Rethinking Spectrum Policy:
A Fiber Intensive Wireless Architecture

Mark MacCarthy
Rapporteur

THE ASPEN INSTITUTE

Communications and Society Program
Charles M. Firestone
Executive Director
Washington, DC
2010

To purchase additional copies of this report, please contact:
The Aspen Institute
Publications Office
P.O. Box 222
109 Houghton Lab Lane
Queenstown, Maryland 21658
Phone: (410) 820-5326
Fax: (410) 827-9174
E-mail: publications@aspeninstitute.org

For all other inquiries, please contact:
The Aspen Institute
Communications and Society Program
One Dupont Circle, NW
Suite 700
Washington, DC 20036
Phone: (202) 736-5818
Fax: (202) 467-0790

The Aspen Institute
One Dupont Circle, NW
Suite 700
Washington, DC 20036

Published in the United States of America in 2010
by The Aspen Institute

Printed in the United States of America

ISBN: 0-89843-520-X

10-005

1770CSP/10-BK

Contents

This report is written from the perspective of an informed observer at the Aspen Institute Roundtable on Spectrum Policy. Unless attributed to a particular person, none of the comments or ideas contained in this report should be taken as embodying the views or carrying the endorsement of any specific participant at the Roundtable.

Foreword

Among the several annual roundtables of the Aspen Institute Communications and Society Program, the one on spectrum policy may be the most arcane. But the Aspen Institute Roundtable on Spectrum Policy (AIRS) is nonetheless important. Our society has caught up to its importance. Since Guglielmo Marconi's invention of the wireless, spectrum has moved from a curiosity to a crucial resource. Today, over half the planet's population is connected by wireless devices. More software services are moving to the Cloud, and we are contemplating an Internet of Things, that is, devices communicating with each other on the Net.

The following report, by Georgetown University professor Mark MacCarthy, details the deliberations of a convening at the Aspen Wye River Conference Center in November 2009. This came at a time when the Federal Communications Commission was intensively engaged in preparing its National Broadband Plan, and indeed the executive director overseeing that effort, Blair Levin, was the keynote speaker at the meeting.

It was also a time when those seeking more spectrum for wireless devices were engaging in what I would call "spectrum envy," a desire to use valuable spectrum held by over-the-air broadcasters, the federal government, satellite companies, and others. Thus we brought together those representing government agencies, including the Federal Communications Commission, National Telecommunications and Information Administration, Department of Defense; non-profit organizations active in the field; executives from telecommunications, broadcasting, cable, software, wireless and communications equipment companies; and leading academics and thinkers in the field to take a fresh look at how policy-makers should be thinking about these issues.

The session was fruitful. Some solutions that this group thought promising a few years ago had not lived up to the promise. Some participants presented updated versions of solutions that have been around for awhile. And new ideas emerged, particularly with regard to some holistic thinking about the integration between fiber and wireless networks to increase capacity of the latter. The following report provides a context, a recounting of conclusions, and a rich exposition of the reasoning used in arriving at those points.

In the end, we are seeing a virtual explosion of uses for wireless technologies, and we are only at the beginning of this expansive period. Demand seems insatiable, and certainly beyond foreseeable availability of spectrum—even if the enviable spectrum were made available to the newer players. For that reason, participants also turned to ways of using the spectrum better: perhaps by reusing the spectrum in smaller cells, by moving fiber deeper into the network, and by conserving use, most likely though better pricing signals. But with issues of tight money and many competing demands in the telecommunications market, incentives for investment will be key.

Of course, not all participants agree with this assessment. One participant, for example, believed that new architectures and innovation will lessen the projected demand, while another participant suggested that spectrum flexibility and auctioning is the long-term answer. We each—policy-makers, investors, communications providers, and consumers—have a long road ahead.

Acknowledgments

I want to take this opportunity to thank our sponsors for making this Roundtable possible: AT&T, CableLabs, Cisco Systems, Comcast Corporation, Credit Suisse, Google, Intel Corporation, Lockheed Martin, Microsoft, National Association of Broadcasters, Qualcomm Incorporated, Regulatory Source Associates LLC, Stifel Nicolaus, Verizon Communications, and The Walt Disney Company. A special thank you goes to Mark MacCarthy, our rapporteur, for compiling such a complex set of discussions into a coherent and informative report.

Finally, I thank Sarah Snodgress, project manager, and Tricia Kelly, assistant director of the Communications and Society Program, for their efforts in producing this report and the Roundtable itself.

Charles M. Firestone
Executive Director
Communications and Society Program
Washington, D.C.
February 2010

Rethinking Spectrum Policy:
A Fiber Intensive Wireless Architecture

Mark MacCarthy

Rethinking Spectrum Policy: A Fiber Intensive Wireless Architecture

Mark MacCarthy

Introduction

In November 2009, the Aspen Institute Communications and Society Program held the latest in its continuing series of roundtable discussions on spectrum policy. Entitled "Rethinking Spectrum Policy," the conference brought together senior people from the industry (including technical experts), the Federal Communications Commission, the Executive Branch (including the White House, NTIA and the Department of Defense), Capitol Hill (including staff members from the House Energy and Commerce Committee), British Ofcom, academia and public interest groups. While the conference dealt with spectrum management more broadly, the principal focus was on what could be done to respond to the projections of exponential growth in the demand for wireless services. These projections have given rise to requests for substantial additional spectrum to be allocated to wireless to expand system capacity to meet this growing demand.

The most important findings of the conference must be emphasized at the outset: demand for wireless services will continue to explode in the coming years. While measures to find spectrum for those services need to continue, efficiency gains and increases in the amount of spectrum available—whether from spectrum reallocations, improved receivers, shared use, or secondary markets—will not likely, by themselves or in combination, meet the projected exponential increases in demand for wireless broadband services. Policy-makers and network businesses will also need to re-examine network architecture, and consider changing the mix between fiber and wireless to address this issue. This approach involves driving fiber deeper into wireless networks, deploying the inexpensive antennas needed to connect the fiber infrastructure to the wireless networks, and developing the software to handle the signal processing at the central office. Such adjustments will pose particular difficulties in investment strategies.

The discussion at this conference bears on the issues to be raised in the Obama Administration's strategic guide for communications policymaking, the National Broadband Plan. The focus on driving fiber deeper into wireline networks and the approaches to gain more spectrum address solutions for meeting increased demand for wireless broadband access. The National Broadband Plan needs to look at incentives to invest in these approaches.

The conference discussion reached several more specific conclusions which can be summarized in the following propositions:

(1) The projections of exponential growth in demand for broadband wireless access services are credible.

(2) Given the current network architecture, the recent estimates of significantly expanded future spectrum requirements to satisfy exponential growth in demand may be reasonable.

(3) A spectrum inventory as mandated by legislation pending in the House and Senate would be useful but not definitive in understanding the extent to which reallocation would be able to respond to the growth in wireless demand.

(4) It is important to consider the extent to which spectrum reallocation from broadcasters, other private sector users and the federal government is a legitimate policy response to the growth in wireless demand, but it will not, by itself, satisfy wireless demand.

(5) The Federal Communications Commission (FCC) might have a useful role to play in acting as a backstop regulator to encourage minimum performance standards for receivers so as to increase spectrum capacity.[1]

(6) Increases in spectrum capacity based upon smart devices using unlicensed spectrum has long-term potential, but these devices are not likely to be useful policy tools as a short-term response to the growth in wireless demand.

(7) Market-based approaches such as flexible licenses and license auctions have the potential to free some spectrum to respond to the growth in wireless demand, but not nearly enough to provide what will be required.

(8) Demand for wireless spectrum can be restrained by various kinds of usage sensitive pricing that charges heavy users for the additional demands they put on wireless systems, but political and marketplace resistance might prevent the full use of this marketplace response to the growth in wireless demand.

(9) A fiber intensive wireless network architecture should be considered, in parallel with the allocation of additional spectrum, as complementary long-term solutions to the problem of exploding demand for wireless services. It will be a challenge to find the right public strategy to encourage investment for this purpose.

This report attempts to summarize the main results of the conference and apply the conclusions to current policy debates regarding spectrum. The conference was a creature of its time and place, not an exchange of views on timeless principles. The participants in the conference brought with them a tacit knowledge of the current state of play of these policy debates which readers might not necessarily have. For this reason, the report starts with an overview of this policy background.

Background

In the United States, the FCC manages private sector and non-federal government spectrum and the National Telecommunications and Information Administration (NTIA) manages federal government use of the spectrum, both military and civilian. They manage the spectrum through the allocation and assignment of frequencies. Frequency allocation takes place when a spectrum band is reserved by the FCC or NTIA for a particular type of service such as broadcasting. The FCC typically breaks down these allocations into narrow allotments and service rules. For example, allocations made to the land mobile service are divided into allotments for business users and public safety users.

Assignment refers to the process of authorizing a particular entity to operate a radio transmitter on a specific frequency, channel or group of channels at a particular location under specific conditions. The FCC grants its authorizations in the form of an exclusive license. Previously, the FCC assigned licenses where there were mutually exclusive applications on the basis of comparative hearings.

Because the process was administratively cumbersome and inefficient, in the early 1980s Congress gave the FCC authority to conduct lotteries as a means to choose among competing applications. In the early 1990s, after it became clear that lotteries also led to inefficient results, Congress gave the FCC authority to use auctions to choose among mutually exclusive applicants.

While the assignment process has undergone substantial revisions, the allocation and reallocation process has not. Some licenses have been issued that allow for flexible use. For example, the FCC has authorized licensees to use frequencies over large geographic areas rather than authorizing use at single geographic points. Licensees can choose to “disaggregate” their frequencies, that is, split them up by frequency and “partition” them—in laymen’s terms, split them up by geography, and sell them on a secondary market.

Most FCC allocation decisions for private sector use, however, still function under allocation principles that were developed many years ago. These FCC principles include:[2]

- The dependence of the service on radio rather than wire;
- The probable number of people who will receive benefits from the service;
- The relative social and economic importance of the service, including safety of life and protection of property factors;
- The probability of practical establishment of the service, and the degree of public support which it is likely to receive;
- The degree to which the service should be made available to the public, that is, on a limited scale or on an extended competitive scale;

- When it is proposed to shift a service from its present location in the spectrum, data should be presented showing the feasibility and cost of the shift, particularly with respect to the technical, economic and other considerations involved, and the length of time and manner for completing the shift.

The administrative process for allocating and reallocating spectrum takes these factors into account. The process is lengthy and administratively cumbersome, but no better system has been adopted.

In the last decade, commentators and critics have urged policymakers to move away from this administrative allocation and reallocation process for private sector communications services. The debate in this area has focused on two main alternatives. The property approach relies on the assignment of property rights to the spectrum, and market forces to allocate the spectrum to its most efficient use. The commons approach relies on advanced devices that can seek out and avoid interference and thereby transform the radio spectrum into an economic commons. Under this approach, the FCC would establish rules to coordinate these devices, for instance, power restrictions and technology formats that allow different users to share airspace without exclusive licenses or property rights.

In recent years another issue has animated debate about spectrum policy. This is the viewpoint that wireless broadband should provide a "third pipe" into the home to bring a competitive alternative to the existing cable and telephone providers of wireline broadband.

During a previous Aspen Institute Roundtable on Spectrum Policy in June 2004, participants held high hope for the use of "cognitive" or "software-defined" radio devices. The report concluded that these devices would make open spectrum available for far more users and to make sharing of already-occupied spectrum a reality.[3] The report seemed to endorse the conclusion that these new technologies created the possibility that licensing itself would no longer be required.

Two recent FCC proceedings seemed to address these hopes for a third pipe and for unlicensed devices. In July 2007, the FCC revised its rules related to the auction of spectrum at 700 MHz. This auction was possible because of the transition of broadcasters off their analog spectrum to new digital spectrum. The new rules were designed in part to promote wireless broadband deployment. The auctions that followed concluded in March 2008. However, no major new player appeared. Established carriers, including Verizon Wireless, AT&T, US Cellular and Cellular South won most of the licenses. In June of 2009, broadcasters completed the transition from their analog spectrum, which had been auctioned, to their new digital spectrum.

In November 2008, the FCC released new rules for the unlicensed use of the television white space spectrum. The rules allow wireless devices to operate in broadcast television spectrum on a secondary basis without first having to obtain a license from the FCC. Broadcasters had opposed the move because they thought it might interfere with over-the-air broadcast signals. This FCC decision represented a victory for an unusual coalition of industry and public interest advocates that had been pushing for a commons perspective. The devices that can be used in the TV white spaces must be approved by the FCC, must be able to locate frequencies not in local use by broadcasters and avoid emissions that might degrade TV reception. They must have geo-location capability and the ability to check a database of broadcaster frequencies.

The stimulus package that was approved by Congress early in 2009 provided funding for both wireline and wireless broadband facilities, and mandated the development of a national broadband plan by early 2010. The broadband plan will contemplate developing policy for both wireline and wireless broadband and must contain an element explaining how spectrum allocation decisions relate to the goal of universal, accessible broadband infrastructure. Similar policy objectives inform the FCC's thinking on its strategy for broadband investment.

In September 2009, the Commission recognized the connection between the spectrum issues and the broadband plan by issuing a notice asking for comment on whether the United States will have sufficient spectrum available to meet demands for wireless broadband in the near future.[4] Several commentators including the wireless industry's trade association, CTIA, submitted requests for additional spectrum for the purpose of meeting broadband demand. In a speech to a CTIA meeting in October 2009, FCC Chairman Julius Genachowski seemed to endorse the need for additional spectrum by referring to a looming spectrum crisis in broadband.[5] Shortly after that, FCC broadband advisor, Blair Levin, publicly discussed the possibility of reallocating broadcast spectrum for wireless use, or concentrating several broadcast signals in a market on less bandwidth and conducting an auction of the remaining spectrum with all or some of the proceeds going to the broadcasters.[6]

Demand for Wireless Broadband Service

Participants reviewed estimates of exponential increases in the demand for wireless services and concluded that the projections are credible. The primary basis for this conclusion is the likelihood that unicasting[7] of video content will continue to grow rapidly on wireless networks.

Participants reviewed the estimates of mobile data traffic from several sources.[8] CTIA's most recent semi-annual wireless survey as of mid-year 2009 showed growth across the board:

- The number of wireless subscribers was 276,610,580, up 13.9 million from June 2008;
- Wireless minutes of use exceeded 1.1 trillion in the first half of 2009, up 3 percent year-to-year;
- The number of cell sites was up 11.5 percent year-to-year.[9]

Cisco Systems' report on mobile data traffic forecast from January 2009 projected substantial growth in consumer demand. Cisco projects that mobile data traffic will double every year between 2008 and 2013, resulting in traffic 66 times 2008 levels. Mobile data traffic will grow at a compound annual growth rate (CAGR) of 131 percent between 2008 and 2013. By 2013, 83 percent of this projected mobile usage will come from mobile devices and portable laptops. A single high-end phone generates more data traffic than 30 basic-feature cell phones. A portable laptop computer with a mobile data card generates more data traffic than 450 basic-feature cell phones. Sixty-four percent of mobile data usage will be for video services, which is the fastest growing category of usage—150 percent CAGR between 2008 and 2013.[10]

Video appeared to be the source of the largest increase in demand. Mobile users have begun to use their mobile devices for downloading and streaming video. They are not satisfied to access this content solely through wireline connections, and want it available through their mobile devices. According to participants, there is some indication that, as in the wireline broadband world, a small number of users are responsible for a very large part of the video demand. In addition, important mobile services might require substantial "burst capacity" if service is going to be delivered in a timely fashion. As one participant noted, a doctor wanting to download an MRI image in real time is not going to be willing to wait twenty minutes.

Participants observed that the projected increases in demand are consistent with the recent experience of some of the carriers, taking note of AT&T's report to the FCC in August of 2009 that mobile data traffic on their network has increased by 5,000 percent over the past three years.[11]

According to the Nielsen Company, the availability of data capacity on smart phones is not always used. Nielsen estimates that there were 40 million active users of the mobile Internet as of May 2008, but that 95 million subscribers had access to the Internet on their mobile phones, indicating a substantial proportion of subscribers who paid for access were either disinterested or unaware of the service.[12] This suggests that there is still more latent demand in the system, as users discover their smart phone capabilities and begin to use them.

A consensus developed that the estimates of increased consumer demand for mobile wireless services are credible. The wireless industry has typically experienced positive feedback where supply seems to call forth its own demand. When spectrum is provided to carriers, they use it to create mobile communications networks that are attractive to consumers. This leads to improvements in devices and the development of new applications. These innovations, in turn, spur further demand for services, which then creates a need for more spectrum.

One participant suggested that demand for mobile data services was limited only by increases in inexpensive memory capacity on laptops and other mobile devices that connect to the wireless network. Similarly, another participant noted that storage capacity of these devices was a good proxy for the demand for wireless services. He noted that every 13 years there is a 100-fold increase in storage capacity, while the efficiency in mobile spectrum use increases only two or three times during the same period. Participants noted that these natural cycles of increased demand could be supplemented by dramatic new demand coming from machine-to-machine applications such as smart grid technology and remote monitoring services.

Nevertheless, not all participants agree that the projections are valid. For example, if pricing approaches changed as discussed in a later section, consumers could alter their usage.

Demand for Wireless Spectrum

Increased demand for wireless services does not automatically mean a need for increased spectrum. Wireless network capacity is a function of the amount of spectrum available, spectrum efficiency, and frequency reuse, typically obtained in wireless networks by reducing the size of cell sites. Participants recognized that there are substantial uncertainties in deriving estimates of the amount of spectrum that might be needed to meet the increase in consumer demand for wireless services. Of course, the more spectrum available to the wireless carrier the more information can be carried by their wireless network. As a result, one way to meet the increasing demand for wireless mobile services is to increase the spectrum available to the carrier providing the service. Participants reviewed the way spectrum demand can be calculated as a function of (1) the number of active subscribers, (2) subscribers' average data rate required and (3) spectrum efficiency.[13]

Some organizations have attempted to estimate the need for additional spectrum to meet growing wireless demand. In 2006, the International Telecommunications Union (ITU) issued a report based on contributions from members of its working group on wireless services on the demand for spectrum for wireless services. Its report projected a total spectrum requirement of as much as 840 MHz by 2010, 1300 MHz by 2015 and 1720 MHz by the year 2020.[14] As one of the participants pointed out, however, this estimate is for a single network. For three networks the ITU estimate is 1980 MHz by 2020 and for four networks the ITU-estimated capacity requirement is 2240 MHz by 2020.

Participants noted that the total amount of spectrum that will be available for wireless services in the United States does not come close to these estimated requirements. One study estimated that the total amount of licensed spectrum that is theoretically available for wireless services under current allocation schemes is only 680 MHz.[15] These estimates of future spectrum requirements combined with the existing spectrum allocations for wireless were the basis for the recent CTIA request to the FCC for an additional 800 MHz for licensed commercial wireless use within the next six years.[16] Participants recognized the need for continuing study to more accurately estimate future spectrum requirements to satisfy demand for commercial wireless services.

Participants discussed spectrum efficiencies, femto sites (low-power base stations), more towers, and mobile broadcasting as alternative ways to meet the demand for wireless broadband services. In the end, however, participants concluded that none of these alternatives—either individually or in combination—are enough.

Increasing spectrum efficiency is another way to increase network capacity and meet the demand for wireless broadband services. Historically, substantial increases in throughput took place as the mobile industry moved from analog to digital and then from second generation (2G) to third generation (3G) technology. For example, the typical data throughput rate for 2G is 100 thousand bits per second (kbps); 3G throughput is 10 times that, or 1 million bits per second. According to one study, the new generation, 4G, will have a throughput rate of 10 million bits per second, 10 times greater than the previous generation.[17] These faster transfer speeds are what provides the added value for many of the new mobile applications, especially video. They resulted from increases in spectrum used and from increases in spectral efficiency.

The efficiency with which a system can move information through its channel can improve over time, but it is limited by Shannon's law. Shannon's law is a fundamental physical law stating that the maximum amount of information that a channel can carry depends upon its bandwidth and the strength of the desired signal relative to the strength of the noise in the channel. Participants noted reports that the next generation of wireless mobile services, 4G, will be more spectrum efficient than previous generations. Long Term Evolution, for example, is estimated to have a spectral efficiency of 1.5 bps/Hz compared to the initial version of 3G EV-DO, which has an estimated spectral efficiency of .5 bps/Hz.[18] One participant observed that further improvements in spectral efficiency cannot be expected to continue indefinitely, noting that the efficiency of 4G service is approaching 75 percent of the Shannon's law limit. Other participants agreed, noting that some increases in efficiency were likely to continue, but that alone they would not enable channel capacity to increase enough to meet projected demand for wireless services.

Participants noted that the increased use of femto cells could also decrease the demand for spectrum. A femto cell is a low-power, short-range base station that users connect to an existing wireline broadband connection to expand coverage within a home or office. It takes wireless signals in the immediate area and transfers them through a wireline Internet connection for processing by the network operator. Because the cell size is so small, spectrum can be efficiently reused, taking substantial demand off of the wireless network outside the customer's premises. It also reduces the power requirements of the outside network since the signal no longer has to go through the walls of the customer's home or office. The backhaul connection to the operator could be a regular wireline Internet connection and could replace the backhaul connection provisioned by the carrier.

Participants thought the femto architecture had great promise especially since each individual femto device would be inexpensive. But, since millions of these femto cells would need to be deployed, widespread deployment of the technology would be expensive and long-term in the aggregate. Some additional structural issues need to be resolved, such as how to manage the millions of femto cells and integrate them effectively with macro cells in U.S. wireless networks. Moreover, it would not solve the problem of demand for high capacity video and other services outside the customer premises.

Participants also analyzed the prospects of increasing network capacity by further shrinking the cell size through an increase in the number of cell sites. Historically, this has been one of the most effective ways that carriers have increased network capacity. It takes advantage of the fact that decreasing the radius of a cell disproportionately increases frequency reuse, and hence capacity of the network. For example, decreasing the average cell coverage radius by one-half increases the capacity by a factor of four. One problem is that the location of tower sites is increasingly problematic. The carriers are increasing the number of cell sites at a rate of 14 percent a year, according to CTIA, and can be expected to increase that. But the limits of locating additional towers in urban areas are fast approaching. In addition, traditional base stations are very expensive.

Multicasting broadband video was another promising technology that participants considered. In this broadcast model, each mobile subscriber receives the same video content at the same time. This is very efficient when a large group of recipients all want to receive the same content at the same time, for instance to watch the Super Bowl game in real-time, because the content can be offloaded from the cellular network onto a multicast network. In contrast, unicasting sends different streams of data to each user. It is efficient when the recipients want to receive different content at the same time which is typically the case when users want to see different videos on YouTube. If unicasting is used to distribute the same content at the same time, however, it is inefficient because network capacity is unnecessarily used to carry multiple streams of identical content. Multicasting on the broadcast model is more efficient in that circumstance.

Some participants questioned whether the broadcasting model is appropriate for a wireless mobile network, where few if any people would want to watch the same content on their mobile devices at the same time. They thought that most of the video downloading and streaming would have to be unicast to accommodate the interests of people to do a variety of things at the same time. Reserving a portion of the spectrum solely for multicasting video seems inefficient. Some existing businesses employ the multicasting model, however, using spectrum obtained at auction for the sole purpose of simultaneously delivering streams of video programming to subscribers. These businesses might very well be successful in the marketplace. To the extent that they are successful, this would help to relieve some of the demand for capacity to provide video services on the larger wireless networks. But the consensus was that this success would not, by itself, solve the nation's wireless spectrum crunch.

Without endorsing any particular request for additional spectrum, participants reached a consensus conclusion that existing commercial wireless carriers in their current network architecture and business model will need more exclusively licensed spectrum to meet the exponentially growing demand for wireless broadband services. Continuing study will be important to assess the need for future spectrum requirements more accurately.

Inventory

If there is a need to find additional spectrum to meet the growing demand for wireless broadband services, where can it come from? What spectrum is underutilized or inefficiently used? How should this be determined? Participants discussed proposals for an inventory as a way to identify additional spectrum for possible reallocation or sharing. Participants thought that an inventory would be important to determine private sector and federal spectrum use and requirements in order to fully understand the potential for reallocation.

Participants settled on a framework for obtaining additional spectrum that separated the idea of clearing a band completely, from the idea of freeing the band for additional users or uses. In some cases, it might be possible to find an alternative location on the spectrum or use wireline services to meet existing users' needs, effectively clearing the spectrum for new uses. In other cases, it might be possible to use existing spectrum in a more efficient manner, thereby freeing capacity for shared use. A discussion of ways to obtain additional spectrum should distinguish freeing capacity from clearing bands.

Participants recognized that a study of current use might be useful in understanding what spectrum might be available. According to one study, less than 20 percent of the frequency bands below 3 GHz were in use over the course of a business day.[19] Participants endorsed the general proposition that the government cannot efficiently manage a resource it does not measure.

Participants considered a proposal developed by Phil Weiser for private parties to identify unused spectrum assignments and petition the FCC for reassignment.[20] While some participants thought this qui tam proposal[21] could uncover abandonment of assigned licensees or provide information to a dynamic database, most were concerned that it might provide an excuse for rent seeking behavior by attorneys, that its implicit requirement for utilization might encourage unnecessary usage just to retain the spectrum, and that it would not save any administrative or monitoring expenses since ultimately the FCC would have to confirm the private party's assessment of disuse.

Participants reached the conclusion that a government-run inventory of use is a good step. One participant suggested that use measurements could be taken with spectrum analyzers mounted on vehicles of commercial delivery fleets with the resulting usage compiled into a dynamic database that could be regularly updated. Incorporating the results of the inventory in a dynamically updated database would facilitate sharing or secondary markets. The results of such an inventory might change behavior to increase efficient spectrum use.

While participants endorsed the concept of a quantitative inventory, there was substantial but not universal agreement that such a comprehensive inventory is not a necessary first step for clearing or sharing. The FCC and NTIA should not wait to complete an inventory before moving ahead with clearly advantageous steps to reallocate or free spectrum.

Several participants warned that the lack of activity on a particular band at a particular moment is not an indication of inefficient use or lack of use. If government spectrum is involved, for example, the reason for inactivity might be that the band is being used by passive sensors or reserved for infrequent but essential use at a time of national emergency. Level of utilization at a point in time is not the relevant metric if bursts of utilization are essential. If commercial spectrum is involved, then the licensee might be reserving it for future use as its system is built out. In addition, a snapshot of spectrum use on a particular day might be meaningless, since companies change their use of the spectrum on a daily basis. The tests should be measurements of efficiency and effectiveness, not technical usage, since not using assigned spectrum at a particular point in time might be the highest use.

The participants reached the conclusion that lack of use does not automatically mean that the spectrum is a good candidate for reallocation or sharing. But usage information is still very useful. It can identify abandonment. Earlier inventories discovered that some businesses had abandoned their spectrum without ever notifying the government. The NTIA inventory that took place in the Advanced Wireless Service (AWS) proceeding in 2002 identified over 1700 assigned licensees, 600 of which were not being used at all. Furthermore, if spectrum is underutilized and there is a good reason, then allocation and assignment stay the way they are. But if there is no justifiable national security or economic reason for underutilization, then it might be a candidate for reallocation or sharing.

Conversely, full utilization does not mean the current allocation of the spectrum should remain. Spectrum might be fully utilized, but the same service could be provided more efficiently in another band or through wireline. In short, efficiency is a better measure than underutilization for determining reallocation. However, it was also suggested that it is not appropriate to try to impose a single measure of efficiency for all radio services.

Underutilization might be a better test for freeing spectrum, or sharing it with other users. But bringing other users into the band creates the risk of interference. There might be a small number of users but the consequences of interference with the current use are so great that it overwhelms the small number of users. Participants agreed that enforcement measures would be important to ensure protection of authorized users in the context of spectrum sharing.

Legislation pending in both the House and Senate requires a quantitative inventory of existing spectrum. Participants generally supported this legislation. However, in the House of Representatives, H.R. 3125, introduced by Representative Henry Waxman, contains a provision to identify the least utilized bands and calls for the NTIA and FCC to make a recommendation of which, if any, of the least utilized spectrum bands should be reallocated. Since this provision appears to set up underutilization as the criterion for reallocation, some government representatives and other participants found it inappropriate.

Many participants thought that quantitative assessments such as the one mandated in legislation are of limited usefulness. Inevitably, these assessments would be very complex, they could never be complete and they would leave out important uses. There is no harm in conducting them, but they are not definitive.

Participants suggested a different way to conduct an inventory—qualitative assessments. Qualitative assessments involve having a knowledgeable person describe what is happening in the band and what is planned for the future. These qualitative assessments can help plan for sharing or reallocation. Many participants expressed a preference for a description of the capabilities as well as current and planned uses of the spectrum over a quantitative assessment of current use.

Several points emerged as a consensus of the group:

- A spectrum inventory as mandated by legislation pending in the House and Senate would be useful but not definitive in understanding the extent to which reallocation would be able to respond to the growth in wireless demand;

- Utilization is the wrong metric for making recommendations for reallocation. Measurements of efficiency and effectiveness rather than utilization are the key factors for communications services;

- Underutilization might be an important factor in determining whether to share spectrum or to allow it to be used for other purposes, but the dangers of interference have to be assessed;

- A useful inventory should concentrate on how the spectrum is currently used, its particular mission and future planned uses. It should cover both government and commercial uses.

Spectrum Reallocation

While participants recognized that all private sector and federal government uses of spectrum need to be evaluated for possible reallocation to meet wireless broadband demand, the discussion on reallocation focused mostly on spectrum used by broadcasting, satellite, private land mobile radio, and government.

The basic conclusion from this discussion was that the extra spectrum from broadcasters and other private sector parties would at best provide an additional several years of relief from wireless broadband demand pressure. Furthermore, while there could be substantial improvement in the efficiency with which government uses its spectrum, there are not large sections of government spectrum available for reallocation. Sharing of government spectrum, rather than the more desirable reallocation, is the most likely result. It is important to consider the extent to which spectrum reallocation from broadcasters, other private sector users and the federal government is a legitimate policy response to growth in wireless demand, but it will not, by itself, satisfy wireless demand.

As a result of the digital transition, broadcasters occupy 294 MHz of spectrum for terrestrial broadcasting. Many participants argued that this spectrum should be reallocated for wireless broadband use or auctioned for flexible use so that wireless carriers can bid on it. In their view, broadcasting is used by only 10 to 15 percent of the population and will continue to decline. Broadcasters are losing advertising revenue as well. The economic value generated by the use of this spectrum for broadcasting is shrinking and, in view of the alternative uses, is no longer something society can afford. Mobile, in contrast, is growing. The number of subscribers is going up. Usage is going up. Revenue is going up. In strictly economic terms, according to this view, spectrum should go from broadcasting to mobile.

Various analysts have estimated the value of the broadcast spectrum if it were reallocated and auctioned to the highest bidder. A recent study by Colman Bazelon for the Consumer Electronics Association puts the market value of the broadcasters' spectrum if it were available for wireless broadband at about $62 billion.[22]

Broadcasters at the conference argued that the non-economic advantages of continuing over-the-air broadcasting provide adequate justification for continuing this allocation to broadcasting. These public benefits include free service to households that do not subscribe to multichannel video services such as cable or satellite, local news and public affairs that are not provided in any quantity by other electronic media, and emergency notification such as health warnings, school closings and dangerous weather conditions. In light of the crisis in journalism, the urgency of local broadcasters providing these services is only likely to increase.

Some participants argued that carriage of local broadcasting stations on local cable systems combined with subsidized cable subscriptions would enable broadcasters to continue their public service programming to their current audience. Broadcasters responded that carriage on cable could not be relied on once the over-the-air license is gone.

Others noted that a single standard definition signal can be transmitted using substantially less spectrum than is currently allocated to local broadcasters. The full 6 MHz channel is equivalent to a 19.4 megabits per second (Mbps) bit stream, but a single channel of standard definition video can be transmitted with only 7 Mbps. They proposed reallocating the unneeded portion of this spectrum, still leaving broadcasters with enough to accomplish their public service mission.[23] Broadcasters responded that they need this additional spectrum for high-definition broadcasting for special events, for multicasting, for securing the full value of their retransmission consent rights, and for mobile video.

The discussion made it very clear that these proposals face serious objections and resistance from the incumbent broadcasters. This political resistance makes it very unlikely that an FCC-mandated reallocation of broadcaster spectrum in any of the forms discussed would be successful, and if successful, would come only at the end of a protracted political struggle.

In any case, participants concluded that the amount of spectrum available from broadcasters is simply not enough to meet the growing demand. Broadcasters have at most 294 MHz to contribute. But CTIA is asking for 800 MHz, and the ITU estimates of spectrum needs for four wireless carriers is 2240 MHz by 2020. The few hundred megahertz of broadcast spectrum involved will only absorb demand growth for a short period of time; some participants suggested one year, others as many as three. Participants agreed that reallocating broadcast spectrum would provide a partial solution and could have desirable efficiency gains. But they also agreed that, by itself, it will not be a long-term solution to the problem.

In addition to the broadcast spectrum, participants discussed two other areas where commercial spectrum might be reallocated. The first was private land mobile radio spectrum around 450 MHz. These frequencies are among the oldest allocated in the United States and are used by businesses (for services such as dispatching), public safety and paging services. Participants thought the propagation characteristics of this spectrum especially attractive; there are chipsets already developed and in use, and the spectrum is globally harmonized. As a result, the benefits of reallocating as little as 10 MHz would be significant. It would require a relocation fund, which could be financed out of the proceeds of an auction.

The second non-broadcast commercial spectrum considered was satellite spectrum. Participants proposed the relaxation of commercial satellite spectrum restrictions to allow it to be used for purely terrestrial purposes. This ancillary terrestrial component of the satellite service would provide wireless carriers with some additional capacity, at a spectrum bandwidth with characteristics similar to those involved in the Advanced Wireless Service (AWS) allocation. The amount of spectrum involved was estimated by one participant at 60 MHz.

Participants concluded that, while each incremental addition of spectrum is better than doing nothing, neither of these non-broadcast commercial bands have the size to make them commensurate with the exploding demand for wireless services.

In noting these limitations on spectrum reallocation, participants were careful to also observe that spectrum reallocation would still be worthwhile. Each of the proposed reallocations would only be a partial or stopgap solution to the spectrum problem. But individually and collectively they would ease the problem from what it would be if no additional spectrum were allocated.

Government spectrum might be available for reallocation. However, many participants pointed to the lengthy administrative process and uncertain results of trying to reallocate government spectrum. The process that led to auctioning licenses for Advanced Wireless Services in 2006 illustrates the difficulties. The process of reallocating the government portion of that spectrum began at least in 1993, but the auctions themselves were not held until 2006.[24]

This procedure for reallocating government spectrum could be used in the future. It involves an analysis of the viability of reallocating spectrum currently used by government agencies, funding and time to do the analysis, and money to relocate the existing government users. The limiting factors are time to conduct the analysis, make the transition and pay for relocation costs. Participants concluded that any attempt to reallocate government spectrum would take at least 10 to 12 years using this administrative process.

There was extensive discussion about the incentives of government agencies to be rational users of spectrum. Since they do not face market pressure, what would make them efficient in their use of the spectrum? Why would they agree to turn over the spectrum they currently have for reallocation?

Government participants and others pointed out that certain government functions must operate in specific bands due to their physical characteristics. These functions must operate in specific bands in order to meet certain mission requirements and cannot be relocated without impact to critical government services. Relocations are impossible when there is no technical alternative. One participant described a standard of efficiency that government agencies might use to improve the prospects of successful reallocation. He noted that barriers to spectrum reallocation can be created by failing to make relatively small initial investments in infrastructure that lock in current allocations. He called for making small incremental investments relative to the size of the total investment when it could yield either greater spectrum efficiency or greater flexibility to relocate as things change over time. For instance, some satellites are currently locked into using a frequency that could be more efficiently used for other things. But it does not make sense to switch because the asset is then stranded and the service it supplies is lost. If the satellite had been equipped with software radio, the switch might have been feasible. So going forward it would make sense to install software radio or other equipment that can switch frequencies so as to provide for flexibility over time. It might cost more, but if the incremental cost is small relative to the total investment in the infrastructure, it would make good sense.

Government agencies and other spectrum users need to be alert to such possible efficiencies. But what are their incentives for doing so? Some participants thought that there is already sufficient incentive for government agencies to use spectrum more efficiently due to current spectrum constraints, and because they expect that less rather than more spectrum will be available to them in the future. But most participants thought more incentives are needed and suggested a variety of tools that might encourage efficiency and make spectrum available for reallocation to other purposes. Though some disagreed, these measures include:

- Government requests for proposals (RFPs) for wireless systems could contain a requirement for spectrum efficiency;
- Government agencies could be charged a spectrum shadow price that expresses the value of the spectrum they are using;
- Government agencies could be rewarded for giving up spectrum by keeping some of the value of the revenue earned at auction;
- Employees in government could be encouraged by giving awards for the best proposals to improve use of spectrum. For instance, a total of $500,000 could be awarded each year to the 100 employees who come up with the best spectrum saving ideas;
- Auction revenue could be set aside for federal agencies to improve spectrum efficiency or sharing.

Participants thought these measures would likely improve government incentives to be more spectrum efficient. However, government representatives and other participants at the conference cautioned that it is a misunderstanding if people think there is a large amount of government spectrum that is inefficiently used or underused and that could be made available in substantial quantities for auction. The improvements listed above are much more likely to free spectrum for sharing than to make it available for reallocation.

This discussion produced several conclusions:

- It is important to consider the extent to which spectrum reallocation from broadcasters, other private sector users and the federal government is a legitimate policy response to growth in wireless demand, but it will not, by itself, satisfy wireless demand;

- It would take ten or more years to reallocate either the television broadcast spectrum or federal government spectrum;

- The extra spectrum from broadcasters would at best provide an additional several years of relief from wireless broadband demand pressure;

- In the case of federal government spectrum, incentives for efficiency would produce shared spectrum rather than much more desirable cleared spectrum.

Receiver Standards

Participants spent considerable time discussing potential increases in efficiency created by improved receivers. Interference occurs at the receiver not in the airwaves. The extent of possible interference depends in large part on the selectivity of the receiving equipment. If the receiver can be made more selective, so that it responds only to the appropriate signals in its bands and rejects other in-band or adjacent signals, then other uses of this spectrum are possible. Spectrum capacity could be significantly increased by improving the quality of receivers.

The FCC might have a useful role to play in acting as a backstop regulator to encourage minimum performance standards for receivers so as to increase spectrum capacity. One government official went a step further and advocated that the FCC should have a more definitive role in *establishing* and *enforcing* minimum performance standards for receivers. But, the danger would be in setting standards too rigidly in a way that would reject innovative devices. The best option might be for private standard-setting bodies to take the lead in developing performance standards, with regulators playing a backup role if necessary. In addition, government should find ways to encourage the use of improved devices for its own use of the spectrum.

Two studies informed the discussion. One participant reported that the FCC had done a study of what it would cost to make UHF receivers more selective so stations could be packed closer together. The costs were minimal, but the FCC did not have the authority to regulate receivers and manufacturers did not want government control over equipment design. According to this participant, the failure to take that opportunity at the time has cost the country billions of dollars. A second study from the UK reported that an increase of 10db in selectivity of receivers could be had for $1.

Many participants distinguished between closed and open systems. In a closed system, the licensee controls the receivers. The licensee can modify the receivers or shut them down. This is the case in wireless broadband devices. In this circumstance, it is possible to imagine a negotiation in which those wanting spectrum would come to the licensee and offer to buy or lease extra spectrum obtained from improving the selectivity of the receiver. In the open situation, the licensee does not have control over the devices. This is the case in broadcasting. In other open situations, the devices themselves are unlicensed and there is no licensee who has control over the devices.

Problems arise with sharing when devices are not under the control of a licensee. In 2004, the Defense Department began testing a land mobile radio system. These tests resulted in substantial interference with garage door openers in communities located near military bases. There was a political outcry and pressure on the Defense Department to stop the test. These garage door openers were Part 15 devices, that is, unlicensed devices authorized by Part 15 of the FCC's rules to operate on licensed frequencies but required to accept any interference that might occur from licensed use. Participants pointed out that poorly designed devices that can be interfered with significantly and easily create a non-sharable condition. Users of Part 15 devices are not tracked the way licensed users are. So there is no way to know in advance the level of interference.

This led to a discussion of whether the FCC has authority to set receiver standards and if so, whether and how it should use such authority. Participants noted that the regulations for unlicensed Part 15 devices, including the TV band unlicensed devices, concern emissions, not reception.

A recent court case held that the FCC has authority to regulate the function of receiving signals, but not the internal processing. In its decision rejecting the FCC's broadcast flag ruling, the D.C. Circuit court concluded that the FCC has authority to regulate devices used for the receipt of radio communication while those devices are engaged in communication. It may not regulate the device, however, after the transmission is complete. It may not, for example, set standards for internal processing.[25]

Some participants thought the FCC had authority to set receiver standards for commercial equipment indirectly. According to this view, the FCC could say that a licensee gets interference protection only if its receivers meet certain selectivity criteria. The FCC could specify the characteristics of the receiver and if the equipment manufacturer failed to deliver, then interference would be the problem of the user. The FCC appeared to be acting on this authority when, in 2003, it opened a proceeding to determine if it should mandate or encourage performance standards related to the immunity interference of devices, that is, their ability to reject unwanted signals. These minimal performance standards could create opportunities for more efficient use of the spectrum by making sure that licensees seeking interference protection had devices that tolerated interference. In 2007, it terminated this proceeding.

Participants warned of the dangers of excessive FCC authority or action in this area. No one wanted the FCC to be in the business of setting computer standards unrelated to the reception of communications. Even in the area of reception standards, participants wanted the FCC to be cautious. One participant pointed out that the iPhone receiver is very poor. Should the FCC be in a position to ban the iPhone because its receiver is too poor?

Most of the group accepted the idea that receiver standards should be developed by private industry bodies. There might need to be signaling by the regulator concerning what standards need to be developed, and licensing that specifies conformance with expected performance interference standards. But decisions should be made in the first instance by private standard-setting bodies with backstop authority for the regulatory body to step in if that fails.

Participants concluded that while receiver standards might increase spectrum capacity, they will not be a substitute for more spectrum or improved network architecture. It will take considerable time for these receiver standards to be adopted and even longer to implement them.

Shared Use

Participants looked carefully at the possibilities for "cognitive" or "software-defined" radios that have advanced capabilities to detect interfering signals and switch to unoccupied bands. These receivers are at the heart of the possibilities for opportunistic sharing of spectrum, where unlicensed devices could share spectrum on a secondary basis when such use would not interfere with licensed uses.

Despite previous high expectations for these devices, participants expressed a substantial degree of skepticism concerning the short-term opportunities created by cognitive radios. Instead, the major conclusion participants reached was that increases in spectrum capacity based upon smart devices using unlicensed spectrum has long-term potential. But questions, for example, about their protection against interference, raise doubts by some that these devices will be useful policy tools as a response to the growth in wireless demand.

The potential of these devices was highlighted with the FCC's decision in the broadcaster white space proceeding that authorized unlicensed devices to operate in the broadcast spectrum in a way that did not subject the broadcaster signal to interference. Shared use is important in both commercial and government spectrum because it allows more uses and users to take advantage of the same spectrum band.

There was substantial agreement that these devices are several years away from actual deployment. Participants agreed that the technology is still evolving and it is not where it needs to be at the moment. Some suggested a time line of 10 to 12 years for significant improvements. In addition, the participants agreed that a critical enabler for increased use of this technology is the development and implementation of appropriate enforcement mechanisms to protect incumbent authorized users.

A major difficulty is a chicken-and-egg problem that seems to be stopping the necessary investment in device development. Millions of dollars of investment in development needs to take place to make smart receivers suitable for actual deployment in real markets. But this investment is not being sunk into development because there is no guaranteed path for the devices to be deployable. The spectrum they would have to share is not available for the devices to use. On the other side, people holding licenses to spectrum where the devices could be used do not want to move ahead with sharing because there is no proof that the devices that have been developed in the lab will actually work out in the real world. It is possible that an allocation of some spectrum on a regional basis where devices that are being researched by DARPA, NIST, NSF and their grantees could be deployed and tested. If government provided this clear path to deployability through regional spectrum test beds, it would not have to worry about the funding problem for development investment. The chicken and egg problem would be overcome.

Regulatory certainty was another issue that received some discussion. If the marketplace is going to move toward more devices capable of shared use, the regulatory environment has to create a clear path. If it wants to encourage shared use, it has to begin setting out this regulatory framework now, so that the marketplace can begin to make the investments it needs to develop workable technology.

Some participants reported a different problem with sharing—commercial licensees do not want to share spectrum with unlicensed devices without being compensated. Proposals to respond to this concern are considered in the secondary market section of the report. The fact that there might be a market response to problems in sharing spectrum suggests that these two models for spectrum management—property versus commons—might not be so far apart in practice, despite the large theoretical gap separating them.

An additional problem concerns the limits on government's rational economic behavior, and its avoidance of sharing situations in the absence of requirements. To respond to these concerns participants made several recommendations that might increase the development and deployment of these devices:

- Expand the white areas database to other spectrum users to make possible a larger universe of potentially shared spectrum. Make the database available for dynamic shared use;

- Use the spectrum relocation fund to encourage government agencies to share spectrum, not just to vacate it. Funds should be for sharing, not just clearing;
- Increase research and development funding for technologies that will enable shared use;
- Allocate spectrum for shared use device deployment and testing;
- Establish robust enforcement mechanisms to protect incumbent authorized users.

Secondary Markets

Participants explored the idea of secondary markets as a way to increase the spectrum capacity available to wireless networks to meet demand for wireless services. However, they concluded that while market-based approaches such as flexible licenses and license auctions do have the potential to free some spectrum to respond to the growth in wireless demand, these approaches do not provide nearly the amount of spectrum that will be required.

The idea behind secondary markets is for the FCC to issue flexible licenses that allow licensees to trade their licenses. If licensees can buy and sell their rights to use the spectrum, then the market will allocate the use of the spectrum to the highest and best use.

One of the major problems with this approach is how to get spectrum out from its currently allocated and assigned use, where the government dictates what the spectrum is to be used for and who has the right to use it. The simplest idea is to repeal any restrictions on the use of the spectrum and allow current licensees to sell their spectrum to the highest bidder, thereby reallocating the spectrum through private action.

Various collective action problems suggest, however, that simply repealing the rules against trading alone will not be enough. There are transaction costs from buyers finding willing sellers for the amount of spectrum they have. There are hold-out problems where current licensees may have the ability and the incentive to act strategically to extract a larger proportion of the gains from trade. These problems may prevent efficient trades from taking place even if rules preventing them are removed.

The specific case that interested the participants was how to move the broadcast spectrum into the marketplace. Participants suggested that current rules prevented the broadcasters themselves, or anyone to whom they would sell or lease their spectrum, from providing anything but one-way services on their currently allocated spectrum. There was a provision for ancillary and supplemental services, but under FCC rules these services could not involve more than a limited percentage of the spectrum, would require the payment of a spectrum fee for such use and could involve only one-way transmission of information. Some broadcasters such as public broadcasting licensees had used this provision for a national data casting service, but, absent changes from the FCC, it was unlikely to provide the flexibility needed to create a real secondary market for broadcasters.

The first suggestion was simply to eliminate these restrictions and allow broadcasters to sell their spectrum. Some participants thought that geographic market fragmentation and other collective action problems would sort themselves out over time if the rules allowed transactions. But most participants thought that the various collective action problems discussed above made that alternative less than ideal.

Several participants commented favorably on the "two-sided auction" approach. This proposal calls for the FCC to hold a nationwide auction of the broadcast spectrum under terms suggested by Kwerel and Williams in a 2002 paper.[26] Under this "two-sided auction" approach broadcasters would be free to participate in the auction or would be able to retain their spectrum for broadcast purposes. The auction could cover the entire broadcast spectrum or require broadcasters to retain enough spectrum to offer one free standard definition video signal. To reveal the opportunity costs involved in the current broadcast licenses, broadcasters could be given various incentives such as the ability to engage in the flexible use of their spectrum if they participated in the auction. If broadcasters decided to participate they would not be committed to accepting any of the bids they received for their spectrum.

Some felt that a two-sided auction would be better than removal of restrictive rules because it would reduce transaction costs by having a nationwide bid. It would increase the transparency of the opportunity costs and reduce holdouts. Other participants worried, however, that allowing voluntary participation in the auction by broadcasters would not allow large national blocks of spectrum to be made available for purchase by national wireless carriers.

An "overlay" approach to the broadcast spectrum also received substantial discussion.[27] This plan would:

- Divide the 294 MHz DTV Band into seven national overlay licenses;

- Allocate for each overlay seven contiguous TV channels (42 MHz), reducing borders (as opposed to non-contiguous channel allotments);

- Allot overlays exclusive, flexible-use rights as defined in the 700 MHz licenses previously sold at auction, subject to incumbents' encumbrances;

- Grandfather DTV broadcast incumbents indefinitely;

- Require DTV stations to distribute video content free-to-viewer, but make the mandate platform-neutral;

- Sell overlay licenses at auction;

- Limit two per customer.

A key element of these proposals is that broadcasters would be able to keep all or some of the revenue associated with the sale of their licenses. But participants, especially broadcaster representatives, expressed skepticism that government would allow this. Some were convinced that these gains would be regarded as windfall profits, an unjust enrichment at the public expense, and disallowed as unfair. Others worried that at a time of budget deficits Congress would want to seek out all possible ways of obtaining revenue to balance the budget, including revenue from any spectrum auction. For this reason, there was significant doubt that this proposal would be attractive to broadcasters.

Beyond this, the broadcaster representatives expressed no interest in moving toward such a voluntary auction. They expressed the view that their current allocation, encumbered as it is by the restriction to broadcasting, satisfies their business and public service needs in providing a free over-the-air signal, HDTV programming, retransmission fees, multicasting and mobile broadband. They were suspicious that what might start as a voluntary suggestion might inevitably become a mandate. For this reason, this idea of moving the broadcast spectrum to wireless broadband appears to be as politically difficult as the idea of simply reallocating it.

Even if politically feasible, this proposal to auction broadcaster spectrum faces the same limitations as the proposal to reallocate it. There is simply not enough broadcaster spectrum to satisfy the demand for spectrum capacity to meet the rising demand for wireless services.

To find additional spectrum, some participants suggested that all limits be removed from all FCC licenses and that all licensees be allowed to trade. One application of this idea is to satellite spectrum, where if the current rules limiting terrestrial use of the spectrum are eliminated there could be large economic gains. One participant estimated that the enterprise value of one major satellite company per MHz/pop is \$.04. The spectrum they own that is encumbered by restrictive FCC rules is comparable to the AWS spectrum which was auctioned for \$.54 per MHz/pop. As a result, 90 percent of the value of this spectrum is destroyed by the rules limiting use. He suggested taking away these rules and allowing the affected 60MHz of spectrum to find its way into the market.

One additional market-based idea was to create a dynamic database built off the TV white space database. By consulting the database a user could find spectrum that he or she would be willing to pay for or bid on. It might be possible, for example, to reserve spectrum for a short period of time (the next twenty minutes) or a longer period of time. Essentially this database would become a private dynamic spectrum management system, supplementing the existing licensing system. The more inventory of spectrum in such a system the better it would work. Spectrum reserved for future use, for example, could be deposited in the database and the licensee could obtain revenue from its lease.

Other participants agreed that unused capacity could be identified and listed in such a database. If this dynamic database could be built up over time there might not be a need to clear spectrum at all. The system would work on a band-by-band basis identifying times of availability, power restrictions, angle of reception, and other conditions so as to work around incumbents. Compensation for licensees who want to be paid for the use of their spectrum could be arranged through an ASCAP like system, which would distribute payments into the royalty pool on the basis of spectrum use. This would ensure that hold-outs are not able to limit the amount of inventory in the system, and yet ensure that licensees would be compensated for the use of their licensed spectrum.

This idea is similar to the idea proposed several years ago by Eli Noam—licensees who paid for their spectrum would have the option of joining a private rights clearing organization.[28] Other users could then get access to underutilized spectrum in a way that gives priority to the existing license holder. They pay a fee to a spectrum rights corporation, modeled after the private rights clearing organizations, which distributes the pool of fees to the spectrum rights holders on the basis of usage of their spectrum. For rights holders who did not pay for their spectrum, such as broadcasters, the program would be compulsory and the revenue could be shared with the rights holders and distributed for other purposes such as public interest programming.

While the possibilities of such a system seem promising in the long-run, participants thought that it may be limited in responding in the short-term to the need for additional spectrum to increase wireline capacity. Significant development work would need to be done to make such a database operational. It depends heavily on the existence of devices that could use different parts of the spectrum at different times, and such devices are still in development. In addition, carriers are still looking for exclusive-use spectrum that would be available full-time for meeting the demand for wireless services.

Participants thought that government agencies could also participate in secondary markets by leasing unused spectrum for commercial use, while not in government use or while systems are under development. But several steps need to be taken first. One is to create defined usage rights and recognized spectrum access for government users so that it is clear what spectrum they have and for what purpose they are using it. This would help government users when they go into the secondary market. If the military or other government users of spectrum are expected to trade spectrum or to lease it, their spectrum rights have to be defined very clearly. This needs to be done before mechanisms, including provisions for receipt of funds for spectrum use and other necessary legal changes, are set up for government users to enter a secondary market.

Pricing

Participants noted that pricing is directly connected to the demand for mobile wireless services. They agreed with the conclusion reached by one study that mobile demand has been stimulated by flat rate data plans that encourage data consumption.[29] One way to respond to the exponential increase in demand for wireless services is to ration it through different pricing arrangements. Participants discussed several pricing regimes designed to do that.

- *Tiered Pricing:* Usage caps on the maximum amount of capacity that an individual customer could consume over some period (like a month) without incurring a (possibly substantial) additional charge;

- *Time of Day Pricing:* Similar restrictions or higher prices imposed on usage at times of the day when demand is expected to be at its peak;

- *Usage Sensitive Pricing*: Charges directly related to the amount of data transmitted.

Some participants questioned whether usage caps would reduce demand at peak periods. Since the need for network capacity is connected to peak demand, a pricing scheme that does not reduce demand at peak periods would not reduce pressure to increase network capacity. Others noted that time of day or other pricing schemes could discipline usage at peak demand times. Encouraging off-peak usage in this way would not limit overall usage over a monthly period, and still would alleviate pressures on system capacity.

These pricing schemes are designed to influence consumer expectation, requiring them to choose more carefully when and how they use network wireless capacity. In a normal marketplace, it is expected that these pricing arrangements would be adopted by carriers as a way to respond to demand that might exceed capacity.

However, many participants expressed the view that consumer rebellion and possible political intervention would prevent widespread adoption of pricing as a means of reducing demand. They pointed to the negative experience that Time Warner Cable recently had in just proposing to test usage sensitive pricing for their cable modem services.

There does not appear to be any current legal obstacle to different pricing schemes. Participants agreed that, in principle, these pricing arrangements are consistent with net neutrality if they are genuine attempts to discipline demand and not covert ways to discriminate or to engage in strategic behavior to disfavor competitors. The concern is with consumer and political backlash.

Carrier representatives noted that some plans provide usage sensitive pricing for voice service or text messages, but that data charges are flat rate. They explained that it is extremely difficult to clarify data usage caps to consumers, since few consumers know what it means to be limited to say 1GB of usage a month. Consumers do not think in terms of megabits or gigabits, so it would be hard for them to evaluate and to restrict their behavior to limits expressed in these terms. Marketing these plans to consumers would also be extremely difficult.

Others pointed out that carriers are able to increase prices in other areas such as disconnect charges despite substantial consumer and political concern. If carriers need to discipline demand, they might need to raise prices despite its unpopularity. The political backlash would not result in binding legislation or regulation and the new limits would ultimately be allowed to function in the market. Some participants pointed out that tiered pricing is already in effect for certain domestic wireless services such as broadband access for laptop computers which use substantial amounts of spectrum.

In other markets tiered data plans are already in use. Canada, for example, uses tiered pricing. One carrier has several tiers, ranging from a $30 base Monthly Service Fee and up to 500 MB of data usage, to an $85 Monthly Service Fee and up to 5 GB of data usage. If monthly usage exceeds 5 GB, then customers pay 3¢ per additional MB. With proper prepping of the marketplace, these pricing schemes were accepted without substantial customer or political repercussions.

In the end, participants concluded that demand for wireless spectrum can be restrained by various kinds of usage sensitive pricing that charges heavy users for the additional demands they put on wireless systems, but political and marketplace resistance might prevent the full use of this marketplace response to the growth in wireless demand.

Network Architecture

Participants agreed that efficiency gains and increases in the amount of spectrum available—whether from spectrum reallocations, improved receivers, shared use, or secondary markets—would not likely by themselves or in combination meet the projected exponential demand for wireless broadband services. Given the nature of broadband demand, which seems constrained mostly by supply, it would be a never ending job to find spectrum to meet demand. In particular, participants concluded that the extra spectrum from broadcasters would at best provide an additional year or two of relief from wireless broadband demand pressure. And although pricing adjustments might discipline and diminish demand, they might also prompt political or consumer backlash.

This led the participants to consider changes in network architecture. After substantial discussion, they concluded that additional frequency reuse through dramatically smaller cell-site coverage areas is worth considering as a possible long-term solution. Decreasing the size of cells in high demand areas requires high-capacity fiber-optic cable for backhaul from the access point to the remainder of the wireless network. One participant summed up this perspective by saying that the solution to this problem is fiber, not just spectrum. A fiber intensive wireless network architecture should be considered, in parallel with allocation of additional spectrum, as complementary long-term solutions to the problem of exploding demand for wireless services.

The participants recognized the important implications of this conclusion for the policy issues under discussion in the FCC's National Broadband Plan. One of the main policy issues in the Plan is the role of government in promoting wireline broadband access. Making sure that fiber is as ubiquitous as possible is a key element in that strategy, so it can furnish the largest platform for the applications and services that broadband makes possible. Participants recognized that the desire to push fiber closer to the home (or all the way to the home or office) in the wireline area is closely linked to the need to provide additional capacity to meet the exponential growth in wireless data demand. Driving fiber deeper into the network promotes both wireline and wireless broadband access. Participants thought that fiber's role in addressing the demand for wireless broadband reinforces the focus of the Broadband Plan to push fiber deeper into the network.

The participants discussed how to push for dramatically decreased cell site size through a change in wireless network architecture. The essential idea is to use very inexpensive, low-power access points mounted on utility poles, lampposts or buildings and connect them by fiber back to the required signal processing equipment and other intelligence at a central location. By centralizing the signaling processing and intelligence, the cost of the access point and network is minimized. Software at the central location is needed to accomplish signal switching and monitoring of the mobile customer.

This denser network topology can increase network capacity without additional spectrum by increasing the frequency-reuse factor. It is similar to a Distributed Antenna System (DAS), which are in use today in various places including the U.S. Congress, Stanford University and Disneyworld. Unlike today's bay stations, these antennas are inexpensive because they do not need to perform any processing functions. They are amplifiers, not transmitters. Their job is to amplify a signal that is created at the central office. One participant described this wireless network architecture as "femto cells on steroids," where the wireless antenna is substantially less expensive than a femto cell because it relies on extensive software processing back in the central office.

Several participants described this architecture as a hybrid, combining features of a wireline and a wireless network. One participant said that many networks, including the existing wireless network, are really hybrids with a boundary between the wireless and the wireline part of the network. The idea for this improved architecture is to move the boundary between the wireless and the wireline network, to get the signal into fiber as soon as possible. By moving the boundary in this fashion, the hybrid network relies on the wireless connection only for the very last leg of the connection and uses the wireline network for the long distance portion.

Finding a suitable site for a cell tower is less of an issue with a distributed antenna system. There is no need for large cell towers. Small antennas can be attached to utility poles, lampposts, power poles or buildings. Even locations with underground utilities and limited power poles should not pose a problem because the antenna is so small it can fit into a number of unobtrusive locations, for instance a light bulb socket.

How much additional fiber is needed was the subject of extensive discussion. One issue is whether fiber needs to be brought to the home. One participant noted that the cost to bring fiber to every home in the UK was 25 billion pounds and half that to bring it to the lamppost. He added that once the streets are dug up to get the fiber to the neighborhood, it is sensible to bring it to the home. Another participant noted that the cost of installing fiber goes up with the square of the number of terminating end points on the network. So to get fiber to all homes might cost two or three times what it costs to get to the lamppost. Others noted that the U.S. is a large country and the cost of fiber to the home would be hundreds of billions of dollars.

Participants agreed, however, that substantial benefits can be achieved without bringing fiber all the way to the home. Industry representatives noted that fiber is present in 95 percent of neighborhoods and that in areas where wireless congestion is the greatest there is already a substantial amount of fiber. One participant estimated that in urban areas there might need to be an antenna every nine blocks, and that fiber would have to be available at those points. The overall view, however, was that fiber should be driven as deeply as possible into the network.

Many agreed that fiber can make the cell sites smaller and make existing spectrum go further, but objected that this solution does not take seriously the idea that all information needs are increasing exponentially. Wireless needs cannot be met by using fiber because fiber is not enough of a substitute. Other participants pointed out that capacity limits are different for fiber than for wireless, that fiber capacity can be increased substantially over time, and that the capacity of one fiber is greater than the capacity of the entire radio spectrum.

Participants agreed that an additional aspect of this architecture is the use of femto cells or similar systems to provide wireless coverage inside buildings. These antennas would be connected to fiber serving the building and linked in this fashion to the rest of the network. This arrangement would avoid the need for high power transmitters outside the building to carry a wireless signal through the walls. While femto cells by themselves have the limitations already described in an earlier section of this report, as part of this larger network architecture, they would play an important role in reducing the need for additional spectrum.

Some thought that traditional wide-coverage cells would still be needed for certain purposes such as serving customer devices in vehicles moving at very high speeds in urban areas. These systems would also be needed in less densely populated exurbia and rural areas, where it might not be economically feasible to run fiber.

How much additional spectrum might be required with this architecture? The spectrum requirements depend on the size of the cells. Participants thought that with widespread deployment of distributed antennas, little additional spectrum would be required. Some speculated on the possibility that the kind of spectrum required might not include the very desirable spectrum below 3GHz.

If this architecture is the solution, then why are the carriers not currently implementing it with the full backing of Wall Street investors? Some thought that the amount of fiber needed would be extensive, especially if rural unserved and underserved areas were to receive fiber connections. It might not be cost effective for a single company to do this. They spoke of the fiber infrastructure as a utility, a facility that could be shared by several commercial wireless providers. This raised the possibility of a government role in funding this infrastructure.

Carrier representatives in the group noted that all of this could be done, but it would not be cheap. It would take substantial capital investment. To add capacity, they said, network operators can either obtain more spectrum or make investments in network architecture. Both cost money, but investments in network architecture are more expensive than spectrum.

Wireless companies believe that fiber is not the problem. Where there is congestion today, there is a lot of fiber. And fiber is not necessary in areas where there is no congestion. Fiber is not the problem in downtown Manhattan, for example. Fiber everywhere might help when people are in or near their homes. But home is not the problem. The problem is downtown Manhattan with the high concentration of people moving on the street and in and out of buildings.

In these dense urban areas, the problem is not the existence of fiber cable in the ground, but the integration of the fiber into the wireless network. The suggested new wireless network architecture calls for pushing fiber deeper into the network. And, in congested urban areas where the fiber already exists in the ground, the problem is alleviated by connecting the fiber to the wireless access points that wirelessly distribute the signal to the mobile devices. In this way, the network is more fiber-intensive as the signal is carried for more of its journey on fiber cable rather than over-the-air. And the smaller wireless areas are able to reuse the frequencies more intensively.

Carrier representatives noted these points. They said that they have substantial fiber in the ground, especially in highly congested urban areas. They also have a large number of remote access points that are reached by this fiber. They could build cell sites at each of these remote access points. But it is very expensive to add a traditional cell site and not enough could be added each year to reach each of these remote access points within a reasonable amount of time. Zoning, local ordinances and historical environmental concerns can also be inhibiting factors. Other participants noted that the problem of connecting the fiber already present in urban areas with the exiting wireless network is more easily solved with the less expensive DAS antennas than with the traditional cell towers.

Carrier representatives also noted that the use of smaller cells such as femto cells inside buildings is something they are doing today, but that it is expensive to furnish, maintain and manage the equipment that is used inside the buildings.

In the end, carrier representatives thought that the new architecture might make sense provided there are investment dollars to support it. They noted that internal corporate demand for investment dollars vastly exceeds their actual capital expenditure budgets. Money is the restraining factor preventing this idea from becoming a reality. What kind of revenue stream can support this investment? Will increased pricing to support this added investment be sustainable in a competitive environment? Will it just reduce profits?

They also wondered what the role of government might be other than to provide support for these expensive investments in new network architecture. In the absence of some improvement in the investment possibilities, they viewed less dramatic improvements in network architecture as a short-term solution to the demand problem. Additional spectrum is still needed for the next generation of wireless technology, 5G. Although that is many years away, they thought that the lengthy process of clearing additional spectrum makes it desirable to start the reallocation process now.

All agreed that technical, business and regulatory questions remain. Some believe that there needs to be some hard thinking about the political trade offs involved. It would take substantial political capital to require spectrum reallocation of broadcaster spectrum. Would that political capital be better spent on policy initiatives to get fiber into the ground and to make the connection between existing fiber and existing wireless network infrastructure? There were no answers to these political questions.

The promise of a fiber intensive wireless network architecture is not that it avoids the need for additional spectrum for broadband wireless services. Additional spectrum from the sources discussed at the conference—spectrum reallocation, improved receivers, shared use, or secondary markets—will all help to provide additional network capacity to meet growing demand. But the broadband capacity of fiber is unmatched by any possible additional allocation of spectrum. Thus, it is worth considering whether a key long-term complement to more spectrum would be to deploy fiber more deeply and to integrate it more closely into wireless networks. The discussion at the conference highlighted the urgency of developing the details of this proposal and defining the possible role of government in implementing it.

Developments

After the conference, there were relevant developments in communications policy related to the discussion at the conference. These included:

- The request on November 17, 2009 by leadership of the House Energy and Commerce Committee for a spectrum audit by the General Accountability Office;

- The decision by the FCC on November 4, 2009 to release the white spaces database;

- The decision by the FCC on December 2, 2009 to issue a new notice seeking comment on ways to free up broadcast spectrum for use by wireless broadband;

- A hearing on December 15, 2009 in the U.S. House of Representatives Energy and Commerce Committee, Subcommittee on Communications Technology and the Internet on spectrum inventory;

- Letters by the NTIA and DOJ on January 4, 2010 endorsing additional spectrum for wireless broadband, but auctioned in a way that favors new entrants.

Perhaps the most relevant development is still to come. It is the release of the FCC's National Broadband Plan in early 2010. The participants in the Aspen Institute Roundtable on Spectrum Policy would be pleased if the results of their deliberations recorded in this report were helpful to policymakers formulating this important strategic guide.

Notes

1. One government official believed that the FCC should have a more definitive role in establishing and enforcing minimum performance standards for receivers so as to increase spectrum capacity.

2. From the Report of Proposed Allocations from 25,000 Kilocycles to 30,000 Kilocycles, Docket No. 6651, January 15, 1945, quoted in John Robinson, "Spectrum Management Policy in the United States: An Historical Account," Office of Plans and Policies, Federal Communications Commission, 1985, Appendix A. Available online: http://www.fcc.gov/Bureaus/OPP/working_papers/oppwp15.pdf.

3. Robert M. Entman, "Challenging the Theology of Spectrum," A Report from the Aspen Institute Roundtable on Spectrum Policy, 2004, p. 3. Available online: http://www.aspeninstitute.org/sites/default/files/content/docs/communications%20and%20society%20program/CHALLENGINGTHETHEOLOGY.PDF.

4. Comment Sought on Spectrum for Broadband – NBP Public Notice #6, GN Docket Nos. 09-47, 09-51, 09-137, Public Notice, DA 09-2100, Sept. 23, 2009, p. 1. Available online: http://hraunfoss.fcc.gov/edocs_public/attachmatch/DA-09-2100A1.pdf.

5. "America's Broadband Future," Prepared Remarks of Chairman Julius Genachowski, October 7, 2009. Available online: http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-293891A1.pdf.

6. John Eggerton, "Broadcasters Defend Their Spectrum: FCC's Levin approaches industry in search for settlement," *Broadcasting and Cable*, October 2, 2009. Available online: http://www.broadcastingcable.com/article/367021-Broadcasters_Defend_Their_Spectrum.php?rssid=20068.

7. Traditional over-the-air broadcasting transmits content from a central location on a one-to-many basis to everyone in the broadcaster's coverage. Multicasting is a similar one-to-many distribution method in a packet network. Unicasting is associated with a packet network where the digital content is individually delivered to an individually addressed recipient. It is likely to be the dominant way wireless video will be distributed.

8. The effect of pricing strategies on reducing the demand for wireless services is discussed in a later section.

9. "The Facts About the Wireless Industry: An Independent Review," CTIA, June 2009.

10. "Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update," Cisco Systems, Inc., January 29, 2009, p. 2. Available online: http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.pdf.

11. Kristin Rinne, Senior Vice President Architecture and Planning, AT&T, Remarks at the FCC Wireless Broadband Workshop, August 13, 2009, p. 6. Available online: http://www.broadband.gov/docs/ws_06_tech_wireless_transcript.pdf.

12. "Critical Mass: The Worldwide State of the Mobile Web," The Nielsen Company, July 2008, p. 3. Available online: http://mmaglobal.com/uploads/NielsenMobile_Mobile%20Internet_Critical%20Mass_ July%202008.pdf.

13. Participants were provided with the following sample calculation which shows how one can derive an estimate of spectrum required to satisfy a given amount of demand. The key other variable is the spectrum efficiency factor. Estimate the number of subscribers in the busiest cell in the busiest period (S). Estimate the average data rate required by each subscriber (D) when active. Estimate the percentage of subscribers that will be active in the busiest period (P). Compute the total data rate (T) required in the cell by multiplying S x D x P. Divide T by the spectrum efficiency factor (E) to obtain the total spectrum capacity required (C). Example: S=1,000, D=1Mbps, F=0.1 then T = 100 Mbps; if E=2.5bps/Hz, then C=25 MHz.

14. "Estimated Spectrum Bandwidth Requirements for the Future Development of IMT-2000 and IMT-Advanced," International Telecommunications Union, Report ITU-M.2078, 2006. Available online: http://www.itu.int/publ/R-REP-M.2078-2006/en.

15. "Mobile Broadband Spectrum Demand," Rysavy Research, December 2008, p. 23-24: "This figure includes 50 MHz of cellular spectrum, 24 MHz in the SMR bands, 120 MHz of broadband PCS spectrum, 90 MHz in the AWS-1 band, 70 MHz in the 700 MHz bands, 195 MHz in the BRS and EBS bands, and 132.425 MHz in the MSS ATC spectrum." Available online: http://www.rysavy.com/Articles/2008_12_Rysavy_Spectrum_Demand_.pdf.

16. Comments of the CTIA – The Wireless Association® NBP Public Notice #6, October 23, 2009, p. 2: "CTIA has asked the Commission to identify and allocate a significant amount of additional spectrum—at least 800 MHz—for licensed commercial wireless use within the next six years." Available online: http://files.ctia.org/pdf/filings/091023_CTIA_Comments_NBP_PN.pdf.

17. "Mobile Broadband Spectrum Demand," Rysavy Research, December 2008, p. 7. Available online: http://www.rysavy.com/Articles/2008_12_Rysavy_Spectrum_Demand_.pdf.

18. Ibid. 14.

19. Comments of the New America Foundation, Public Knowledge and Media Access Project, GN Docket No. 09-51, June 8, 2009, p. 16. The study was a 2004 National Science Foundation study. Available online: http://www.newamerica.net/files/NAF_etal_NationalBroadbandPlan_Comments.pdf.

20. Phil Weiser, "The Untapped Promise of Wireless Spectrum," The Brookings Institution, Discussion Paper, July 2008. Available online: http://www.brookings.edu/papers/2008/07_wireless_weiser.aspx.

21. A qui tam proceeding is one in which someone who discovers, for example fraudulent conduct, shares in any recovered sums.

22. Coleman Bazelon, "The Need for Additional Spectrum for Wireless Broadband: The Economic Benefits and Costs of Reallocations," October 23, 2009.

23. Additional proposals included allowing the broadcasters to simply sell their spectrum and retain some or all of the proceeds and to create an overlay auction of the broadcast spectrum. These ideas are discussed in the section on secondary markets.

24. The process involved several crucial steps, all of which took time. In the Omnibus Budget Reconciliation Act of 1993, Congress directed the Secretary of Commerce to identify at least 200 Mhz of spectrum below 5 GHz for transfer to non-federal government services. An initial evalua-

tion in 1995 indicated that the spectrum in the band 1710 to 1755 could not be cleared completely. See "Seventh Report And Order (FCC 04-246) Amendment Of Part 2 Of The Commission's Rules To Allocate Spectrum Below 3 GHz For Mobile And Fixed Services To Support The Introduction Of New Advanced Wireless Services, Including Third Generation Wireless Systems," October 14, 2004, p. 3. Available online: http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-04-246A1.pdf. But in 2002 the NTIA concluded that this spectrum could be reallocated for commercial use. See the NTIA report, "An Assessment of the Viability of Accommodating Advanced Mobile Wireless (3G) Systems in the 1710-1770 MHz and 2110-2170 MHz Bands," July 22, 2002. Available online: http://www.ntia.doc.gov/ntiahome/threeg/va7222002/3Gva072202web.htm. On September 18, 2006, the FCC auctioned 90 MHz of radio spectrum for AWS, including this 45 MHz in the 1710 MHz to 1755 MHz band that was previously used by federal agencies. Federal government users were relocated pursuant to the Commercial Spectrum Enhancement Act. See "Commercial Spectrum Enhancement Act (CSEA) H.R. 5419," 108th Congress, Title II of P.L. 108-494 section 201 (2004) Public Law 108–494, December 23, 2004. Available online: http://wireless.fcc.gov/services/aws/resources/HR5419.pdf. Their relocation costs were paid for out of a special fund created by this legislation, called the Spectrum Relocation Fund. Auction proceeds were initially deposited in this fund and were used to pay federal entities for relocation. The remaining funds left over after paying relocation costs were transferred to the general fund of the Treasury. The AWS auction raised $13.7 billion. Relocation costs were approximately $1 billion. See "Commercial Spectrum Enhancement Act, Report to Congress on Agency Plans for Spectrum Relocation Funds," Office of Management and Budget, February 16, 2007, p. 3. Available online: http://www.ntia.doc.gov/ reports/2007/OMBSpectrumRelocationCongressionalNotification_final.pdf. Successful bidders were the commercial wireless providers including T-Mobile, Verizon Wireless, SpectrumCo (Sprint and cable partners), MetroPCS, Cingular (now AT&T) and Leap Wireless. See Federal Communications Commission, Top Bidders, Auction of Advanced Wireless Services Licenses, September 20, 2006. Available online: http://wireless.fcc.gov/auctions/default.htm?job=auction_ summary&id=66. One use of the fund was to pay for the Tennessee Valley Authority to convert its system from wireless to landlines.

25. American Library Association v. Federal Communications Commission, No. 04-1037, (D.C. Cir. May 6, 2005).

26. Evan Kwerel and John Williams, "A Proposal for a Rapid Transition to Market Allocation of Spectrum," Office of Plans and Policies, Federal Communications Commission, OPP Working Paper No. 38, November 2002. Available online: http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-228552A1.pdf.

27. Thomas Hazlett, "Tragedy TV: Rights Fragmentation and the Junk Bank Problem," September 29, 2009. Paper for the Information Economy Project Conference on "Tragedies of the Gridlock Economy," George Mason University School of Law, October 2, 2009. Available online: http://mason.gmu.edu/~thazlett/pubs/Hazlett_TragedyTV_Updated093009.pdf.

28. Eli Noam, "The Fourth Way for Spectrum," *Financial Times*, May 29, 2003. Available online: http://www.elinoam.com/eli/fourth_spectrum.pdf. See also Eli Noam, "Spectrum Auctions: Yesterday's Heresy, Today's Orthodoxy, Tomorrow's Anachronism—Taking the Next Step to Open Spectrum Access," 41 Journal of Law & Economics 765 (Oct. 1998).

29. "Mobile Broadband Spectrum Demand," Rysavy Research, December 2008, p. 10: "flat rate pricing plans for modem cards and smartphones have resulted in user acceptance of mobile data and have significantly increased data consumption." Available online: http://www.rysavy.com/Articles/2008_12_Rysavy_Spectrum_Demand_.pdf.

APPENDIX

The Aspen Institute Roundtable on Spectrum Policy

Rethinking Spectrum Policy

November 11-13, 2009
Aspen Wye River Conference Center
Queenstown, Maryland

Conference Participants

Robert Alderfer
Office of Management and Budget

Marvin Ammori
Assistant Professor
and
Faculty Advisor
Space & Telecommunications Law JD/LLM Program
University of Nebraska-Lincoln College of Law

Rebecca Arbogast
Managing Director
Stifel Nicolaus

Paige Atkins
Director, Defense Spectrum Organization
Defense Information Systems Agency

Bill Bailey
Vice President
Government Relations
The Walt Disney Company

Dean Brenner
Vice President, Government Affairs
Qualcomm Incorporated

Mary Brown
Director, Technology and Spectrum Policy
Global Policy and Government Affairs
Cisco Systems

Michael Calabrese
Vice President and Director
Wireless Future Program
New America Foundation

Jonathan Chaplin
Director
Credit Suisse

Susan Crawford
Special Assistant to the President for Science, Technology and Innovation Policy, and
Member of the Staff
National Economic Council
Executive Office of the President

Charles M. Firestone
Executive Director
Communications and Society Program
The Aspen Institute

Note: Titles and affiliations are as of the date of the conference.

Scott Goodwin
Associate General Counsel
National Association of Broadcasters

Richard Green
Former President and Chief Executive Officer
CableLabs

Anoop Gupta
Corporate Vice President
Technology Policy and Strategy
Microsoft Corporation, USA

Dale N. Hatfield
Executive Director
Silicon Flatirons Center
and
Adjunct Professor
University of Colorado at Boulder

Thomas Hazlett
Professor of Law and Economics
George Mason University School of Law

Anna-Maria Kovacs
Founder and President
Regulatory Source Associates, LLC

John Leibovitz
Deputy Bureau Chief
Wireless Telecommunications Bureau
Federal Communications Commission

Amy Levine
Subcommittee Counsel
Subcommittee on Communications, Technology and the Internet
Committee on Energy and Commerce
U.S. House of Representatives

Mark MacCarthy
Adjunct Professor
Communication, Culture and Technology Program
Georgetown University

Joan Marsh
Vice President
Federal Regulatory Affairs
AT&T Services, Inc.

Andrew McLaughlin
Deputy U.S. Chief Technology Officer
Office of Science and Technology Policy
Executive Office of the President

Eli Noam
Director
Columbia Institute for Tele-Information, and
Professor of Finance and Economics
Columbia Business School
Columbia University

Note: Titles and affiliations are as of the date of the conference.

Peter Pitsch
Executive Director,
Communications Policy, and
Associate General Counsel
Intel Corporation

Charla Rath
Executive Director
Spectrum and Public Policy
Verizon Wireless

Roger Sherman
Chief Counsel
Communications and Technology
Policy
Committee on Energy and
Commerce
U.S. House of Representatives

Lawrence E. Strickling
Assistant Secretary for
Communications and
Information
National Telecommunications
and Information Administration
U.S. Department of Commerce

Jennifer Warren
Vice President
Technology Policy and Regulation
Lockheed Martin

William Webb
Head of Research and
Development
Ofcom

Staff:

Sarah Snodgress
Project Manager
Communications and Society
Program
The Aspen Institute

Note: Titles and affiliations are as of the date of the conference.

About the Author

Mark MacCarthy is currently teaching and doing research at Georgetown University's Communication, Culture and Technology Program. He teaches courses on the development of the electronic media, technology policy and Internet freedom. He is also an adjunct member of the Department of Philosophy where he teaches courses in political philosophy and philosophy and privacy. He does research and consults in the areas of information privacy and security, the future of the media, intermediary liability, open standards, electronic and mobile commerce and other technology policy issues.

He was Senior Vice President for Global Public Policy at Visa Inc., responsible for policy initiatives affecting electronic commerce, new technology and information security and privacy. He was a senior manager with the Wexler-Walker Group, a Washington public policy consulting firm, and headed the Washington office of Capital Cities/ABC. His government service includes positions as a professional staff member on the U.S. House of Representative's Committee on Energy and Commerce, where he handled communications policy issues, and as an economist at the U.S. Occupational Safety and Health Administration.

Dr. MacCarthy has a PhD in philosophy from Indiana University and an MA in economics from the University of Notre Dame.

Select Publications from the Aspen Institute Communications and Society Program

Scenarios for a National Broadband Policy, by David Bollier

The report of the 24th Annual Aspen Institute Conference on Communications Policy in Aspen, Colorado, captures the scenario building process that participants used to map four imaginary scenarios of how the economy and society might evolve in the future, and the implications for broadband policy. It identifies how certain trends—economic, political, cultural, and technological—might require specific types of government policy intervention or action. The report also highlights a number of cross-cutting themes and questions that participants believe the Omnibus Broadband Initiative should address. 2010, 52 pages, ISBN Paper: 0-89843-517-X, $12.00

ICT: The 21st Century Transitional Initiative, by Simon Wilkie

The report of the 23rd Annual Aspen Institute Conference on Communications Policy in Aspen, Colorado addresses how the United States can leverage information and communications technologies (ICT) to help stimulate the economy and establish long-term economic growth. The report, written by Roundtable rapporteur Simon Wilkie, details the Aspen Plan, as developed in the summer of 2008, prior to the economic meltdown beginning in September 2008 and prior to the election of Barack Obama as President. The Plan recommends how the Federal Government—through executive leadership, government services and investment—can leverage ICTs to serve the double bottom line of stimulating the economy and serving crucial social needs such as energy efficiency and environmental stewardship. 2009, 80 pages, ISBN Paper: 0-89843-500-5, $12.00

A Framework for a National Broadband Policy, by Philip J. Weiser

While the importance of broadband access to functioning modern society is now clear, millions of Americans remain unconnected, and Washington has not yet presented any clear plan for fixing the problem.

Condensing discussions from the 2008 Conference on Communications Policy and Aspen Institute Roundtable on Spectrum Policy (AIRS) into a single report, Professor Philip Weiser of the University of Colorado at Boulder offers a series of specific and concrete policy recommendations for expanding access, affordability, and adoption of broadband in the United States. 2008, 94 pages, ISBN Paper: 0-89843-484-X, $12.00

The Future of Video: New Approaches to Communications Regulation, by Philip J. Weiser

As the converged worlds of telecommunications and information are changing the way most Americans receive and relate to video entertainment and information, the regulatory regimes governing their delivery have not changed in tune with the times. These changes raise several crucial questions: Is there a comprehensive way to consider the next generation of video delivery? What needs to change to bring about a regulatory regime appropriate to the new world of video? The report of the 21st Annual Conference on Communications Policy in Aspen, Colorado, outlines a series of important issues related to the emergence of a new video marketplace based on the promise of Internet technology and offers recommendations for guiding it into the years ahead. 2006, 70 pages, ISBN Paper: 0-89843-458-0, $12.00

Clearing the Air: Convergence and the Safety Enterprise, by Philip J. Weiser

The report describes the communications problems facing the safety enterprise community and their potential solutions. The report offers several steps toward a solution, focusing on integrating communications across the safety sector on an Internet-Protocol-based backbone network, which could include existing radio systems and thus make systems more dependable during emergencies and reduce costs by taking advantage of economies of scale. The conference participants stressed that the greatest barriers to these advances were not due to lagging technology but to cultural reluctance in adopting recent advances.

Writes Weiser, "The public safety community should migrate away from its traditional reliance on specialized equipment and embrace an integrated broadband infrastructure that will leverage technological innovations routinely being used in commercial sectors and the military." 2006, 55 pages, ISBN Paper: 0-89843-4, $12.00

Reforming Telecommunications Regulation, by Robert M. Entman

The report of the 19th Annual Aspen Institute Conference on Telecommunications Policy describes how the telecommunications regulatory regime in the United States will need to change as a result of technological advances and competition among broadband digital subscriber line (DSL), cable modems, and other players such as wireless broadband providers. The report proposes major revisions of the Communications Act and FCC regulations and suggests an interim transitional scheme toward ultimate deregulation of basic telecommunications, revising the current method for universal service subsidies, and changing the way regulators look at rural communications. 2005, 47 pages, ISBN Paper: 0-89843-428-9, $12.00

Challenging the Theology of Spectrum: Policy Reformation Ahead, by Robert M. Entman

This report examines the theology of spectrum—that is, the assumptions and mythology surrounding its management and use. The report looks at how new technologies affecting spectrum, such as software-defined radio, can challenge the conventional wisdom about how spectrum should be managed. Such innovations allow for access to unused frequency space or time on frequencies that are otherwise licensed to an exclusive user. 2004, 43 pages, ISBN Paper: 0-89843-420-3, $12.00

Spectrum and Network Policy for Next Generation Telecommunications, by Robert M. Entman

The report of the 18th Annual Aspen Institute Conference on Telecommunications Policy offers policy alternatives in both spectrum and network policy to achieve new gains for the telecommunications field. The first essay suggests new management approaches to encourage more efficient uses of spectrum while preserving the commitment to reliability of service and public safety values. The second essay debates the competitive structure of the telecommunications industry and its implications for building next-generation networks (NGN) and identifies three areas to encourage optimal development of the NGN: operate the NGN on a price-deregulated basis and begin to address access regulation issues, secure the intellectual property rights of content suppliers, and adjust the system of subsidized pricing to bring about competitively neutral pricing. 2004, 92 pages, ISBN Paper: 0-89843-394-0, $12.00

Balancing Policy Options in a Turbulent Telecommunications Market, by Robert M. Entman

This report assesses the future of communications regulatory paradigms in light of desirable changes in spectrum policy, telecommunications market environments, and regulatory goals. It suggests four models of regulation, including government allocation, private spectrum rights, unlicensed commons, and a hybrid system of dynamic spectrum access. It also addresses how changes in spectrum and other telecommunications policies, as well as new business realities, might affect current regulatory regimes for the telecommunications industries. The report includes an essay on spectrum management, "The Current Status of Spectrum Management," by Dale Hatfield. 2003, 79 pages, ISBN Paper: 0-89843-370-3, $12.00

Telecommunications Competition in a Consolidating Marketplace, by Robert M. Entman

In the telecommunications world, what would a fully competitive environment look like? What communications initiatives should policymakers develop—considering the ultimate welfare of the consumer—to implement change in the regulatory climate? This report explores ways to reshape the current regulatory environment into a new competitive space. It addresses competition not only within but across separate platforms of communications such as cable, wireline telephony, wireless, satellite, and broadcast. The report also includes an essay on an innovative approach to wireless regulation, "Opening the Walled Airwave," by Eli Noam. 2002, 64 pages, ISBN Paper: 0-89843-330-4, $12.00

Transition to an IP Environment, by Robert M. Entman

This report examines a "layered approach" to regulation. By viewing telecommunications in four separate layers—content, application, network, and data link—policy discussions can address concerns in one layer without negatively affecting useful existing policy in other layers. Also presented are beliefs that the growth of broadband should prompt a new discussion about universal service reform. The report also includes "Thoughts on the Implications of Technological Change for Telecommunications Policy," by Michael L. Katz. 2001, 78 pages, ISBN Paper: 0-89843-309-6, $12.00

Six Degrees of Competition: Correlating Regulation with the Telecommunications Marketplace, by Robert M. Entman

This report addresses basic conceptual questions about what the nature of regulation should be in a competitive, broadband future. It also examines how fundamental policy issues such as interconnection, mergers, spectrum allocation, jurisdiction, universal service, and consumer protection should be handled in the interim. The report also includes "Regulation: The Next 1000 Years," by Michael L. Katz. 2000, 65 pages, ISBN Paper: 0-89843-279-0, $12.00

Reports can be ordered online at *www.aspeninstitute.org/publications* or by sending an email request to *publications@aspeninstitute.org*.

About the Communications and Society Program

www.aspeninstitute.org/c&s

The Communications and Society Program is an active venue for global leaders and experts from a variety of disciplines and backgrounds to exchange and gain new knowledge and insights on the societal impact of advances in digital technology and network communications. The Program also creates a multi-disciplinary space in the communications policy-making world where veteran and emerging decision-makers can explore new concepts, find personal growth and insight, and develop new networks for the betterment of the policy-making process and society.

The Program's projects fall into one or more of three categories: communications and media policy, digital technologies and democratic values, and network technology and social change. Ongoing activities of the Communications and Society Program include annual roundtables on journalism and society (e.g., journalism and national security), communications policy in a converged world (e.g., the future of video regulation), the impact of advances in information technology (e.g., "when push comes to pull"), advances in the mailing medium, and diversity and the media. The Program also convenes the Aspen Institute Forum on Communications and Society, in which chief executive-level leaders of business, government and the non-profit sector examine issues relating to the changing media and technology environment.

Most conferences utilize the signature Aspen Institute seminar format: approximately 25 leaders from a variety of disciplines and perspectives engaged in roundtable dialogue, moderated with the objective of driving the agenda to specific conclusions and recommendations.

Conference reports and other materials are distributed to key policymakers and opinion leaders within the United States and around the world. They are also available to the public at large through the World Wide Web, *www.aspeninstitute.org/c&s.*

The Program's Executive Director is Charles M. Firestone, who has served in that capacity since 1989, and has also served as Executive

Vice President of the Aspen Institute for three years. He is a communications attorney and law professor, formerly director of the UCLA Communications Law Program, first president of the Los Angeles Board of Telecommunications Commissioners, and an appellate attorney for the U.S. Federal Communications Commission.