvements in system capacity. Furthermore, EV-DO allows for the same broadband channel to be used in every base station, or every sector of a base station (*i.e.*, frequency reuse = 1). The utilization of sectorization on each cell site further improves the capacity per site and extends coverage due to high antenna gains versus omni-directional antennas and reduced interference levels.

For example, for an EV-DO system deployed in an urban environment, with 3-sector cell sites and configured to use all 3 channels per sector, the aggregate capacity available on the outbound is between ~ 9.5 and 10.5 Mbps per cell site over 6 MHz. For an open-area morphology, the equivalent range is from ~ 12 Mbps to 15 Mbps per cell site. On the inbound, the estimated capacity lies between ~ 3.8 and 4.5 Mbps per cell site for the large-city morphology and ~ 5.6 to 6 Mbps in an open-area environment. These estimated throughput values have been calculated assuming the use of data-intensive applications such as FTP file transfers, video streaming, and image transfer—so-called "full-buffer" applications.

EV-DO IS MORE SPECTRALLY EFFICIENT THAN SAM

The system spectral efficiency estimates presented in this exhibit provide a direct, useful measure of system performance: the actual bandwidth (in bits per second) that is available to a group of users roaming in a particular cell. The evaluation methodology takes into account both the ability of a technology to take advantage of strong link quality through the use of high-level modulation techniques, and the likelihood with which strong link qualities are experienced in the field.[4]

Based on this initial analysis, we conclude the following:

- For SAM deployments using omni cell site configurations and a spectral reuse factor of 7, we estimate a downlink[5] data carrying capacity of 1.12 Mbps per cell site. This capacity corresponds to a downlink system spectral efficiency of roughly 1.12 Mbps / 6 MHz or 0.18 bps/Hz/cell.

- For EV-DO deployments using three 1.25 MHz broadband carriers in three-sectored cell site configurations (reuse factor of 1), using EV-DO parameters from Table 1, we estimate a downlink data carrying capacity of 9.5-10.5 Mbps per cell site. Using assumptions from Table 2, we estimate 9 Mbps per cell site. Hence, the system spectral efficiency of EV-DO is estimated at between 1.6 and 1.75 bps/Hz/cell for the outbound (forward) link

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[4] A mobile radio system may adopt a high-level modulation to boost data rates but this would merely reflect the rate capability for a single user when very close to a cell site.

[5] We were unable to find data on the uplink performance of SAM in the open literature.

Therefore, our current assessment indicates that the system spectral efficiency of EV-DO is at least an order of magnitude larger than SAM efficiency. Such system efficiency can be improved further by means of available techniques like increasing the number of sectors per cell site. For example, current estimates when using six sectors per cell site is a 1.6-fold capacity increase on both outbound and inbound links compared to a 3-sector site. Moreover, today's availability of 4-branch receive diversity (at a cell site) allows for a balanced throughput between outbound and inbound thereby enhancing transfer of inbound applications (*e.g.*, quicker uploads of images from the user equipment to the base station).

EXHIBIT C: BROADBAND REGIONAL PLANNING

SUMMARY

The most cost-effective and spectrum efficient approach for network design is to promote and advocate network and spectrum sharing among public safety entities. Such a paradigm shift would provide capability for nationwide roaming and interoperability and access to multimedia applications by the public safety community. Shared national, regional or sub-regional networks that are available to all state and local agencies under those jurisdictions are readily realizable using commercial broadband technologies. Furthermore, logical access controls, instead of fixed frequency assignments, allow control of network access.

SHARED USE OF SPECTRUM USING COMMERCIAL BROADBAND TECHNOLOGIES

The major benefit of current commercial broadband technologies is in the efficient sharing of spectrum resources. In particular, most commercial mobile broadband technologies that are built around spread-spectrum or OFDM do not require the kind of frequency planning needed with analog, TIA-102, or TIA-902 based systems. With broadband, the same carrier frequency can be reused in adjacent cells. While it is true that the larger the bandwidth the higher the supportable data rate, broadband technologies that are in the market today use radio resources much more effectively to provide a much higher capacity for the same bandwidth.

At the heart of broadband is the premise that spectrum is most effectively utilized when shared by the multiple protective services within the smallest jurisdiction. If every agency within a single jurisdiction, such as a township, deploys its own broadband system, more spectrum than currently available will be needed. Such an approach, while very costly when implemented nationwide, would lead to inefficient use of spectrum resources. It should be noted that the Federal Communications Commission encourages sharing by multiple agencies of systems operating at 700 MHz, which would represent an appropriate step towards achieving low-cost interoperability. Under current wideband plans, given the number of wideband channels available and the potentially large reuse factor required, a typical wideband deployment would necessitate cooperative agreements between counties to allow sharing a single infrastructure. If that were the case, the capacity offered by broadband will be of greater advantage.

While it is true that broadband channelization does not present the kind of (traditional) granularity available to individual agencies, the amount of bandwidth, and capabilities, that can be made available on a shared basis, and per agency, represent indeed a paradigm shift. On an aggregate, the build-out and operation of individual networks, per agency, is a costly exercise. Furthermore, the limited bandwidth that could be offered through the utilization of wideband technologies is likely to hamper public safety in their day-to-day operations.

A DEPLOYMENT APPROACH

Given the natural geographical contiguity of jurisdictions and the frequency reuse of one supported by broadband technologies, a number of deployment options could be considered. The fastest, most spectrally and cost efficient deployment of broadband technologies is achieved

through the use of a single regional shared network serving state, county, and local agencies.[1] Because each cell site within a single radiofrequency ("RF") coverage footprint is configured to support three broadband channels, each jurisdiction and agency within such jurisdiction will have full access to all three broadband channels, and thus access to a wide spectrum of data applications. Figure 1 depicts such a deployment.

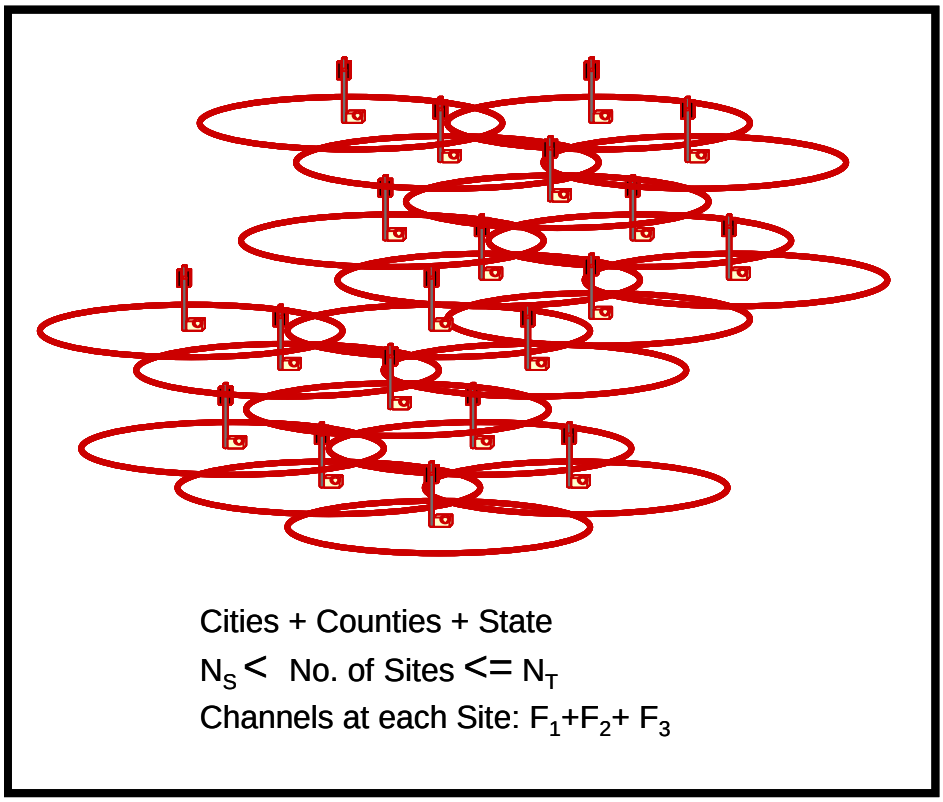

Figure 1: Geographical Deployment (Least Expensive)

The approach illustrated in Figure 1 is similar to shared Project 25 ("P25") state networks that have been deployed today, *e.g.*, Alaska, Michigan, etc. In shared broadband networks, the full spectrum is available for all to use.[2] An alternative approach is deployment of a single, shared system covering a group of contiguous counties, including cities, in which 1 to 2 broadband channels are (re)used throughout.

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[1] As used herein, the term regional means either a 'geographical' Public Safety Region ("PSR") or a state, depending upon whether the PSR comprises multiple states or the state comprises multiple PSRs

[2] A parallel approach already has been established in the 4.9 GHz rules wherein the full 50 MHz is available to every agency.

By contrast, Figure 2 depicts deployment of individual state, county, and local broadband RF networks, where one broadband channel is assigned to each public safety entity (versus shared use of all available broadband channels). Under this scenario, (i) State X builds its state-wide network and all state agencies share channel F_1; (ii) each county within State X deploys its own county-wide network to be shared by county agencies using channel F_2; and (iii) each municipality deploys its own individual network shared by local agencies on channel F_3. Although roaming and interoperability are supported by such a deployment,[3] such a design represents the costliest and lengthiest deployment route. Furthermore, it is the least spectrally efficient deployment given the distinct spatial traffic load presented by public safety users.

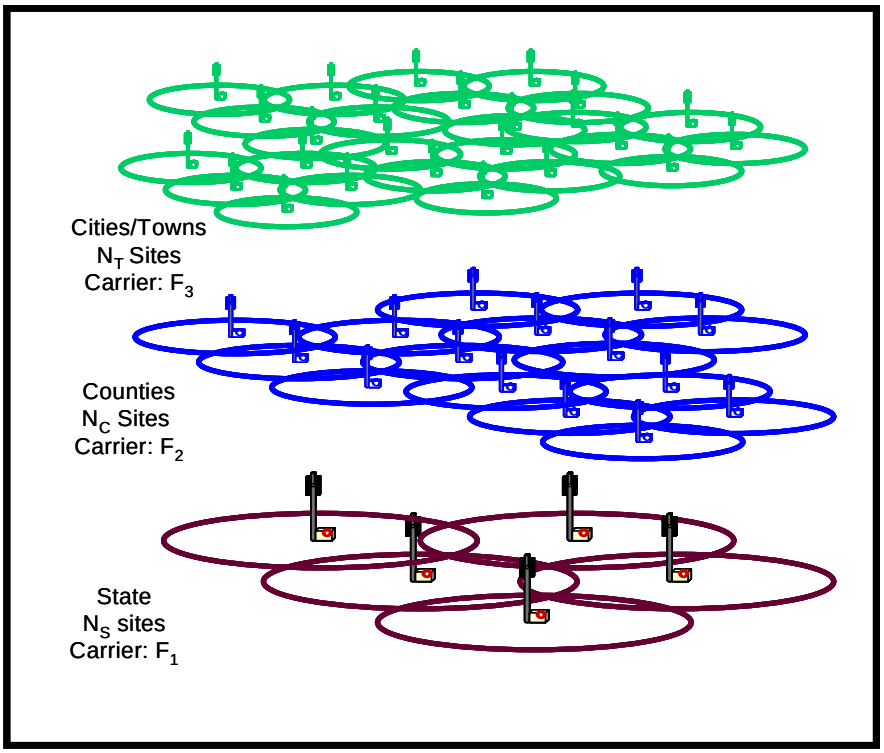

Figure 2: Geographical Deployment (Costliest)

[3] End-users devices are capable of operating in different channels, or bands.

EXHIBIT D: SAFECOM STATEMENT OF REQUIREMENTS

SUMMARY

This exhibit summarizes application requirements specified in the "Statement of Requirements for Public Safety Wireless Communications & Interoperability" issued by the U.S. Department of Home Security's Project SAFECOM ("SAFECOM SOR").[1] Spectrum allocated to state and local public safety agencies supports a variety of communications needs during day-to-day, task force, and incident responses. The SAFECOM SOR provides a structured framework for specifying first responder communications needs, understanding the role played by the different frequency bands allocated to first responders in public safety operations, and identifying gaps between spectrum allocations and operational requirements. The SAFECOM SOR ultimately concludes that all public safety data applications, including the most data-intensive application—video, must be supported at each level of the public safety network-of-networks hierarchy.

DESCRIPTION OF PUBLIC SAFETY NEEDS

The SAFECOM SOR divides first responders' communications needs into the following hierarchy:

Personal Area Network (PAN)—The PAN for a first responder can take many different forms. Primarily, it is intended to represent a set of devices on the person of a first responder that communicate with the first responder's [public safety communications device ("PSCD")] as necessary. The devices on a PAN will include such items as heart rate monitors, location sensors, etc. This information could, and would in many cases, be transmitted to other areas of the network. These devices are intended to function as "plug-and-play" devices, *i.e.*, transparent automatic configuration is assumed.

Incident Area Network (IAN)—An IAN is a network created for a specific incident. This network is temporary in nature and is typically centered on a wireless access point attached to the first responders' vehicle. Multiple vehicles dictate multiple wireless access points, all of which coordinate their coverage and transmissions seamlessly and automatically.

Jurisdiction Area Network (JAN)—The JAN is the main communications network for first responders. It is responsible for all non-IAN voice and data traffic. It handles any IAN traffic that needs access to the general network, and provides the connectivity to the

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[1] Statement of Requirements for Public Safety Wireless Communications & Interoperability, The SAFECOM Program, US Department of Homeland Security, version 1.1, January 26, 2006 ("SAFECOM SOR").

EAN. Additionally, it is the component of the network that will handle any and all communications from a first responder PSCD should a connection with the local IAN fail or be otherwise unavailable.

Extended Area Network (EAN)—The city systems are in turn linked with county, regional, state, and national systems or EANs. It is expected that this network could be both wired and wireless, depending on the type of infrastructure deployed in the area, *i.e.*, microwave point-to-point, fiber, etc.[2]

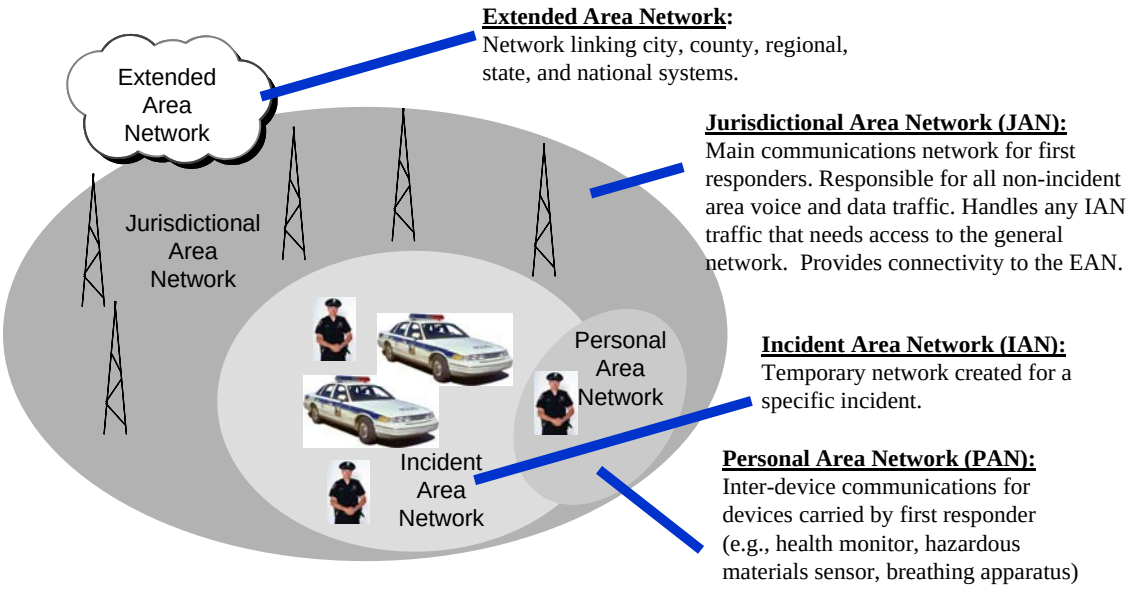

Figure 1: Graphical Depiction of SAFECOM's Public Safety System-of-Systems Hierarchy.

According to the SAFECOM SOR,

> Voice communications are critical, but voice communication requirements are not the only issue. Because of advances in technology, public safety operations are increasingly dependent on the sharing of data, such as images and video. New technologies promote the convergence of information and communications systems with the result that mobile units are increasingly being viewed as merely wireless nodes within information networks.[3]

Using a number of operational scenarios representative of day-to-day, planned, and incident responses, the SAFECOM SOR presents a body of requirements for realtime and non-

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[2] *See* SAFECOM SOR, at 5-6.

[3] *See* SAFECOM SOR, at 1.

realtime data applications and voice services that need to be supported in the Personal Area Network, Incident Area Network, Jurisdiction Area Network and Extended Area Network. These applications requirements are summarized in Figure 2.

	Personal Area Network	Incident Area Network	Jurisdiction Area Network	Extended Area Network
Instant Messaging		●	●	●
Session Signalling		●	●	●
Geolocation		●	●	●
Voice Paging		●	●	●
Full-Duplex Voice		●	●	●
Automatic Database transaction		●	●	●
Remote Database Access		●	●	●
Device Status/Telemetry	●	●	●	●
Web Browsing		●	●	●
Email		●	●	●
Bulk File Transfer		●	●	●
Near-real-time Video Streaming		●	●	●
Full-Duplex Videoconferencing		●	●	●

Figure 2: Applications Required to be Supported in Each Level of the SAFECOM System-of-Systems Hierarchy.

The most bandwidth-intensive application among the applications listed in Figure 2 is near-real-time video streaming. Support of this application is required under the SAFECOM SOR in the Incident Area Network, Jurisdiction Area Network, and Extended Area Network. Accordingly, to satisfy the specifications set forth in the SAFECOM SOR, public safety agencies need access to spectrum with appropriate propagation characteristics to support these applications in each of the three network segments.

EXHIBIT E: RANGE ANALYSIS OF EV-DO REV. A AND TIA-902.SAM

SUMMARY

This exhibit provides a comparison of cdma2000 1x Evolution-Data Optimized Rev. A ("EV-DO") and TIA-902.SAM ("SAM") radiofrequency ("RF") cell ranges. Typical RF design parameters for EV-DO and standard SAM performance recommendations[1] were used to develop this exhibit. Our analysis suggests that for a comparable cell-edge data rate, the cell range achievable with EV-DO is greater than that of SAM. This tentative conclusion is applicable for current commercial power class devices and is independent of whether SAM base stations use directive antennas.

EV-DO CELL RANGES

In RF planning, a link budget is usually employed to determine the maximum allowable path loss between a base station antenna and a user terminal antenna. For EV-DO technology, analysis results indicate that, because EV-DO base stations supporting active users always transmit at the maximum power, the forward link can achieve acceptable performance at the same path loss dictated by the reverse link budget (*i.e.*, the system is not limited by the forward link coverage). Therefore, the EV-DO reverse link budget can be used to calculate the maximum allowable path loss between the user terminal transmit antenna and base station receive antenna. Once the maximum path loss is decided and an appropriate propagation loss model selected, the maximum path loss can be converted into a cell range by considering local variables such as base station antenna tower height, terrain, and clutter.

The cell range strongly depends on link budget parameters and propagation loss assumptions. The range estimates provided in this section serve as an example only. For a fair comparison with another technology, the link budget and propagation loss parameters of both technologies must be properly aligned. As shown in Figure 1, the maximum allowable path loss is calculated by taking into account the user terminal transmit power and base station receiver sensitivity as well as the gains and losses between the user terminal and base station.

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[1] TIA-902. CAAB, Radio Communications Performance Recommendations-Public Safety Wideband Data Equipment – SAM (Feb. 2003).

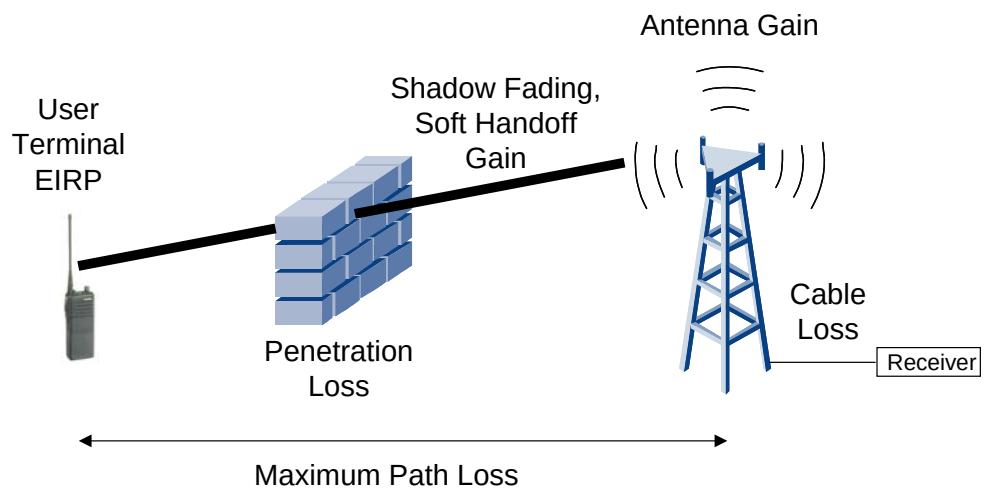

Figure 1. Reverse link budget illustration

The terms characterizing the link from the user terminal to the base station are captured in equation 1. In other words, when the user terminal transmits at maximum power and experiences propagation loss and shadow fading, the user terminal signal power received at the base station antenna port must equal or exceed the base station receiver sensitivity, S_{min} (all in dB):

$$EIRP_{max} - L_{body} - Fade + SHO_{gain} - BL/VL - PL + G_{ant} - L_{cable} \geq S_{min}$$

Equation 1.

where

- $EIRP_{max}$ (in dBm) = Maximum user terminal effective radiated power with respect to isotropic antennas
- L_{body} (in dB) = Body (or head) loss
- *Fade_Margin* (in dB) = Shadow fade margin to ensure cell edge coverage probability for a given shadow fade standard deviation
- *SHO gain* (in dB) = Gain (*i.e.*, a reduction in the shadow fade margin) for a cell edge user communicating with two base stations simultaneously
- *BL/VL* (in dB) = Building or vehicle penetration loss, whichever is applicable
- *PL* (in dB) = Average point-to-point propagation loss between user terminal antenna and cell site antenna
- G_{ant} gain (in dB) = Base station antenna gain
- L_{cable} (in dB) = Base station cable loss

- S_{min} (in dBm) = Minimum base station receiver sensitivity accounting for the base station receiver noise floor, noise rise caused by other EV-DO user interference (from the serving sector and other sectors) and the signal to noise ratio required for a proper quality

From the above expression, we solve for the maximum allowable path loss (in dB) through the so-called budget equation:

$$PL_{\max} = EIRP_{\max} - L_{body} - Fade_Margin + SHO_{gain} - BL/VL + G_{ant} - L_{cable} - S_{\min}$$

Equation 2

In the following table, we provide an example of the upper 700 MHz EV-DO maximum path losses and cell ranges for various nominal data rates. Table 1 shows the parameters governing the EV-DO reverse link budget that are identical to the parameters used in the previous capacity section.

user terminal maximum EIRP	29 dBm (mobile Class I) and 25 dBm (mobile Class II) for Band Class 7 (upper 700 MHz C and D Blocks) per 3GPP2 C.S0033
Body loss	0 dB
Shadow fade margin	9 dB (considering 7 dB shadow fade standard deviation and 90% edge coverage, corresponding to 95% area coverage)
Soft handoff gain	3.4 dB
Building penetration loss	0 dB for suburban/open areas or 10 dB for urban areas
base station antenna gain	16.1 dBi for a 3-sector antenna
base station cable loss	2 dB
base station receiver sensitivity	Taking into account a 4 dB base station noise figure, a 5.5 dB noise rise, the signal to noise ratio required to achieve 1% Packet Error Rate (PER) for 2-path Rayleigh fading, the worst mobile speed case and base station dual receive diversity

Table 1: EV-DO Rev A Link Budget Parameters for Public Safety 700 MHz Band

In EV-DO, reverse link (inbound) transmissions occur in up to four sub-packets of four slots each, with early termination when RF conditions allow sufficient energy to be collected at the receiver in less than four sub-packets. The rate considering full 16-slot transmission is called the "nominal rate." The rate considering the actual slots used (*i.e.*, the packet size divided by the required slot transmission time) is called the "effective rate." Nominal rates range from 4.8 kbps to 460.8 kbps while the effective rates range from 4.8kbps to 1843.2 kbps. In fact, the peak data rate of 1843.2 kbps requires that the largest packet size be transmitted in only one sub-packet (four slots).

The maximum path losses (with respect to isotropic antennas) and the associated cell ranges with and without penetration loss for different EV-DO nominal data rates are shown in

Table 2. When providing the effective rate in the table, the average number of sub-packet transmissions is considered. In other words, the effective rate reflects the average physical layer rate that can be delivered to the user at that path loss, which is the benefit of Hybrid Automatic Retransmission Request ("HARQ"). In deriving the cell range associated with a maximum path loss, the following assumptions for urban, suburban and rural areas are made:

- Okumura Hata Davidson propagation model for large cities, suburban and open areas
- Flat terrain
- Base station antenna height of 164 feet for urban/suburban areas and 262 feet for open areas
- Mobile antenna height of 7 feet for urban areas and 6.5 feet for suburban/open areas

Nominal Physical Layer Data Rate (kbps)		4.8		9.6		76.8		307.2		460.8	
Effective Physical Layer Data Rate with HARQ (kbps)		8.8		17.5		130.2		478.1		717.2	
Mobile EIRP (dBm)		25	29	25	29	25	29	25	29	25	29
Maximum Path Loss without Building Penetration Loss (dB)		154.5	158.5	153.5	157.5	147.2	151.2	143.6	147.6	142.0	146.0
Maximum Path Loss with 10 dB Building Penetration Loss (dB)		144.5	148.5	143.5	147.5	137.2	141.2	133.6	137.6	132.0	136.0
Urban Area	Cell Range without Building Penetration Loss	10.7 km 6.6 miles	14.1 km 8.8 miles	10.0 km 6.2 miles	13.1 km 8.1 miles	6.5 km 4.0 miles	8.6 km 5.3 miles	5.1 km 3.2 miles	6.7 km 4.2 miles	4.6 km 2.9 miles	6 km 3.7 miles
	Cell Range with 10 dB Building Penetration Loss	5.4 km 3.4 miles	7.1 km 4.4 miles	5.1 km 3.1 miles	6.6 km 4.1 miles	3.3 km 2.1 miles	4.3 km 2.7 miles	2.6 km 1.6 miles	3.4 km 2.1 miles	2.3 km 1.4 miles	3.0 km 1.9 miles
Suburban Area	Cell Range without Building Penetration Loss	20.3 km 12.6 miles	24.6 km 15.3 miles	19.1 km 11.9 miles	23.5 km 14.6 miles	12.4 km 7.7 miles	16.3 km 10.1 miles	9.7 km 6.0 miles	12.8 km 7.9 miles	8.7 km 5.4 miles	11.4 km 7.1 miles
Open Area	Cell Range without Building Penetration Loss	53.4 km 33.2 miles	61.0 km 37.9 miles	51.6 km 32 miles	59.0 km 36.7 miles	40.5 km 25.2 miles	47.3 km 29.4 miles	35.1 km 21.8 miles	41.2 km 25.6 miles	32.9 km 20.4 miles	38.6 km 24.0 miles

Table 2: EV-DO Rev. A Maximum Path Losses and Cell Ranges for Public Safety 700 MHz Band

The achievable cell edge channel rate on the reverse link varies with cell range. When the maximum allowable path loss is reduced, the achievable cell edge data rate increases. Therefore public safety agencies may choose to deploy a higher cell density for the purposes of achieving higher cell edge data rates. Nevertheless, due to resource sharing, the achievable throughput will be a function of the number of users contending for resources as described in Exhibit B (System Spectral Efficiency Comparative Analysis).

It is worth noting that when planning an EV-DO radio network, there is a trade-off between capacity and coverage. Based on public safety agencies' capacity requirements, EV-DO cell capacity could be traded off for RF coverage. For example, if the number of users decreases such that the base station receiver noise rise is reduced from 5.5 dB to 2.5 dB, then the uplink maximum path loss will be increased by 3 dB. This 3 dB improvement can be translated into a roughly 50% increase in the cell area since the propagation loss slope for Okumura Hata Davidson model in urban area is about 34 dB/decade. Because the EV-DO coverage is limited

by uplink budget, the forward link can still maintain acceptable performance within the increased footprint determined by reverse link budget.

Moreover, there are additional techniques available that may be used to extend the uplink (inbound) range of EV-DO Rev. A. Such techniques include any, or a combination, of the following methods:

- A 6-sector base station configuration, with its higher antennas gain, can improve the maximum path loss by about 2-3 dB and the cell capacity for both links.
- A 4-Branch receive diversity at the base station could increase the uplink (inbound) maximum path loss by approximately 3 dB if the reverse link capacity remains the same as in the 2-Branch receive diversity case.
- Tower Top Low Noise Amplifiers ("TTLNA") can be deployed to improve the reverse link maximum path loss by about 2-3 dB when the gain of the TTLNA is set appropriately.
- Repeaters may be used to extend the cell range in rural areas or highways.

A COMPARATIVE ANALYSIS

Because cell range is a critical factor in assessing a technology, a range comparison between EV-DO and SAM is described herein. The analysis is based on our current understanding of the limited information regarding SAM available from the minimum performance standards. These estimates could be refined when more details become available. An uplink (inbound) budget comparison is attempted through the derivation of a number of sample link budgets. These are provided in Table 3 and include:

- SAM 50 kHz QPSK with an omni base station antenna gain of 8 dBi or 6 dBd[2]
- SAM 50 kHz QPSK with a 3-sector base station antenna gain of 16.1 dBi
- EV-DO (9.6 kbps and 19.2 kbps nominal physical layer data rates) with an isolated 3-sector cell, 16.1 dBi base station antenna gain and 25 dBm Class II mobile EIRP
- EV-DO (9.6 kbps and 19.2 kbps nominal physical layer data rates) with an isolated 3-sector cells, 16 dBi base station antenna gain and 29 dBm Class I mobile EIRP

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[2] *See* D.Buchanan, S.O'Hara, Broadband Technologies Wideband Technologies Group Update, NPSTC Open Committee Meeting (Nov. 18, 2004).

- EV-DO (9.6 kbps and 19.2 kbps nominal physical layer data rates) with embedded 3-sector cells, 16 dBi base station antenna gain and 25 dBm Class II mobile EIRP

An isolated cell refers to a single remote cell. An embedded cell is a cell that is part of a cluster of cells. The absence, or presence, of external load (*i.e.*, other cell interference) is what distinguishes both types.

The following assumptions were made throughout:

- The base station cable loss, mobile antenna gain and log-normal fade margin are identical for both technologies.

- Soft handoff gain for embedded EV-DO cells is 3.4 dB while no handoff gain is considered for an isolated EV-DO cell.

- The uplink (inbound) capacity in the embedded EV-DO case is also considered in the isolated EV-DO case in which case the receiver interference margin for an isolated cell is 2.5 dB compared with 5.5 dB for embedded cells. The bottom line of link budgets - the maximum allowable path loss for an isolated EV-DO cell is comparable to that for embedded EV-DO cells.

- EV-DO base station receiver sensitivity is derived by considering 2-path Rayleigh fading (due to dual receive diversity) and a 50 kmph mobile speed.

- Per TIA-902.CAAB, the SAM base station receiver sensitivity for QPSK and 1% BER is -98 dBm under TU50 fading and the mobile maximum transmit power is 30 W or 44.8 dBm.

- SAM throughput at the cell edge is about 27.6 kbps for 50 kHz QPSK.[3] This throughput appears to represent the throughput excluding pilot channel, sync channel and physical/MAC layer overheads. The 27.6 kbps throughput falls between the EV-DO effective Radio Link Protocol ("RLP") data rate of 15.4 kbps (corresponding to 9.6 kbps nominal physical layer data rate) and 32.8 kbps (corresponding to 19.2 kbps nominal physical layer data rate) when considering HARQ gain.

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[3] D.Buchanan, S.O'Hara, "Broadband Technologies WG Update", NPSTC Open Committee Meeting (Nov. 18, 2004).

Reverse Link Budget for 1xEV-DO Rev A and SAM	Units	**SAM 50 kHz**	**SAM 50 kHz**	**DO Isolated**	**DO Isolated**	**DO Isolated**	**DO Isolated**	**DO Embedded**	**DO Embedded**
EVDO Physical Data Rate (kbps) or SAM Modulation Type		QPSK	QPSK	9.6	19.2	9.6	19.2	9.6	19.2
EVDO Effective RLP Data Rate with HARQ or SAM Cell Edge Throughput	kbps	27.6	27.6	15.4	32.8	15.4	32.8	15.4	32.8
Maximum Transmitted power per traffic channel at antenna input	dBm	44.8	44.8	23	23	27	27	23	23
Transmitter Antenna Gain	dBi	2	2	2	2	2	2	2	2
Transmitter EIRP per traffic channel	dBm	46.8	46.8	25	25	29	29	25	25
head/body loss	dB	0	0	0	0	0	0	0	0
Receiver Antenna Gain	dBi	8	16.1	16.1	16.1	16.1	16.1	16.1	16.1
Receiver Cable and Connector Losses	dB	2	2	2	2	2	2	2	2
Receiver sensitivity	dBm	-98.0	-98.0	-122.9	-121.0	-122.9	-121.0	-120.0	-118.1
Soft Hand-off Gain	dB	0	0	0	0	0	0	3.4	3.4
Explicit diversity Gain	dB	0	0	0	0	0	0	0	0
Log-normal fade margin	dB	9	9	9	9	9	9	9	9
Building/Vehicle Penetration Loss	dB	0.0	0.0	0	0	0	0	0	0
Maximum Path Loss w/respect to isotropic antennas	dBi	141.8	149.9	153.0	151.1	157.0	155.1	153.5	151.6

Table 3. Link Budget Comparison between EV-DO Rev. A and SAM in Public Safety 700 MHz Band

The following observations can be made:

- The maximum path loss of SAM with a 27.6 kbps cell-edge throughput and a 16 dBi base station antenna gain is 1.2 dB less than that of an isolated 3-sector EV-DO cell with a 19.2 kbps nominal rate or 32.8 kbps effective RLP data rate, a 16.1 dBi base station antenna gain, 25 dBm mobile EIRP, and without soft handoff gain.

- The maximum path loss of SAM with a 27.6 kbps cell-edge throughput and a 16 dBi base station antenna gain is 1.7 dB less than that of an embedded 3-sector EV-DO cell with a 19.2 kbps nominal rate or 32.8 kbps effective RLP data rate, a 16.1 dBi base station antenna gain, 25 dBm mobile EIRP, and with soft handoff gain.

- The maximum path loss of SAM with a 27.6 kbps cell edge throughput and a 16 dBi base station antenna gain is 5.2 dB less than that of isolated 3-sector EV-DO cell with a 19.2 kbps nominal rate or 32.8 kbps effective RLP data rate, a 16.1 dBi base station antenna gain, 29 dBm mobile EIRP, and without soft handoff gain.

- The maximum path loss of SAM when using a base station omni antenna is 10 dB smaller than any of the EV-DO scenarios considered.

- On the basis of TIA-902.CAAB specifications, the use of 150 kHz wide channels could lead to an additional 4 dB reduction in the maximum path loss yielding smaller ranges.

CONCLUSION

As set forth above, it does not appear that SAM has a significantly larger uplink (inbound) range than EV-DO Rev A. To the contrary, for an equivalent cell-edge data rate, it appears that the range of an EV-DO Rev A cell is larger.

EXHIBIT F: ENHANCEMENTS TO EV-DO AIR INTERFACE

This exhibit provides examples of the type of highly structured protocols that were seamlessly incorporated in the cdma2000 1x Evolution-Data Optimized ("EV-DO") air interface standard to enhance interoperability and to support the delivery of multimedia services. The exhibit also lists some of the advantages that can be derived from the deployment of a technology that supports IP Multimedia Subsystem ("IMS") protocols.

EV-DO

- Quality of service ("QoS") support for realtime and non-realtime Internet Protocol ("IP") multimedia services.

- Support of QoS differentiation across IP traffic flows for one or more users. These features allow user devices to support applications with differing QoS requirements simultaneously. In addition, the features allow QoS differentiation across different users which can be used to provide preferential access to different classes of users.

- Support of priority mechanisms to provide differentiation among different users and application data flows transferred to and from a user's device.

- Short paging intervals and fast radio link establishment mechanisms for delay sensitive applications such as push-to-talk.

- Native support of IP header compression for enhanced spectral efficiency.

- Improved security through mutual authentication between the end user terminal and the network and stronger encryption using longer (*i.e.*, 128 or 256 bit) cryptographic keys.

- Introduction of protocols for the efficient delivery of broadcast and multicast content over the air interface, such as Broadcast Multicast Service. Using these features, a single copy of a multicasted packet is sent over the air interface in a sector which is received by all mobiles in the multicast group. This feature provides unlimited scalability in terms of number of users for push-to-talk applications and video streaming applications.

- Mechanisms that provide the ability to determine the locations of end users using assisted-GPS or network-assisted geo-positioning techniques.

IMS

IMS uses an open-standard core network architecture with open interfaces for support of IP multi-media services. The architecture has been adopted by the 3rd Generation Partnership Project 2, which standardizes cdma2000, and the 3rd Generation Partnership Project, which standardizes UMTS. The wide adoption of this architecture by commercial operators worldwide

for wireless and wireline services ensures a steady and stable migration path for public safety data services.

- IMS's common architecture implements Session Initiation Protocol ("SIP") based signaling among call session control functions in the network core, user devices, and application servers. This allows the network operators/jurisdictions significant control over the services available to users. For example, jurisdictions can restrict access of a particular service to only those public safety users that are duly authorized to use such service.

- IMS provides a generic framework to introduce new SIP-based applications into the network as they become available.

- IMS allows (i) pooling of session control and media resource functions (*e.g.*, transcoding, speech synthesis, voice recognition, conferencing, etc.) across applications and (ii) user registration, session establishment, user/device authentication, and end-to-end QoS management. All these features are required for end-to-end interoperability. Moreover, resource pooling further reduces cost and avoids the need for duplication of fundamental capabilities within applications (*e.g.*, group membership of public safety teams, presence management and other common functions).

- IMS hides user device idiosyncrasies from applications, allowing applications to be easily ported and supported across a variety of user devices (*e.g.*, full-functioned Personal data assistants, PCM/CA card modems, handsets).

- IMS supports full interoperability with other IMS-based network domains and with non-IMS-based network domains (*e.g.*, the Public Switched Telephone Network).

- IMS products leverage economies of scale across all wireless and wireline service providers worldwide.

EXHIBIT G: PROTECTION OF NARROWBAND OPERATIONS

SUMMARY

This exhibit demonstrates that adoption of the Lucent Plan will not cause harmful interference to the narrowband channels in the 700 MHz public safety band and examines certain other issues related to the deployment of wideband or broadband technologies within the 700 MHz band. Specifically, when comparing the interference impact in the 700 MHz band of broadband channelization on narrowband services, we conclude the following:

- Any potential interference to narrowband services caused by out-of-band emissions ("OOBEs") and blocking resulting from deployment of broadband technologies will have minimal impact on narrowband services. Although the existing rules of the Federal Communications Commission ("Commission") protecting narrowband channels are more stringent than the rules protecting National Public Safety Planning Advisor Committee ("NPSPAC") channels from cellular operations, products nevertheless will be designed to comply with the existing rules. Further, despite the stringent out OOBE rules, it is possible to design broadband transmitters for the public safety 700 MHz band based on commercial broadband platforms.

- Potential interference to narrowband services due to broadband operations in the 700 MHz band will be equal or lesser in magnitude than interference caused by wideband operations. Further study of broadband or wideband operations in this band should aim to assess the impact on the narrowband service's signal-to-noise ("SNR") ratio rather than absolute noise level, especially at the edge of a narrowband cell.

- If the non-linearity characteristics of a narrowband mobile receiver are truly significant, then it is expected that few 50 kHz channels can be deployed in a given wideband antenna site, which will impact the overall cell capacity of wideband antenna sites.

In addition, when examining the impact of a mixed-mode broadband plus wideband scenario, as suggested in both the NPSTC and Motorola Plans, the mutual contribution of broadband and wideband channels to inter/cross-modulation could lead to a worse degradation than if either wideband or broadband is considered on an individual basis.

BACKGROUND

As demonstrated by interference issues that have been experienced in the 800 MHz band, it is imperative that the introduction of broadband or wideband technologies does not create undue interference to voice communications deployed in the narrowband portions of the public safety 700 MHz band. Because the current band plan consists of a wideband block sandwiched between two narrowband blocks, the presence of a wideband or broadband technology in the

wideband block could potentially affect narrowband channels if no precautions are taken. Potential sources of out of band interference are depicted in Figure 1.

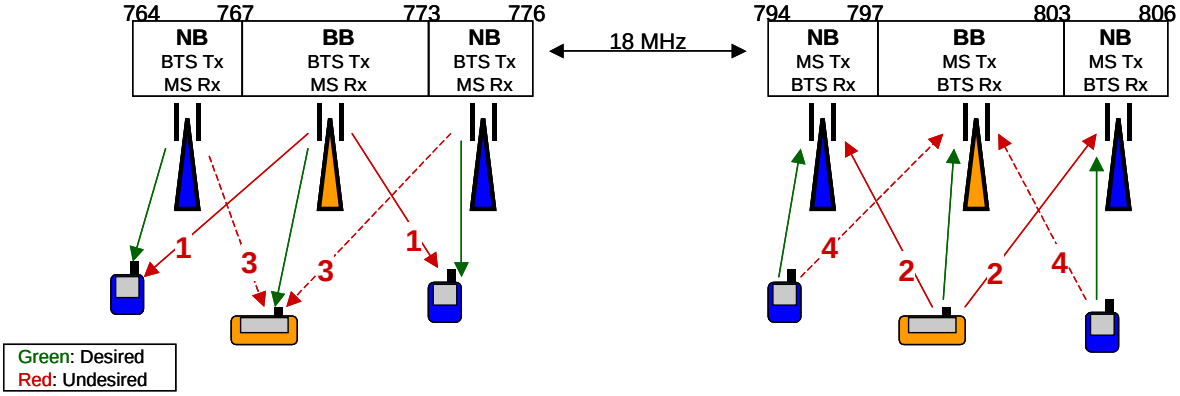

Figure 1: Potential Sources of Out-of-Band Interference.

Potential interference sources to narrowband reception (links 1 and 2 in Figure 1) that could be of concern include:

- <u>OOBE:</u> Broadband transmitter OOBEs falling into narrowband receive channel cannot be attenuated by the narrowband receive filter. These emissions could result in narrowband receiver de-sensitization.

- <u>Blocking:</u> Broadband transmitter carrier powers attenuated by the narrowband receive Radio Frequency ("RF"), Intermediate Frequency ("IF") and baseband filters could still cause narrowband receiver de-sensitization or blocking.

- <u>Inter/Cross-modulation:</u> Multiple broadband transmitter carriers attenuated by the narrowband RF receive filter could cause the narrowband receiver front end to generate inter/cross-modulation products falling into a narrowband receive channel. These inter/cross-modulation products are caused by non-linearities present in the narrowband receiver RF front end.

Any type of interference can be mitigated through a variety of techniques including frequency separation, antenna placement, antenna engineering, geographic separation or filtering. These issues are discussed in detail below.

OUT-OF-BAND EMISSIONS

OOBEs occur when spurious emissions from a particular transmitter fall into an unintended receiver channel. While OOBEs are generally the result of inadequate filtering or poor transmit linearity at the transmitter, established rules will ensure that such emissions falling into either narrowband block are below a limit. Current Commission rules based on the 76+10logP formula indicate that any fixed station spurious emission falling in a narrowband channel must lie below –46 dBm/6.25 kHz. When compared with the existing rule governing

commercial cellular spurious emissions falling into NPSPAC channels, application of this rule roughly represents an extra 21 dB of attenuation. Therefore, in addition to RF translation, similar broadband products operating in the cellular band will likely require additional or different filtering at the block edge to ensure the emission limit of –46 dBm/6.25 kHz in a narrowband mobile receiver and –35 dBm/6.25kHz in a narrowband fixed station.

On the basis of Lucent's experience with commercial broadband deployments in international markets and a base station transmit path feasibility study, corresponding transmit radio, amplifier, and filters can be designed with emission masks which comply with the -46dBm/6.25 kHz rule. More specifically, such a filter is achievable assuming a guard band of 1.125 MHz between the narrowband and wideband blocks. Therefore, the amount of out OOBEs due to the transmission of up to three active broadband channels centered in the wideband block can be controlled so as to meet the current –46dBm/6.25kHz rule with minor modifications to commercial transmission equipment, thereby allowing public safety agencies to leverage the scale economies of commercial broadband equipment.

Mobile broadband transmitters are subject to power control and therefore do not always transmit at maximum power. For instance, cdma2000 1x Evolution-Data Optimized ("EV-DO") mobiles operating in commercial spectrum transmit at a relatively low maximum power of +25 dBm EIRP. For the most part, transmission at this power level only occurs when the mobile is located at the edge of a serving cell. Due to the mobile's power control mechanisms, an EV-DO mobile transmits at the minimum sufficient power needed to maintain the acceptable quality target at the serving base station receiver. With power control, mobile transmit power can be as low as –50 dBm. The IS-98 standard specifies emission limits for [EV-DO] mobile transmitters that are similar (modulo a 230 kHz offset) to the required rules for protection of narrowband services.

BLOCKING

TIA-102.CAAB-A specifies a receiver spurious rejection level of 80 dB for P25 mobiles. According to TIA-102.CAAA, when an unwanted signal of –36 dBm (*i.e.*, 80 dB above the reference sensitivity –116 dBm) is injected into a P25 mobile receiver, the P25 mobile receiver sensitivity degradation shall not exceed 3 dB. Accordingly, this would imply a P25 filter rejection value of -36+125 or ~89 dB. A P25 receiver noise floor of –125 dBm is derived from the sensitivity specification of –116 dBm and the co-channel rejection specification of 9 dB. Using the -46dBm/6.25 kHz rule, the broadband base station OOBEs falling into a P25 mobile receive channel bandwidth of 12.5 kHz is –43 dBm (scaled from –46 dBm/6.25 kHz). The Adjacent Channel Leakage Ratio ("ACLR") of an interfering transmitter is defined as the ratio of interfering carrier power to emission power falling into an adjacent channel. When a broadband base station transmit power is 43 dBm, its ACLR is 86 dB. On the other hand, the Adjacent Channel Selectivity ("ACS") of an affected receiver is defined as the rejection offered by the mobile receive filter in the interfering carrier frequency. The P25 mobile receiver ACS is 89 dB, comparable to the ACLR. The combination of ACLR and ACS gives an overall Adjacent Channel Interference Ratio ("ACIR"), a measure of interference susceptibility. In this example, where a broadband base station may interfere with a P25 mobile, the ACIR (which is a function of the broadband base station ACLR and P25 mobile ACS) equals roughly 84 dB. Two extreme interference scenarios can be considered:

- A collocation scenario in which the broadband and narrowband base stations are housed at a common transmission site; and

- Non-collocation scenario where the broadband base stations are at the edge of the narrowband cell coverage.

In the collocation scenario, the desired signal power received by a narrowband mobile from the serving base station is significantly stronger than the received ACI from the broadband base station due to the 84 dB ACIR. Therefore, the narrowband mobile can achieve a signal-to-noise ratio ("SNR") required for appropriate quality.

In the non-collocation scenario, the P25 mobile received ACI from a broadband base station is about –116 dBm (or 43 dBm – 75 dB – 84 dB), where 75 dB is the typical base station-to-mobile minimum coupling loss due to base station antenna shadowing. If the P25 mobile received desired signal power is greater than –107 dBm, then the narrowband mobile can maintain an acceptable SNR. Otherwise, only P25 mobiles within the immediate proximity of the broadband base station will be affected by ACI. Since this region is small, the probability that P25 mobiles are affected is also small. Therefore, potential interference due to OOBEs and blocking will have minimal impact on narrowband services.

INTER/CROSS-MODULATION

Intermodulation distortion is created when cross products of high-power unintended signals fall into the receiver. Non-linearities present in the receiver RF front end, in turn, can generate inter/cross-modulation products that interfere with the desired narrowband signal. The following analysis is based on assumptions on the non-linearity performance of a P25 mobile's RF front end derived from two-tone 3rd-order minimum performance metrics specified in TIA-102.CAAA-A. The discussion herein is limited to potential interference occurring in the narrowband block (Link 1 in Figure 1) due to the presence of broadband or wideband signals in the wideband block. Throughout the analysis, it is assumed that coupling loss is such that the narrowband power density level is ~-70 dBm/Hz.

The presence of significant non-linearity in the transmit-receive path of a particular channel and the lack of RF rejection at the front-end of a P25 receiver ultimately leads to an increase in in-band noise floor and sideband generation. This potential interference is of main interest in a near-far scenario in which a P25 receiver at the edge of its cell picks up a strong signal from a nearby broadband site. In contrast with narrowband intermodulation, where the interest lies in assessing the impact two tones at frequency F_1 and F_2 have on receivers tuned to $2F_1$-F_2 or $2F_2$-F_1, the impediment with broadband and wideband is more closely related to 3rd-order cross-products resulting from the mixing of broadband and narrowband signals. This is because the RF passband of the P25 receiver is likely to span the entire 12 MHz of the public safety 700 MHz (outbound) band.

In order to compare the inter/cross-modulation response in the presence of either a broadband or wideband signal, a non-linear model of the P25 receiver was developed, with a

particular interest in calibrating the 3rd-order model on the basis of a two-tone rejection ratio. In that regard, it was derived that based on a noise floor of –125 dBm, an intermodulation rejection ratio of 75 dB, a 3rd-order input intercept of +1 dBm and a narrowband tone of ~ -29 dBm, the 3rd order products are expected to hover around -130 dBm/Hz. All plots that follow are based on this specific model with the additional caveat that the mixing will be between a single narrowband channel and a multitude of non-narrowband channels.

Figure 2 illustrates an example of a simulated scenario in which one broadband carrier and one narrowband carrier, both with identical average transmit powers, are present at the input of the RF front of a narrowband receiver. The broadband channel is centered at 768.75 MHz, the closest channel location to the lower narrowband block. The narrowband channel is centered at 766 MHz. The plot highlights a situation in which the narrowband portable or mobile receiver is nearby a tower with collocated broadband and narrowband equipment. The composite spectrum at the input of the RF front end is shown in blue. The resulting spectrum due to non-linearity is shown in red. The illustration shows expected cross-modulation spectral growth around the desired narrowband tone and intermodulation products around, and to the right of the broadband channel. It must be emphasized that, irrespective of the apparent width of the spectrum, the main focus of attention must be on the narrowband signal only because everything outside of the narrowband signal's bandwidth will be filtered out to some extent in following IF stages.

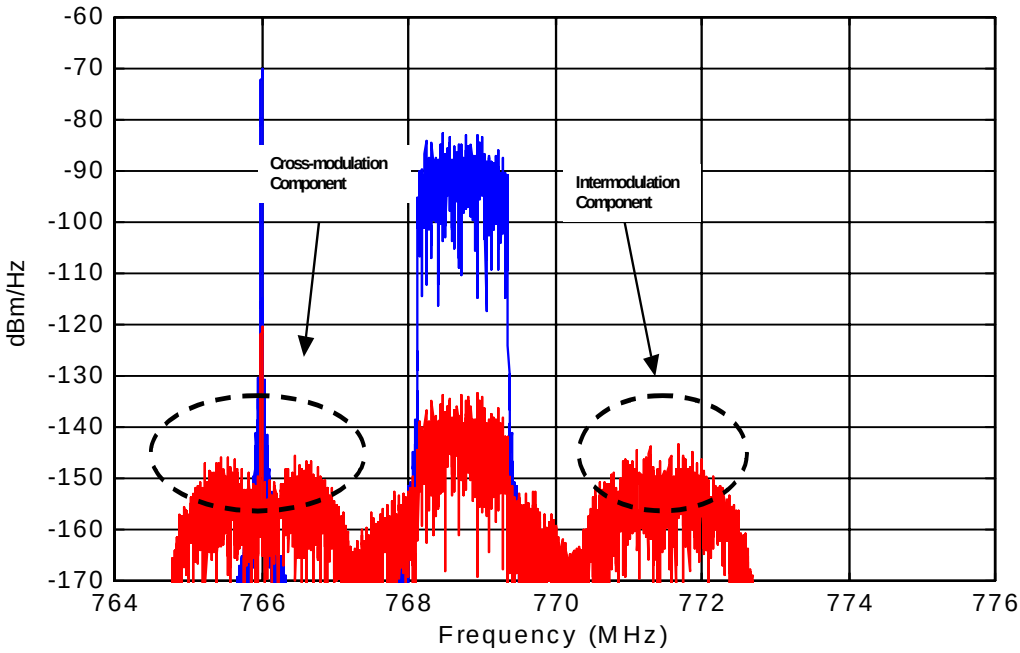

Figure 2: Representation of broadband/narrowband inter/cross-modulation

The cross-modulation noise has the familiar double-hump shape with a dip at the (desired) narrowband channel. This is analogous to what would be expected in cdma receivers in

the presence of strong jammers and non-ideal transmit-receive isolation.[1] The level of such interference, *i.e.*, the portion of the red curve falling within the bandwidth of the 766 MHz narrowband channel, is a function of both broadband and narrowband signal levels. If either signal level goes up (down), the corresponding cross-modulation interference goes up (down). This cross-product phenomenon is not unique to broadband—it applies to any signals transmitted in the wideband block. The main difference in the cross-modulation interference lies in the spectral shape of the noise growth around the narrowband channel.

No amount of frequency coordination can practically eliminate cross-product interference since all channels present at the front-end of the P25 receiver, *i.e.*, that are within the 12 MHz passband of the RF filter, will combine. Only through improvement in the P25 receiver front end, appropriate engineering design, or increased spacing between narrowband and wideband channels can such interference be reduced. Managing the spacing interval, however, is not a trivial task since the wideband block lies between two narrowband blocks.[2]

When compared to broadband, spectral growth around a desired narrowband channel is likely to be more severe when caused by the presence of a wideband transmitter due to wideband's higher power density. Assuming that TIA-902 uses a cluster size of seven, a bandwidth of 1.25 MHz will support nearly three 50 kHz wideband channels per cell site. The resulting output of the non-linear narrowband receiver when a composite narrowband and three wideband signals (with identical average transmit power) are present at its input is depicted in Figure 3. When compared with the results from Figure 2, the amount of expected interference is equal to, or higher than, in the broadband case. Accounting for the 1.125 MHz guardband envisaged for broadband under the Lucent Plan, more than three 50 kHz channels could be assigned to a single cell. However, the allocation of more than three 50 kHz channels at a given antenna site to increase capacity will likely lead to higher levels of cross-modulation interference.

Therefore, irrespective of the technology employed in the wideband block, any non-linearity characteristic in the P25 receiver will yield some form of in-band or out-of band interference. In particular, because power density levels of TIA-902 are higher than in typical broadband signals, the potential for interference is expected to be greater with respect to this wideband standard than for a broadband technology.

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[1] *See, e.g.,* V. Aparin, L.E.Larsson, "*Analysis and Reduction of Cross-Modulation Distortion in CDMA Receivers,*" IEEE Trans. Microwave Theory & Techniques, Vol.51, No.5, 1591-1602 (May 2003).

[2] We note that, in the aggregate, a 6MHz broadband – 6 MHz narrowband band plan is more immune to cross-product interference than the current 3 MHz narrowband - 6MHz broadband – 3 MHz narrowband 700 MHz band plan on which the Commission requested comment.

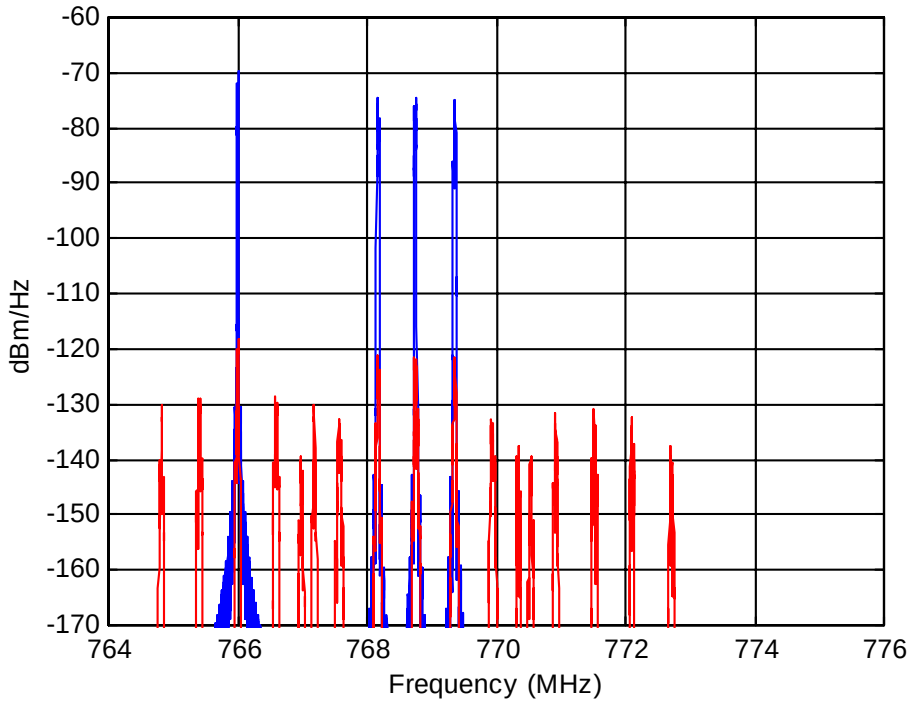

Figure 3: Representation of wideband/narrowband inter/cross-modulation

If the number of broadband channels is increased to three, the amount of distortion is expected to grow as depicted in Figure 4.

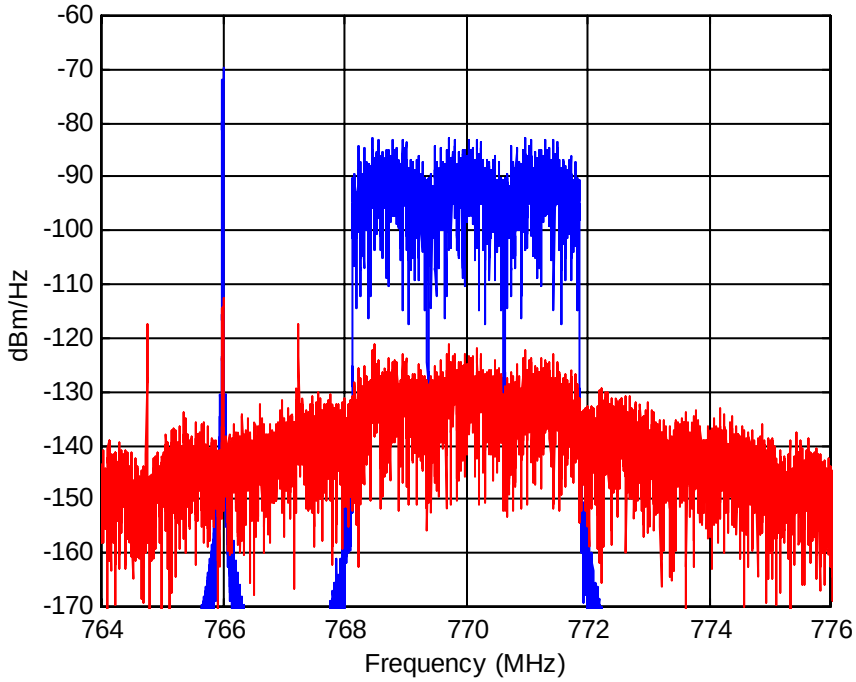

Figure 4: Inter/Cross-Modulation with Three Broadband Channels

Using the reuse cluster assumption of seven, a bandwidth of 3.75 MHz will accommodate roughly ten 50 kHz channels per wideband site. Therefore the resulting distortion due to non-linearity in the P25 mobile receiver is depicted in Figure 5. A comparison of Figures 4 and 5 indicates that inter/cross-modulation due to deployment of broadband is not worse than that caused by wideband. To the contrary, although it has been assumed herein that for all cases the average power is kept the same, the claim that a smaller guardband is needed between a wideband block and a narrowband block implies that more 50 kHz wideband channels can be deployed at every wideband cell site. At the same time, more channels will be needed to accommodate the eventual traffic load. Therefore, if P25 receivers exhibit high levels of non-linearity, as assumed herein, a compromise will have to be found to optimize both a wideband cell capacity and inter/cross-modulation interference to narrowband services.

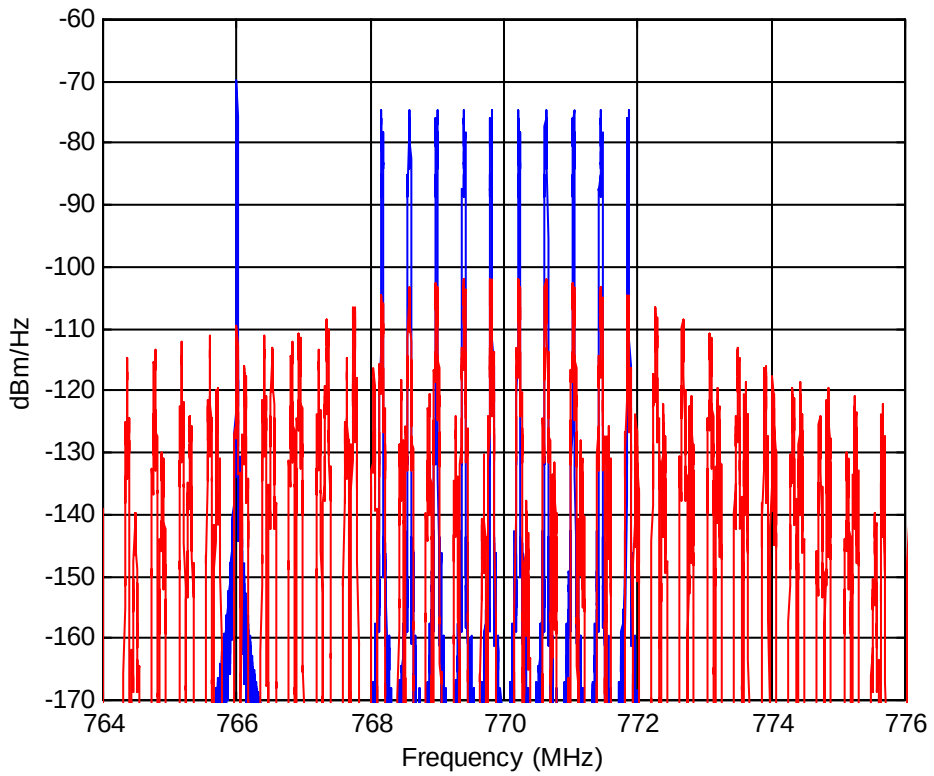

Figure 5: Inter/Cross-Modulation with Ten 50 kHz Wideband Channels

In addition to possible improvement in the P25 front-end electronics to reject RF energy from the wideband block, the height of the broadband/wideband tower and the associated antenna pattern are among the major design parameters that can be engineered to further reduce distortion. It is expected that if such interference is likely within a narrowband cell, it will occur in the vicinity of the broadband/wideband tower within a ring whose area should account for a very small fraction of the P25 cell area.

It is important to recognize that while the interference level may appear significant in both broadband and wideband scenarios, the overall SNR may still be adequate for proper voice reception per TIA-102 specifications. When broadband is considered, two cases can be distinguished: (i) when narrowband and broadband transmitters are collocated and (ii) when they are not.

In the case of collocated transmitters, both the narrowband and broadband signals are at their highest power levels compared to a nearby narrowband receiver. Hence, cross-modulation interference is at the highest level. However, since the narrowband receive power is so high, the effective SNR in the presence of broadband interference is very high.

In the case of non-collocated transmitters, the extreme situation occurs when the narrowband receiver is at the edge of its cell—*i.e.*, the received narrowband signal is at its lowest level—and the narrowband receiver is close to a broadband or wideband site. In such a situation, the dominant interference factor becomes the level of the received broadband or wideband signal and its resulting spreading due to the narrowband receiver non-linearity. This is illustrated in Figure 6, which depicts a situation where the P25 received signal at the narrowband cell edge is designed for 40 dBu or ~ –130dBm/Hz and a broadband or wideband tower is located at that edge. Notwithstanding other interference causes or shadowing effects, both plots indicate that, based on our specific non-linearity model, maintaining an adequate narrowband SNR nearby a broadband or wideband tower at the narrowband cell edge will be challenging, especially for the narrowband channels closer to the wideband block. The situation will be worse with fixed wideband emitters transmitting at more than the 20 W average power considered herein.

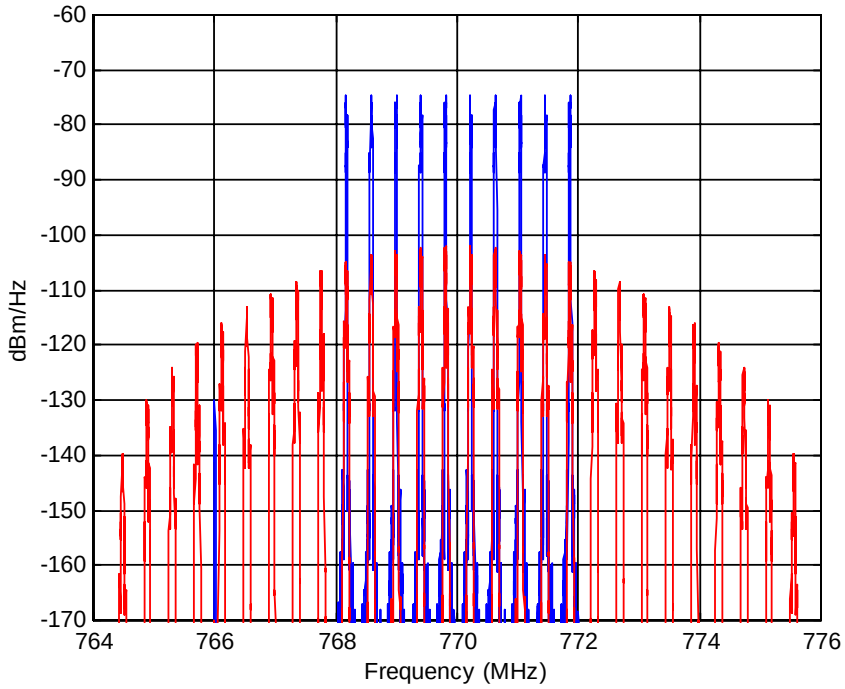

Figure 6a: Near-Far Scenario–Non-Collocated Narrowband and Wideband

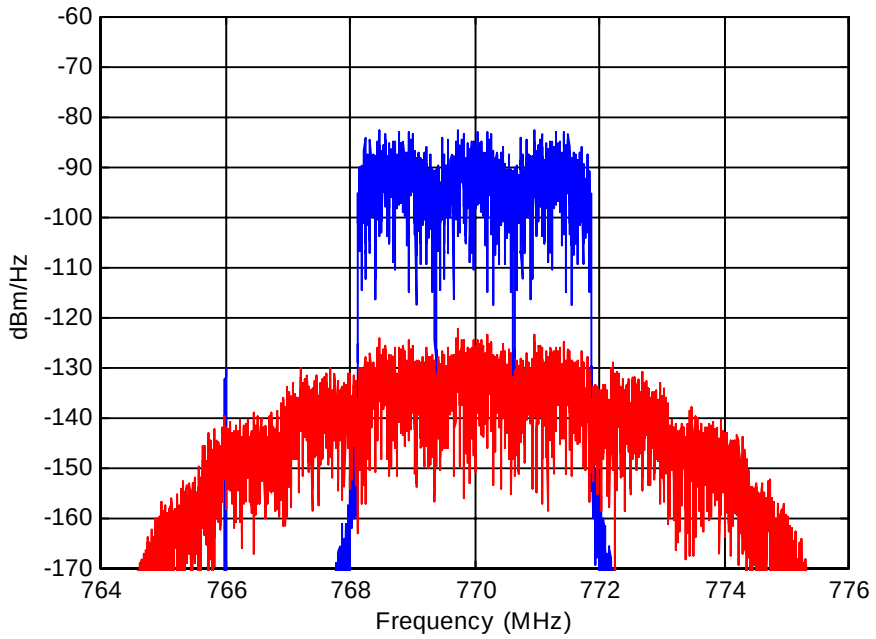

Figure 6b: Near-Far Scenario–Non-Collocated Narrowband and Broadband

Importantly, because deployment at 700 MHz is in its infancy and there is a dearth of more reliable non-linear data available, proper engineering guidelines could be devised to virtually minimize the intermodulation impact. On the other hand, because public safety networks are designed for a specific coverage level (*e.g.*, 95% or 97% coverage reliability), the significance of the fractional area over which interference occurs should be compared to the respective 5% to 3% of expected RF holes in the overall design. The probability of that inter/cross-modulation event occurring, *e.g.*, during an incident or a day-to-day communications, near the broadband/wideband site makes the potential for interference a very rare event rather than an everyday-everywhere problem. Additionally, the probability of all channels being active at the same time also will have an impact. For example, an inactive broadband channel may contribute a few dB less than when operating at maximum transmit power.

MIXED MODE OF OPERATION

Both the NPSTC and Motorola Plans advocate the use of broadband channels but nevertheless reserve blocks of spectrum for wideband channels. In doing so, problems highlighted previously would simply accumulate if channels are not chosen appropriately. When interference due to broadband would appear as a rise in the noise floor, the impact of wideband would add distortion to the spectral shape of the desired narrowband signal. While collocated equipment would be less of a problem owing to the expected larger narrowband SNR, as noted earlier, the near-far situation would be of most concern. For the sake of argument, we have examined one of the NPSTC Plan's proposal that includes three broadband channels and three 50 kHz (interoperability) channels on either side of that broadband block. The inter/cross-modulation results (shown in red) are depicted in Figure 7 with the received composite input signal shown in blue. The noticeable intermodulation degradation is the result of potentially

mixing broadband, wideband, and narrowband channels. This should be compared to Figure 6(b).

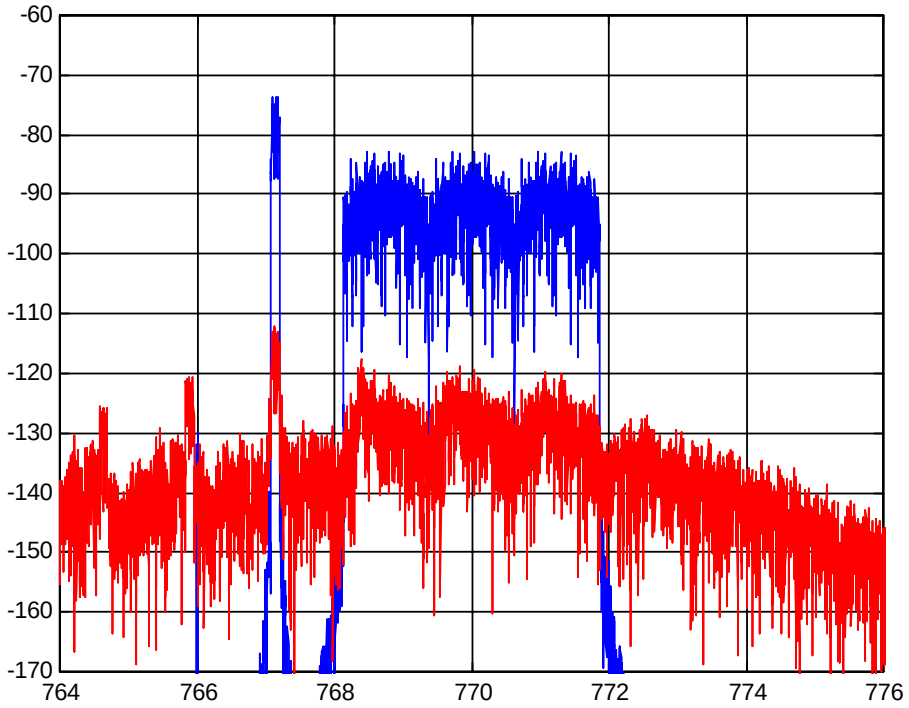

Figure 7: Mixed Mode Illustration

From a deployment perspective, it is strongly recommended that broadband or wideband transmitters be collocated with P25 sites to prevent P25 mobile receiver intermodulation issues and other near-far problems. Ultimately, the data rate at the edge of the broadband, or wideband cell, will be chosen to ensure a 1:1 coverage overlay with the P25 cell footprint.

We note that the premise behind our analysis was based partly on Motorola's claims that intermodulation due to broadband is more severe than with wideband.[3] Ultimately, field or bench testing on P25 mobiles operating in the 700 MHz public safety band will be required to assess the true nature of this potential impediment.

USE OF GUARDBANDS TO PREVENT INTERFERENCE

Field experience with commercial wireless service indicates that narrowband and broadband technologies can coexist with smaller guardbands than those being considered for the

[3] Ex-Parte Notice of Motorola, WT Docket No.96-86 (Oct. 26, 2005).

700 MHz public safety band with very satisfactory performance. Although, as set forth above, the existing stringent OOBE rule of –46dBm/6.25kHz can be satisfied, we believe that such a rule could be relaxed. Compared to cellular OOBE rules, at –13 dBm/100kHz or –25dBm/6.25kHz, the existing 700 MHz OOBE rule is 21 dB more severe despite analog NPSPAC channels being adjacent to the cellular A block. As a digital technology and in view of its coding mechanism, P25 should be able to tolerate more interference that analog FM. Although additional analysis would be necessary to specify a new, less restrictive threshold, such a liberalized OOBE rule could lead to the deployment of more than three broadband channels per 6 MHz of spectrum.