ATTACHMENT A:

TECHNICAL REVIEW:

THE ONGOING NEED FOR OVER-THE-AIR BROADCASTING

Current and Future Roles in the U.S. Economy and Society

Technical Review:
The Ongoing Need for Over-the-Air Broadcasting

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For
The Association for Maximum Service Television, Inc. (MSTV)
And
The National Association of Broadcasters (NAB)

December 22, 2009

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Executive Summary

The Federal Communications Commission's (FCC's) Notice of Inquiry on a National Broadband Plan has elicited comments from some in the wireless industry expressing concerns that the United States has insufficient spectrum available for the projected demand for future wireless broadband services. This technical paper has been prepared on the behalf of the Association for Maximum Service Television, Inc. and the National Association of Broadcasters as part of an initial response to a request from the FCC for information on the spectrum use of the television broadcast industry.

The purposes of this paper are to:

a) Determine and briefly describe the role that broadcast television should play in the 21st Century digital economy.

b) Provide a data-based perspective for the public policy discussion about the wireless broadband "spectrum crisis" by reviewing the spectrum currently available for broadcasting and broadband, examining broadband wireless claims for future spectrum demand, which are based on an International Telecommunication Union (ITU) spectrum estimation model, and examining whether spectrum and technology are available to address future broadband needs.

Some of the key observations of this paper are outlined in bold below.

1. **The over-the-air (OTA) television broadcasting industry serves the public interest and with the conversion to digital television can complement and contribute to wireless broadband services and applications.**

The United States has the most dynamic, diverse, and innovative market for information technologies in the world. The ability of the U.S. to remain globally competitive amid rising demand for high speed Internet access and digital content in an increasingly mobile consumer environment is presenting policy makers with critical decision points in regulating and allocating spectrum for advanced wireless services. However, policy solutions can ensure broadband deployment while at the same time advancing the critical role of – and continuous technological improvements to – digital over-the-air television.

Broadband and broadcasting services are twin pillars of the digital economy. Digital television (DTV) broadcasting should be viewed as a complement, rather than as an alternative, to wireless broadband. OTA television broadcasting serves the public interest in many ways, including in its capability to provide a portion of the public need for cost-effective and widely available broadband services. Broadcasting offers the optimal solution for delivery of bandwidth-intensive applications such as real-time video to a large number of users in the same geographic area and is superior to unicast solutions by orders of magnitude. Innovation in broadcasting technology is responsible for increased spectral efficiency while simultaneously introducing new advanced television services. Broadcasters can offer more viewing choices at higher quality for free to the public.

Due to advanced physical layer modulation and coding coupled with advances in computing and memory technologies, the broadcast industry is poised to serve a significant fraction of market demand for both fixed and mobile wireless broadband. The Advanced Television Systems Committee (ATSC) standards provide for IP data downloads that can be used for distributions of e-books, movies, and music. With intelligence and data storage built into devices, broadcasting can offer consumers a near "on-demand" functionality. With the introduction of mobile television service, scheduled for wide-scale deployment in early 2010, broadcasting will offer this functionality in new mobile devices, laptops, and vehicles. In summary, broadcasting can be a natural and spectrally efficient complement to wireless broadband.

Following the successful conclusion of the transition to DTV earlier this year, broadcasters are now doing "more with less" spectrum and OTA broadcast services are at a critical turning point. Experts project that mobile video will dominate traffic over mobile broadband networks in the coming years, with up to two-thirds of broadband usage growth forecast to be from video. Broadcasting is the most spectrally efficient way to meet this need. Therefore, broadcasting is an essential complement to other mobile broadband technologies and will play a unique role in delivering valuable content – which is free, local, and universally available – to the U.S. viewing public.

2. A data-based perspective of the "spectrum crisis" shows:

a. Broadcast television bands are a small fraction of the spectrum between 225 and 3700 MHz.

At the present time, broadcast television services are allocated exclusively only 5.18% of the spectrum in the range of 225 MHz to 3700 MHz. Further, the amount of spectrum used by broadcast television has been reduced by more than 140 MHz as a result of the DTV and Broadcast Auxiliary Services (BAS) transitions, while broadcasters have implemented (and continue to implement) a number of new innovations related to HDTV, multicasting, and mobile DTV for consumers.

b. Over the last 5 – 7 years, the FCC has provided substantial licensed spectrum suitable for wireless broadband use.

There is almost 750 MHz in the 225 MHz to 3700 MHz range currently available for licensed broadband use. While proponents of more spectrum for wireless broadband claim that the United States has far less spectrum in the pipeline than other countries, this is not a meaningful comparison because many of these countries have not yet assigned recovered spectrum from their transitions to digital television or identified other frequency bands for wireless broadband that have already been allocated in the United States. In addition, a substantial amount of spectrum that has been identified for wireless broadband use in the United States is either currently unused or only beginning to be used by wireless operators. Finally, simply allocating more spectrum for wireless broadband will not necessarily solve any claimed spectrum crisis. Spectrum is a resource. Merely allocating more of a certain resource does not mean that the resource will be used or used efficiently.

c. Future forecasts of wireless mobile broadband spectrum requirements derived from the ITU spectrum model are flawed or, at best, highly suspect.

The licensed wireless industry contends that additional spectrum must be identified and allocated over the next six years in order to provide a total of about 1300 MHz to meet its demand projections. However, these requirements were directly based on a "one size fits all" figure from a 2006 ITU spectrum requirements study and model estimating the needs for future IMT-Advanced systems. Unsurprisingly, the ITU study's solution requiring 1300 MHz for IMT-2000 and IMT-Advanced is highly sensitive to parameter values in the model.

The ITU study did not fully consider future broadcast television, wired solutions, or emerging femtocell possibilities in apportioning demand for high-speed multimedia and video and, in addition, assumed a diminishing market share for wireless local area networking. These assumptions have the consequence of increasing the apparent need for significantly increased licensed spectrum. To test this premise, the ITU spectrum estimation software tool was used to vary the video and high-speed multimedia market share assumptions and it was found that the projected spectrum needs were reduced by approximately 800 MHz and no additional spectrum would be required by even 2020.

Further evidence of the questionable accuracy of the ITU model is an examination of today's spectrum requirements for wireless broadband. The ITU model was used to examine a "baseline" of near-term wireless spectrum demand using the ITU 2010 spectrum needs projections. The same ITU model results that CTIA-The Wireless Association® (CTIA) uses to show a shortfall of 800 MHz in 2015 also suggests that there is a similar shortfall of hundreds of megahertz in 2010. There is clearly not a shortfall today of hundreds of megahertz or even close to this magnitude. One, therefore, must question whether a model that fails to accurately assess spectrum requirements in the near-term should be relied on for speculative future requirements. While the wireless industry may need a larger total spectrum allocation than 500 MHz over the next decade, it has not made this case, and the 1300 MHz number is highly speculative. Any spectrum requirements should be based on models reflecting the U.S. market.

d. Broadband spectrum requirements should be based on demand models that more accurately reflect the U.S. market, including the fact that there are other competitive providers of video services.

As policymakers address the spectrum "gap" it is imperative that better estimates be obtained and based on U.S. industry projections and demand studies. Indeed, a comprehensive examination is needed of the full range of spectrum that can be used for advanced wireless applications including both licensed and unlicensed bands. Fostering competition in wireless broadband requires an economically viable, innovative and dynamic wireless digital broadcast industry in competition with emerging broadband 3G/4G cellular, advanced wired Internet access (FiOS, for example) and continued improvements in wireless Local Area Network (LAN) technologies.

3. Improving spectral efficiency with emerging technology is a critical factor to meet increasing bandwidth requirements, and technology advances will make possible the effective use of higher spectrum bands.

Several technologies are emerging to increase spectral efficiency for wireless broadband systems, including network multiple-input multiple-output (MIMO) wireless systems, which use multiple antenna technology. Other promising areas include user collaboration and femtocells, the latter of which may have a dramatic impact on frequency reuse. These developments would reduce the claim for additional spectrum that has been advanced by the wireless industry.

The FCC's Broadband Task Force also appears to be focusing only on bands of frequencies less than 3.7 GHz. However, a rapid trend demonstrates that technology advances make possible the effective use of higher and higher spectrum bands. A number of different bands, both licensed and unlicensed, should be investigated and considered for wireless broadband.

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I. Introduction

In April 2009 the Federal Communications Commission (FCC) issued a Notice of Inquiry requesting comment on a National Broadband Plan[1], which has resulted in expressions of concern from some in the wireless industry that the United States does not have enough spectrum available to meet future demand for wireless broadband services. In a Public Notice[2] released on December 2, 2009 the Commission requested information on the spectrum use of the television broadcast industry.

In light of these recent events, the following technical review has been written on behalf of the Association for Maximum Service Television, Inc. and the National Association of Broadcasters to achieve two main purposes. The first purpose is to underscore the critical and irreplaceable role of free, over-the-air television as an integral component to a vital 21st Century broadband wireless economy. The paper will show that broadcast television is a natural and spectrally efficient complement to wireless broadband. The second purpose is to provide the ongoing public policy discussion with a technology and data-based perspective about the broadband "spectrum crisis." The paper will also show that claims about the future spectrum requirements for wireless broadband need to be critically assessed and scrutinized.

A transformation is under way in free, over-the-air television with the recent rollout of digital television (DTV) service and the finalization of the Advanced Television Systems Committee (ATSC) Mobile DTV Standard (originally known as the Mobile/Handheld or M/H Standard) for mobile television. Equipment manufacturers already have produced prototype mobile devices and transmission systems, and dozens of television stations plan to broadcast mobile DTV programs in the coming year. The changeover from analog to digital communications technologies heralds a period of intense innovation in television broadcast and its applications, just as similar changeovers signaled periods of change over the years in wired telephony, cellular communications, satellite communications, photography, music and movies.

The future promise of digital television is made possible by enhanced spectral efficiencies and digital system flexibility, which allow more programming and new applications to exist within a spectral allocation that formerly served a single analog television channel. This enables digital broadcast to complement[3] other broadband communications technologies and opens exciting opportunities in the convergence of broadcasting, Internet and personal communications.

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[1] *See* the FCC 09-31 Notice of Inquiry: "A National Broadband Plan for Our Future," released April 8, 2009.

[2] *See* the FCC DA 09-2518 Public Notice: "Data Sought on Uses of Spectrum," released December 2, 2009.

[3] The term "complement" here is used from the consumers' point of view. For example, mobile DTV operations may provide consumers with local news, emergency information, weather, traffic and entertainment programming that complements and supplements other mobile video services. The use of the term does not mean to preclude the possibility that DTV also will provide competition to those other video offerings.

Television broadcasters are essentially doing "more with less" spectrum, following the release of 108 MHz for wireless broadband applications and public safety requirements as part of the transition to digital television.[4] Yet some policymakers see a looming "gap" between the spectrum currently available for broadband wireless and certain estimates of future spectrum requirements. They have cited the long lead times to clear new bands for advanced wireless uses – an average of 6 to 13 years – as a driver for near-term decisions to close the spectrum "gap."[5]

As policymakers, industry stakeholders and the public consider the development of the FCC's National Broadband Plan[6] and its implications for spectrum policy, it is essential to ensure that the over-the-air digital marketplace for high-definition television (HDTV) and multicast services has the regulatory flexibility and certainty needed to meet future consumer demands and technology requirements. Over-the-air television broadcasting in general, and mobile DTV in particular, are complements rather than impediments to wireless broadband solutions.

This paper is organized as follows. In Section II we review the role of broadcast television in the digital economy with a focus on its important role in enhancing federal public policy objectives in the broadband domain. In Section III we carefully examine the so-called "spectrum crisis" with an analysis of the spectrum estimation methodology adopted by the International Telecommunication Union (ITU), which forms much of the basis for projected spectrum needs in wireless broadband. Section IV examines the impact of technological evolution on spectrum requirements. Section V highlights the unique capabilities that broadcasting technologies offer to enhance efforts in deploying ubiquitous broadband. Section VI offers conclusions.

II. Role of Broadcast Television in the Digital Economy

Broadcast television technology, including mobile DTV applications, provides a range of spectrum-based services that address many of the public interest and economic growth requirements associated with the FCC's goals of ubiquitous deployment of accessible broadband, including civic participation, consumer welfare,

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[4] As a result of the transition from analog to digital television, completed in June 2009, spectrum that corresponded with channels 52-69 was freed for advanced wireless uses (84 MHz) and public safety requirements (24 MHz). Of the 84 MHz designated for wireless broadband, the FCC placed 60 MHz up for auction in 2008.

[5] *See* B. Levin, "You Can't Coach Height: A Winning Spectrum Strategy," Oct. 29, 2009, http://blog.broadband.gov/?entryId=10624 ("Levin Blog"). Elsewhere, the FCC has cited the 13 years it has taken from the first step of reallocating 700 MHz (1996) to its availability for use (2009). *See* FCC Presentation, Broadband Gaps, November 18, 2009, Open Meeting.

[6] *See* the FCC 09-31 Notice of Inquiry ("Broadband NOI"): "A National Broadband Plan for Our Future," released April 8, 2009.

investment and innovation.[7] Efficient and innovative uses of existing broadcast television spectrum are also key components to advancing the FCC goal of smarter spectrum management policy.[8] In this regard, broadcast DTV technology meets the goals of innovation, competition and spectrum efficiency.

- **Innovation**: The ATSC recently approved its A/153 Mobile DTV Standard for mobile DTV, which offers a highly spectrally efficient and low-cost implementation technology to satisfy the demand for real-time video and audio on a mobile platform.[9]

- **Competition**: As wireless carriers continue with planned deployments of mobile broadcast offerings[10], mobile DTV services provide an important competitive balance to the competitiveness of the overall wireless marketplace.[11]

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[7] *See Broadband NOI*, paras. 63-105. The Inquiry lists the series of public policy goals that the Recovery Act requires the FCC to advance in the national broadband plan, including advancing consumer welfare, civic participation, public safety and homeland security, education and private sector investment.

[8] *See* Prepared Remarks of Chairman Julius Genachowski, "America's Mobile Broadband Future," *International CTIA Wireless I.T. and Entertainment*, Oct. 7, 2009. "Smart spectrum policy will be part of the solution."

[9] *See* R. V. Ducey, M. R. Fratrik, and J. S. Kraemer, "Broadcasters' Competitive Advantages in the Mobile Video Marketplace," July 29, 2008, http://www.openmobilevideo.com/_assets/docs/broadcasters/BroadcasterCompetitiveAdvantages.pdf. ("The incremental capital cost (i.e., variable cost after the sunk cost of the analog-to-digital conversion) at the transmitter to send a M/H signal could be as low as $100,000.")

[10] *See* GSM Association ("GSMA") press release, "GSMA Endorses Integrated Mobile Broadcast (IMB)," September 9, 2009. (The GSM Association has endorsed a new 3GPP standard – Integrated Mobile Broadcast (IMB) – which it said will "allow its members to accelerate the adoption of mobile data and broadcast services worldwide." A white paper released along with the GSMA press release acknowledged the extent to which Mobile DTV availability could alter the role of IMB deployments: "… if an operator decided to make an investment in IMB in a market where low-cost mobile Digital TV reception is already available, it could be that IMB would be used to provide an alternative primary service, such as non-linear multimedia content distribution services. Income generated from the linear TV Broadcasting service in such a market may be insufficient to justify a business case, and so IMB would need to offer other services to generate sufficient Return on Investment."

[11] The FCC has cited competition as a tenet of its promotion of broadband deployment, including mobile wireless broadband. Chairman Genachowski said in remarks, "America's Mobile Broadband Future" to the International CTIA WIRELESS I.T. & Entertainment on Oct. 7, 2009: "The PCS auctions of the 1990s showed the power of a competitive marketplace. They allowed new carriers to enter the market and resulted in a huge uptick in dollars spent, cell sites built, and jobs created, even as prices declined to make cell phones accessible to the mass market. The FCC will be vigilant in promoting competition."

- **Spectrum Efficiency**:[12] The sheer complexity of the broadband deployment challenge in the U.S. means that a one-size-fits-all approach for platforms will not facilitate deployment of all advanced applications, for all users in all geographic areas. As a point-to-multipoint system, broadcasting offers the optimal solution for efficiently transmitting high-quality HDTV and digital video content in small bandwidth segments to large audiences in the same geographic region. The DTV data rate of nearly 20 Mbps in one 6 MHz channel is competitive with the delivery speeds of other wireless technologies.[13] The efficiency tradeoff is clear – it is more efficient to broadcast a DTV program on a single channel to 1,000 viewers than to transmit the same information a thousand times.

The innovative public benefits provided by television broadcast service are a pillar of the U.S. digital economy. Over-the-air broadcasters have made significant technological contributions that have both facilitated and complemented the wireless broadband revolution. As part of the transition to digital television, broadcasters freed 108 MHz of spectrum in the 700 MHz band, which was auctioned by the FCC in 2008 to facilitate additional wireless offerings and provide billions of dollars in auction receipts to the U.S. Treasury. In what the FCC called "an unprecedented engineering feat,"[14] the transition led to major new investments, including billions of dollars spent by consumers on digital receiving equipment to continue access to free local programming, news, weather, sports and other services. Mobile DTV is the next innovation that broadcasters are launching. The technology is available today[15], 30 stations are already operational[16] and many more will be rolling out services in the next few months.[17]

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[12] We use the terminologies spectral efficiency and spectrum efficiency to refer to both the data rate per unit bandwidth sent over a point-to-point link and the data rate per unit bandwidth sent over a network. From a communication theory perspective, these are two separate analytical measures. The context of the discussion should make clear which notion of spectral efficiency is intended.

[13] 19.39 Mbps is the data rate that the ATSC standard provides within a 6 MHz channel. A broadcaster can offer a mix of video/data streams within that 19.39 Mbps payload, including fixed terrestrial SD, HD, and mobile DTV.

[14] *See* FCC Press Release, "1 Day Until DTV Transition: Focus at End of Technological Transition is on People," June 11, 2009.

[15] *See* Open Mobile Video Coalition Press Release, "With Standard Adopted, Broadcasters Poised to Bring Mobile DTV to American Consumers," Oct. 16, 2009: "Technology manufacturers such as LG Electronics, Samsung Electronics, Harris Corporation, Rohde & Schwarz and Dell have produced prototypes devices and working transmission systems."

[16] *See* G. Dickson, "Mobile DTV Standard Approved: ATSC formalizes broadcast standard, clears way for retail sales next year," *Broadcasting and Cable*, Oct. 16, 2009, http://www.broadcastingcable.com/article/358341-Mobile_DTV_Standard_Approved.php.

[17] *See* Open Mobile Video Coalition Press Release, "Broadcasters Target Washington, D.C. for Mobile Television Consumer Showcase," April 20, 2009. Broadcasters are launching an ATSC Mobile DTV consumer showcase in the Washington DC metro market with at least seven participants, including Fox Television Stations' WDCA-DT, Gannett Broadcasting's WUSA-DT, ION Media Networks' WPXW-DT, NBC Universal's WRC-DT, PBS' WHUT-DT and MHz Networks, Sinclair Broadcast Group's operated WNUV-DT,

Mobile DTV provides a complementary service to mobile broadband and can off-load capacity to a dedicated network to increase a mobile broadband provider's use of spectrum.

Broadcast innovations are also fostering new technologies such as Sezmi Corporation's upcoming product, which combines OTA television with content from cable television and Internet video programming.[18] Sezmi is just one company pioneering new uses that broadcast advancements have enabled.

III. Spectrum "Crisis": Facts and Fallacies

The claim that the United States will suffer a spectrum crisis needs to be critically assessed. To undertake this assessment, it is important to examine the availability of spectrum in the United States, how demands (e.g., CTIA's claimed spectrum needs) were estimated, and how spectrum is used today. This report studies the bands currently viable for wireless broadband between 225 MHz and 3700 MHz and also looks at other spectrum that could be viable for wireless broadband use. Note that the scope of this report does not include all spectrum that could be used for wireless broadband and is not intended to conduct a comprehensive spectrum inventory. The goal, however, is to highlight the fact that the current broadcast spectrum allocations represent only a small percentage of the spectrum suitable for wireless broadband use and point out a number of observations about the current spectrum allocated for broadband and the availability and suitability of other spectrum for wireless broadband.

A. Broadcast television bands are a small percentage of the 225 to 3700 MHz spectrum

Today, broadcast television services are allocated a total of 307 MHz in the 225 MHz to 3.7 GHz range.[19] The percentage of spectrum available (exclusively and shared) to television services is summarized in Fig. 1. Only 5.18% of the spectrum in that range is allocated exclusively for television service. Broadcasters recently cleared a total of 143 MHz of spectrum after the lengthy and costly digital television and Broadcast Auxiliary Services (BAS) transitions.[20] Despite this reduction in spectrum, broadcasters have

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and National Datacast. An additional 21 broadcasters have plans to launch Mobile DTV over the next year, for a total of 70 stations in 28 markets covering nearly 39% of U.S. TV households.

[18] *See* Reply Comments Of Sezmi Corporation, NBP Public Notice # 6, GN Dockets No. 09-47, 09-51, 09-137, Nov. 13, 2009, http://fjallfoss.fcc.gov/ecfs2/document/view?id=7020348536.

[19] *See* the count in Appendix B, which includes spectrum allocated for broadcast to homes as well as the spectrum used by broadcasters for Electronic News Gathering in the Broadcast Auxiliary Services band.

[20] This includes 108 MHz in the 700 MHz band and 35 MHz in the Broadcast Auxiliary Service band. *See* R. M. Rast, "The Dawn of Digital TV," *IEEE Spectrum*, October 2005, ITU BDT Seminar, "How much digital dividend? How countries tackle the question?" June 2009, http://www.itu.int/ITU-D/tech/digital-broadcasting/SaranskJune2009/Presentations/Day3/Saransk_June2009_Day3_3.pdf, and J. Krauss, "The

implemented (and continue to implement) a number of new innovations related to HDTV, multicasting, and mobile DTV.

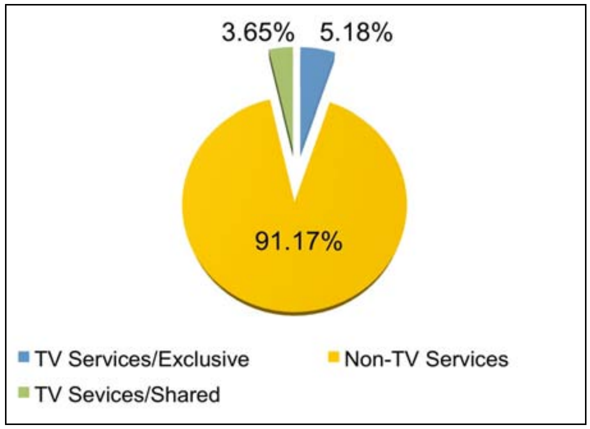

Figure 1: Allotment of spectrum to television services showing shared and exclusive spectrum percentages in the 225 MHz to 3.7 GHz range of frequencies.

B. Snapshot of today's spectrum allocations

The FCC's Broadband Task Force has suggested that 584 MHz (including 50 MHz in the pipeline) of spectrum is available for wireless broadband use.[21] The FCC spectrum assessment is reprinted in Fig. 2.

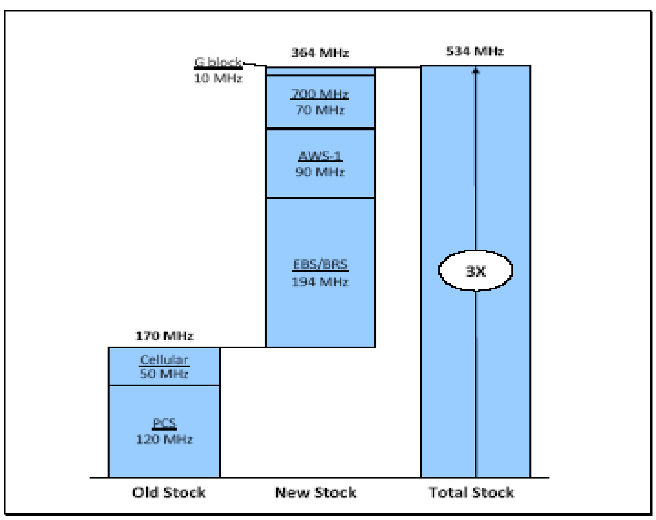

Figure 2: Spectrum available for mobile broadband has tripled
Source: FCC Presentation, September 29, 2009 Open Meeting

FCC's White Spaces Decision," *CEDMagazine*, Jan. 1, 2009 http://www.cedmagazine.com/Article-Capital-Currents-010109.aspx.

[21] *See* FCC, "September Commission Meeting September 29, 2009: 141 days until Plan is due," Sept. 29, 2009, slide 69, http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-293742A1.pdf, (534 MHz of total spectrum, 364 MHz newly available (700, AWS-1, BRS/EBS, G-Block), 170 MHz existing (PCS, Cellular)).

Several groups have produced other estimates of the usable spectrum for wireless broadband. As part of an economic study, the Consumer Electronics Association (CEA) and The Brattle Group counted 664 MHz of the spectrum below 3 GHz as "licensed and available for mobile broadband uses."[22] In contrast, CTIA has counted 459.5 MHz (409.5 MHz currently available plus 50 MHz in the pipeline) for wireless broadband. These estimates are presented in Table 1 below:

Table 1: Comparison of spectrum available for mobile broadband between 225 and 3700 MHz

Band Name	**Band Location**	**Brattle Group Count (MHz)**	**FCC Count (MHz)**	**CTIA Count (MHz)[23]**	**Modified Count (MHz)[24]**
PCS	1.9 GHz	120	120	120	120
Cellular	800 MHz	50	50	50	50
SMR	800 MHz / 900 MHz	20	-	19	20
BRS/EBS	2.5 GHz	174	194	55.5	194
AWS	1.7 GHz / 2.1 GHz	90	90	90	90
700 MHz	700 MHz	80	80	80	80
G Block	1.9 GHz	10	10	5	10
ATC Spectrum	1.5 GHz / 2 GHz	55	-	-	55
H Block	1.9 GHz	10			10
AWS-II	1.9 GHz / 2 GHz	-	20	20	20
AWS III	2.1 GHz	25	20	20	20
WCS	2.3 GHz	30	-	-	30
WBS	3.65-3.7GHz	-	-	-	50
TOTAL SPECTRUM SUITABLE FOR MOBILE BROADBAND		664	584	459.5	749

Sources: Brattle Group Study, FCC Broadband Presentation (Sept. 2009), CTIA FCC Ex Parte filing, GN Docket No. 09-51 (September 29, 2009).

Table 1 also includes a revised spectrum tally that includes all spectrum up to 3.7 GHz. Note that the band from 3650-3700 MHz is licensed for Wireless Broadband Services and is available for fixed and mobile wireless broadband operations.[25] This band appears well-suited for deployment of WiMAX or WiMAX-like systems. The Wireless Communications Association International (WCAI) recently formed a working

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[22] The Brattle Group, "The Need for Additional Spectrum for Wireless Broadband: The Economic Benefits and Costs of Reallocations," Oct. 23, 2009.

[23] This is a best-effort reconstructed breakdown of the CTIA count that includes allocated spectrum and pipeline spectrum.

[24] The modified count tabulates the usable spectrum up to 3.7 GHz.

[25] *See* "FCC: Wireless Services: 3650-3700 MHz Radio Service: Services," http://wireless.fcc.gov/services/index.htm?job=service_home&id=3650_3700. Part 90 Subpart Z - Wireless Broadband Services in the 3650-3700 MHz Band.

group to enable wireless broadband in the 3.65GHz band.[26] There are over 1,100 licensees and over 5,400 base stations registered nationally.[27] This band has several interesting regulatory issues including exclusion zones and licensee cooperation requirements.[28]

The proponents of more spectrum for wireless broadband claim that the United States has far less spectrum in the pipeline than other countries. Thus, CTIA has cited several international examples to show that the 50 MHz in the pipeline of the United States lags behind other industrialized nations.[29] But this is not a meaningful comparison because many of these countries have not yet assigned recovered spectrum from their respective transitions to digital television or identified other frequency bands for wireless broadband than have been allocated in the United States. For example, France and the United Kingdom are still finalizing plans on how to handle their digital dividend spectrum holdings.[30] Similarly, Germany's digital dividend auctions will take place early in 2010.[31] In contrast, the CTIA assigned spectrum figure of 409.5 MHz includes the "700 MHz [digital dividend] spectrum not yet in use".[32] The CTIA figure, however, does not include almost 300 MHz of other spectrum that has been made available by the FCC for broadband use.[33]

Spectrum assigned but not fully utilized: Over the last four years, the Commission has reallocated and/or fashioned a favorable regulatory framework for 354 MHz of spectrum in its 700 MHz and AWS (Advanced Wireless Services) I auctions, and its

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[26] *See* WCAI Press Release, "WCAI Launches Industry Effort to Unlock 3.65 GHz Band Potential," http://www.wcai.com/images/pdf/2009_wcai11-18.pdf.

[27] *See* P. J. Sinderbrand, "The 3.65 GHz Band: Unlocking Its Potential," http://www.wcai.com/images/pdf/2009_wcaiWebinar11-18.pdf.

[28] *See* Solectek White Paper, "The U.S. WiMAX 3.65 GHz Opportunity: The History of the Band and How WISPs Can Register for FCC Approval," *WiMAX Forum*, http://www.solectek.com/files/pdf/techtalk/wp-365GHz.pdf.

[29] *See* Written Ex Parte Communication, CTIA, GN Docket No. 09-51, Sept. 29, 2009.

[30] *See* UMTS Forum Press Release, "Europe's Golden Opportunity to Capitalise on Digital Dividend," Feb. 16, 2009, http://www.umts-forum.org/content/view/2700/174/. ("In France, 72 MHz of digital dividend spectrum in the 790-862 MHz UHF band has been earmarked for mobile services as part of the Government's "France numérique 2012" plan, unveiled last Autumn and confirmed late December by the recent official Digital Dividend allocation scheme." and "It is anticipated that Ofcom will hold its auction for the UK's digital dividend spectrum during 2010." and "Other EU and CEPT member states (Sweden, Finland, Switzerland) have aligned on the same band to support expansion of affordable access to broadband communication services."

[31] *See* A. Mitchell, "German Spectrum Auction Set to Proceed in 2010," *4G Trends*, Oct. 14, 2009, http://4gtrends.com/?p=1821. German regulator Bundesnetzagentur will move forward with a planned auction of 340 MHz next year, including allocations in the 790 to 862 MHz band being released by broadcasters as part of the digital dividend. [The CTIA figures denote 340 MHz of spectrum in Germany's pipeline.]

[32] *See* Written Ex Parte Communication, CTIA, GN Docket No. 09-51, Sept. 29, 2009.

[33] *See* Table 1.

Broadband Radio Service (BRS)/Educational Broadband Service (EBS) order. While several carriers have deployed third generation wireless systems in AWS-I spectrum,[34] including T-Mobile USA, Leap and MetroPCS, the use of BRS/EBS and 700 MHz is still in its infancy.

Clearwire has access to 100 MHz of BRS/EBS spectrum in nearly all major markets and is aggressively deploying Mobile WiMAX.[35] The company plans to serve 30 million consumers by the end of 2009 and expects to have coverage to offer service to 120 million consumers by the end of 2010.[36] Meanwhile, AT&T, Verizon, and MetroPCS have announced plans to deploy Long Term Evolution (LTE) in the 700 MHz band, with deployments beginning in 2010 and some full build-outs scheduled to be completed in the 2012-2013 timeframe.[37]

Moreover, public statements and studies suggest that Clearwire and T-Mobile USA's new networks use less than half of their respective network deployment capacities. A Signals Research article on Sprint's Xohm WiMAX network (now part of Clearwire) in Baltimore reported that the initial launch required 30 MHz of spectrum to provide services.[38] This leaves approximately 70 MHz of spectrum for future growth. In the case of T-Mobile USA, the highest bidder in the AWS-1 auction, its 3G network was deployed using 10 MHz of the 30 MHz of AWS spectrum purchased in the 2006 AWS-1 auction. They have 20 MHz in reserve for future use.[39]

A review of the spectrum from 225 to 3700 MHz suggests that a substantial amount of spectrum has been identified for wireless broadband use and a significant portion of this spectrum is unused or only beginning to be implemented by wireless operators.

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[34] *See* S. Fox and J. Walkenhorst, "Mobile Broadband in the Americas: Momentum Building in the AWS Band," http://www.gsmworld.com/documents/Momentum_Building_in_the_AWS_Band_Report.pdf.

[35] *See* Press Release, "Clearwire Completes Transaction With Sprint Nextel and $3.2 Billion Investment to Launch 4G Mobile Internet Company," http://newsroom.clearwire.com/phoenix.zhtml?c=214419&p=irol-newsArticle&ID=1231029&highlight.

[36] *See* Press Release, "Clearwire Reports Second Quarter 2009 Results," August 11,2009, http://newsroom.clearwire.com/phoenix.zhtml?c=198722&p=irol-newsArticle&id=1319734.

[37] *See* Verizon LTE Innovation Center, "Verizon Wireless LTE Network," https://www.lte.vzw.com/AboutLTE/VerizonWirelessLTENetwork/tabid/6003/Default.aspx. Om Malik, "AT&T Moves Up Its LTE Rollout, Admits To Network Issues," *GigaOm*, May 27, 2009, http://gigaom.com/2009/05/27/att-moves-up-its-lte-rollout-admits-to-network-issues/. MetroPCS Press Release, "Unlimited Wireless Carrier MetroPCS Announces Vendors for 2010 4G LTE Launch," Sept. 15, 2009, http://investor.metropcs.com/phoenix.zhtml?c=177745&p=irol-newsArticle&ID=1331809&highlight.

[38] *See* M. Thelander, "Sprint launches XOHM," *Signals Flash*, Sept. 29, 2008, http://www.signalsresearch.com/Docs/flash_092908.pdf.

[39] *See* M. Dolan, "T-Mobile's Neville Ray: We will have more G series phones in 2009," *Fierce Wireless*, Jan. 29, 2009, http://www.fiercewireless.com/story/t-mobiles-neville-ray-we-will-have-more-g-series-phones-2009/2009-01-29?utm_medium=nl&utm_source=internal&cmp-id=EMC-NL-FW&dest=FW -ixzz0Viee1vEr. ("(T)he network we are launching uses 10 MHz of spectrum and we have 30 MHz so we have headroom to grow.")

C. Will adding more spectrum increase broadband penetration?

In any communications system, spectrum is a resource. Allocating more of a certain resource does not mean that the resource will be used or used efficiently. As documented in the draft report *Next Generation Connectivity: A review of broadband Internet transitions and policy from around the world*, surveys conducted by the Harvard University Berkman Center for Internet & Society found no common driver for third generation wireless penetration.[40] In fact, these studies showed varying levels of penetration across different economies, regulatory structures, and spectrum policies, but no consistent correlation between these approaches and wireless penetration.

In order to integrate new spectrum into network operations, carriers must invest in a number of areas throughout the entire network. One of the most critical areas will be improvements in backhaul links to facilitate the data demands of wireless devices.[41] For example, Verizon has already invested heavily by laying fiber to cell sites, in large part to support future LTE deployments,[42] and Clearwire has invested in microwave backhaul links to support future mobile WiMAX sites.[43] T-Mobile USA is upgrading its towers to achieve speeds of 50 –100 Mbps with fiber.[44] These examples demonstrate that the issue of future strain on the backhaul infrastructure is one of great importance and has been recognized internationally.[45]

Simply allocating more spectrum for wireless broadband will not solve the claimed spectrum crisis. Building a wireless broadband system with sufficient scale to be financially viable requires a large outlay of capital and a great deal of expertise. Clearwire, a relatively new player building out a nationwide wireless broadband network, is finding that "fostering innovation and investment in the risky, capital-intensive wireless communications market is complex and will not be solved with a

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[40] *See* DRAFT Berkman Center for Internet & Society at Harvard University, "Next Generation Connectivity: A review of broadband Internet transitions and policy from around the world," Oct. 2009. *See also* Comments Sought on Broadband Study Conducted by the Berkman Center for Internet and Society, NBP Public Notice #13, GN Docket Nos. 09-47, 09-51, 09-137, Oct. 14, 2009.

[41] *See* O. Malik, "Mobile Data Growth Boosting Backhaul Demand," *GigaOm*, May 27, 2009, http://gigaom.com/2009/05/27/mobile-data-growth-boosting-backhaul-demand/.

[42] *See* K. Fitchard, "Verizon lays fiber to 1000 cell sites," *Telephony Online*, Nov. 2, 2009, http://telephonyonline.com/3g4g/news/verizon-fiber-cell-sites-1102/. ("Verizon has committed to deploying fiber Ethernet to the 90% of the cell sites in its territory by the end of 2013, closely following VZW's LTE rollout schedule.")

[43] *See* D. Jones, "Clearwire's Backhaul Bet," *Unstrung*, http://www.unstrung.com/document.asp?doc_id=154063.

[44] *See* T. Duryee, "Mobile Broadband Consumption Is Creating Problems On All Sides Of The Equation," *MocoNews.Net*, Dec. 4, 2009, http://moconews.net/article/419-mobile-broadband-consumption-is-creating-problems-on-all-sides-of-the-e/.

[45] *See* European Commission, Radio Spectrum Policy Group, Final Position Paper, Working Group on Wireless Broadband, May 14, 2009.

single silver bullet. Additional spectrum resources, for example, while important, alone will not create a solid foundation for innovation."[46]

D. Issues with ITU spectrum estimation

From the above-mentioned Table 1, it can be seen that a significant amount of spectrum already has been identified for wireless broadband use. In addition, a number of experts, including the FCC's own source for research, Harvard University's Berkman Center for Internet & Society, find no clear nexus between allocating more spectrum and broadband penetration and performance. Nonetheless, as noted above, there is the claim by the wireless industry of a broadband spectrum crisis in the United States.

The principal support for this claim is an ITU model of spectrum needs. CTIA uses this ITU model to support its argument that 800 MHz is needed for wireless broadband by 2015.[47] The ITU model is examined in this section. As shown below, this examination finds that the ITU model is very sensitive to input assumptions. For example, modifying certain video and other assumptions used in the CTIA estimation changes the results of the ITU model to suggest that no additional spectrum is required by even 2020.

In addition, the ITU model was used to examine today's wireless spectrum demand. To do this, the ITU model's spectrum projections for 2010 were examined. For example, the ITU model results that CTIA cites to show a shortfall of 800 MHz in 2015 also suggest that there is a similar shortfall of hundreds of megahertz in 2010. There is clearly not a shortfall today of hundreds of megahertz, a fact confirmed by the growth in this industry sector. One, therefore, must question whether a model that fails to accurately assess spectrum requirements in the very near-term should be relied on for speculative future requirements.

The details of these examinations of the ITU model are shown below.

Generic ITU Model: The spectrum needs projection produced by the ITU spectrum estimation methodology is the primary basis for the CTIA request for at least 800 MHz of additional spectrum.[48] The methodology used by the ITU[49] is based upon well-

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[46] *See* Clearwire Comments, "Fostering Innovation and Investment in the Wireless Communications Market," GN Docket 09-157, Sept. 30, 2009.

[47] *See* CTIA, "Wireless Crisis Foretold: The Gathering Spectrum Storm … and Looming Spectrum Drought," Sept. 2009.

[48] Id.

[49] *See* Recommendation ITU-R M.1768, "Methodology for calculation of spectrum requirements for the future development of the terrestrial component of IMT-2000 and systems beyond IMT-2000," 2006.

known trunking theory[50] applied in a complex scenario involving many service classes, heterogeneous user requirements and multiple communications systems (IMT-2000, IMT-Advanced, radio Local Area Network [LAN] with wired backhaul, and broadcast systems).[51]

The problem lies in the application of the ITU methodology to real-world policy considerations. First, the overall model is extraordinarily complex with many parameters characterizing, 1) assumptions about wireless access technologies and the future evolution of their spectral efficiencies, 2) service categories, 3) current and future applications utilizing broadband access, and 4) current and future assumptions about the application market. As is well known in statistical estimation theory, estimates and predictions based on high-dimensional models must be examined with a skeptic's eye as the sensitivity to errors in model structure and parameters is typically high.[52]

The use of a highly variable multi-dimensional model based on inferences from a three-year-old requirements document should not be relied on as "evidence" of spectrum needs and the timing of these needs. Instead, the FCC should use a more stringent, data-driven projection of U.S. need:

- At a minimum, such projections must assess the extent to which wireline substitutes would more cost-effectively meet overarching broadband requirements in the period of time evaluated.

- In addition, such "pipeline" projections must be evaluated in the overall context of the broadband deployment scenarios for whether licensed, advanced wireless applications are the "best pipe" versus other broadband options, including wireline alternatives and other types of spectrum-based deployments (e.g., unlicensed). A recent European Commission report noted the need for balance based on not just data speeds, but a broader range of parameters. It pointed out that the wired option typically provides higher speeds than the best wireless option.[53]

- Similarly, unlicensed options such as Wi-Fi, because of their small operational area and limited number of users within each operational area, offer (and will continue to offer) consumers an effective alternative to licensed broadband. Apple's

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[50] *See* T. Irnich and B. Walke, "Spectrum Estimation Technology for Next Generation Wireless Systems: Introduction and Results of Application to IMT-2000," in *Proc. 2005 IEEE International Symposium on Personal, Indoor, and Mobile Radio Communications*, pp. 2801-2809, 2005.

[51] *See* J. Kaufman, "Blocking in a Shared Resource Environment," *IEEE Transactions on Communications*, vol. COM-29, no. 10, pp. 1474-1481, Oct. 1981.

[52] *See* R. Bellman, *Adaptive Control Processes: A Guided Tour*, Princeton University Press, Princeton, NJ 1961.

[53] *See* European Commission, Radio Spectrum Policy Group, Final Position Paper, Working Group on Wireless Broadband, May 14, 2009.

advertising for the iPhone 3G emphasizes this point when it notes that the iPhone 3G "seamlessly switches between EDGE, faster 3G, and even faster Wi-Fi".[54]

Specific Results from a Generic Model: A cursory review of the ITU estimation model demonstrates that it is not a reliable predictor of spectrum requirements for any country, let alone the United States, in the near or mid term. The ITU study sought to estimate the additional spectrum to be needed by one wireless network for each country in, respectively, 2010, 2015 and 2020, with "higher" market settings for countries whose mobile markets developed earlier and "lower" market settings for those with markets that were still developing. To derive the projection of 800 MHz of additional spectrum that, allegedly, will be needed by 2015, CTIA "conservatively" points to the ITU's projection for 2015 for a total U.S. spectrum requirement of 1300 MHz. Using 459.5 MHz as the total amount of mobile broadband spectrum, CTIA concludes that the U.S. "would still need to identify and allocate just over 800 additional MHz of spectrum for commercial wireless services within the next six years."[55]

Reviewing the ITU figures for 2010 and comparing them against the amount of spectrum currently allocated for wireless broadband reveals a fundamental flaw in the use of the model. For 2010, the ITU study estimates that a "lower" market setting country requires 760 MHz of spectrum for one network deployment.[56] This is the identical setting used for the basis of spectrum requirements in 2015. While the total amount of spectrum available for use in the U.S is contested, 760 MHz exceeds what is currently allocated in the United States by any measure (see Section III.B). CTIA ignores the ITU model's 2010 prediction, which would indicate a current spectrum shortfall of 300 MHz (calculated using CTIA's count of 459.5 MHz and subtracting from the ITU 2010 estimate of 760 MHz).[57] The ITU model therefore fails to accurately assess spectrum requirements in the near-term (e.g., 2010) and policymakers should not rely on it to predict future requirements.

Ignoring its accuracy for predicting 2010 spectrum requirements, the need for CTIA to point to the "conservative" scenario of one wireless network and a "low" market setting further underscores that this data is not designed to predict specific country spectrum requirements on a going forward basis. At a minimum, such estimates must take into account technological developments in wireless networks that have developed since 2006 and that are now projected to be operational by 2015.

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[54] *See* Apple web site, http://www.apple.com/iphone/iphone-3gs/high-technology.html.

[55] *See* Written Ex Parte Communication, CTIA, GN Docket No. 09-51, Sept. 29, 2009. "Wireless Crisis Foretold: The Gathering Storm… and Looming Spectrum Drought," at p. 19.

[56] *See* Recommendation ITU-R M.2078.

[57] The ITU model also contains adjustments for countries with multiple networks. Taking into account the fact that the United States has four major wireless carriers each with their own network would further increase spectrum requirements making this error and spectrum shortfall even greater. *See*, for example, Table 26 in Report ITU-R M.2078, "Estimated spectrum bandwidth requirements for the future development of IMT-2000 and IMT-Advanced," 2006.

Radio Access Technology Limitation: In the ITU methodology, demand is apportioned in the first few steps between four radio access technology groups (RATGs). The first two correspond to IMT-2000 and IMT-Advanced. The second two correspond to existing radio LAN systems and digital mobile broadcasting systems. The ITU model makes assumptions[58] that a growing percentage of demand will be apportioned to IMT-2000 and IMT-Advanced systems, which has the effect of increasing their spectral requirements. This approach short changes the potential for broadband traffic to be carried by LAN with wired Internet and/or via digital broadcast technologies.

The ITU approach seeks to predict a global spectral requirement for IMT-2000 and IMT-Advanced without adjustment to account for country specific differences, such as population density or application demand. From a United States point-of-view, this makes little sense for deployment decisions. The U.S. has a varied and unique environment (including geography, population density, consumer demands, access requirements) that is not properly modeled by a "one-size-fits-all" approach.

Assessing the ITU Spectrum Requirements Estimation Tool - SPECULATOR: The ITU spectrum estimates were based on a model by the Wireless World Initiative New Radio (WINNER) group.[59] WINNER is a consortium coordinated by Nokia Siemens Networks which consists of 41 partners, primarily European telecommunications equipment manufacturers or carriers[60], seeking to improve mobile broadband network technology.[61]

WINNER developed a spectrum estimation tool called SPECULATOR, which the ITU selected as its official tool for spectrum estimation.[62] This spectrum estimation tool and the methodology behind it are described in two ITU-R reports, ITU-R M.2078 Report entitled *Estimated spectrum bandwidth requirements for the future development of IMT-2000 and IMT-Advanced* (2006) and Recommendation ITU-R M.1768 *Methodology for calculation of spectrum requirements for the future development of the terrestrial component of IMT-2000 and systems beyond IMT-2000* (2006). The methodology in the tool uses various factors to derive its estimates, including "service categories (a combination of service type and traffic class), service environments (a combination of service usage pattern and teledensity), radio environments, market data analysis and

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58 *See* Report ITU-R M.2078, "Estimated spectrum bandwidth requirements for the future development of IMT-2000 and IMT-Advanced," 2006.

59 *See* WINNER, "Spectrum Requirements for System beyond IMT-2000," D 5.10.2 v 1.0, p. 2, March 2, 2007, http://www.ist-winner.org/WINNER2-Deliverables/D5.10.2.pdf.

60 *See* WINNER Partner Page, http://www.ist-winner.org/partners.html. The number of partners is found at the WINNER Main page, http://www.ist-winner.org/.

61 *See* WINNER About Page, http://www.ist-winner.org/about.html.

62 *See* WINNER, "Spectrum Requirements for System beyond IMT-2000," D 5.10.2 v 1.0, p. 2, March 2, 2007, http://www.ist-winner.org/WINNER2-Deliverables/D5.10.2.pdf.

traffic estimation by using these categories and environments, traffic distribution among radio access technique groups (RATGs), required system capacity calculation and resultant spectrum requirement determination."[63]

The primary risk with using the ITU spectrum estimation methodology is that calculations appear to be highly sensitive to input modifications. Because these inputs are primarily based on forecasts and approximations, care must be used when making decisions based on this single spectrum estimation model.

The SPECULATOR tool is available on the ITU-R website,[64] which allows anyone to see how the model is sensitive to changes. The tool is a Microsoft Excel spreadsheet that incorporates multiple worksheets and macros that correspond to the calculation methodology. According to WINNER[65], the SPECULATOR tool defaults to the higher market setting. Upon downloading the SPECULATOR tool, it shows spectrum requirements as shown in Table 2. The 2015 total spectrum requirement from SPECULATOR is 1300 MHz, which is the estimate that CTIA uses to calculate its 800 MHz request. (calculated using CTIA's count of 459.5 MHz and subtracting from the ITU 2015 estimate of 1300 MHz)

Table 2: Unmodified SPECULATOR output showing CTIA spectrum request

Spectrum for RATG	**Year 2010**	**Year 2015**	**Year 2020**
RAT Group #1	840 MHz	880 MHz	880 MHz
RAT Group #2	0 MHz	420 MHz	840 MHz
Total	**840 MHz**	**1300 MHz**	**1720 MHz**

To understand the sensitivity of the SPECULATOR output to changes in assumptions, we attempted to modify the data to take into account the following considerations:

Consideration 1) **Video is already provided by broadcast television systems.** The availability of broadcast television may allow video to be off-loaded from the wireless broadband networks.

Consideration 2) **Spectrum above 3 GHz may be viable for future wireless broadband systems.** Future wireless broadband networks might effectively use

[63] *See* Recommendation ITU-R M.1768, "Methodology for calculation of spectrum requirements for the future development of the terrestrial component of IMT-2000 and systems beyond IMT-2000," p. 1, 2006.

[64] *See* ITU, "'SPECULATOR' tool for estimating the spectrum requirements for the future development of IMT-2000 and IMT-ADVANCED," http://www.itu.int/oth/R0A06000010/en.

[65] *See* IST-2003-507581 WINNER and IST-4-027756 WINNER II, "Tool for estimating the spectrum requirements for the future development of IMT-2000 and IMT-ADVANCED"

other bands, especially with technology such as femtocells. Section IV.B discusses several bands.

Consideration 3) **Wireline broadband networks offer an alternative to wireless broadband.** Wired systems (e.g., those using fiber-to-the-home technology) provide very high data rates.

To approximately model these considerations, we modified SPECULATOR as outlined in Appendix A. The changes included the following:

Change 1) Set all super-high multimedia capacity requirements to zero. As discussed in ITU-R M.1768,[66] the super-high multimedia "service type accommodates super-high data rates multi-media applications, which are currently provided with fibre-to-the-home (FTTH) services in case of wired communication systems." This change roughly models all three considerations.

Change 2) Set all high multimedia capacity requirements to zero. As discussed in ITU-R M.1768,[67] the high multimedia "service type accommodates high data rate applications, including multi-media video streaming services, which are provided with xDSL service in fixed wired communication systems." This change roughly models all three considerations.

Change 3) Set all multicasting capacity requirements to zero. The discussion in ITU-R M.1768[68] states, "Examples of services that can be provided efficiently in mobile multicast transmission modes include mobile TV type services and low data rate messaging services." This change roughly models all three considerations.

After modification, SPECULATOR shows spectrum requirements summarized in Table 3. The results are dramatic. These modifications entirely remove the 2015 requirement for 800 MHz of additional spectrum.

[66] *See* p. 10 of Recommendation ITU-R M.1768, "Methodology for calculation of spectrum requirements for the future development of the terrestrial component of IMT-2000 and systems beyond IMT-2000," 2006.

[67] *See* p. 10 of Recommendation ITU-R M.1768, "Methodology for calculation of spectrum requirements for the future development of the terrestrial component of IMT-2000 and systems beyond IMT-2000," 2006.

[68] *See* p. 17 of Recommendation ITU-R M.1768, "Methodology for calculation of spectrum requirements for the future development of the terrestrial component of IMT-2000 and systems beyond IMT-2000," 2006.

Table 3: Modified SPECULATOR output showing sensitivity to changes in assumptions about i) video usage, ii) availability of spectrum above 3GHz, and iii) broadband alternatives.

Spectrum for RATG (in MHz)	Year 2010	Year 2015	Year 2020
RAT Group #1	200 MHz	240 MHz	160 MHz
RAT Group #2	0 MHz	220 MHz	540 MHz
Total	**200 MHz**	**460 MHz**	**700 MHz**

Note that we do not claim that wireless broadband providers will not need additional spectrum by 2015. The modifications made in this simple example represent an extreme case intended to demonstrate that numbers taken from spectrum estimation models should not be accepted at face value and extrapolated for different policy scenarios. Inputs and variables used for the calculations must therefore be subject to a rigorous assessment and robust technical and policy discussion. *To fully assess the future spectrum needs of wireless broadband, a thorough study focused on the United States is needed.*

E. Importance of video to future mobile broadband traffic

Demand projections commissioned by CTIA have focused solely on the need for licensed spectrum to meet projected growth, referring to unlicensed networks as an “unproven solution” due to technical and business difficulties and poor indoor coverage.[69] This conclusion ignores various market forces that could meet projected demand growth for broadband, particularly given the sizeable amount of spectrum made available for unlicensed, as well as licensed, applications in recent years. This incomplete assessment of future market forces is particularly flawed in failing to consider the role of broadcast TV for delivering video and which will substantially reduce the role that licensed wireless networks play in carrying mobile video content.

Video applications, including mobile TV, are expected to dominate the data traffic of mobile broadband networks. For example, Cisco Networks forecasts that by 2013 video will represent almost two-thirds of mobile data traffic (see Table 4).[70] Video transcoding company Ripcode derives a similar estimate.[71] Technology and media

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[69] *See* Rysavy Research, “Mobile Broadband Spectrum Demand,” Dec. 2008, as submitted by CTIA as part of Written Ex Parte Communication, GN Docket No. 09-51, Sept. 29, 2009.

[70] *See* Cisco, “The Cisco Visual Networking Index Global Mobile Data Traffic Forecast Update (2009),” http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.pdf. Table 1

[71] *See* C. Schuk, “Mobile video poised to outpace other mobile traffic,” *Broadcast Engineering*, July 21, 2009, http://broadcastengineering.com/RF/mobile-video-poised-outpace-0721/index.html. (“Based on current rates of growth, transcoding company RipCode estimates that by 2013, two-thirds of all mobile traffic will be video.”)

specialist Coda Research Consultancy forecast that mobile video traffic will reach over 450TB per month in 2015 and will represent almost two-thirds of video traffic.[72]

Table 4: Expected rise in mobile video applications

	2009	2010	2011	2012	2013
Percent of mobile traffic for Video	45.47%	51.93%	56.99%	60.42%	63.66%
Amount of video traffic carried (TB per month)	38,681	107,714	274,820	650,310	1,390,548

Source: Table 1, The Cisco Visual Networking Index Global Mobile Data Traffic Forecast Update (2009).

IV. Technology Evolution and Its Effect on Wireless Broadband Spectrum Needs

A. Technology evolution in cellular

The wireless broadband industry's claims for more spectrum inadequately take into account the greater efficiencies in spectrum utilization that can be achieved by new and improved cellular technologies. According to wireless industry legend Martin Cooper, the theoretical "practical capacity," defined as the total number of messages that can be sent over all spectrum over all parts of the world using the best available techniques, has doubled every 30 months.[73]

In order to increase the data rates and availability of wireless broadband in the United States, investment in cellular technological innovation is necessary. There are a number of emerging standards and technologies that may increase the system spectral efficiency of wireless systems deployed in the United States. Before spectrum need projections are finalized and disruptive spectrum reallocation decisions are made, the potential of these emerging technologies needs to be properly assessed.

Emerging Standards: A large number of emerging technologies are poised to improve the system spectral efficiency of wireless broadband systems. Some of these technologies have already found their way into emerging standards, while others are still areas of active research.

The deployment of wireless broadband in the United States is still in its infancy. Both T-Mobile and AT&T cover most of the U.S. population with EDGE and

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[72] *See* Coda Research Consultancy, "US Mobile Traffic Forecasts: 2009-2015," Report Extract, 2009, http://www.codarc.co.uk/usmobiletraffic/us%20mobile%20traffic%20report%20extract.pdf

[73] *See* M. Cooper, "Personal communications and spectrum policy for the 21st century," *Telecommunications Policy*, 2007.

HSDPA/UMTS.[74] Verizon and Sprint each primarily use CDMA2000 EV-DO.[75] While these technologies facilitate the delivery of increased data services, there is growing interest in technologies that go beyond 3G systems such as mobile Worldwide Interoperability for Microwave Access (WiMAX) and 3GPP LTE. Mobile WiMAX has been deployed in limited areas around the United States, primarily by Clearwire[76], and LTE deployments are currently in limited trials.[77]

Despite the promise of LTE and mobile WiMAX, there is debate as to whether either technology can be deemed a true fourth generation (4G) system. Currently, most standardization work is focused on 4G wireless networks. The ITU IMT-Advanced criteria for 4G wireless are expected to specify the most widely considered definition.[78] IMT-Advanced systems must satisfy a variety of criteria in order to be certified.[79] Various technologies are expected to be considered, including 3GPP LTE-ADVANCED and mobile WiMAX 2.0.[80] Before allocating additional spectrum for wireless broadband access, it is important to determine how these technologies evolve and their implications for spectrum need for wireless broadband.

Emerging Research Areas: In addition, a variety of new research areas are emerging that could further increase system spectral efficiency and reduce or obviate the need for spectrum reallocation. Current research focuses on a number of techniques that would potentially improve the spectral efficiency of wireless broadband systems. Here follows a brief overview and references for several possible technologies that could further enhance the system spectral efficiency of wireless broadband networks.

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[74] *See* T-Mobile, "Personal coverage check- Cell phone coverage maps for your calling coverage and service coverage areas," http://www.t-mobile.com/coverage/pcc.aspx?MapType=Data&WT.mc_n=3GMapCoverage&WT.mc_t=onsite. and AT&T, "AT&T Coverage Viewer: Cities supporting AT&T 3G/Mobile Broadband," http://www.wireless.att.com/coverageviewer/popUp_3g.jsp.

[75] *See* Verizon, "Coverage locator – Verizon Wireless," http://www.verizonwireless.com/b2c/CoverageLocatorController. and Sprint, "Sprint Business - Sprint mobile broadband coverage: Enter zip code," http://www.sprint.com/business/products/products/evdoEnterZip.jsp.

[76] *See* Clearwire Press Release, "Clearwire Reports Second Quarter 2009 Results," http://investors.clearwire.com/phoenix.zhtml?c=198722&p=irol-newsArticle&ID=1319734&highlight=.

[77] *See* Verizon Press Release, "Verizon Wireless Completes Successful LTE 4G Data Calls In Boston And Seattle," August 14, 2009, http://news.vzw.com/news/2009/08/pr2009-08-14f.html.

[78] *See* Vicki Livingston, "IMT-Advanced or "4G" Technologies Under ITU Consideration," *Market Wire*, http://www.reuters.com/article/pressRelease/idUS193250+08-Oct-2009+MW20091008.

[79] *See* ITU IMT-ADVANCED website, http://www.itu.int/ITU-R/index.asp?category=study-groups&rlink=rsg5-imt-advanced&lang=en.

[80] *See* Vicki Livingston, "IMT-Advanced or "4G" Technologies Under ITU Consideration," *Market Wire*, http://www.reuters.com/article/pressRelease/idUS193250+08-Oct-2009+MW20091008.

Network MIMO: Multiple-input multiple-output (MIMO) wireless systems use multiple antenna technology (leveraged at the base station and/or mobiles) and have been shown to provide substantial spectral efficiency improvements. While MIMO systems are included in LTE and WiMAX, more recent research has focused on advanced multicell MIMO systems.

Most systems today are focused on hierarchical cellular frameworks. In this configuration, a geographic region is divided into cells. Historically, these cells have very limited interaction and interfere with each other. Multicell MIMO systems allow the downlink and/or uplink of a wireless broadband system to be jointly processed across multiple base stations simultaneously.[81] This is a major innovation because performance criteria can now be optimized throughout several cells jointly. This gives advanced spatial diversity and can provide a large network throughput.

Work on network MIMO, which currently concentrates on theoretical analysis, shows substantial benefits. One study of network MIMO, evaluated using a full WiMAX indoor simulator,[82] showed mean throughput at least twice as large as that obtained using conventional frequency reuse.

User Cooperation: The standard wireless architecture employed today allows a mobile user to communicate only with the base station. However, research has consistently shown that network throughput can substantially increase if users are allowed to collaborate.[83] Collaboration can take a number of different forms. One of the first proposed collaborative schemes was relaying. More recently, ideas taken from wireline network coding have been proposed for use in wireless networks. A wireless network coded system applies ideas from coding theory to data packets. The application of wireless network coding to cellular systems, which is still a topic of research, could possibly be applied between users, between base stations, or at higher levels of abstraction throughout the network, thereby achieving greater spectral efficiency and reducing spectrum needs.

Femtocells: Femtocells represent a fundamental change in cellular architecture. An example of a femtocell is a small base station that uses some broadband technology (e.g., Ethernet or wireless LAN) for backhaul communication.[84] This kind of base station would have a small coverage area and would likely be deployed in homes or small businesses.

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[81] *See* J.G. Andrews, W. Choi, R.W. Heath, Jr., "Overcoming interference in spatial multiplexing MIMO cellular networks," *IEEE Wirelesss Communications*, vol. 14, pp. 95-104, Dec. 2007.

[82] *See* S. Venkatesan, H. Huang, A. Lozano, R. Valenzuela, "A WiMAX-Based Implementation of Network MIMO for Indoor Wireless Systems," *EURASIP Journal on Advances in Signal Processing*, 2009.

[83] *See* L. Le and E. Hossain, "Multihop Cellular Networks: Potential gains, research challenges, and a resource allocation framework," *IEEE Communications Magazine*, vol. 45, pp. 66-73, Sept. 2007.

[84] *See* V. Chandrasekhar, J. Andrews, and A. Gatherer, "Femtocell Networks: A survey," *IEEE Communications Magazine*, vol. 46, pp. 59-67, Sept. 2008.

Femtocells have the potential to dramatically increase capacity by leveraging the dual benefits of high-quality short-range links and improved frequency reuse. Because of their limited coverage, a geographic area could potentially support a high concentration of base stations.[85] Femtocell research is an active area with investigations focused on the mitigation of interference, the provision for quality of service over IP backhaul, and scalability.[86] Care must be taken when comparing femtocell throughput to standard cellular layouts because of the base station density.[87]

B. Technology for "new" bands

The FCC's Broadband Task Force appears to be focusing on frequency bands below 3.7 GHz. However, a rapid trend demonstrates that technology advances make possible the effective use of higher and higher spectrum bands. A number of different bands above 3.7 GHz may be viable future options (see Table 5) and should be investigated and considered for wireless broadband.

Table 5: Bands located above 3.7 GHz that could play a future role in wireless broadband access.

Band Location	4.9 GHz	5 GHz	28 GHz	38-40 GHz	60 GHz
Spectrum count (MHz)	50	555	1300	1400	7000

4.9 GHz: The 4940-4990 MHz band is allocated nationally for public safety broadband. This band has been mentioned for wireless backhaul. As pointed out by the Utilities Telecom Council, "While the band is intended for use to support crisis incidents with broadband limited area communications, some vendors are marketing equipment in the band as a low cost alternative to license backhaul."[88]

5 GHz: The U-NII band of unlicensed spectrum available in the 5 GHz band could provide 555 MHz of spectrum and is poised for more intensive use. The recently ratified IEEE 802.11(n) standard can utilize the 5 GHz spectrum and promises better performance, coverage, and features over existing IEEE 802.11b,g WLAN systems in the 2.4 GHz band.[89] Because of the large amount of bandwidth available and the adoption of a new WLAN standard, this band could play an important role in femtocell architectures.

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[85] Id.

[86] Id.

[87] *See* M.-S. Alouini and A.J. Goldsmith, "Area spectral efficiency of cellular mobile radio systems," *IEEE Transactions on Vehicular Technology*, vol. 48, pp. 1047-1066, July 1999.

[88] *See* Comments of Utilities Telecom Council, GN Docket Nos. 09-47, 09-51, 09-137, Oct. 23, 2009.

[89] *See* W. Rash, "802.11n: The Wi-Fi Revolution Nobody Noticed," *eWeek*, Nov. 19, 2009, http://www.eweek.com/c/a/Mobile-and-Wireless/80211n-The-WiFi-Revolution-Nobody-Noticed-517334/.

28 GHz: The 27.5-31.3 GHz band (often referred to as the local multipoint distribution service or LMDS band) is being used for the rollout of commercially viable fixed wireless access systems.[90] There has been increasing interest in this band for use as wireless backhaul.[91]

Several of the service categories discussed by the ITU are for stationary applications.[92] In line-of-sight settings, LMDS systems could fill the role for high speed fixed wireless. Despite the fact that there is still much uncertainty about how LMDS deployments will evolve, LMDS may fulfill some demand for future wireless broadband network traffic.

38-40 GHz: The 38.6-40 GHz spectrum band in the United States is an additional viable spectrum resource for wireless broadband. Much like the 60 GHz band[93], it has unique signal attenuation features that could allow a high level of frequency reuse.[94] IDT is leasing this spectrum for fixed, point-to-point wireless service.[95]

60 GHz: The 60 GHz band(s) is another potential source for broadband wireless access. 60 GHz systems operate between 57-64 GHz.[96] This large amount of unlicensed spectrum has primarily been considered as a candidate band for new wireless LAN systems. Recently, the Wireless Gigabit Alliance (WiGig) finished its technical specification for 60 GHz WLAN technology.[97] Moreover, the spectrum range for IEEE 802.16 activities and standards has already extended to frequencies as high as 66 GHz.[98]

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[90] *See* FCC, "FCC: Wireless Services: Local Multipoint Distribution Service: LMDS," http://wireless.fcc.gov/services/index.htm?job=service_home&id=lmds.

[91] *See* C. Gabriel, "IDT and Level 3 highlight new interest in LMDS for mobile backhaul," *4G Trends*, http://4gtrends.com/?tag=lmds

[92] *See* Recommendation ITU-R M.1768, "Methodology for calculation of spectrum requirements for the future development for the terrestrial component of IMT-2000 and systems beyond IMT-2000."

[93] *See* the discussion of the 60 GHz band, available in C. Park and T. S. Rappaport, "Short-Range Wireless Communications for Next-Generation Networks: UWB, 60 GHz Millimeter-Wave WPAN, and ZigBee," *IEEE Wireless Communications*, vol. 14, pp. 70-78, August 2007.

[94] *See* V. Kukshya, T. S. Rappaport, H. Izadpanah, G. Tangonan, R. A. Guerrero, J. K. Mendoza, and B. Lee, "Free-space optics and high-speed RF for next generation networks propagation measurements," in *Proc. IEEE Vehicular Technology Conference*, vol. 1, pp. 616-620, 2002.

[95] *See* IDT Spectrum, "IDT Spectrum Leasing & Equipment: How spectrum works for you," http://www.idtspectrum.com/howitworks.html.

[96] *See* P. Smulders, "Exploiting the 60 GHz Band for Local Wireless Multimedia Access: Prospects and Future Directions," *IEEE Communications Magazine*, Jan. 2002. And C. Koh, "The Benefits of 60 GHz Unlicensed Wireless Communications," http://www.terabeam.com/solutions/whitepapers/benefits-60ghz.php.

[97] *See* WiGig press release, "WiGig Alliance Announces Completion of its Multi-Gigabit Wireless Specification," Dec. 10, 2009, http://wirelessgigabitalliance.org/news/814/.

[98] *See* IEEE 802.16, IEEE Standard for Local and metropolitan area networks, Part 16: Air Interface for Broadband Wireless Access Systems, http://standards.ieee.org/getieee802/download/802.16-2009.pdf.

Systems operating at 60 GHz are subject to a variety of system attenuation challenges primarily related to oxygen absorption and rain.[99] However, the 60 GHz band might be a viable alternative for some of the application needs documented in the ITU spectrum estimation calculations.[100] Due to its signal attenuation properties, a 60 GHz system would allow a dense frequency reuse. It could facilitate improved system spectral efficiencies when combined with techniques such as femtocell systems.

The licensing requirements vary across the above bands. A common theme among the unlicensed bands listed above is involvement in femtocell deployment. Small cell sizes are especially suitable for densely populated areas such as office buildings and apartments. These lower power cells can leverage existing network infrastructure and improve system spectral efficiency by heavy frequency reuse.[101] Technology that lowers cell sizes has been cited by the Femto Forum and New America Foundation as a key factor in meeting future demand while decreasing costs.[102]

Leveraging femtocell and WLAN technology to offload wireless broadband demands off of larger cells using licensed spectrum is logical and spectrally efficient. Carriers may, in some sense, leave the last hop of network design up to the users.

Increasingly, carriers are considering these dual network strategies at the macro and micro levels to meet increasing traffic demands. To this end, carriers are employing strategies that seek to offload traffic from their macro 3G and 4G networks to micro networks using femtocells or WLAN networks. WLAN capabilities are increasingly being built into devices and carriers are increasingly establishing relationships with Wi-Fi providers or are operating WLAN networks to offload data traffic from their macro networks to these micro networks.[103] One carrier provides

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[99] *See* Terabeam, "Performance Characteristics of 60-GHz Communication Systems," http://www.terabeam.com/downloads/whitepapers/TB_60_Ghz.pdf.

[100] *See* Recommendation ITU-R M.1768, "Methodology for calculation of spectrum requirements for the future development for the terrestrial component of IMT-2000 and systems beyond IMT-2000."

[101] *See* Femto Forum press release, "Femto Forum Outlines Case for LTE Femtocells," May 20, 2009, http://www.femtoforum.org/femto/pressreleases.php?id=107.

[102] Id. ("In fact, an analysis of Cooper's law - which holds that wireless capacity doubles every 30 months – shows that the dominant factor in improvements to date has been the use of smaller cells as opposed to other methods such as revised modulation techniques, better coding or the use of more frequencies.") and M. Calabrese and B. Lennett, "Mobile Data Demand and the Need for Increased Spectrum Access," *New America Foundation*, Oct. 2009, http://www.newamerica.net/files/CalabreseLennett_MobileDataDemand.pdf. ("An insight that can be derived from the trends noted above is that the quantity of available spectrum is not by itself the most important factor in meeting projected mobile data demand. Most important is to shrink the effective size of the cell to the level of the home, business – and even to the individual.")

[103] *See* K. Fitchard, "The Magic of the Microcell," *Telephony Online*, Nov 3, 2009, http://telephonyonline.com/connectedplanet/news/magic-microcell-1103/. (AT&T's John Stankey, president and CEO of AT&T Operations, discusses AT&T's dual network strategy utilizing both licensed and unlicensed spectrum.)

discounted unlimited voice calling when a customer uses their WLAN home network to carry the voice traffic.[104] While it may be unclear how technology and business models will evolve to increase the use of these unlicensed technologies, carriers are planning for their use.

C. Broadband Convergence: Relationship between wireless and wireline

One of the great technological benefits that the United States has over most countries is its massive wired infrastructure. Wireline broadband systems, such as digital subscriber line (DSL), cable, and fiber optic systems, provide fast and reliable broadband options to millions of American customers. According to an April 2009 survey by the Pew Internet and American Life Project, 80-81% of Americans rely on wired connections.[105] Given the reliability benefits of wireline and existing infrastructure, any spectrum policy must take into account the availability and interaction with wired systems.

Of particular importance are fiber wireline networks that offer very high data rates (and the potential for future rate increases). Both fiber-to-the-home and fiber-to-the-node systems are available in the United States. According to one recent study, the number of fiber-to-the-home subscribers in North America is 5.3 million and is increasing by more than 1.5 million customers each year.[106] In addition, these fiber-to-the-home networks already pass 17.2 million homes and 15% of homes in North America.[107] Of particular note is the high rate at which AT&T U-Verse and Verizon FiOS networks continue to add customers. In the third quarter of 2009, Verizon added 198,000 net new FiOS internet customers[108] and AT&T U-Verse added 252,000 net new broadband customers.[109]

Wired broadband systems should play a critical role in future broadband deployment. Fiber links offer numerous advantages over wireless links.[110] There are a

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[104] *See* T-Mobile USA HotSpot Calling Service. More information available through http://www.t-mobile.com. and C. Ziegler, "T-Mobile goes national with HotSpot @Home WiFi Calling," *Engadget*, http://mobile.engadget.com/2007/06/27/t-mobile-goes-national-with-hotspot-home-wifi-calling/.

[105] *See* the Pew Internet and American Life Project, "Home Broadband Adoption 2009," at p. 21, http://www.pewinternet.org/~/media//Files/Reports/2009/Home-Broadband-Adoption-2009.pdf.

[106] *See* Fiber-to-the-Home Council, "North American Fiber to the Home Connections Surge Past Five Million," Sept. 29, 2009, *http://www.ftthcouncil.org/en/newsroom/2009/09/29/north-american-fiber-to-the-home-connections-surge-past-five-million*.

[107] Id.

[108] *See* Verizon press release, "Verizon Wireless and FiOS Growth Fuels Continued Strong Cash Flow," Oct. 26, 2009, http://investor.verizon.com/news/view.aspx?NewsID=1019.

[109] *See* AT&T press release, "Record Wireless Gains, Double-Digit Growth in IP-Based Revenues, Strong Cash Flow Highlight AT&T's Third-Quarter Results," http://www.att.com/gen/press-room?pid=4800&cdvn=news&newsarticleid=27290.

[110] *See* B. Mukherjee, "WDM optimal communication networks: Progress and challenges," *IEEE Journal on*

number of different ideas about how government policy can encourage more fiber deployments.[111] If the penetration of fiber-to-the-home increases, a number of problems related to spectrum could also be solved. Deploying in-home femtocell and Wi-Fi networks that communicate through these fiber links could provide high rate wireless broadband with small cell sizes and extensive frequency reuse.

High speed broadband access delivered by cable companies is also integral to the United States broadband market. According to National Cable and Telecommunications Association statistics, cable high-speed internet passes 121.4 million homes.[112] The introduction of the latest cable high speed internet standard Data-Over-Cable Service Interface Specifications (DOCSIS) 3.0 supports 160 Mbps or higher downstream and 120 Mbps or higher upstream data rates.[113] According to analysis by one firm, DOCSIS 3.0 will be available to 99% of U.S. homes passed by high-speed cable networks by 2013.[114]

V. Broadcasting: Uniquely Situated to Meet High Data Rate Video and Data Download Demands Now and in the Future

A. Broadcast: Ideally suited for wireless

In a wireless broadcasting system, a common signal is transmitted to all users. Broadcast systems typically have no uplink (though the convergence of wireless technologies may allow for multi-standard devices to be employed) and distribute the same data using all available resources (i.e., resources such as time, frequency, power, etc. are not divided among the users).

In contrast, a wireless unicasting system typically sends a different data stream to each user. Unicasting systems normally have an uplink and divide resources among users. These systems normally require control and other signaling overhead necessary to control the interaction and communication with multiple users.

Unlike a wire, a wireless transmission is not spatially localized. Depending on the antenna and propagation characteristics, a wireless transmission can cover a

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Selected Areas in Communications, vol. 18, pp. 1810-1824, Oct. 2000.

[111] *See* N. Thompson, "The Need for Speed: Why is the United States still waiting for the future to download?," *Washington Monthly*, http://www.washingtonmonthly.com/features/2009/0905.thompson.html.

[112] *See* National Cable and Telecommunications Association, "Availability," http://www.ncta.com/StatsGroup/Availability.aspx.

[113] *See* CableLabs press release, "CableLabs® Issues DOCSIS® 3.0 Specifications Enabling 160 Mbps," Aug. 7, 2006, http://www.cablelabs.com/news/pr/2006/06_pr_docsis30_080706.html.

[114] *See* T. Spangler, "Report: DOCSIS 3.0 To Blanket U.S. By 2013," *Multichannel News*, May 1, 2009, http://www.multichannel.com/article/231033-Report_DOCSIS_3_0_To_Blanket_U_S_By_2013.php.

substantial geographic area. In unicasting, the broadcast nature of wireless is often an impediment because of the interference created to users and neighboring cells. Typically, the unicasting rate available to any one user decreases as the number of users increases due to issues such as scheduling and interference. In wireless broadcasting, the system is designed to leverage the broadcast nature of wireless for highly efficient content distribution. The broadcasted signal is independent of the number of other users receiving the same signal.

B. IP over broadcast

Technological improvements to the national broadcast network go beyond traditional video distribution. The country's current broadcast network can be usefully characterized as an almost 20 Mbps fat pipe downlink that covers virtually all of the United States. Through this downlink, a variety of content could be distributed using datacasting. Datacasting has a number of applications.[115] New developments have focused on using IP data transmission over terrestrial broadcast for datacasting.[116]

One example of a datacasting service is the datacasting network of National Datacast.[117] In this system, a network of over-the-air broadcasters can send out content (not limited to video) over a wide area through the DTV signal. This data can then be stored on datacasting DTV receiving equipment for later retrieval.

C. Benefits of mobile broadcasting

Recent innovation in broadcast technology has resulted in the rapid development and adoption of the ATSC Mobile DTV Standard. This mobile standard allows large audiences to view real-time video without any of the network issues associated today with real-time video. Broadcasters can deploy ATSC Mobile DTV in their existing 6 MHz bands with relatively modest equipment costs.[118]

The deficiencies of wireless broadband delivery for real-time video have been widely experienced at sporting events and other large events. During the January 2009

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[115] *See* S. A. Valcourt, "Datacasting as a Public Network Service," in *Proc. International Conference on Broadband Networks*, Oct. 2005 and VBox Communications, "Welcome to the new world of datacasting," http://www.vboxcomm.com/datacasting.htm.

[116] *See* W. Lei, G. Gagnon, H. Liu, and A. Vincent, "IP Over Terrestrial ATSC DTV Channels: Performance Evaluations on Data Transmission Throughput," *IEEE Transactions on Broadcasting*, vol. 52, pp. 121-128, June 2006.

[117] *See* National Datacast, "How it works," http://www.nationaldatacast.com/pages/how-it-works.htm.

[118] *See* MobiTV, "ATSC-M/H: The Promise of Free to Air Mobile Simulcast," http://www.mobitv.com/technology/whitepapers/ATSC.PDF. (Estimates the cost of $70k to add a mobile simulcast) and M. Perez, "Mobile TV Gets Big Push," *Information Week*, Jan. 9, 2009, http://www.informationweek.com/news/personal_tech/TV_theater/showArticle.jhtml?articleID=212701642&subSection=All+Stories. (Cites an approximate cost of $250,000 to add mobile DTV capabilities to existing transmission stations.)

inauguration of President Obama, reports documented that cell phone users experienced a variety of difficulties despite carriers' efforts to boost capacity. The broadcast MediaFLO system did not suffer any of these issues.[119] Both MediaFLO and ATSC Mobile DTV are designed to broadcast, in real-time, widely viewed programs, breaking news, sports, and special events to large audiences.

ATSC Mobile DTV systems deliver a high quality video for viewing on a mobile screen. Like broadcast television, most programming is expected to be available for free (in addition to some subscription and for-purchase programming).[120] Unlike the ATSC A/53 signal, ATSC Mobile DTV was designed specifically to deal with the mobile effects (e.g., doppler shift).[121] The standard adds a variety of physical layer enhancements to allow mobile reception in a variety of propagation environments.[122] In fact, peak mobile speeds can be up to 300 km/hour.[123] Since battery consumption is a major challenge in streaming video, the ATSC Mobile DTV Standard also has several battery saving features including power cycling and time-slicing.[124]

The ATSC Mobile DTV Standard has a number of application layer features to improve the viewing experience. The system has features such as an electronic program guide and viewer tracking with Nielsen information.[125] The interactive nature of the application layer can support datacasting that could be used for a number of applications (e.g., traffic information, visual radio, sports scores, Homeland Security and National Weather Service alerts, etc.).[126] More improvements for second generation mobile DTV are already being developed.

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119 *See* M. Reardon, "FLO TV gets high marks on Inauguration Day," *CNET News*, Jan. 21, 2009. http://news.cnet.com/8301-1035_3-10147468-94.html.

120 Initial trials of mobile DTV will be available to anyone with receiving equipment. However, note that the ATSC Mobile DTV Standard allows for subscription service. *See* ATSC press release, "ATSC ADOPTS MOBILE DIGITAL TV STANDARD," Oct. 16, 2009, http://www.atsc.org/communications/press/2009-10-16-ATSC_approves_mobile_dtv.php.

121 *See* ATSC, "Proposed Standard: ATSC-Mobile DTV Standard, Part 1 – ATSC Mobile Digital Television System (A/153 Part 1:2009)," Sept. 10, 2009, p. 12, http://www.atsc.org/standards/cs_documents/a153-2009-09-10/S4-130r16-A153-Part-1-ATSC-M-H.pdf. (Final Standard Publication Pending).

122 Id.

123 *See* J. Adrick, "ATSC M/H System Implementation," http://www.oab.org/cffm/custom/PDFs/Jay%20Adrick%20presentation.pdf.

124 *See* ATSC, "Proposed Standard: ATSC Mobile DTV Standard, Part 2 – RF/Transmission System Characteristics (A/153 Part 2:2009)," Sept. 10, 2009, p. 65, http://www.atsc.org/standards/cs_documents/a153-2009-09-10/S4-131r17-A153-Part-2-RF-Transmission.pdf. (Final Standard Publication Pending).

125 *See* J. Adrick, "ATSC M/H System Implementation," http://www.oab.org/cffm/custom/PDFs/Jay%20Adrick%20presentation.pdf.

126 Id.

D. Broadcast is a natural and spectrally efficient complement to wireless broadband

The transmission of video over wireless broadband networks can be very taxing and consume a large portion of the system capacity. The broadcast transmission of video provides numerous benefits from a system capacity perspective. A single broadcast video stream can be efficiently designed to cover a large geographic area.

Another benefit of over-the-air broadcast television is that the data stream is there "for free." No uplink transmission is required to tell the broadcast system to transmit a particular program at a particular time. In order to allow a mobile user to watch a show at his/her leisure, digital video recording (DVR) technology can be employed. TiVO offers a device that combines broadband and OTA broadcast content.[127] Sezmi Corporation also combines OTA television with content from cable and Internet connectivity for niche programming.[128] Assuming hard drive technology continues to evolve, users will be able to record larger and larger amounts of broadcast video and watch the video in a high quality format at their leisure.

When a mobile device can support both broadcast reception and wireless broadband transmission, this opens up a number of new possible research and implementation areas of interest. User demands for a common video stream (e.g., users watching television coverage at a football game) can quickly overwhelm a wireless broadband system. Users with a device that supports both mobile broadcast video and wireless broadband could avoid this crisis by only using the broadcast feed. A smart device (or system) could dynamically recognize what is the "best" downlink distribution for any data request. This could allow a wireless broadband system to offload video data rate demands to the broadcast network and use the available network throughput for other applications.

In addition, future technology may enable hybrid video transmission.[129] One application would be a video stream being received from over-the-air broadcast and augmented with extra side information received over a wireless broadband link. When the video decoder combines both data streams together, a much higher quality video would result.

It is also critical to take into account the future uses of broadcast television spectrum. As user demand for high quality mobile video increases, future

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[127] *See* TiVO, "HDTV over the air: Free high-definition antenna signals," http://www.tivo.com/whatistivo/overtheairhd/index.html.

[128] *See* Reply Comments Of Sezmi Corporation NBP Public Notice # 6, GN Dockets No. 09-47, 09-51, 09-137, Nov. 13, 2009, http://fjallfoss.fcc.gov/ecfs2/document/view?id=7020348536.

[129] *See* C.H. Liew, S. Worrall, M.A. Mota, A. Navarro, "Hybrid WiMAX and DVB-H Emulator for Scalable Multiple Descriptions Video Coding Testing," in *Proc. IEEE International Symposium on Consumer Electronics*, June 2007. (See the DVB-H discussion)

improvements in resolution, image quality, and video technology may necessitate increased broadcast data rates.

One of the most intriguing emerging formats is three-dimensional (3D) television. Various groups, including the Society of Motion Picture and Television Engineers (SMPTE)[130] 3D@Home Consortium [131] and CEA[132] are actively pursuing 3D television efforts. Broadcasting 3D TV may require approximately 1.5 to 2 times the data rate.[133] When looking at future demand for over-the-air television, broadcasting spectrum estimation needs should consider that next generation broadcasting technology will likely incorporate 3D.

There is also much interest in 3D television for handhelds and mobile devices. Initial work has been conducted to modify the South Korean T-DMB standard to support 3D television.[134] The European Union (EU) has two projects addressing 3-D mobile television research.[135] The MOBILE3DTV project is primarily focused on the delivery of 3-D video over DVB-H.

As another example, ATSC is studying the delivery of 3-D content via over-the-air digital broadcast television.[136] While it is unclear what specifications will emerge, it is highly probable that any system would require a sizable increase in data rate to support. The work by Gotchev et al.[137] discusses either using stereo video (V+V) transmission or video and depth (V+D) transmission. For high quality video, the additional video or depth stream would have to be conveyed as overhead.

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[130] *See* SMPTE Engineering Work Statement, 3D Home Display Formats, http://www.smpte.org/standards/meeting_schedule/3dtf_mtg_details/Approved_TF_3D_2008-0703.pdf.

[131] *See* 3D@Home website, http://www.3dinthehome.org/.

[132] *See* CEA, "R4 WG16 3D Technologies," http://www.ce.org/Standards/CommitteeDetails.aspx?Id=000011074016.

[133] *See* M. Forman, A. Aggoun, and M. McCormick, "A Novel Coding Scheme for Full Parallax 3D-TV Pictures," *in Proc. IEE International Conference on Acoustics, Speech, and Signal Processing*, vol. 4, April 1997 and J. D. Sutter, "3-D Television Expected to Come to Homes in 2010," *CNN*, http://www.cnn.com/2009/TECH/09/18/3D.home.television/index.html.

[134] *See* S. Cho, N. Hur, J. Kim, K. Yun, S.-I. Lee, "Carriage of 3D Audio-Visual by T-DMB," in *Proc. IEEE International Conference on Multimedia and Expo*, July 2006.

[135] *See* MOBILE3DTV Website, http://sp.cs.tut.fi/mobile3dtv/ and 3DPhone website, http://www.3dphone.org/.

[136] *See* M. Grotticelli, "SCTE and ATSC explore 3-D program delivery," *Broadcast Engineering*, March 2, 2009, http://broadcastengineering.com/news/scte-atsc-explore-program-delivery-0302/ .

[137] *See* A. Gotchev, A. Smolic, S. Jumisko-Pyykkö, D. Strohmeier, G.B. Akar, P. Merkle, N. Daskalov, "Mobile 3D television: Development of core technological elements and user-centered evaluation methods toward an optimized system," in *Proc. IST/SPIE Conference on Electronic Imaging*, vol. 7256, 2009.

VI. Conclusions

Ubiquitous, free, and local broadcast television plays vital social, public safety, economic and technical roles in the United States. Spectrum policy decisions must not short-change or short-circuit the growing importance of broadcast digital television as part of the foundation needed for a diverse and economically robust wireless broadband industry. With regulatory stability, continued investment and innovation will make digital broadcast television and related services a potent complement to other broadband systems.

This paper has presented a data-based perspective on the current public policy discussion on the wireless broadband "spectrum crisis." Although some would argue that a large amount of additional spectrum is needed over the next few years to meet demand projections for wireless broadband, the target number of 800 MHz of additional required spectrum is highly speculative and does not stand up to serious scrutiny. As demonstrated in this paper, the 800 MHz number, based on a 2006 ITU spectrum study, is overly sensitive to assumptions about future broadband demand and how that demand will be served by the larger broadband services eco-system (which can and should include digital broadcast, wireless LAN technologies, and wired solutions). Assumptions made in the ITU study favor cellular technologies and show a need for 800 MHz of additional spectrum by 2015. If these assumptions are modified to reflect video demand being serviced by systems better suited to deliver it (e.g., digital broadcast, wire and fiber, wireless LAN, and/or femtocells with ultra-high frequency reuse), then the same ITU methodology predicts that almost no additional spectrum is needed by the cellular industry.

Additionally, the study underlying the 800 MHz number attempts to model wireless spectral efficiency over time as though it were linearly improving at a modest rate. Past experience shows that spectral efficiency improvements occur as step changes enabled by paradigm-shifting innovations, which are impossible to predict. This is evident in looking at the past history of spectral efficiencies in mobile wireless communications, which jumped in steps upon the introduction of innovations such as the cellular concept and frequency reuse, the introduction of digital modulation, cell splitting and sectorization, code-division multiple access (CDMA), orthogonal frequency division multiple access (OFDMA), and MIMO antenna systems. These "step-change" innovations have all occurred because cellular systems researchers have had to put a premium on spectral efficiency motivated by its relative scarcity. In fact, as described in Section IV, a number of technologies are emerging that could alleviate or obviate the need for more spectrum. Even more telling, significant portions of spectrum presently allocated to cellular systems may not be fully utilized. Further improvements in cellular spectral efficiency will only be delayed if cellular system spectrum is over-provisioned.

Lastly, broadcasting offers the optimal solution for delivery of bandwidth-intensive applications such as video to large numbers of users in the same geographic area. It is superior to the current unicast solutions of the cellular industry by orders of magnitude. If spectrum is truly scarce, then broadcasting is an essential complement to other mobile broadband technologies. Thus, if future spectrum policy precludes a role for digital television broadcast in delivery of broadband video and multimedia, it will no doubt be required to "reinvent the wheel" in only a very short time.

As policymakers attempt to assess and address the alleged spectrum "crisis", it is imperative that better estimates be obtained, which are properly based on U.S. industry projections and demand studies. In fact, it is appropriate to undertake a comprehensive examination of the full range of spectrum that can be used for advanced wireless applications, including both licensed and unlicensed bands. Fostering competition in wireless broadband requires an economically viable, innovative, and dynamic wireless digital broadcast industry in competition with emerging broadband 3G/4G cellular, advanced wired Internet access such as FiOS and U-Verse, and continued improvements in wireless LAN technologies.

APPENDIX A

Instructions for modifying SPECULATOR tool used to demonstrate capacity requirements' role on spectrum requirements

All modifications to SPECULATOR will be done directly in the worksheet. No modifications will be done to the macros. The SPECULATOR tool was treated as a black box. The examination did not attempt to change any of the mathematical modeling. Our goal was only to modify the file enough to allow us to see the effect of capacity requirement changes on predicted spectrum needs.

The modifications change the capacity requirement for service categories SC1, SC2, SC6, SC7, SC11, SC12, SC16, and SC17 to zero. The modifications also change the multicast system capacity requirements to zero. Note that these modifications are only an approximate way of accounting for the effect of video on the spectrum requirement and the availability of spectrum above 3 GHz. The unicast and multicast service categories that are zeroed can carry data other than video signals. The effect of these modifications demonstrates the sensitivity of the ITU model.

Steps:

1) Download the SPECULATOR tool from http://www.itu.int/oth/R0A06000010/en
2) Open the SPECULATOR tool in Excel
3) For both the PSCapacity_calculation and CS-CapacityCalc worksheets go to Tools then Protection then Unprotect Sheet…
4) In the PSCapacity_calculation worksheet, the tables are entered as numbers and not generated as equations. To do this, we will have to reenter the equations.
    a. For columns B through AK on row 144, enter =max(COLUMN124:COLUMN143) into the cell in row 144 and column COLUMN (where COLUMN is B,C,….,AK)
    b. For columns B through AK on row 173, enter =max(COLUMN153:COLUMN172) into the cell in row 173 and column COLUMN (where COLUMN is B,C,….,AK)
    c. For columns B through AK on row 205, enter =max(COLUMN185:COLUMN204) into the cell in row 205 and column COLUMN (where COLUMN is B,C,….,AK). Note: we will zero this out, so it is not necessary to make this change.
    d. For columns B through AK on row 234, enter =max(COLUMN214:COLUMN233) into the cell in row 234 and column COLUMN (where COLUMN is B,C,….,AK). Note: we will zero this out so it is not necessary to make this change.
    e. For columns B through AK on row 265, enter =max(COLUMN245:COLUMN264) into the cell in row 265 and column COLUMN (where COLUMN is B,C,….,AK)

f. For columns B through AK on row 294, enter =max(COLUMN274:COLUMN293) into the cell in row 294 and column COLUMN (where COLUMN is B,C,….,AK)
g. In columns B through M on row 48, enter =COLUMN144 in the cell in row 48 at column COLUMN (where COLUMN is B,C,….,M)
h. In columns B through M on row 49, enter =N144 through =Y144, respectively, in the cells on row 49 in columns B through M.
i. In columns B through M on row 50, enter =Z144 through =AK144, respectively, in the cells on row 50 in columns B through M.
j. In columns B through M on row 61, enter =COLUMN173 in the cell in row 61 at column COLUMN (where COLUMN is B,C,….,M)
k. In columns B through M on row 62, enter =N173 through =Y173, respectively, in the cells on row 62 in columns B through M.
l. In columns B through M on row 63, enter =Z173 through =AK173, respectively, in the cells on row 63 in columns B through M.
m. In columns B through M on row 101, enter =COLUMN265 in the cell in row 101 at column COLUMN (where COLUMN is B,C,….,M)
n. In columns B through M on row 102, enter =N265 through =Y265, respectively, in the cells on row 102 in columns B through M.
o. In columns B through M on row 103, enter =Z265 through =AK265, respectively, in the cells on row 103 in columns B through M.
p. In columns B through M on row 114, enter =COLUMN294 in the cell in row 114 at column COLUMN (where COLUMN is B,C,….,M)
q. In columns B through M on row 115, enter =N294 through =Y294, respectively, in the cells on row 115 in columns B through M.
r. In columns B through M on row 116, enter =Z294 through =AK294, respectively, in the cells on row 116 in columns B through M.

5) In the PSCapacity_calculation worksheet, enter 0 in the cells B74-M74, B75-M75, B76-M76, B87-M87, B88-M88. B89-M89. This zeros out the multicast packet switched system capacity requirement for RATG1 and RATG2.
6) In the PSCapacity_calculation worksheet, enter 0 in the cells B134-AK134, B135-AK135, B139-AK139, and B140-AK140. This zeros out the rows corresponding to SC11, SC12, SC16, and SC17.
7) In the PSCapacity_calculation worksheet, enter 0 in the cells B163-AK163, B164-AK164, B168-AK168, and B169-AK169. This zeros out the rows corresponding to SC11, SC12, SC16, and SC17.
8) In the PSCapacity_calculation worksheet, enter 0 in the cells B255-AK255, B256-AK256, B260-AK260, and B261-AK261. This zeros out the rows corresponding to SC11, SC12, SC16, and SC17.
9) In the PSCapacity_calculation worksheet, enter 0 in the cells B284-AK284, B285-AK285, B289-AK289, and B290-AK290. This zeros out the rows corresponding to SC11, SC12, SC16, and SC17.
10) In the CS-CapacityCalc worksheet, enter 0 in the cells B98-AK98 and B127-AK127. This zeros out the circuit switched multicast capacity requirements.

11) In the CS-CapacityCalc worksheet, enter 0 in the cells B17-AK17, B18-AK18, B22-AK22, B23-AK23. This zeros out the capacity requirements for SC1, SC2, SC6, and SC7.
12) In the CS-CapacityCalc worksheet, enter 0 in the cells B46-AK46, B47-AK47, B51-AK51, B52-AK52. This zeros out the capacity requirements for SC1, SC2, SC6, and SC7.
13) In the CS-CapacityCalc worksheet, enter 0 in the cells B138-AK138, B139-AK139, B143-AK143, B144-AK144. This zeros out the capacity requirements for SC1, SC2, S6, and S7.
14) In the CS-CapacityCalc worksheet, enter 0 in the cells B167-AK167, B168-AK168, B172-AK172, B173-AK173. This zeros out the capacity requirements for SC1, SC2, S6, and S7.
15) The final spectrum requirements will be shown on worksheet Adjs&AggSpectrum in the table called Final Spectrum Requirements.

BEFORE

Final Spectrum Requirements (MHz)			
Spectrum for RATG	year 2010	year 2015	year 2020
RAT Group #1	**840**	**880**	**880**
RAT Group #2	**0**	**420**	**840**

AFTER

Final Spectrum Requirements (MHz)			
Spectrum for RATG	year 2010	year 2015	year 2020
RAT Group #1	**200**	**240**	**160**
RAT Group #2	**0**	**220**	**540**

APPENDIX B

Broadcast Television Spectrum Count

The details on how the broadcast television spectrum in the range 225 – 3700 MHz was obtained are below:

Exclusive television bands
512-608 MHz and 614-698 MHz for a total of 180 MHz (or 180/3475 = 5.18%)

Shared television bands
470-512 MHz and 2025-2110 MHz for a total of 127 MHz (or 127/3475 = 3.65%)

Total broadcast television bands = 307 MHz