

**AVOIDING THE SPECTRUM CRUNCH:
GROWING THE WIRELESS ECONOMY
THROUGH INNOVATION**

HEARING
BEFORE THE
SUBCOMMITTEE ON TECHNOLOGY AND INNOVATION
COMMITTEE ON SCIENCE, SPACE, AND
TECHNOLOGY
HOUSE OF REPRESENTATIVES
ONE HUNDRED TWELFTH CONGRESS

SECOND SESSION

WEDNESDAY, APRIL 18, 2012

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**AVOIDING THE SPECTRUM CRUNCH:
GROWING THE WIRELESS ECONOMY
THROUGH INNOVATION**

WEDNESDAY, APRIL 18, 2012

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON TECHNOLOGY AND INNOVATION,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, DC.

The Subcommittee met, pursuant to call, at 2:10 p.m., in Room 2318 of the Rayburn House Office Building, Hon. Benjamin Quayle [Chairman of the Subcommittee] presiding.

RALPH M. HALL, TEXAS
CHAIRMAN

EDDIE BERNICE JOHNSON, TEXAS
RANKING MEMBER

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

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Subcommittee on Technology and Innovation Hearing

*Avoiding the Spectrum Crunch:
Growing the Wireless Economy through Innovation*

Wednesday, April 18, 2012

2:00 p.m. -- 4:00 p.m.

2318 Rayburn House Office Building

Witnesses

Dr. James Olthoff, Deputy Director, Physical Measurement Laboratory, National Institute of Standards and Technology

Mr. Richard Bennett, Senior Research Fellow, Information Technology and Innovation Foundation

Mr. Christopher Guttman-McCabe, Vice President, Regulatory Affairs, CTIA—The Wireless Association

Ms. Mary Brown, Director, Technology and Spectrum Policy, Cisco Systems, Inc.

Dr. Rangam Subramanian, Chief Wireless and Technology Strategist, Idaho National Laboratory

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON TECHNOLOGY AND INNOVATION

HEARING CHARTER

Avoiding the Spectrum Crunch: Growing the Wireless Economy through Innovation

Wednesday, April 18, 2012
2:00 p.m. – 4:00 p.m.
2318 Rayburn House Office Building

I. Purpose

On Wednesday, April 18, 2012, the Committee on Science, Space, and Technology Subcommittee on Technology and Innovation will hold a hearing to review efforts supporting the flexible and innovative utilization of spectrum, while ensuring the continued growth of the wireless economy.

II. Witnesses

Dr. James Olthoff, Deputy Director, Physical Measurement Laboratory, National Institute of Standards and Technology

Mr. Richard Bennett, Senior Research Fellow, Information Technology and Innovation Foundation

Mr. Christopher Guttman-McCabe, Vice President, Regulatory Affairs, CTIA—The Wireless Association

Ms. Mary Brown, Director, Technology and Spectrum Policy, Cisco Systems, Inc.

Dr. Rangam Subramanian, Chief Wireless and Technology Strategist, Idaho National Laboratory

III. Background

Spectrum is a range of frequencies, divided into blocks or bands of frequencies that are “allocated” for particular services. Spectrum supports a wide variety of radio services, including public safety, defense, navigation, broadcasting, as well as both commercial and private wireless communications. These services are vital to our economy and to jobs—virtually every industry and business depends on spectrum for efficiency and competitiveness. As Thomas Power of the

National Telecommunications and Information Administration states, spectrum is “fast becoming a pillar of America’s digital infrastructure.”¹

Maximizing the yield from this essential 21st century resource will create jobs, drive economic growth, and encourage innovation, and investment.² Since spectrum is a finite resource, the purpose of spectrum policy, law, and regulation is continuing to accommodate new services without disrupting services while providing the maximum possible benefit to the public.³

Spectrum is best described as a natural resource that exhibits some of the properties of what economists call an unusual “common good,”⁴ because it is not destroyed by use—instead when one user stops using a portion, it can be readily used by another. However, spectrum use is limited by its scarcity because, at any given time and place, use of one portion precludes another user from using that same portion.⁵ As a result of this characteristic, the use of spectrum must be regulated—with controlled access and rules for use—because unchecked use raises the possibilities of uncoordinated use and resulting interference.⁶

The use of the electromagnetic spectrum in the United States is managed using a dual organizational structure. Understanding the Federal Government’s use of spectrum requires an understanding of the interplay between Federal and non-Federal use of the same spectrum. The Federal Communications Commission (FCC) manages all commercial, and state and local government spectrum use.⁷ The National Telecommunications and Information Administration (NTIA) manages the Federal Government’s use.⁸ All spectrum allocations stem from agreements between NTIA and the FCC. In other words, there are no statutory “Federal” or “non-Federal” bands.

Federal Communications Commission (FCC)

The Federal Communications Commission (FCC) is an independent federal regulatory agency responsible directly to Congress. Established by the Communications Act of 1934, it is charged with regulating interstate and international communications by radio, television, wire, satellite, and cable. The FCC oversees the spectrum bands that facilitate the use of wireless communications by commercial interests, as well as state and local governments. The agency’s spectrum goals include ensuring that all wireless operations co-exist; that public safety communications are effective; that innovative and modern services are provided to the public; and that access to spectrum results from open and transparent processes. The FCC regulates the

¹ Thomas Power, National Telecommunications and Information Administration, Remarks at the 12th Annual International Symposium on Advanced Radio Technologies (July 28, 2011), available at <http://www.ntia.doc.gov/speechtestimony/2011/remarks-ntia-chief-staff-thomas-power-12th-annual-isart-conference>.

² Federal Communications Commission, Our Work, <http://www.fcc.gov/our-work> (last visited on April 13, 2012).

³ CHARLES MATHIAS, SPECTRUM STRATEGY 6 (2011), available at www.gao.org/news/Mathias_Spectrum%20Strategy.pdf; LINDA K. MOORE, CONGRESSIONAL RESEARCH SERVICE, SPECTRUM POLICY IN THE AGE OF BROADBAND: ISSUES FOR CONGRESS 4 (2012).

⁴ A common good meaning “[o]ther than the cost of designing, building, and operating radio stations, its use is free. Each user has no incentive to individually use the spectrum efficiently since there is no savings, and is, in fact, motivated to secure for his own use the maximum amount of spectrum. However, uncoordinated, wasteful use can easily result in everyone suffering interference, that prevents satisfactory operation, and denies access to new users.” National Telecommunications and Information Administration, Basic Elements of Spectrum Management: Regulating the Use of the Spectrum, <http://www.ntia.doc.gov/legacy/osmbome/roosa3.html> (last visited on April 13, 2012).

⁵ National Telecommunications and Information Administration, Basic Elements of Spectrum Management: Regulating the Use of the Spectrum, <http://www.ntia.doc.gov/legacy/osmbome/roosa3.html> (last visited on April 13, 2012).

⁶ *Ibid.*

⁷ See 47 U.S.C. §151.

⁸ See 47 U.S.C. §902.

use of radio frequency bands of the electromagnetic spectrum by a spectrum management process called frequency allocation. The FCC is also responsible for administering spectrum auctions, the funds from which are paid to the U.S. Treasury.

National Telecommunications and Information Administration (NTIA)

The National Telecommunications and Information Administration (NTIA) of the U.S. Department of Commerce was established in 1978. The NTIA is the President's principal advisor on telecommunications and information policy issues, and in this role frequently works with other Executive Branch agencies to develop and present the Administration's position on telecommunications and information policy issues. In addition to representing the Executive Branch in both domestic and international telecommunications and information policy activities, NTIA also manages the Federal Government use of spectrum; performs cutting-edge telecommunications research and engineering, including resolving technical telecommunications issues for the Federal Government and private sector; and administers infrastructure and public telecommunications facilities grants.⁹

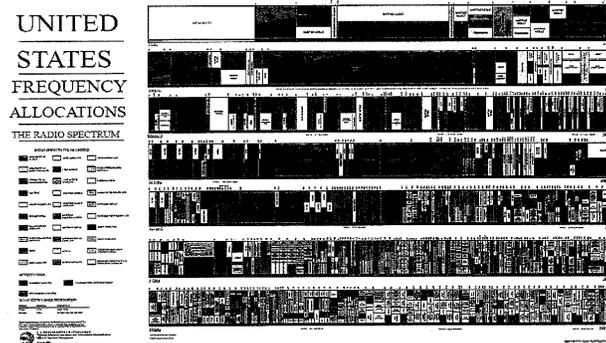


Figure 1. The United States Frequency Allocation Chart.
http://www.ntia.doc.gov/files/ntia/publications/spectrum_wall_chart_aug2011.pdf

Government Spectrum Usage

The Federal Government uses spectrum to provide critical public services, and seeks to deploy the most efficient technology consistent with available resources. The Department of Defense (DOD) uses a significant portion of the Federal Government spectrum for national security

⁹ See National Telecommunications and Information Administration, About NTIA, <http://www.ntia.doc.gov/about> (last visited April 16, 2011).

purposes. The law enforcement agencies (e.g., Department of Homeland Security, Justice, Treasury, and Interior Departments) use spectrum for command and control of their forces, just as state and local police and fire departments do, with the exception that they must be able to operate throughout the United States. The Federal Aviation Administration uses it for safety services such as aeronautical radio navigation, precision landing systems for all weather operations, surveillance, and air/ground communications. The Department of Energy uses it to transmit power control data and commands for their dams and power grids. The National Aeronautics and Space Administration uses Federal spectrum during satellite launches for communications with satellites to collect data and command them.

In understanding the Federal Government's use of the spectrum, one must appreciate the interplay between Federal government and non-Federal government use of the same spectrum. In addition to the shared use of the same sections of spectrum for unrelated purposes, there is a substantial interface between government and non-government radio operations. Government radio facilities provide private sector ships and aircraft communications, navigation, and surveillance service; Federal law enforcement agencies have intercommunication with their state and local government counterparts; Federal electrical power systems interconnect with non-Federal power systems, both domestic and international; Civil Air Patrol stations communicate with the military, and so forth.

Public Safety

Prior to September 11, 2001, states and municipalities were largely responsible for first responders' emergency communications and providing effective response. However, long before 9/11, as radio technologies evolved, the awareness for better coordination and communications interoperability heightened.¹⁰ Assigning spectrum for public safety wireless communications is a responsibility of the FCC; however, the ultimate decision regarding how spectrum access is to be divided has yet to be made. Some municipalities and states could develop commercial partnerships providing access to public safety spectrum in return for various resources, such as access to infrastructure or lease payments. Alternatively, the monetary value of spectrum access may be derived from commercial license auctions. Some proposals, including legislation introduced in the 112th Congress,¹¹ designate all or part of spectrum auction proceeds to funding public safety communications investments and operating costs. Proceeds would be deposited in a special fund, allowing grant administrators to borrow against anticipated future revenue so that grants could be provided immediately. Twice, Congress has created special funds to receive and distribute revenue from spectrum auctions for specific purposes,¹² which departs from existing law requiring that auction proceeds be credited directly to the Treasury as income.¹³

The end of analog television broadcasting freed up some spectrum for public safety use. Public safety agencies have announced the intention to combine portions of spectrum already assigned

¹⁰ See FROST & SULLIVAN, INTEROPERABLE COMMUNICATIONS FOR FIRST RESPONDERS 2 ("The challenge of interoperable communications for first responders was first addressed in 1970 when the FIRESCOPE Incident Command System was developed in Southern California as a result of a catastrophic wild fire.")

¹¹ S. 28 (Rockefeller), S. 1040 (Lieberman), S. 911, as amended (Rockefeller), and H.R. 607 (King).

¹² The Deficit Reduction Act of 2005 (P.L. 109-171, Title III) established the Digital Television Transition and Public Safety Fund to receive this auction revenue and use some of the proceeds for the transition to digital television, public safety communications, and other programs. The Commercial Spectrum Enhancement Act (P.L. 108-494, Title II) established a Spectrum Relocation Fund to hold the proceeds of certain spectrum auctions for the specific purpose of reimbursing federal entities for the costs of moving to new frequency assignments.

¹³ 47 U.S.C. 309 (j) (3) (A)

for public safety use, known as the Public Safety Broadband License, to build a nationwide broadband network(s). The Public Safety Spectrum Trust (PSST), a not-for-profit corporation, originally granted the FCC the spectrum access that became the Public Safety Broadband License.¹⁴

The Middle Class Tax Relief and Job Creation Act of 2012 (P.L. 112-96) gave NTIA the new responsibility of creating and supporting a First Responder Network Authority, responsible for planning, building, and managing a new, nationwide broadband network for public safety communications. Together NTIA and the First Responder Network Authority must establish the grant program requirements for a State and Local Implementation Fund, while NTIA will determine the grant amounts for states participating in the network.

As part of this effort, the National Institute of Standards and Technology (NIST) will work with NTIA, the First Responder Network Authority, private industry, and public safety organizations to conduct research and develop new standards, technologies, and applications to advance public safety communications. Core components of this program will include documenting public safety requirements and driving the adoption of those requirements into the appropriate standards; developing the capability for communications between currently deployed public safety narrow band systems and the future nationwide broadband network; and establishing a roadmap that seeks to capture and address public safety's needs beyond what can be provided by the current generation of broadband technology and driving technological progress in that direction. The Middle Class Tax Relief and Job Creation Act allocates up to \$300 million to NIST, dependent on the funds received from future spectrum auctions, to be spent through FY 2022.

Commercial Spectrum Usage and the "Spectrum Crunch"

There has been extreme growth in the number of active frequency authorizations at both NTIA and the FCC; at both agencies, there are twice as many assignments now as there were in 1980. As spectrum becomes more crowded, efforts to ensure that spectrum is used as efficiently as possible to maximize its availability and use by all become more urgent. Until recently, advanced technology has always kept slightly ahead of the demand for spectrum. As demand for spectrum increased, technology has developed that can perform the same function at higher unused frequencies or increase spectrum efficiency and re-use of existing frequencies. Now, as demand for spectrum is growing more rapidly, the technical advances needed to meet that demand may be "pushing the envelope" of practicality, at least in the short term.

Mobile data traffic has increased at an exponential rate over the last several years as the use of Wi-Fi networks and smart phones has proliferated. According to the Cisco Visual Networking Index Global Mobile Data Traffic Forecast, the amount of mobile data traffic more than doubled for the fourth year in a row in 2011.¹⁵ In fact, global mobile data traffic in 2011 was more than eight times larger than *total* Internet data traffic (both mobile and non-mobile) in 2000.¹⁶ Much

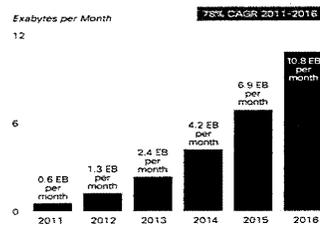
¹⁴ See Public Safety Spectrum Trust, <http://www.psst.org/about.jsp> (last visited April 13, 2012).

¹⁵ Cisco, Cisco Visual Networking Index (VNI) Global Mobile Data Traffic Forecast Update, 2011-2016 4 Feb. 14, 2012, available at http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.pdf.

¹⁶ *Ibid.*

of this massive data growth is due to the increase of video data traffic, which accounted for over 50 percent of data traffic in 2011 for the first time.¹⁷

Cisco projects global mobile data traffic to grow to 10.8 exabytes per month in 2016, which would be 18 times the amount of usage in 2011.¹⁸ Similarly, according to Cisco projections, North American mobile data traffic would increase 16.5 times from 119 petabytes per month in 2011 to 2.0 exabytes per month in 2016.



Source: Cisco VNI Mobile 2012.
 Figure 2. Global Mobile Data Traffic, 2011 to 2016. Image excerpted from the Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2011–2016.
http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.html

The FCC currently allocates a limited amount of spectrum for mobile broadband usage. A 2010 FCC paper projected that there would be a broadband spectrum deficit of 300 megahertz by 2014, based on an analysis of current and projected data usage.¹⁹ This projected shortage has implications for service quality, cost, and innovation. As a result, the FCC's National Broadband Plan recommended that 500 megahertz be made available for mobile, fixed and unlicensed broadband over the next 10 years to meet projected growth in demand.²⁰

¹⁷ *Ibid.*

¹⁸ *Ibid.*

¹⁹ Federal Communications Commission OBI Technical Paper Series, *Mobile Broadband: The Benefits of Additional Spectrum*, October 2010. http://transition.fcc.gov/Daily_Releases/Daily_Business/2010/db1021/DOC-302324A1.pdf.

²⁰ Federal Communications Commission, *National Broadband Plan, Connecting America*.

<http://www.broadband.gov/plan/5-spectrum/#r5-8>.

IV. Issues for Examination

Policy Challenges

Given continued growth projections and spectrum's finite nature, additional allocations of spectrum will only address the "spectrum crunch" for an indefinite period of time. Smartphone sales have eclipsed PC sales, and mobile broadband is being adopted faster than any computing platform in history. A smartphone places 24 times as much demand on spectrum as an old feature phone. A tablet device places 120 times as much demand on spectrum. According to the FCC, multiple experts agree that mobile demand for spectrum will increase more than 35 times in the next few years (3,500%).

The amount of additional spectrum needed due to the increased demand created by mobile broadband could be difficult to achieve through the auction process unless large amounts of new radio frequencies can be identified and released for that purpose. Without abandoning competitive auctions, spectrum policy could benefit from including additional ways to assign or manage spectrum that might better serve the deployment of wireless broadband and the implementation of a national broadband policy. Policies to provide additional spectrum for fixed or mobile broadband services are generally viewed as drivers that would stimulate technological innovation and economic growth. A policy that prioritizes providing spectrum to spur innovation, for example, could create new markets, new models for competition, and new competitors.

As industry leaders and policy makers seek ways to more effectively utilize spectrum, they will need to be cognizant of potential challenges as spectrum use becomes more crowded. This crowding may affect applications and services on neighboring blocks of spectrum. It may also affect the growth of unlicensed, localized spectrum use such as household Wi-Fi networks and wireless health applications. Research and development will be necessary to find ways to minimize interference among both neighboring blocks of spectrum and shared spectrum.

Research and Development

Although radio frequency spectrum is abundant, usable spectrum is currently limited by the constraints of technology. Developments in technology will be necessary to provide more lasting solutions to the spectrum crunch. At any given location or time, much of the spectrum is "unused". Research into dynamic spectrum access, or "opportunistic use," has the potential to organize wireless communications to achieve the same kinds of benefits that have been seen to accrue with the transition from proprietary data networks to the Internet. Adaptive technologies could allow communications to switch instantly among network frequencies that are not in use to maximize network performance.

In June 2010, the President issued a memorandum titled: *Unleashing the Wireless Broadband Revolution*.²¹ The memorandum called upon the Secretary of Commerce to "create and implement a plan to facilitate research, development, experimentation, and testing by researchers

²¹ Presidential Memorandum: Unleashing the Wireless Broadband Revolution (June 10, 2010), available at <http://www.whitehouse.gov/the-press-office/2010/06/10/presidential-memorandum-unleashing-wireless-broadband-revolution>.

to explore innovative spectrum-sharing technologies....” The National Information Technology Research and Development (NITRD) Wireless Spectrum R&D (WSRD) Senior Steering Group (SSG) was formed in response to this charge, to coordinate spectrum-related research and development activities across the Federal Government. The purpose of the WSRD SSG is twofold: to help coordinate and inform ongoing activities across Federal agencies; and to facilitate the identification of shortcomings in the Government’s R&D portfolio with respect to technologies that allow a more efficient use of spectrum.

The WSRD SSG has identified spectrum R&D activities at the following Federal agencies: the Department of Commerce, the Department of Defense (includes each military department’s R&D activities, and DARPA), the Department of Energy, the Department of Homeland Security, the Department of Justice, the Federal Aviation Administration, the FCC, the NTIA, the National Aeronautics and Space Administration, and the National Science Foundation. Research focus areas include dynamic mechanisms to share spectrum; wireless test beds; simulation tools relevant to spectrum efficiency, access, and sharing; systems and models to transition from legacy architectures to new spectrum sharing architectures; hardware, protocols, and policy; and research into the security of spectrum-sharing technologies.

The WSRD SSG has highlighted the importance of coordinating Federal spectrum R&D with private industry, and works with academia and the private sector to help develop priorities, encourage private investment, and develop public/private partnerships when appropriate.

Chairman QUAYLE. The Subcommittee on Technology and Innovation will come to order. Good afternoon. Welcome to today's hearing entitled, "Avoiding the Spectrum Crunch: Growing the Wireless Economy through Innovation." In front of you are packets containing the written testimony, biographies, and truth in testimony disclosures for today's witnesses.

I now recognize myself for five minutes for an opening statement.

In today's hearing, we are going to be reviewing efforts to ensure the innovative use of spectrum and the continued expansion of the wireless economy. This Subcommittee is uniquely positioned to address issues facing high-growth industries, and today's hearing is a continuation of our series focused on advancing U.S. innovation.

The U.S. wireless industry has been experiencing exponential growth. There are entirely new jobs and sectors of our economy, like the app market, that we never envisioned a few years ago. Our wireless industry is the most competitive and innovative in the world, in part because it has been able to operate under flexible, market-driven policies unfettered from excessive government intervention. These policies encourage mobile companies to compete by providing innovative, user-friendly services and offering consumers the best possible experience. Thanks to a cycle of innovation and competition, U.S. consumers win.

In recent years the number of active spectrum frequency authorizations at both the Federal Communications Commission and the National Telecommunications and Information Administration, has dramatically increased. In fact, at both agencies there are twice as many spectrum assignments now as there were in 1980.

As spectrums become more crowded, it is necessary to ensure that it is being used as efficiently as possible and that we have the policies in place to encourage industry's continued investment in growth. Maximizing the yield and availability from this essential resource will continue to help create jobs and encourage innovation.

The U.S. wireless economy has experienced tremendous growth. The subscriber connections growing from 38.2 million in 2006, to 322.9 million in 2011. Growth in data traffic has been even greater as modern devices such as smartphones and tablets are much more data intensive. This massive data growth exacerbates the strain on spectrum availability.

Advances in technology have always kept ahead of the demand for spectrum, but now as demand for spectrum is growing more rapidly, the technical advances needed may be pushing the envelope of practicality, at least in the short term.

To ensure the future growth of this dynamic sector, it is imperative that research and development efforts continue to identify more effective ways to utilize spectrum. We also need to ensure that government policies are not creating impediments and that we are creating an environment where companies will continue to invest in new technologies.

Our hearing today should highlight specific efforts by both the Federal Government and industry to address the spectrum challenges within our Subcommittee's jurisdiction and to enable the continued growth of the wireless economy through innovation.

We thank our witnesses for being here today, and we look forward to your testimony.

[The prepared statement of Mr. Quayle follows:]

PREPARED STATEMENT OF SUBCOMMITTEE CHAIRMAN DAN QUAYLE

Good afternoon. I would like to welcome everyone to today's hearing, which is being held to review efforts to ensure the innovative use of spectrum and the continued expansion of the wireless economy. This Subcommittee is uniquely positioned to address issues facing high-growth industries, and today's hearing is a continuation of our series focused on advancing U.S. innovation.

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We thank our witnesses for being here today and we look forward to your testimony.

Chairman QUAYLE. I now recognize the gentlelady from Maryland, the Ranking Member, Ms. Edwards, for her opening statement.

Ms. EDWARDS. Thank you, Mr. Chairman, and thank you for calling this hearing on the ways that we can address the impending spectrum crunch. I want to thank the witnesses in advance for your testimony today.

The United States has long been a leader in information and communications technologies, with the majority of the top firms being American companies. However, in a sector that is all about the next big innovation, we can't afford to rest on our past accomplishments. Wireless broadband is expected to trigger the next wave of innovation and holds enormous potential to create high-quality jobs and economic growth.

For example, one estimate shows that providing an additional 300 megahertz of spectrum to wireless broadband uses will gen-

erate 300,000 new jobs and \$230 billion in GDP within five years. Advances in wireless technologies also hold the promise to benefit the public. For example, the use of mobile technologies for patient monitoring is expected to vastly improve the quality of patient care and reduce health care costs by as much as \$6 billion by 2014.

Smartphones, tablets, and other mobile devices are already part of our everyday lives. Consumers and businesses have learned to expect access to information at anytime from anywhere. This demand has resulted in the rapid growth of wireless data flowing across our networks. In fact, the amount of wireless traffic has increased by more than 100 percent in the last year alone, and that demand is expected to rise by a factor of 20 by 2015.

The only way to accommodate this growing demand is to increase the amount of spectrum available for wireless services. The incentive auctions authorized in the *Middle Class Tax Relief and Job Creation Act of 2012* will help to free up some of this valuable spectrum.

However, if the United States wants to continue to lead the wireless revolution, then we have to make more efficient use of our spectrum. Advances in research and development are central to the goal of freeing up spectrum for wireless broadband. Spectrum is a finite resource, and in order to improve its use, we need to develop innovative spectrum-sharing technologies that allow multiple users to share the same slice of spectrum without interference or degradation of services.

Imagine a mobile device that has the ability to scan across a spectrum, identify frequencies that are currently available or not in use, and send its communication without delay. Spectrum could be fully and effectively utilized under this type of dynamic system, but it is only possible through advances in research, development, and testing.

I look forward to hearing from our witnesses today about the Nation's wireless test bed capabilities, our current research and development needs, and what the Federal Government is or can be doing to accelerate the efficient use of spectrum and the development of innovative wireless technologies.

I am also interested in hearing more about NIST's plans for the development of a nationwide interoperable Public Safety Broadband Network. I am pleased to see that the role for NIST that Ranking Member Johnson and I supported and advocated for in the creation of an advanced wireless communication system for our first responders in H.R. 3642 was included in the *Middle Class Tax Relief and Job Creation Act*.

I look forward to working with NIST and to make sure that this effort is successful and that our first responders have the broadband network they need to keep us safe.

We need to ensure that the United States remains a leader in information technology, and wireless broadband is key to making this happen. The United States ranked ninth out of the OECD countries in relation to wireless broadband access. We need to do all that we can to ensure that the global wireless revolution grows from American innovations and benefits American companies and the American people.

Thank you, Mr. Chairman, for calling this hearing, and I yield the balance of my time.

[The prepared statement of Ms. Edwards follows:]

PREPARED STATEMENT OF SUBCOMMITTEE RANKING MEMBER DONNA F. EDWARDS

Mr. Chairman, thank you for calling this hearing on ways to address the impending spectrum crunch. And thank you to the witnesses for being here today.

The U.S. has long been a leader in information and communication technologies, with the majority of the top firms being American companies. However, in a sector where it is all about the next big innovation, we can't afford to rest on our past accomplishments. Wireless broadband is expected to trigger the next wave of innovation and holds enormous potential to create high-quality jobs and economic growth. For example, one estimate shows that providing an additional 300 megahertz of spectrum to wireless broadband uses will generate 300,000 new jobs and \$230 billion in GDP within five years.

Advances in wireless technologies also hold the promise to benefit the public. For example, the use of mobile technologies for patient monitoring is expected to vastly improve the quality of patient care and reduce health care costs by as much as \$6 billion by 2014.

Smartphones, tablets, and other mobile devices are already a part of our everyday lives. Consumers and businesses have learned to expect access to information at anytime from anywhere. This demand has resulted in the rapid growth of wireless data flowing across our networks. In fact, the amount of "wireless traffic" has increased by more than 100 percent in the last year alone and that demand is expected to rise by a factor of 20 by 2015. The only way to accommodate this growing demand is to increase the amount of spectrum available for wireless services.

The incentive auctions authorized in the *Middle Class Tax Relief and Job Creation Act of 2012* will help to free up some of this valuable spectrum. However, if the U.S. wants to continue to lead the "wireless revolution," then we have to make more efficient use of our spectrum.

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I am also interested in hearing more about NIST's plans for the development of a nationwide, interoperable public safety broadband network. I am pleased to see that the role for NIST that Ranking Member Johnson and I supported and advocated for in the creation of an advanced wireless communications system for our first responders in H.R. 3642 was included in the *Middle Class Tax Relief and Job Creation Act*. I look forward to working with NIST to make sure that this effort is successful and that our first responders have the broadband network they need to keep us all safe.

We need to ensure that the U.S. remains a leader in information technology, and wireless broadband is the key to making this happen. The U.S. is ranked ninth out of the OECD countries in relation to wireless broadband access. We need to do all that we can to ensure that the global "wireless revolution" grows from American innovations and benefits American companies.

Thank you, Mr. Chairman for calling this important hearing. I yield back the balance of my time.

Chairman QUAYLE. Thank you, Ms. Edwards.

At this time, I would like to introduce our witnesses, and then we will proceed to hear from each of them in order. Our first witness is Dr. James Olthoff, Deputy Director of the Physical Measurement Laboratory at the National Institute of Standards and

Technology. Dr. Olthoff has been with NIST for over 20 years, and as deputy director he is responsible for the oversight of all calibration services at NIST.

Next we will hear from Mr. Richard Bennett, who is a Senior Research Fellow at the Information Technology and Innovation Foundation. Mr. Bennett has extensive experience in network engineering and is the inventor of four networking patents.

Our third witness is Mr. Christopher Guttman-McCabe, Vice President of Regulatory Affairs at CTIA–The Wireless Association. Mr. Guttman-McCabe’s experience in the telecommunication field comes from work in regulatory mandates, licensing, compliance, and general policy matters.

Our fourth witness is Ms. Mary Brown, Director of Technology and Spectrum Policy for Cisco Systems. Ms. Brown handles Cisco’s policies surrounding IP-based technologies, wireless, and networking, and she has expertise in telecommunications issues and Internet law and policy.

Our final witness is Dr. Rangam Subramanian. Did I get that close? Chief Wireless and Technology Strategist at Idaho National Laboratory. Dr. Subramanian also serves on the National Information Technology Research and Development Senior Steering Group on wireless spectrum sharing research and development.

Thank you again to all of our witnesses for being here this morning. As our witnesses should know, spoken testimony is limited to five minutes each. After all witnesses have spoken, Members of the Committee will have five minutes each to ask questions.

I now recognize our first witness, Dr. James Olthoff, for five minutes.

**STATEMENT OF DR. JAMES OLTHOFF, DEPUTY DIRECTOR,
PHYSICAL MEASUREMENT LABORATORY,
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY**

Dr. OLTHOFF. Thank you. Chairman Quayle, Ranking Member Edwards, Members of the Subcommittee. My name is Dr. James Olthoff. I am the Deputy Director of the Physical Measurement Laboratory at the National Institute of Standards and Technology. Thank you for the invitation to testify before you today on what has come to be called the “spectrum crunch,” and what NIST is doing to advance innovation in wireless communications.

Mr. Chairman, the Administration understands the critical need to ensure that sufficient spectrum is available for wireless services. In 2010, the President directed the Department of Commerce, through NTIA and working with the FCC and affected federal agencies, to make available for commercial wireless use an additional 500 megahertz of federal and non-federal spectrum at frequencies near current cell phones bands.

Let me briefly discuss some of the research activities underway at NIST related to the spectrum crunch issue.

NIST recently launched a five-year program to provide industry with the new, sufficiently precise measurement methods and the channel measurement data it needs to lead internationally in the development of innovative millimeter-wave wireless technologies.

While the technical challenges to mobile communications at millimeter-wave frequencies are great, the benefits of utilizing this large bandwidth at millimeter-wave frequencies cannot be ignored. This new program will support industry with new tools for use in developing mobile millimeter-wave wireless systems. NIST innovation and expertise applied to the challenges of higher-speed wireless will offer new metrology so that U.S. industry can realize effective utilization of the entire millimeter-wave region.

NIST is familiar with the needs of current U.S. telecommunications industry through its interactions with the Cellular Telecommunication Industry Association Certification Programs. Additionally, NIST is leveraging recent funding from DARPA, with whom we are developing improved oscilloscope-based techniques to characterize millimeter-wave receivers and also investigating the use of reverberation chambers for the testing of radiated power.

We are also leveraging our interactions with the IEEE on standards for 60 gigahertz systems. This work will accelerate the modeling, design, verification, standardization, and interoperability of mobile millimeter-wave wireless systems of the future, positioning the United States at the forefront of the competitive telecommunications industry.

The ability to measure and also model components, circuits, and entire systems at higher frequencies and bandwidths will provide tools for more economical wireless system development that can take advantage of this new spectrum.

In addition to more precise high-frequency measurements, NIST is also looking at challenges related to radio frequency measurements and the spectrum crunch, particularly electromagnetic compatibility and interference issues. Work at NIST develops and promotes electromagnetic measurements, standards, and technology to support a broad range of technical needs. NIST programs focus on accurate and reliable measurements throughout the radio spectrum, in particular, radio and microwave frequencies.

We carry out these programs in close coordination with our colleagues in industry, academia, and other government agencies, such as NTIA, the Departments of Defense, Energy, and Homeland Security to ensure that we are responsive to their most pressing measurement needs. One of our primary goals is to extend new measurement tools and theories to higher operating frequencies, wider signal bandwidth, and smaller length scales. These are required for next-generation applications in microelectronics, high-speed communications, computing, and data storage.

The President has recognized the need for further investments in this area. In the fiscal year 2013 budget request for NIST, the President proposed a \$10 million Advanced Telecommunications Initiative that would accelerate innovation in advanced telecommunications. This request would provide funds for NIST modeling and measurement science that would address key areas to enable significant innovation and communications in both the commercial and public safety sectors.

Finally, the recently-enacted *Middle Class Tax Relief and Job Creation Act of 2012* contains a provision very similar to that envisioned by the President's National Wireless Initiative that would

provide NIST with up to \$300 million to help develop cutting-edge technology for public safety users.

The overriding objective of this anticipated funding is to build a broadband system to allow first responders and other public safety personnel anywhere in the Nation to send and receive data, voice, and other communications to save lives, prevent casualties, and avert acts of terror. Such improvements depend upon advances in measurement science, modeling standards, and testing.

The technological challenges that stand in the way are significant. Public safety considerations impose demanding specifications, including mission-critical voice services, enhanced security requirements, unique applications, and specialized testing needs.

In conclusion, NIST is leveraging its expertise in measurement science and standards in a number of areas to help improve the effectiveness of wireless communications in the United States. NIST will continue to work with partners across the Federal Government, academia, and industry to drive technological innovations that will enable U.S. manufacturers to maintain their leadership in wireless telecommunications.

Thank you. I would be happy to answer any questions you may have.

[The prepared statement of Dr. Olthoff follows:]

Testimony of

**Dr. James Olthoff
Deputy Director
Physical Measurement Laboratory
National Institute of Standards and Technology
U.S Department of Commerce**

before the

**Subcommittee on Technology and Innovation
Committee on Science, Space, and Technology
United States House of Representatives**

**Avoiding the Spectrum Crunch: Growing the Wireless
Economy through Innovation**

April 18, 2012

Chairman Quayle, Ranking Member Edwards, members of the Subcommittee, my name is Dr. James Olthoff. I am the Deputy Director of the Physical Measurement Laboratory (PML) at the National Institute of Standards and Technology (NIST) of the United States Department of Commerce. Thank you for the invitation to testify before you today on the so-called "spectrum crunch," and what NIST is doing to advance innovation in wireless communications. The Federal Communications Commission (FCC) website defines "spectrum crunch" in the context of mobile broadband as follows: "demand for mobile broadband service is likely to outstrip spectrum capacity in the near-term."¹ NIST's efforts, in collaboration with other Federal partners such as the National Telecommunications and Information Administration (NTIA) of the Department of Commerce, are helping to drive innovation here at home, thereby helping U.S. manufacturers and industries succeed on the global playing field.

The President and Secretary of Commerce John Bryson are committed to pursuing policies that promote innovation in the use of spectrum through research and development. The President has stated, "This new era in global technology leadership will only happen if there is adequate spectrum available to support the forthcoming myriad of wireless devices, networks, and applications that can drive the new economy."² The projects and activities about which I will testify today share a common theme of accelerating innovation for the benefit of U.S. manufacturers and consumers in the wireless telecommunications sector.

NIST's mission is to promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life.

I am pleased to discuss today NIST's efforts to address the "spectrum crunch," as well as related activities impacting the wireless space.

Overview

In a February 2012 Report, *The Economic Benefits of New Spectrum For Wireless Broadband*, the President's Council of Economic Advisors states, "the only feasible way to realize the full potential of wireless broadband is to make new spectrum available for wireless services."³ The Chairman of the Federal Communication Commission (FCC) echoes this concern, stating, "The biggest threat to the future of mobile in America is the looming spectrum crisis."⁴

The United States is at a technological crossroads that is unique in our lifetimes: The FCC has recently allocated spectrum at frequencies in the 70, 80 and 90 GigaHertz (GHz) range that is thirty times the total cellular bandwidth available today. Concurrently, semiconductor processing advancements have, for the first time, enabled inexpensive silicon radio chips that operate above 50 GHz.

¹ <http://www.fcc.gov/encyclopedia/spectrum-crunch>

² <http://www.whitehouse.gov/the-press-office/presidential-memorandum-unleashing-wireless-broadband-revolution>

³ http://www.whitehouse.gov/sites/default/files/cea_spectrum_report_2-21-2012.pdf at 2.

⁴ Cellular Telecommunications Industry Association Keynote, October 2009

President Obama understands the critical need to ensure sufficient spectrum is available for wireless services – to drive economic growth, create jobs, promote innovation, support federal agencies’ missions, and improve public safety. In 2010, the President directed the Department of Commerce, through NTIA and working with the FCC and affected Federal agencies, to make available for commercial wireless use an additional 500 MHz of federal and non-federal spectrum. Additionally, the President’s National Wireless Initiative – much of it enacted as part of the Middle Class Tax Relief and Job Creation Act – invests in NIST’s cutting-edge wireless innovation R&D, establishes at long last a modern, nationwide interoperable public safety wireless broadband network, and puts in place multiple incentives and other reforms to drive more efficient use of spectrum by both private entities and federal agencies.

NIST is proud to be a full partner in these efforts. The following research activities underway at NIST are attacking the spectrum crunch and related issues:

Millimeter-Wave Research

NIST is working to provide industry with the new, sufficiently precise measurement methods it needs to lead internationally in the development of innovative millimeter-wave wireless technologies and associated standards. NIST’s work will impact both the state of the art in telecommunications and the national economy as a whole.

New more precise test methods are needed to help industry utilize these new frequency ranges. The current 1 GHz methods used by the telecommunications industry must become nearly 70 times more precise to maintain equivalent accuracy, because measurement errors on the order of a few degrees can translate into erroneously demodulated information bits.

NIST innovation and expertise applied to the challenges of higher-speed wireless will offer new metrology so that US industry can realize significant increases in efficiency – not only in standardization, but in system modeling design, test and spectrum utilization – over the entire millimeter-wave region.

NIST is familiar with the needs of current U.S. telecommunications industry through its interactions with the Cellular Telecommunications Industry Association certification programs. NIST is leveraging recent funding from DARPA, with whom we are (1) developing oscilloscope-based techniques to provide a calibrated broadband modulated signal source for use in characterizing millimeter-wave receivers and (2) investigating the use of reverberation chambers for free-field testing of radiated power. Our interactions with the Institute of Electrical and Electronics Engineers (IEEE) on standards for 60 GHz systems are well under way (IEEE 802.15.3c) and, even though new transmission protocols will need to be developed, our experience on these committees will be leveraged.

As stated above, this work will accelerate the modeling design, verification, standardization, and interoperability of the Gbps (Giga Bits per second) millimeter-wave wireless systems of the future, positioning the US at the forefront of the competitive telecommunications industry. The ability to measure – not just model – components, circuits and entire systems at higher

frequencies and bandwidths will provide tools for more economical wireless system development that can take advantage of this new spectrum.

The potential economic impact of this challenging work is great. This new bandwidth is large enough to provide inexpensive, ubiquitous multi-Gbps mobile and fixed wireless access throughout the US, encouraging business growth through improved connectivity, and energy savings through mobile telecommunications. New mobile applications are envisaged, such as virtual meetings and telemedicine, and a cost-effective solution to fiber's "last mile." The economic impacts that may be realized if the U.S. telecommunications industry can become the ground-breaking international leader in this technology far exceed the current multi-hundred-billion-dollar industry.

Electromagnetic Compatibility and Radio frequency

In addition to more precise frequency measurements NIST is also looking at challenges related to radio frequency in spectrum, particularly electromagnetic compatibility and interference issues.

Work at NIST develops and promotes electromagnetic measurements, standards, and technology to support a broad range of technical needs. NIST's programs focus on accurate and reliable measurements throughout the radio spectrum, in particular at radio and microwave frequencies. Key program directions include: (1) the development of advanced measurement technologies required by both research-and-development and manufacturing communities; (2) the development and characterization of standard reference artifacts, measurement methods, and services that provide the basis for international recognition of measurements; and (3) the provision of expert technical support for national and international standards activities.

NIST carries out our programs in close coordination with our colleagues in industry, academia, and other government agencies, such as NTIA, the Departments of Defense, Energy, and Homeland Security to ensure that we are responsive to their most pressing measurement needs. Examples that reflect the breadth of areas influenced by our programs include high-speed microelectronics for computation and telecommunications, advanced antenna systems for applications in military radars and deep space communications, remote observation of the Earth's biosphere, acquisition and quantitative characterization of high-speed waveforms, medical diagnostic imaging, and reliable communications for our Nation's emergency first responders.

NIST provides a broad range of state-of-the-art calibration services for fundamental radio-frequency and microwave quantities, which ensures that the U.S. scientific and industrial base has access to a measurement system that is reliable, accurate, and internationally accepted. Furthermore, NIST extends new measurement tools and theories to higher operating frequencies, wider signal bandwidth, and smaller length scales. These are required for next-generation applications in microelectronics, high-speed communications, computing, and data storage. In addition, NIST also develops new methods to measure the electromagnetic properties of materials and understand the interactions of electromagnetic waves with advanced materials.

The Radio-Frequency Fields Group develops theory and measurement techniques for the characterization of fundamental properties of advanced antenna systems and for the accurate measurement of electromagnetic fields. These capabilities are applied to the measurement of emissions and susceptibilities of electronic systems and devices. Of growing interest is the development of advanced measurement methods to characterize complex modulated telecommunication signals and the study of challenges faced by advanced communications when operated in complex real-world environments.

Within the Radio-Frequency Fields Group are two areas of research related to radio-frequency and spectrum: the Wireless Systems Metrology Program, and the Field Parameter Metrology Program.

Wireless Systems Metrology Program

The Wireless Systems Metrology Program supports the growing wireless industry by developing methods to test the operation and functionality of wireless devices in the presence of various types of distortion.

The Wireless Systems Metrology Program is also concerned with the impact of nonlinear distortion on the transmission of wireless signals, which can be especially severe for new wideband modulated signal transmissions. Accurately measuring distortion behavior of nonlinear radio-frequency devices is a key element in understanding how such devices will perform once incorporated into a system. Even under weakly nonlinear conditions, low-noise devices such as those used in receiver front ends will exhibit nonlinear behavior that includes harmonic generation and intermodulation distortion. The program has studied problems that commonly arise in performing and interpreting nonlinear measurements, such as power- and wave-based representations and the effects of terminating impedance on intermodulation distortion.

Researchers are also working to develop traceability to fundamental parameters such as power and electric field.

The program has had a number of accomplishments:

- Demonstrated that a reverberation chamber can be used to generate a variable multipath environment, which allows wireless devices to be tested in the laboratory rather than in field tests. This is an accurate and repeatable approach that improves on "Can you hear me now?"
- Developed standards to ensure reliable wireless communications for emergency responders in difficult radio environments.
- Assisted the National Institute of Environmental Health Sciences, which is conducting a long-term animal study to evaluate health risks associated with cellular telephone fields, by testing the performance of 21 reverberation chambers that will be utilized in the study.

Field Parameter Metrology Program

Consider the consequences if nearby electronics could interfere with a jet's instruments or cause an automobile to stall. The Field Parameter Metrology Program develops ways of measuring

electromagnetic (EM) emissions and susceptibilities to electronic interference of electronic devices and systems. The program maintains the capability to provide EM field strength measurements.

Applications include the communications needs of first-responders to emergencies, measurements of the shielding effectiveness of advanced materials, effects from and on other electronic components, the statistics of electromagnetic fields in rooms and buildings, and the effects on biological subjects.

This program generates reference EM fields and calibrates EM probes required for their accurate measurement. Accurate EM field measurements are needed to characterize our wireless world and ensure that the valuable electromagnetic spectrum is optimally used, that electronic systems are compatible and neither sources nor victims of EM interference, and that people are not exposed to hazardous fields. As instrumentation and electronics achieve higher clock rates, EM field parameter metrology is needed at ever higher frequencies. The program is working to extend current methods and facilities to higher frequencies, and develop new test methods to increase accuracy and reduce measurement costs.

Research has begun on a quantum based electric field strength measurement probe that will potentially improve both the accuracy and sensitivity of field strength calibrations by more than an order of magnitude, as well as directly linking the measurements to SI units. The probe can be housed in the tip of an optical fiber, making it both extremely small and non-metallic thus presenting a minimal perturbation to the field being measured. In addition to calibrations, such a probe could find application to spectrum surveys and to the currently unaddressed problem of deterring interfering and emitted fields in-situ, that is, inside complex electronics to better solve electromagnetic compatibility and interoperability problems.

The program provides information to standards organizations to help correlate measurements between various electromagnetic compatibility (EMC) test facilities. The program also cooperates with the national test laboratories of our international partners to perform round-robin testing and comparison of standard antennas and probes. This assures international agreement in their performance and reduces the uncertainties in the areas of metrology that affect international trade. Our goal is to develop and evaluate reliable and cost-effective standards, test methods, and measurement services related to complex EM fields for EMC of electronic devices and other applications in health, defense, and homeland security.

The program has had a number of accomplishments:

- In collaboration with DHS, developed standards for testing communication links used by urban search and rescue robots.
- Helps develop standards for using TEM cells (IEC-61000-4-20) and reverberation chambers (IEC-61000-4-21) for EMC testing.
- Completed and documented high intensity radiated field (HIRF) shielding effectiveness tests on representative commercial aircraft (Boeing 737-200, Boeing 767-400ER, Bombardier Global 5000, Beechcraft Premier 1A Composite Business Jet); the results were delivered to the Federal Aviation Administration (FAA).

Mr. Chairman, we need to do more. The President recognized the need for further investments in this area. In the FY 2013 budget request for NIST, the President proposed the Advanced Telecommunications Initiative.

Advanced Telecommunications Initiative⁵

NIST's FY2013 budget also includes a \$10 million initiative to accelerate innovation in advanced telecommunications. Broadband communications networks have become as essential to today's economy as the electrical power grid was to the Industrial Revolution. To compete effectively in this global business environment, communities and companies will need reliable, secure access to huge amounts of data, available anytime, anywhere. However, the U.S. currently lacks the technology to ensure adequate capacity to achieve a large-scale network capable of this vision.

This network will need to seamlessly integrate wireless and land-based communication technology, and it will rely on revolutionary advances in network architecture. Current networks are already showing signs of strain. There has been a 5,000 percent growth in demand for wireless Internet data in the last three years alone. Currently, three percent of wireless smart-phone customers use up to 40 percent of the total available cell-phone bandwidth⁶ causing large bottlenecks in mobile broadband access.

Services are striving to address the rapid increase in demand, but new technologies and approaches are needed. Add to this the many new fields where reliable, efficient, secure, and low-cost networks are critical, such as medicine (e.g., Health IT, telemedicine), sensor and control networks (e.g., Smart Grid, environmental monitoring), and information systems (e.g., cloud computing), and it is clear that incremental advances in broadband technology or network capacity will not be sufficient to meet the future needs of a hyper-connected world.

The request would provide funds for NIST modeling and measurement science that would address three key areas to enable significant innovation in communications in both the commercial and public safety sectors:

- ***Robust Next-Generation Network Technologies***
A vast chasm exists between academic designs and commercially viable Internet-scale technologies. NIST would help bridge this gap by developing and employing advanced test and measurement techniques to characterize critical design requirements for next-generation Internet architectures. NIST also would work with industry to evaluate and improve emerging designs.
- ***Signal Metrology for 21st-Century Communications***
The latest wireless networks are capable of carrying gigabits of data per second. However, an essential technology—the ability to measure complicated signals at new bandwidths—is not available. NIST's ultrafast electro-optic measurement technology, an approach not currently in place for the wireless industry, can be used as a precision source of quality control for wireless communications, enabling Internet access at these potential high data rates. Working closely with industry, NIST would also use the

⁵ http://www.nist.gov/public_affairs/factsheet/adv_comm2013.cfm

⁶ http://www.pcworld.com/article/173320/atandt_wireless_ceo_hints_at_managing_iphone_data_usage.html

requested funding for research to improve the capacity of fiber optic communications links.

- **700 MHz Public Safety Broadband Demonstration Network**
There is clear need for a unified, interoperable public safety communications system to help the Nation's first responders and other personnel respond most effectively to local, regional, and national emergencies. The Department of Commerce's Public Safety Communications Research program (conducted by NIST with the National Telecommunications and Information Administration) has created a 700 MHz Public Safety Broadband Demonstration Network to provide manufacturers a site for early deployment of their systems, to evaluate systems in a multi-vendor environment, and to stimulate integration opportunities for commercial service providers. The requested funding would support the continued operation of this facility.

Benefits expected from funding of this initiative include:

- a U.S. broadband network with potentially 10 or more times current capacity, but that requires only a marginal increase in capital and operating expenditures;
- progress in developing "frequency-agile" wireless systems based on intelligent hardware faster microchips and other new technologies that take advantage of temporarily available spectrum; and
- continuation of a test-bed and collaboration with the telecommunications industry to help in laying the groundwork for an interoperable public safety communications network that seamlessly delivers voice, data, and video to first responders and other emergency personnel through whatever communication avenues are available.

Advanced Public Safety Communications Research and Development

Finally, the recently-enacted Middle Class Tax Relief and Job Creation Act of 2012 (P.L. 112-96) contains a provision very similar to that envisioned by the President's National Wireless Initiative, that would provide NIST with up to \$300 million to help develop cutting-edge technologies for public safety users. Funding for the program would come from auctions of reallocated spectrum licenses.

The overriding objective is to build a broadband system to allow first responders and other public safety personnel anywhere in the Nation to send and receive data, voice, and other communications to save lives, prevent casualties, and avert acts of terror. Such improvements depend upon advances in measurement science as it pertains to radio-frequency and optimization of available spectrum.

The technological challenges that stand in the way are significant. Current market forces are insufficient to drive the research and development efforts needed to accomplish the transformation in public safety communication technologies and capabilities, as first responders as a group are relatively small compared to the larger market. Also, public safety users often demand specifications, such as mission-critical voice services, enhanced security requirements, unique applications, and specialized testing needs that have not been fully developed or tested in a broadband context. NIST's R&D work can contribute to developing and testing these requirements to enhance first responder's capabilities, while leveraging commercial

infrastructure, where feasible. Achieving these requirements in the most efficient manner possible will be critical to the success of a broadband system for first responders..

In conclusion, NIST's expertise in measurement science and standards is being leveraged in a number of areas to directly help address the numerous technical challenges involved in solving the spectrum crunch issue. NIST will continue to work with partners across the Federal government, academia, and industry, to drive technological innovations that will enable U.S. manufacturers to maintain their leadership in wireless telecommunications.

I would be happy to answer any questions you may have.

Chairman QUAYLE. Thank you, Dr. Olthoff.
I now recognize Mr. Richard Bennett to present his testimony.

**STATEMENT OF MR. RICHARD BENNETT,
SENIOR RESEARCH FELLOW,
INFORMATION TECHNOLOGY AND INNOVATION FOUNDATION**

Mr. BENNETT. Good afternoon, Chairman Quayle, Ranking Member Edwards, and Members. I am Richard Bennett, Senior Research Fellow at the Information Technology and Innovation Foundation and a former network engineer and inventor.

Spectrum policy is important right now because computing is undergoing a dramatic, some would say revolutionary, shift from fixed location systems to mobile devices and applications. Smartphones outsold PCs last year for the first time, and that is a trend that is not going to reverse anytime soon. And last week Facebook bought Instagram for \$1 billion, a little photo-sharing service with only 13 employees, and this jaw-dropping price, \$76 million per employee, was justified in Facebook's point of view because Instagram had already acquired 40 million users in only 16 months of operation, roughly as many as Netflix and Comcast have combined, or will be by the end of next week; they are adding a million a day.

So the mobile revolution marks a new era in computing, and it is powered by spectrum primarily, also microelectronics and software. Another application category that we haven't heard much about yet is, "Mobile Augmented Reality," a category of application that actually interchanges video streams from the user to the Cloud in both directions to enhance the user's experience as he moves around, he or she moved around in the world. In this picture here, you are actually seeing images projected from contact lenses that embedded electronics. This is a technology that actually had been demonstrated, although only for a one-pixel display right now, but, you know, more and more of that is coming.

All of these applications require spectrum, the more the better, and because they are truly mobile, there are limited opportunities to offload their spectrum needs to short distance Wi-Fi networks.

I am a little lost here. Spectrum assignments by regulators around the world have produced this fragmented system of small assignments for a large number of applications like you see in this spectrum chart from NTIA. It reflects what—from the modern perspective it is sort of like the government's attempt to operate an app store. I mean, this is really what this looks like to me, because every one of these tiny little allocations is actually for a particular application. You try to think about how that would work in the kind of app store at the scale that Android and Apple run them today, it is completely—you can't even imagine it.

But there is a technology that is embedded behind this allocation system, and that is frequency division multiplexing, and you know, we don't use that as—we don't rely on that so much anymore. We have packet switching now and networks and technologies that go beyond that.

So one of the tasks of regulators is to put Humpty Dumpty back together again, to take this spectrum map and to realign it so that we have a smaller number of allocations per larger contiguous

chunks that we can use for more diverse purposes by running packet switching, you know, on top of them.

There are, of course, a number of technical tools to enable us to make this transition and to get better use. As the Ranking Member pointed out, dynamic spectrum access is one of those tools, authorized shared access is a more, kind of a third-way approach as we characterize it between fully dynamic or fully unlicensed and fully licensed. It is kind of licensed to a limited number of players who can cooperate.

But the holy grail ultimately that is going to resolve this problem in the long run is something that we call simultaneous shared access. Examples of that are CMA that is actually built into all the smartphones of today, SDMA, which is Space-Division Multiple Access and then multiuser. These exist in nascent form. They are not fully developed in today's networks, and we expect to see more research, making those technologies more robust.

Many government applications are critical for first responders, as has been pointed out. I am not going to go into much detail on that. Our position on the Public Safety Network is it actually would be best for everyone if for the most part that application were recognized to be an application that should run on commercial networks. That position has the advantage of being disapproved of by both the commercial network operators and public safety. So I feel reasonably impartial in, you know, making that.

But the point is that focusing on technologies we now can actually through the lever of government and how investment and research is channeled can actually use the development of technology as a way to resolve apparently intractable policy disputes. The policy dispute behind FirstNet was, you know, who gets access to that spectrum during times of crisis because both the commercial and the public safety users, you know, want it and have, you know, good arguments for it.

So to more or less conclude, one of the topics that is, I think, going to be central and is certainly in the larger public debate about this issue, there is already some questioning about whether the spectrum crunch is real. Well, it is both real and an illusion, and it is simply a matter of the timeline. In 20 or 30 years there won't be a spectrum crunch because we will be able to use spectrum so efficiently that multiple streams of data will actually be able to move over the same frequencies at the same time, but we are literally not there yet. And the research agenda is going to help us to get there.

[The prepared statement of Mr. Bennett follows:]

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Richard Bennett

Senior Research Fellow

Information Technology and Innovation Foundation (ITIF)

Hearing on Spectrum Policy:

Avoiding the Spectrum Crunch: Growing the Wireless
Economy through Innovation

Before the Subcommittee on Technology and Innovation
of the Committee on Science, Space, and Technology
United States House of Representatives

April 18, 2012

Summary of Testimony

Computing is undergoing a dramatic shift from fixed-location desktop and nomadic laptop systems to mobile devices, networks, and applications. *In 2011, the number of smartphones sold worldwide exceeded the number of personal computers sold for the first time.* Only half of Americans have smartphones so far, so the trend will continue for some time. One day appliances and other devices will come to have smartphone capability built in, so the number of “smartphones” will exceed the population many times over.

New users will use mobile social networks, among other applications. Last week, Facebook acquired Instagram, a photo sharing service with only 13 employees, for a billion dollars because Instagram had acquired 40 million users in only 16 months of operation. “Mobile Augmented Reality” is a new application category that extracts information from massive databases in the Cloud relevant to a user’s location, activity, and preferences; it moves video streams between the user and the Cloud. *All of these applications require spectrum – the more the better – and as they’re truly mobile there are limited opportunities to offload their spectrum needs to short distance Wi-Fi networks.*

Spectrum assignments by regulators around the world have produced a highly fragmented system of relatively small assignments for a relatively large number of applications, as we see in the NTIA’s spectrum allocation chart. *We need to realign spectrum into a smaller number of larger allocations for general-purpose commercial networks because such networks have the proven ability to manage the demands of competing users and applications.* In order to do this – a process akin to putting Humpty-Dumpty back together – we need to shift most government applications and all low-value commercial applications onto general-purpose commercial networks. This is where the 500 MHz recommended by the National Broadband Plan will come from, and the only way to get to a more realistic allocation of commercial spectrum. All spectrum assignments ultimately come from a common pool.

Many government applications are critical for first-responders during periods of crisis. We have technologies that permit certain applications to get high-priority treatment on commercial networks. But commercial users also desire more spectrum during such events, so we have a policy conflict. This conflict was resolved by Congress through the creation of FirstNet, the public safety network operated by NTIA, but this is not a satisfactory solution. *Ultimately, FirstNet operations should be commercialized, as soon as devices have been developed that allow trusted priority access policies.* When we have such devices, the balance between public and government use can be specified by contract rather than by spectrum fragmentation.

Striking a balance between commercial and government use will remain a difficult policy problem until mobile network technology advances to the next stage. *Ultimately, technology will enable reliable networks to support multiple simultaneous transmissions (many speakers at once) in the same spectrum, at the same time, and in the same location.* Commercial network operators are motivated to solve this problem, but with the decline of America’s R&D giants – such as Bell Labs – funding for basic research is highly dependent on government’s contributions. Taxpayer money is better spent on such research problems than on building duplicate network facilities such as FirstNet. *Advanced sharing will have tremendous military benefits as well, since it does not depend on cooperative regulators abroad.*

Detailed Testimony

Chairman Quayle, Ranking Member Edwards, and members of the Subcommittee, I appreciate the opportunity to appear before you to discuss the role of spectrum in the development of the mobile economy.

I am a Senior Research Fellow with the Information Technology and Innovation Foundation (ITIF). ITIF is a nonpartisan research and educational institute whose mission is to formulate and promote public policies to advance technological innovation, productivity and competitiveness. Before joining ITIF three years ago, I enjoyed a thirty year career in network engineering and standards, where it was my good fortune to contribute to the initial standards for Ethernet over Twisted Pair and Wi-Fi.

We at ITIF believe the spectrum challenge is critical to the economies of our nation and the rest of the world because computing is undergoing a dramatic shift from fixed-location desktops and nomadic laptop systems to mobile devices, networks, and applications. In 2011, the number of smartphones sold worldwide exceeded the number of personal computers sold for the first time.¹ Only half of Americans have smartphones so far, so the trend toward rapid smartphone and tablet adoption will continue for some time. One day appliances and other devices will come to have smartphone capability built in, so the number of smartphones will exceed the population by several times. This will change the both the Internet and the cellular networks quite dramatically.

The Internet is used by some two billion people, but we can expect that number to triple within the next three to five years. The growth in the use of smartphones and the mobile Internet is even more rapid than the boom we saw in Internet growth at the turn of the century.²

Smartphone users use many of the same applications that we use on laptop and desktop systems for personal productivity, information browsing, education and entertainment, but they also use applications that are enabled by mobility itself. We've already seen a shift in shopping habits during the holiday buying season as smartphone users share information about products, stocks in local stores, lines, and prices.³ Thanks to web sites such as Zillow and Redfin, shopping for housing is a completely different experience today than it was even two years ago, as we can drive a neighborhood, see which houses are for sale or rent, view pictures of their layout, and even analyze their purchase history without leaving the car. Those who walk, run, or cycle for exercise can map their routes, monitor their speed, distance, and heart rate, and estimate calorie burn with mobile exercise apps such as Endomondo and RunKeeper that connect to social networks.

Last week, Facebook acquired Instagram, a photo sharing service with only 13 employees, for a billion dollars, largely because Instagram has acquired 40 million users in only 16 months of operation.

¹ Henry Blodget and Alex Cocotas, "The Future of Mobile" (presented at the IGNITION WEST: Future of Mobile Conference, San Francisco, CA, March 22, 2012), <http://www.businessinsider.com/the-future-of-mobile-deck-2012-3>.

² Mary Meeker, "Internet Trends 2011" (presented at the Web 2.0 Summit, San Francisco, CA, October 18, 2011), <http://www.kpcb.com/insights/internet-trends-2011>.

³ Richard Bennett, "Live Different: Susan Crawford's Broadband Blinkers," *Innovation Files*, December 5, 2011, <http://www.innovationfiles.org/live-different-susan-crawfords-broadband-blinkers/>.

Another social picture sharing service, Pinterest, is the third largest social network only two years after its formation.⁴

“Mobile Augmented Reality” is a new application category that extracts information from massive databases in the Cloud relevant to a user’s location, activity, and preferences; it moves video streams between the user and the Cloud in both directions, sometimes from “Smart Spectacles” that combine a video camera and display screen such as Laster Technologies’ *IEEE Spectrum* 2011 Technology of the Year winner. All of these applications require spectrum – the more the better – and as they are truly mobile there are limited opportunities to offload their spectrum needs to short distance Wi-Fi networks. The spectrum needs of tablets are more in line with those of the laptops they’re replacing, however as tablets are “nomadic” devices that we use in stationary fashion from multiple locations. The spectrum needs of tablets can generally be met through Wi-Fi.



Figure 1 Laster Technologies “Smart Spectacles” wearable video camera and display system. Credit: Laster

The Spectrum Crunch

The National Broadband Plan famously forecasts a need for 300 MHz of licensed and 200 MHz of unlicensed spectrum, less than double the 475 MHz we currently have for licensed⁵ and the 350 MHz we have for unlicensed Wi-Fi alone.⁶

This estimate is low because we’ve seen that network applications are generally able to make use of all available bandwidth: Residential broadband connections, for example, are roughly ten times faster than they were in the late 1990s, and many of these connections are unshared.

Commercial Spectrum Use

Mobile social networks are using infrastructure initially designed for low bandwidth telephone service. Video sharing applications will consume ten times as much capacity per minute as telephony with the best compression we can use. Cellular networks in major cities are running close to capacity during peak periods already. From 2006 to 2009, the first three years the

iPhone was available on the AT&T network, traffic grew 5000%.⁷ This figure probably represents users spending



Figure 2 Augmented Reality in a contact lens. Credit: Raygun Studio

⁴ Bill Tancer, *The 2012 Digital Marketer Trend and Benchmark Report* (Experian Marketing Services, 2012), <http://go.experian.com/forms/experian-digital-marketer-2012>.

⁵ Brad Reed, “LTE Spectrum: How Much Do the Big Carriers Have?,” *Network World*, January 23, 2012, <http://www.networkworld.com/news/2012/012312-lte-spectrum-255122.html?page=1>.

⁶ Wikipedia, “List of WLAN Channels,” encyclopedia, n.d., http://en.wikipedia.org/wiki/List_of_WLAN_channels.

⁷ Michelle Megna, “AT&T Faces 5,000 Percent Surge in Traffic,” *InternetNews*, October 8, 2009, <http://www.internetnews.com/mobility/article.php/3843001/ATampT+Faces+5000+Percent+Surge+in+Traffic.htm>

five times as many minutes on their iPhones as they spent on their dumb phones, and performing tasks that are ten times as data-intensive. AT&T forecasts a need for eight to 10 times as much data capacity over the next five years as it can carry today.⁸ Some of this capacity can be met by improvements in spectrum efficiency (mainly in terms of coding advances,) some by increased tower deployment, some by small cells, but much of it depends on more spectrum.

The balance between these methods is largely economic. Increased spectrum is the least expensive option, building towers the most expensive, and the costs of more spectrum are ultimately born by users. Some analysts believe that advances in technology alone will meet the demand, but this projection ignores the fact that historical advances in spectrum efficiency follow Cooper's Law, doubling every 30 months, while increases in demand follow Moore's Law, doubling every 18 months.⁹ Left to its own devices, technology will fail to meet consumer needs.

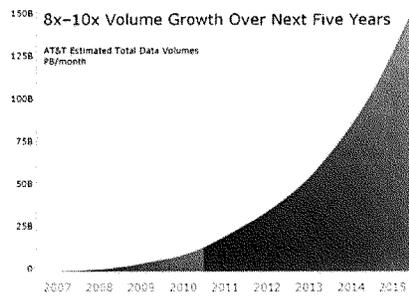


Figure 4 AT&T projects wireless data sent over its network to grow by a factor of 8 to 10 in the next five years. Credit: AT&T.

CARRIER SPECTRUM DEPTH

World's largest carriers have 200MHz, 300MHz, Advanced Wireless Services (AWS) and Personal Communications Services (PCS) spectrum bands which are all being put to use throughout beginning 2010 estimates

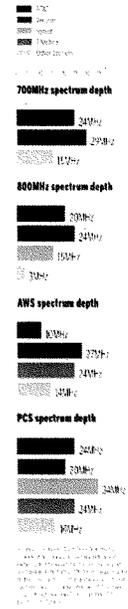


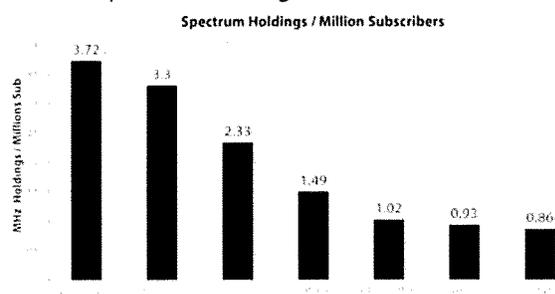
Figure 3 List does not include 150 MHz of Sprint/Clearwire spectrum. Credit: Network World.

⁸ Kris Rinne, "Building the Nation's Most Advanced Mobile Broadband Experience" (presented at the AT&T CIO Executive Forum, Colorado Springs, CO, June 15, 2011), http://www.business.att.com/content/speeches/ATT_Mobility_Network_Evolution_KrisRinne.pdf.

⁹ "Martin Cooper (inventor)," *Wikipedia*, n.d., http://en.wikipedia.org/wiki/Cooper%27s_Law.

The most efficient users of spectrum on a per-user basis over wide areas are the large networks. AT&T and Verizon get by with 0.86 and 0.93 MHz per million subscribers, while Sprint/Clearwire holds 3.72 MHz per million, according to Bernstein Research.¹⁰

Current spectrum holdings



"The clock is ticking on our mobile future, and we cannot solve our mobile challenges by snapping our fingers; we must act without delay to free up spectrum for mobile broadband."

FCC Chairman Genachowski, Mobile Future Forum, 16 March 2011

Figure 5 Credit: Bernstein Research, used by permission from Craig Moffett.

If we can't find spectrum to meet the needs of mobile users as they transition to smartphones, tablets, mobile social applications, augmented reality, and sensor networks, innovation will stall and economic growth will slow. The FCC forecasts that these effects will become visible as early as next year.¹¹

¹⁰ Craig Moffett, *Company Reports* (Bernstein Research, January 11, 2011).

¹¹ Michael Kleeman, *Point of View: Wireless Point of Disconnect* (San Diego, CA: Global Information Industry Center, October 2011), http://giic.ucsd.edu/pdf/pow_wireless_point_of_disconnect_2011.pdf.

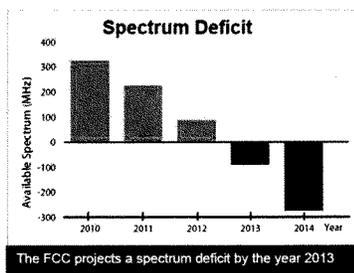


Figure 6 Credit: "Point of View: Wireless Point of Disconnect," Michael Kleeman, Global Information Industry Center

Government Spectrum Use

One source for additional commercial spectrum is the government. Most analysts say that the U. S. government has assigned 300 MHz more prime spectrum to itself than our European neighbors; this spectrum is managed by NTIA. While the U. S. leads the world in the deployment of fourth generation LTE networks, we lag the world in the allocation of spectrum to LTE networks.

The recent NTIA report, *An Assessment of the Viability of Accommodating Wireless Broadband in the 1755 – 1850 MHz Band*, is good news and bad news for the reassignment of government spectrum.¹² The good news is that some government agencies are playing ball, taking the exercise seriously and doing their best to increase the amount of spectrum available for general-purpose commercial networks. The NTIA says the entire band can be made available within ten years, and significant portions of it much earlier.

They caution that some sharing is going to be necessary for quite some time in a few areas, but they're hoping that the sharing is something both the commercial sector and the government can live with. The bad news is that DOD and the FBI still insist they have applications of such importance that they can't live without the allocations of spectrum they currently have. It's likely that the negotiations between the civilian agencies and the NTIA involved spectrum experts while those that took place with the DOD and DOJ involved non-technical administrators. That's what the report seems to indicate.

¹² John E. Bryson and Lawrence E. Strickling, *An Assessment of the Viability of Accommodating Wireless Broadband in the 1755 – 1850 MHz Band* (Washington, DC: U. S. Department of Commerce, March 2012), http://www.ntia.doc.gov/files/ntia/publications/ntia_1755_1850_mhz_report_march2012.pdf.

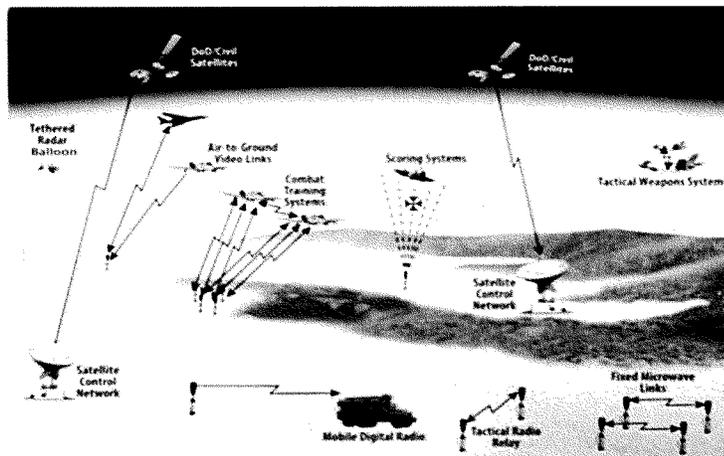


Figure 7 Credit: "An Assessment of the Viability of Accommodating Wireless Broadband in the 1755 – 1850 MHz Band," NTIA, March 2012, (NTIA Report) page 6.

The primary issue in reallocating spectrum from government use is whether the allocation makes sense, and the secondary issue is where in the spectrum map the government's assignments should be. The 1755-1850 spectrum band is important because it's been assigned internationally for mobile broadband, so there are tremendous benefits to U. S. firms and consumers if we can use it for that purpose. While the NTIA appears to have dragged DOD kicking and screaming into the discussion about relocating some of its vital systems to other bands, they don't seem to have made much progress toward getting them to consider alternate ways of performing their missions that don't require 200 to 300 MHz more bandwidth than our European allies have dedicated to their military establishments.¹³ Maybe that's too much to ask just yet. And of course the estimated relocation costs provided by DOJ and DOD are outlandish, considering that all the equipment they've currently got should be replaced within five to ten years as a matter of course anyway, and this exercise has already been ongoing for ten years.

The executive summary declares: "In conducting the analysis, NTIA and the federal agencies endeavored to protect critical federal operations from disruption and to reach comparable capability via other spectrum, commercial services, or means that do not utilize spectrum, where appropriate" but this isn't totally reflected in the body of the report. What we see is a desire to preserve the current set of government applications with as little disruption as possible and very little attention to developing alternatives to the current application-based allocation scheme that was the 20th century's method of handling spectrum.

¹³ Ginger Conton, "Free the Spectrum Now," *CRM Magazine*, May 2002, <http://www.destinationcrm.com/Articles/Older-Articles/The-Edge/Free-the-Spectrum-Now-45519.aspx>.

Here's a summary of the number of allocations to government users in the band. The total number is 3183 discrete allocations for particular purposes.

Table 2-1. Number of Federal Frequency Assignments in the 1755-1850 MHz Band

AGENCY	Fixed Point-to-Point Microwave	Military Tactical Radio Relay	Air Combat Training Systems	Precision Guided Munitions	Law Enforcement Mobile Video Surveillance Applications	High-Resolution Video Surveillance (fixed or transportable)	Telemetry, Tracking, and Commanding for Federal Space Systems	Air-to-Ground Telemetry	Land Mobile Robotic Video Functions (e.g. EOD & Hazardous Waste Disposal, etc)	UAS, UAV, RPV	TOTAL
Air Force	12		771	1		2	220	186	61	65	800
USAID						1					1
Army	45	408	4			36		19	4	378	894
DHS	152				25						177
DOC	8						1				9
DOE	91								2		93
DOI	26				1	1					28
DOJ					7	75			7	6	95
FAA	8										8
HHS						1					1
HUD						6					6
Marine Corps	4	168								21	194
Navy	14	2	430	20			48	333	6	14	837
OPM						1					1
NASA								6		11	17
Treasury						10					10
USCP						5					5
USPS						3					3
VA						4					4
TOTAL	360	579	707	21	33	145	269	514	80	475	3183

Figure 8 Source: NTIA Report, page 16.

A detailed examination of the assignments is illuminating.

Fixed Point-to-Point Microwave

The first application, fixed point-to-point microwave, should raise a red flag immediately because nearly all its 360 allocations can be probably be replaced by a wireline or commercial alternative. Point-to-point microwave is a virtual wire whose history pre-dates fiber optics and it's a laggard in terms of performance and quality.

The report excuses these allocations as being cheaper or higher quality than commercial or wireline alternatives, but that analysis only works if you value the spectrum at zero. Replacing 95% of these allocations with fiber backhaul could end up being a net positive for the government because they could over-provision and lease dark fiber to the commercial sector. The only rational application for fixed point-to-point microwave these days is connecting mountain tops in rural areas where there's no plausible case for fiber and I doubt that's the government's typical use case.

Military Tactical Radio Relay

Per the report, "Tactical Radio Relay is a generic term for a class of transportable fixed microwave systems that support Army, Navy, and Marine Corps training at a number of sites and on tactical operational missions." These systems probably have a stronger use case than fixed microwave, but probably not much of one. The purpose of these allocations should be to connect a training network to a

fiber terminal, and it would be very surprising if DOD needs 579 separate allocations to do this for active training missions. Even if they had hundreds of training missions going on at the same time, they're not in the same place so there's no practical reason they need that many allocations. This is another category of microwave, and there are commercial systems and higher frequencies available to support it that aren't appealing to mobile networks. In fact many of these systems are indistinguishable from commercial mobile broadband systems in function and purpose. Most of these 579 allocations duplicate commercial systems.

Air Combat Training System

The report describe this application as one that "provides, via ground-based and airborne components, real-time monitoring of air combat training including gun-scoring; no-drop bombing; evasion and intercept tactics, techniques, procedures; and electronic warfare." It seems that the major problem with these allocations is systems that require specific frequencies on which to operate. Combat systems have to be capable of operating overseas, in countries that have not made specific allocations of spectrum to invading armed forces, so you'd want to have some flexibility in them. And in fact they are designed that way, with the ability to operate on a number of frequencies (just like a car radio.) See the following table for some options.

Table 3-1. Potential Comparable Spectrum Bands

Initial Categories of Systems	Potential Bands for Relocation	Factors Considered	
Fixed Point-to-Point Microwave	4400-4950 MHz 7125-8500 MHz Wireline or Commercial	14.5-14.7145/ 15.1365-15.35 GHz Possibly Higher [e.g., 25-27.5 GHz]	Equipment is available and there is adequate spectrum.
Military Tactical Radio Relay	1435-1525 MHz 2025-2110 MHz	2110-2165 MHz 2200-2310 MHz*	These bands minimize the need for modifications to equipment [e.g., existing equipment such as Mobile Subscriber Equipment and HCL05 tune up to 2690 MHz, so no equipment modifications are necessary].
Air Combat Training Systems	1350-1390 MHz 1435-1525 MHz 2025-2110 MHz	2200-2300 MHz* 2360-2395 MHz	Airborne operations can be accommodated or are already being performed in these bands; these bands have similar or better propagation characteristics; and coordination with aeronautical telemetry is possible.
Precision Guided Munitions	1350-1390 MHz 1435-1525 MHz 2025-2110 MHz	2200-2300 MHz* 2360-2395 MHz	Airborne operations can be accommodated or are already being performed in these bands; these bands have similar or better propagation characteristics; and coordination with aeronautical telemetry is possible.
Law Enforcement Mobile Video Surveillance Applications	225-328.6/ 335.4-380 MHz 420-450 MHz 902-928 MHz 1350-1390 MHz	1435-1525 MHz 1675-1695 MHz 2025-2110 MHz 2200-2300 MHz* 2360-2395 MHz	Equipment is available; and/or propagation characteristics are similar or better; and/or the incumbent radio services are similar to those in the 1755-1850 MHz band where successful sharing exists.
High-Resolution (fixed or transportable) Video Data Links for Surveillance	225-328.6/ 335.4-380 MHz 420-450 MHz 902-928 MHz 1350-1390 MHz	1435-1525 MHz 1675-1695 MHz 2025-2110 MHz 2200-2300 MHz* 2360-2395 MHz	Equipment is available; and/or propagation characteristics are similar or better; and/or the incumbent radio services are similar to those in the 1755-1850 MHz band where successful sharing exists.
Tracking, Telemetry, and Commanding for Federal Space Systems	2025-2110 MHz 7125-8500 MHz	20/30 GHz	Equipment is available and there is adequate spectrum.
Air-to-Ground Telemetry	1350-1390 MHz 1435-1525 MHz 2025-2110 MHz	2200-2300 MHz* 2360-2395 MHz	Airborne operations can be accommodated or are already being performed in these bands; these bands have similar or better propagation characteristics; and coordination with aeronautical telemetry is possible.
Land Mobile Robotic Video Functions	225-328.6/ 335.4-380 MHz 420-450 MHz 1350-1390 MHz 1435-1525 MHz	1675-1695 MHz 2025-2110 MHz 2200-2310 MHz* 2360-2395 MHz	Propagation characteristics are similar or better and the incumbent radio services are similar to those in the 1755-1850 MHz band where successful sharing exists.
UAS, UAV, RPV	225-328.6/ 335.4-380 MHz 2025-2110 MHz 2200-2300 MHz*	4400-4950 MHz 14.5-14.7145/ 15.1365-15.35 GHz	Although these bands are already used, they can also support the operations conducted in the 1755-1850 MHz band.

* The correct band for consideration is 2200-2290 MHz, however, because NTIA identified two different bands, 2200-2300 MHz and 2200-2310 MHz, in the initial list of candidate comparable bands, these bands are sometimes referenced throughout this report.

Figure 9 Source: NTIA report, page 16.

The DOD is the prime developer of “software-defined radios” that operate at a wide range of frequencies, and these should be used in all military and law enforcement systems within the next five years in the course of normal replacement of obsolete equipment. The instances in which a particular frequency is needed for testing are rare, but they do exist. They can be accommodated, however, by

short term use of the test frequency in a specific area rather than permanent assignment. Test conditions should resemble real-world conditions, after all. 707 allocations are at stake here, as well as the flexibility and utility of real combat systems.

Precision Guided Munitions

These systems “provide critical tactical communications between launched weapons and controlling platforms, allowing for precise and effective targeting.” Like other air combat training systems, they need to function in real-world settings that don’t provide them with a dedicated band and the ability to share and adapt to such conditions. They can be re-assigned to the same bands as air combat training systems.

Tracking, Telemetry, and Commanding

Here’s an application that makes some sense: “DOD satellites provide communications, navigation, surveillance, missile early warning, weather monitoring, and research and development support.” This application needs some specific spectrum assignments because it’s doing things that aren’t generic and don’t have to co-exist with generic systems. These systems have some general utility, and aren’t going to be usurped by commercial systems. Unfortunately, DOD has not build spectrum flexibility into satellites in the past, so they’re less functional than car radios in this respect. They propose to make a minimal change to allow the use of two bands in future satellites (the current “L” band and the future “S” band) but no more. This seems a bit uncooperative given that the “S” band at 2025-2110 MHz is pretty juicy for mobile broadband and there’s a lot of spectrum available above 3 GHz that doesn’t appeal to mobile.

We’d like to see a general principle in place to the effect that we don’t launch billion dollar systems into space that are hard-wired to operate on only one or two frequencies.

Aeronautical Mobile Telemetry

The report says it all: “Aeronautical mobile telemetry systems operate from manned aircraft, unmanned vehicles, aerostats, missiles, or other platforms to provide real-time flight characteristics from the airborne vehicles to the ground, real-time video of cockpit or project information, real-time monitoring of flight research/test parameters, and real-time command and control of the vehicle.

“NASA determined that it can vacate its aeronautical mobile telemetry operations from the entire 1755-1850 MHz band in less than five years. Relocation to the 2025-2110 MHz and 5091-5150 MHz band requires a primary federal allocation for the aeronautical mobile service.” But DOD takes longer and wants more spectrum in return.

Video Surveillance

Of all the applications in the NTIA report, this is the most puzzling. The report declares: “DHS, DOJ, and the Treasury state they need to retain up to 30 megahertz of contiguous spectrum for surveillance in the 1780-1850 MHz band pending the successful development of new technology and the availability of spectrum in the comparable bands.” Granted, keeping the people safe from terrorists, criminals, and tax evaders is a noble work, but video bits are not so special that they need their own network. Commercial networks can easily accommodate the needs of law enforcement for transporting video bits just as they

must do the very same job for consumers every day. There is no justification for putting 30 MHz of contiguous spectrum on hold just after allocating the D Block to the nation-wide public safety network that's about to be built. The NTIA needs to say "no" to this application, resoundingly.

Unmanned Aerial Systems

The report advises that "The use of unmanned aerial systems has grown significantly with deployment of more sophisticated payloads for expanded functions of electronic attack, communications relay, firefighting, science observation, and search and rescue" and asks for the 2025-2110 MHz band to support this app, gulp. That's twice as much spectrum as T-Mobile has today. This is a terrestrial application that seems to have most relevance for temporary uses within U. S. borders. Hence it's difficult to justify such a huge allocation for it.

Government Spectrum Conclusions

It seems that the ice is beginning to melt around federal spectrum allocations in the 1755-1850 MHz band. Civilian agencies are generally working in the right spirit toward the national goal, and military and law enforcement agencies are beginning to recognize that their extravagant historical claims on spectrum rights need to be scaled back, even if they're not entirely happy about it.

This exercise can be judged effective only if the total amount of government spectrum is sharply reduced; simply moving government agencies from one prime spot below 3 GHz to another is actually a failure. Agencies should also realize that they serve the public by performing their roles to the best of their abilities, and these roles do not generally include network operations. The DOD is strangely lacking in enthusiasm for the software-defined radio technology it pioneered. It's important that we understand why.

Meeting the Need for Spectrum

The same RF spectrum exists around the world, but our regulatory process has assigned too much to government use – roughly 300 MHz of the prime frequencies between 500 MHz and 3GHz. We have also assigned too much spectrum to satellite-based Mobile Telephone Services (MSS) with limited capacity and high latency.¹⁴ When the Telstar satellites were launched in the 1960s, there were high hopes that satellites would enable a wide range of applications, but experience shows that satellite networks are a poor substitute for wireline and terrestrial wireless ones in practically all applications except one-way broadcasting. Satellite signals have high delay – on the order of a half-second round trip – and cover an area that's excessively large.

The more general problem around the world is the 100 year history of assigning spectrum to applications rather than to networks. The following diagram illustrates the complexity of the U. S.

¹⁴ European Commission, "eCommunications: Radio Spectrum Policy: Mobile Satellite Services," *Europe's Information Society*, n.d., http://ec.europa.eu/information_society/policy/ecom/radio_spectrum/topics/ecs/mss/index_en.htm.

spectrum allocation system. A more ideal system would have many fewer allocations, each for a substantially larger amount of spectrum.¹⁵

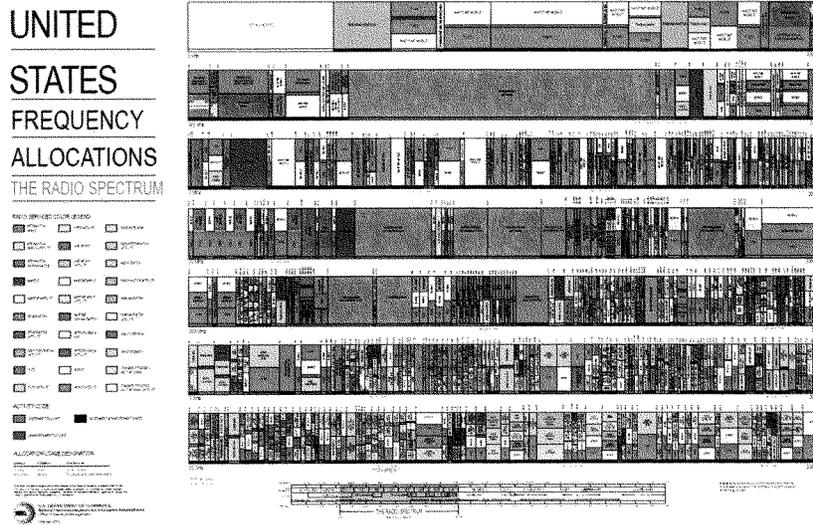


Figure 10 Source: NTIA

From the application perspective, spectrum sharing on commercial networks is a solved problem. We don't have one network for Instagram and another for Pinterest, we have one group of networks that handle a wide range of applications. What we're doing with such technologies as Dynamic Spectrum Access and Authorized Shared Access is reversing the effects of historical spectrum allocation policy. When successful, these approaches will create networks that resemble commercial networks in their application support. This is a way of putting Humpty-Dumpty back together again.

In order to meet the need for network capacity, carriers will supply more spectrum per user. The easiest way to do this is to offload the cellular network onto femto cells and Wi-Fi networks, but this is a limited strategy because it fails to meet the needs of mobility. Wi-Fi is a nomadic network, not a truly mobile one, and femto cells have similar characteristics. The small cells that will help relieve the crunch are deployed outdoors on frequencies that coordinate with the macro cells on which the cellular network is

¹⁵ Richard Bennett, *Spectrum Policy for Innovation* (Washington, DC: Information Technology and Innovation Foundation, September 2011), <http://www.itif.org/files/2011-spectrum-policy-innovation.pdf>.

based. Building micro cells within the macro cellular fabric is a bricks-and-mortar exercise that requires massive investment and zoning approval.¹⁶

Facilitating R&D on Spectrum Sharing and Efficient Use

As Figure 10 indicates, the general problem of spectrum policy today is fragmentation: Regulators have assigned slices of spectrum to myriad applications and it's now all spoken for. The task before us is to reverse the effects of fragmentation, to essentially put Humpty-Dumpty back together again. The easy way to do this is to take spectrum away from low-value applications (such as the government's dedicated video surveillance frequencies, many lightly-used satellite services, and over-the-air TV) and assign it to high-value commercial networks by auction. Sharing is inherent in commercial networks; it's how they make money and they're very good at it.

Network Time Sharing: Dynamic Spectrum Access and Authorized Shared Access

Unlicensed radio systems are most effective over short distances: Bluetooth and Wi-Fi are their signature accomplishments. These systems manage spectrum access at the network edge using "contention" systems that become less efficient as network distances and data rates increase. Licensed commercial systems employ centrally-managed spectrum access controls that are effective at a broad range of speeds over longer distances, but at the cost of much greater planning and more complex infrastructure.¹⁷ Each approach has distinct benefits and ideal deployment scenarios: We would not want to build nationwide networks with Wi-Fi, and we would not want to centrally manage Bluetooth connections between smartphones and headsets.

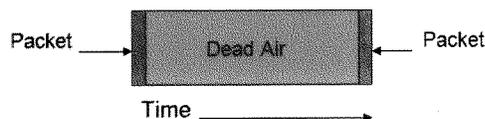


Figure 11 Actual overhead of IEEE 802.11n carrier sensing for single packets sent at high rate.¹⁸

In addition to the spectrum sharing that licensed commercial networks and unlicensed networks already do, research has developed (and will continue to develop) systems that coordinate spectrum use among networks themselves. The best known of such systems are Dynamic Spectrum Access (DSA) and Authorized Shared Access (ASA.) These systems simply coordinate spectrum access among and between network operators where idle spectrum exists and sharing agreements of some kind are in force.

In order for these systems to function, the pool of idle spectrum can be used by capable devices when certain conditions are met and an operator claims the spectrum, either with government permission (as is the case in the White Spaces systems,) or in accord with a commercial agreement between network

¹⁶ Richard Bennett, *Going Mobile: Technology and Policy Issues in the Mobile Internet* (Washington, DC: Information Technology and Innovation Foundation, March 2010), <http://itif.org/publications/going-mobile-technology-and-policy-issues-mobile-internet>.

¹⁷ *Ibid.*

¹⁸ *Ibid.*

operators in other cases, or in terms of an informal agreement in yet other cases. The act of claiming the spectrum makes the network operational, and once this takes place, the process of network operator-mediated sharing among applications follows, with potentially as much efficiency as commercial licensed networks exhibit over a broad range of operating conditions.

These systems will prove beneficial in the short to medium term, until we reach the point where there is no longer any idle spectrum to claim and assign dynamically. At that point, advances in spectrum sharing will depend on more advanced and more beneficial technologies that allow a single frequency to be shared among multiple *simultaneous* users. We don't do this today, and we won't do this with DSA and ASA.

In DSA and ASA systems, as with common commercial systems, users take turns accessing spectrum in round-robin fashion, typically for a few milliseconds at a time. In other words, conventional packet radio systems, whether licensed or unlicensed, fixed or dynamic, only permit the transmission of one packet of data at a time in a given place, time, and frequency.¹⁹ DSA and ASA systems reduce the effects of this fundamental limitation by marshaling more spectrum to each location. The next stage in spectrum engineering is systems that allow for multiple packet transmissions in each time and place on the same range of spectrum.

The most fertile test bed for DSA operations research is the vast pool of lightly-used and locally-used government spectrum. Many government systems that use spectrum only do so occasionally and in specific locations, so this spectrum is ripe for use by both commercial and non-commercial systems in other times and places. The IEEE 802.11y variant of Wi-Fi is a good example of the dynamic sharing of government spectrum.²⁰

Simultaneous Network Sharing

Truly simultaneous spectrum use requires transmissions to be effectively focused or cloaked from each other so as not to create discernible interference; these systems can be called Simultaneous Shared Access (SSA.) One way of doing this is Space-Division Multiple Access (SDMA,) a system that effectively sends a radio beam to a receiver in such a focused way that other receivers don't see it. Another system for simultaneous sharing would be an advanced form of Code Division Multiple Access (CDMA,) a system that scrambles transmissions so that only the intended receiver can unscramble them, and other potential receivers automatically filter them out. Current CDMA systems reduce the data rates of simultaneous transmissions relative to theoretical capacity; advanced CDMA would be less limited in this respect.

Yet another method is Ultra-Wideband (UWB,) a system that uses very wide radio channels "underneath" conventional narrow channels. While conventional cellular channels are 5, 10, or 20 MHz wide, UWB channels are spread over 500 MHz each, so the UWB energy is very faint to cellular

¹⁹ There are some exceptions to this rule, but they apply to systems that reduce packet radio data rates, such as CDMA.

²⁰ Wikipedia, "IEEE 802.11y-2008," *Wikipedia*, n.d., http://en.wikipedia.org/wiki/IEEE_802.11y-2008.

receivers. UWB transmissions are also pulsed so as to appear more like sporadic noise to conventional receivers. Therefore, UWB transmissions blend into the background noise filtered by narrowband receivers by design. Of these three approaches, only CDMA has proved a commercial success so far, but its sharing efficiency is less than expected.

Research spending should focus on Simultaneous Sharing. It would be prudent to organize research funding for simultaneous sharing under a coherent National Science Foundation program. The best way to do this may be to create an NSF Engineering Research Center (ERC) for simultaneous sharing similar to the research centers that already exist in the Microelectronics, Sensing, and Information Technology area, such as the ERCs for Integrated Access Networks, Extreme Ultraviolet Science and Technology, Collaborative Adaptive Sensing of the Atmosphere, and Mid-infrared Technologies for Health and the Environment.

A report released by the White House Council of Economic Advisors in February, *The Economic Benefits of New Spectrum for Wireless Broadband*, touts the benefits of "research on standards, technologies, and applications to advance wireless public safety communications." While such research is clearly necessary and beneficial, we should acknowledge that it is low-risk applied research with a known outcome. In addition to applied research, we need to support pure research that can potentially push the boundaries of mobile networking to the next stage.

The research agenda can be organized on a timeline between short-, medium-, and long-term initiatives, as follows:

Short-term	Authorized Shared Access
Medium-term	Dynamic Spectrum Access
Long-term	Simultaneous Shared Access

When SSA is fully developed and non-SSA receivers are replaced by SSA-capable ones, the problem of spectrum allocation and management will become much simpler than it is today.

Striking the Balance between Commercial and Government Use of Spectrum
Government and the private sector play different roles in the development of technology and the management of shared resources such as spectrum. We expect government to support pure research and to share support of applied research with the private sector. We expect government to set parameters and regulations for economic activities such as mobile networking, and for the private sector to provide actual services to the public. We also expect government to provide some general facilities such as GPS because there was no discernible business case for location-sensing systems when the GPS system was devised and government assumed the role of provider of last resort as is sometimes the case.

These "provider of last resort" situations can become a source of conflict when systems such as GPS or public safety networking become generally useful. In the case of public safety networking, we now have police and first responders around the country operating networks similar in function to commercial

mobile networks. Public safety got into the network operations business when they had no choice but to operate their own networks or to do without. This is no longer the case, as Congress realized when the 9/11 Commission laid out the interoperability problems in New York on the day our country was attacked. A decade after 9/11, Congress assigned operational responsibility for public safety networking to NTIA. This was a step forward, but not the end of the game.

The basic problem with a government-owned and operated public safety network is the conflict of interest between the government as regulator of spectrum allocation and network operations and the government's interests as a user and operator of networks. If public safety networking were to be carried out by commercial networks under contract with public safety agencies (under the technical guidance of NTIA) there would be no conflict and no balance to be struck apart from budgeting for the amount of network capacity needed to perform services deemed necessary by Congress year after year.

Government can fund research, and it can make purchasing decisions to support the commercialization of leading-edge technologies. In so doing, it expands the pool of useable spectrum. Government does not need to compete with the private sector as a provider of network services generally.

Conclusion

Thank you for providing ITIF the opportunity to offer this testimony today. Despite the many challenges we face in converting our system of spectrum assignment from one of administrative fiat to a pragmatic and dynamic system of continual economic stimulus, the rewards are great. The nations that lead the way in the deployment of advanced technologies stand to reap the benefits that increased efficiency brings to economic growth.

While it has become routine for policy analysts to bemoan the U. S. for its position in traditional rankings of wired broadband adoption (where we lag because of low rates of household computer ownership) and speed, we're the clear leader in LTE adoption.²¹ LTE is very significant step in the evolution of mobile networking not only for its radio technology but also because it's a system entirely based on Internet Protocol that stands to not only increase the capacity of mobile networks but to make the Internet itself a more reliable and robust system.

Continued leadership in LTE depends on the continued release of spectrum to the most successful commercial networks through reassignment of government applications and the transfer of licenses from declining systems such as MSS and OTA television broadcasting to high-value mobile broadband. Leadership in the systems that will take the place of LTE and LTE Advanced depends on increased investment in the technologies for simultaneous spectrum sharing that will ultimately relieve the spectrum crunch once and for all.

²¹ *US Tops Global LTE Smartphone Market* (Pyramid Research, October 10, 2011), <http://www.pyramidresearch.com/points/item/111010.htm>.

Chairman QUAYLE. Thank you, Mr. Bennett.
I now recognize Mr. Guttman-McCabe for five minutes.

**STATEMENT OF MR. CHRISTOPHER GUTTMAN-MCCABE,
VICE PRESIDENT, REGULATORY AFFAIRS,
CTIA-THE WIRELESS ASSOCIATION**

Mr. GUTTMAN-McCABE. Thank you. Good afternoon, Chairman Quayle, Ranking Member Edwards, and Members of the Subcommittee. Thank you for including me on today's panel. I am here on behalf of CTIA-The Wireless Association, which represents the wireless carriers, equipment vendors, and software developers that are driving America's leadership in wireless broadband.

I am pleased to tell you that the United States leads the world in the deployment of fourth-generation wireless technologies. While the U.S. is home to less than five percent of the world's population, we have almost 90 percent of the world's LTE subscribers and over 50 percent of the world's WiMAC subscribers. The U.S. wireless ecosystem is setting the pace for innovation with ubiquitous high-speed networks, cutting-edge devices launched here first, and epicenter of the applications world.

Five years ago, for the most part these capabilities didn't exist, yet today we are increasingly using wireless devices, applications, and wireless networks to shop, pay bills, read the news, stay in touch, reduce energy consumption, manage fleets of trucks, control inventory, address health care issues, and teach our children. Not surprisingly, mobile data service demand is exploding. Wireless data traffic grew 123 percent from 2010 to 2011, on top of a doubling the year before and the year before that. The pace of growth actually is accelerating as the last six months of 2011 were 132 percent greater than the last six months of 2010.

To stay ahead of this demand, CTI's members invest more than \$20 billion annually, including more than \$25 billion each of the past two years to extend and upgrade the capabilities of wireless networks. In these difficult economic times, our members actually are increasing their capital investments.

But even at these impressive levels, network investment alone will not allow us to stay ahead of the exploding demand. Conservative estimates project U.S. mobile data traffic will grow by more than a factor of 10 over the next five years. If vehicle traffic in your Congressional district was predicted to grow by a factor of 10 over the next five years, you would want to know that the transportation authorities had a plan and were implementing it. The same should be true of spectrum.

For this reason, and to maintain the advantages that flow from our world-leading position, CTI believes it is imperative that our government embrace policies that will make additional spectrum available on a predictable, near-term basis. CTI urges Congress to ensure that the FCC and NTIA faithfully and expeditiously implement the spectrum legislation enacted by Congress just this past February.

While we believe that the incentive auction process will bring a substantial amount of spectrum to market, that will only be a down payment towards the 500 megahertz that the FCC called for in its

National Broadband Plan and that the President embraced in his memorandum on unleashing the wireless broadband revolution.

In order to progress towards that 500 megahertz target as well as to keep pace with the hundreds of megahertz being freed for commercial use in a number of European and Asian countries, additional spectrum will need to be made available. CTI recommends that the 1755 to 1780 megahertz band be reallocated and paired with the available 2155 to 2180 megahertz band. Making this spectrum available in the short term for commercial use will not only benefit consumers, it will also add billions to the U.S. Treasury.

CTI recognizes that reallocation is challenging, but spectrum clearing represents a substantially better path than a full default to spectrum sharing. While spectrum sharing may have a place as a complement to fully cleared spectrum, dynamic or opportunistically shared spectrum currently is not suitable as a substitute for large blocks of cleared, licensed spectrum.

It is important to note that carriers and manufacturers are aggressively using many tools to try and meet this increasing demand, including the deployment of smaller cells and the use of Wi-Fi offload. Notwithstanding these efforts, the release of additional spectrum into the marketplace remains the single most important thing that can be done to ensure the continued vibrancy of the wireless ecosystem.

While spectrum policy obviously is paramount, there certainly are other factors that can affect the industry's continued success. In particular, CTI urges Congress to be mindful that regulatory and tax policies have a substantial impact on the ability and incentive for our members to invest in new facilities and the development of new technologies.

In sum, while I believe the wireless future is bright, there is a great deal to be done to ensure that we maximize that opportunity and continue U.S. leadership in this vital industry. CTI looks forward to working with you and your colleagues on these important matters. Thank you for the opportunity to appear at today's hearing, and I look forward to your questions.

[The prepared statement of Mr. Guttman-McCabe follows:]



Expanding the Wireless Frontier

Testimony of
Christopher Guttman-McCabe,
Vice President, Regulatory Affairs,
CTIA – The Wireless Association®

Before the
House Science, Space and Technology
Subcommittee on Technology and Innovation

Hearing on
Avoiding the Spectrum Crunch: Growing the Wireless Economy through Innovation
April 18, 2012



Chairman Quayle and Ranking Member Edwards, and members of the Subcommittee, thank you for including me on today's panel. I am here on behalf of CTIA – The Wireless Association®, which represents the wireless carriers, equipment vendors, and software developers that are driving America's leadership in wireless broadband.

I am pleased to tell you that the United States leads the world in the deployment of fourth-generation wireless technologies. While the U.S. is home to less than five percent of the world's population, we claim more than 20 percent of global high-speed wireless broadband subscribers. As a result of this leadership, the U.S. is setting the pace for wireless innovation, creating jobs and building a competitive advantage for our economy.

Investment in advanced wireless networks increases employment and has encouraged the creation of entire new sectors of our economy. Economists Robert Shapiro and Kevin Hassett recently estimated that "every ten percent increase in the adoption of 3G and 4G wireless technologies could add more than 231,000 new jobs to the U.S economy."¹ These jobs aren't just at large companies; increasingly, they are found in smaller, start-up firms that are leveraging the wireless platform to build new businesses. As economist Michael Mandel recently observed in a study for Tech Net, the "app economy" is now a substantial job creator.²

What makes this all the more amazing and impactful is that as recently as five years ago, the notion of "apps" was pretty limited, and unless you were involved in the wireless industry you'd probably never heard of them. Today, we're increasingly depending on them and use apps to shop, pay bills, read the news, and stay in touch. In a way, this is simply a logical extension of the process that has led your wireless device to replace a slew of products – things like PDAs,

¹ Robert Shapiro and Kevin Hassett, "The Employment Effects of Advances in Internet and Wireless Technology: Evaluating the Transitions from 2G to 3G and from 3G to 4G," Jan. 2012, at 2, available at http://ndn.org/sites/default/files/blog_files/The%20Employment%20Effect%20of%20Advances%20in%20Internet%20and%20Wireless%20Technology_1.pdf.

² Michael Mandel, South Mountain Economics, "Where the Jobs Are: The App Economy," Feb. 2012, available at <http://www.technet.org/wp-content/uploads/2012/02/TechNet-App-Economy-Jobs-Study.pdf>.

cameras, MP3 players, GPS devices, or even watches - that you used to carry or wear and that are now included in your smartphone.

The demand for mobile data services is exploding. Wireless data traffic grew 123 percent from 2010 to 2011, and the pace is accelerating, as the last six months of 2011 were 132 percent greater than the last six months of 2010. There also was a 43 percent increase in the number of active smartphones in 2011 as compared to 2010.

To stay ahead of this demand, CTIA's members invest more than \$20 billion annually (including more than \$25 billion last year³) to extend and upgrade the capabilities of wireless networks. But even at these impressive levels, network investment alone will not allow us to stay ahead of the exploding demand that is being driven by consumers' and businesses' appetite for mobile broadband services. Additional spectrum will be necessary too.

The need for additional spectrum has been well-documented both by the government and respected private sector parties. Even conservative estimates project U.S. mobile data traffic to grow by a factor of more than ten between the end of last year and 2015. This demand is being driven by consumers' migration from feature phones to smartphones and tablets that, while employing advances in spectral and computing efficiency, allow users to demand more and thus strain wireless networks in an unprecedented manner. The evolution of machine-to-machine communications will only exacerbate this challenge. If vehicular traffic in your congressional district was predicted to grow by a factor of ten over the next five years, you'd want to know that transportation authorities had a plan to deal with it. The same should be true with regard to spectrum.

For this reason, and to maintain the advantages that flow from our world-leading position, CTIA believes it is imperative that policymakers embrace policies that will make additional spectrum available on a predictable, near-term basis. We also hope you will embrace policies that

³ See <http://www.ctia.org/media/press/body.cfm/prid/2171>.

encourage investment and research and development, and refrain from imposing regulation that can deter the deployment of new infrastructure and technology.

With regard to the first of these priorities, predictable, near-term access to spectrum, CTIA urges Congress to ensure that the Federal Communications Commission and the National Telecommunications and Information Administration faithfully and expeditiously implement the spectrum legislation enacted by Congress this past February in Title IV of the Middle Class Tax Relief and Job Creation Act of 2012 (P.L. 112-96). While we are hopeful that the incentive auction process will result in bringing a substantial amount of spectrum to market for commercial wireless services, that spectrum will only represent a down payment toward the 500 MHz that the Federal Communications Commission called for in its 2010 National Broadband Plan (“NBP”) and that the President embraced in his June 2010 Presidential Memorandum on “Unleashing the Wireless Broadband Revolution.”⁴

In order to progress toward the NBP’s target, as well as to keep pace with what is happening in a number of Western European and Asian countries, where hundreds of megahertz are being freed for commercial use, additional spectrum will need to be made available. Toward this end, CTIA recommends that government operations in the 1755-1780 MHz band be relocated so that band can be paired with available spectrum located at 2155-2180 MHz. This would make available a substantial swath of high-quality spectrum that is already used for commercial purposes in much of the world. Making this spectrum available for commercial use will not only benefit the industry; it also will aid the U.S. Treasury, which is likely to reap significant revenue (estimated at up to \$15 billion) from the auction of these bands.⁵

CTIA recognizes that reallocation is challenging, but spectrum clearing represents a substantially better path than a default to spectrum sharing. While spectrum sharing may have

⁴ See <http://www.whitehouse.gov/the-press-office/presidential-memorandum-unleashing-wireless-broadband-revolution>.

⁵ Coleman Bazelon, The Brattle Group, “The Economic Basis of Spectrum Value: Pairing AWS-3 with the 1755 MHz Band is More Valuable than Pairing it with Frequencies from the 1690 MHz Band,” April 2011. Available at <http://www.brattle.com/documents/UploadLibrary/Upload938.pdf>.

a place as a complement to fully cleared commercial, wide-area networks, dynamically or opportunistically shared spectrum is not suitable as a substitute for large blocks of licensed spectrum. This is because this type of sharing imposes restrictions that are inconsistent with traditional wide-area, high-capacity wireless network operations and which would impair carriers' ability to deliver the type of high-quality, low-latency services upon which users – especially those in business and government – rely. Additionally, while there has long been speculation that advances in technologies like cognitive radio will enable frequency-hopping and decrease the demand for dedicated spectrum, the reality is that these advances have yet to produce a commercially viable solution.

While additional spectrum must be made available for commercial use, additional tools are being used aggressively to meet demand. CTIA's members continue to invest in new facilities, deploying more than 30,000 new sites last year. This process will be aided by siting language included in the recently enacted spectrum legislation. CTIA's members also are moving toward the deployment of smaller cells and the use of wi-fi offload is now a standard industry practice. Our carriers and manufacturers are committed to driving spectrum efficiency to the maximum extent possible. Notwithstanding this commitment to the deployment of additional infrastructure and new efficiency techniques, the release of additional spectrum into the marketplace remains the single most important thing that can be done to ensure the continued vibrancy of the wireless ecosystem.

While spectrum policy is paramount, there certainly are other factors that can affect the industry's continued success. In particular, CTIA urges Congress to be mindful that regulatory and tax policies have a substantial impact on the ability and incentive for our members to invest in new facilities and the development of new technologies.

The history of the commercial wireless market demonstrates that granting an entity the right to the exclusive, flexible use of a block of spectrum, within specified frequency and spatial boundaries, and ensuring that entity's use of the spectrum will not be subject to harmful interference, is a tremendously powerful way for the government to encourage innovation and

investment. Without exclusive licenses – and their attendant protections – it is doubtful that the massive investment and tremendous innovation that has occurred in the mobile wireless services market would have come to pass.⁶

Licensees invest based on the certainty that they will benefit from the advances they implement. This certainty, in turn, is tied to a licensee's bundle of spectrum usage rights, including protection from interference. Companies will not invest billions of dollars in wireless infrastructure if they have little certainty that they can operate at a planned level of quality and make the modifications necessary to meet the demands of a dynamic, evolving marketplace, free from unnecessary regulatory impositions.

On this point, it is noteworthy that on January 18, 2011, the President issued an Executive Order that recognized the burdens associated with regulatory requirements and the negative impact such regulations may have on innovation.⁷ Accordingly, the President directed Executive Agencies to take into account the cost of regulations and to adopt regulations that promote innovation.⁸ Even more recently, Cass Sunstein, who oversees the Office of Information and Regulatory Affairs, directed the heads of Executive Departments and agencies to "to take account of the cumulative effects of new and existing rules and to identify opportunities to harmonize and streamline multiple rules."⁹ In a related blog post, he noted that the "sheer accumulation of regulations can cause real harm, especially for small businesses and startups."¹⁰

⁶ Thomas Hazlett and Evan Leo, "The Case for Liberal Spectrum Licenses: A Technical and Economic Perspective," 26 *Berkeley Technology Law Journal* (2011), 1037-1101, available at http://btjl.org/data/articles/26_2/1037_1102_Hazlett_112111%20Web.pdf.

⁷ Exec. Order No. 13563, "Improving Regulation and Regulatory Review," 76 FR 3821 (Jan. 18, 2011), <http://www.whitehouse.gov/the-press-office/2011/01/18/improving-regulation-and-regulatory-review-executive-order>.

⁸ *Id.*

⁹ See <http://www.whitehouse.gov/sites/default/files/omb/assets/inforeg/cumulative-effects-guidance.pdf>.

¹⁰ See <http://www.whitehouse.gov/blog/2012/03/20/smarter-regulation-reducing-cumulative-burdens>.

CTIA agrees with those points and believes that government policy should preserve and advance spectrum licensees' incentives for investment and innovation by continuing to make spectrum available pursuant to the exclusive- and flexible-use licensing framework and by avoiding the imposition of unnecessary regulations.

Similarly, CTIA urges Congress to recognize that massive capital investment on the order undertaken by the wireless industry is extremely sensitive to changes in the tax code. Measures like the accelerated expensing of capital investment and acceleration of AMT credits enacted under President Bush and continued under President Obama have encouraged the transition from 3G to 4G. Allowing this treatment to expire at the end of 2012 may discourage incremental investment in wireless and other communications infrastructure. Without continued advances in the scope and quality of network infrastructure to support new devices and applications, the virtuous cycle of innovation will grind to a halt.

Additionally, Congress should adopt a permanent or at least multi-year extension of the research and development ("R&D") tax credit. Like many of the other tax provisions mentioned above, extending the R&D tax credit will spur innovation through continued research, which will in turn lead to increased economic growth. The manufacturers and developers that supply the wireless equipment on which our carriers depend invest significant percentages of their revenue in research and development. This process is costly and long-term; it should not be subject to the periodic failing by Congress to extend the R&D credit. In the 1980s, when the wireless revolution began, the U.S. ranked first among OECD countries offering R&D tax incentives. Today, the size of the U.S. credit is smaller than that offered in most other OECD countries and the U.S. is the only country that subjects its credit to the sort of "on again, off again" treatment that has resulted in the credit being expired at the current time.

Last week, I had occasion to travel to Texas and visit with several of CTIA's large manufacturers, each of which maintains a substantial R&D presence in the Dallas area. Collectively, the companies I visited last week spend more than \$10 billion annually on R&D. A substantial amount of that total is spent here in the United States, supporting thousands of good, high-

wage jobs. But if Congress continues to neglect the fact that the U.S. faces fierce global competition for R&D investment dollars, it does so at America's peril. The companies I visited in Dallas are multi-national companies that could just as easily choose to locate those R&D activities in a country that offers more favorable and predictable treatment of R&D investments. That is the exact opposite of what the wireless industry, and the American economy, needs.

In sum, while I believe that the wireless future is bright, there is a great deal to be done to ensure that we maximize the opportunity and continue U.S. leadership in this vital industry. CTIA looks forward to working with you and your colleagues on these matters.

Thank you for the opportunity to appear at today's hearing.

Chairman QUAYLE. Thank you very much.
I now recognize Ms. Brown for five minutes.

**STATEMENT OF MS. MARY BROWN, DIRECTOR,
TECHNOLOGY AND SPECTRUM POLICY,
CISCO SYSTEMS, INC.**

Ms. BROWN. Good afternoon, Chairman Quayle and Ranking Member Edwards and Committee Members. Thank you for the opportunity to talk with you about the dynamic changes Cisco is seeing in the wireless economy.

Today's topic is the spectrum crunch. "Crunch" is a term intended to convey a shortage or scarcity of spectrum where demand exceeds supply. More poetically, crunch is the sound of your teeth gnashing when the Internet fails to launch from your mobile device or you can't send that important email.

Cisco as a technology vendor sees evidence of the spectrum crunch all around us, from our analysis of traffic data and consumer usage to the technologies our service provider customers are asking us to develop to the activity we observe in the spectrum market.

Where is this crunch coming from? Simply put, from all of us. More and more powerful smartphones, tablets, laptops, and other mobile devices accessing rich data, such as video, are sending more and more information wirelessly to the Internet. Cisco's U.S. mobile data forecast projects that the volume of data traffic on mobile service provider networks will increase 16 times from 2011 to 2016. That is just stunning.

So, confronted with the exponential growth in mobile traffic, we believe that action must be taken. Additional spectrum must be found. Congress made a solid down payment earlier this year when it increased spectrum for broadband by authorizing voluntary incentive auctions in H.R. 3630, but more action is needed. Otherwise it could limit and constrain the innovation, job creation, and the economic growth that we all want to see.

So what is causing mobile data demand to rise so steeply? First, consumers' use of mobile data is growing, and there is no end in sight. In 2011, four percent of users were generating more than one gigabyte of mobile data per month, the equivalent of downloading about six TV shows, but by 2016, 74 percent of users will be in the gigabyte club.

Second, the data transmitted will be video in many forms, from YouTube, TV shows, video calls. By 2016, over two-thirds of mobile traffic in the U.S. will be video.

Third, many more people will use multiple devices. In 2011, eight percent of U.S. subscribers used multiple mobile devices, and by 2016, it is 25 percent. In addition, mobile networks will also support machine-to-machine connections. So what do I mean by machine by machine? I mean, smart meters to conserve energy, sensor networks to make our roads and communities safer, and home health care monitoring to reduce health care costs and improve outcomes. By 2016, there will be 726 million mobile connections for just 348 million people in the U.S. That illustrates the power and the impact of machine to machine.

Fourth, mobile devices themselves are changing and driving new traffic demands on networks. For example, by 2013, smartphones will become the most dominant device type responsible for mobile data traffic. From 2011 to 2016, the smartphone evolves from an email device to a fully capable hand-held computer. In 2016, there will be many more things consumers do with their smartphones than we do today.

Policymakers, I believe, understand these challenges and are taking them seriously. In addition to congressional action, the National Telecommunications and Information Administration has just released its report on the 1755 to 1850 megahertz band, evaluating the cost and challenges of relocating federal users in that band. Clearing as much of this spectrum as possible is important to meet consumer demand for mobile broadband and keep the U.S. in the forefront of technology leadership.

The technology sector, for its part, is also innovating quickly to try to help our service provider customers meet consumer demand and tell additional spectrum can be placed in service. New chipset designs, base stations, and antenna technology and network management tools are a few of the offerings designed to bring more efficiency from available spectrum. Carriers are aggressively deploying Wi-Fi and Femto cells in an effort to offload mobile traffic to fixed networks where possible. AT&T and Verizon Wireless are deploying LTE or 4G networks, which are more efficient than the prior 3G technology, and carriers continue to deploy additional cell sites to reuse existing spectrum.

But even with all these efforts, we cannot expect technology alone to solve the spectrum crunch. So what are the next steps? I encourage Congress to investigate specific spectrum bands that can be repurposed for mobile broadband and to realize that additional legislative action will be necessary.

We look forward to working with you, the Administration, and the commercial sector to identify spectrum opportunities, including in bands now used by federal agencies. Thank you, again, for the opportunity to appear today, and I look forward to your questions.

[The prepared statement of Ms. Brown follows:]

Testimony of Mary Brown
CISCO SYSTEMS, INC.
Before the
Subcommittee on Technology and Innovation
Committee on Science, Space, and Technology
U.S. House of Representatives
Hearing on "Avoiding the Spectrum Crunch: Growing the Wireless
Economy through Innovation"
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Rayburn House Office Building – Room 2318

Summary

The explosive growth in the wireless economy is a global phenomenon. The U.S. technology sector has led that mobile broadband revolution. The U.S. is where global technology companies come to develop mobile broadband technologies, where the mobile app industry took root, where innovation is happening, and where thousands of new jobs are being created. Innovation in the private sector occurs when there is a market for entrepreneurs and innovators to sell their inventions. Spectrum tailored for use by mobile broadband networks is a necessary ingredient in the creation of that market. Without the market opportunity presented by additional radio spectrum for broadband, our country's technology leadership could stagnate and huge economic and social benefits may not be fully realized.

Cisco's US mobile data forecast projects that mobile data traffic will increase 16 times from 2011 to 2016 for a compound annual growth rate of 74 percent. If those numbers are too large to comprehend, then think of it this way -- the increment of growth in mobile data traffic from 2012 to 2013 will be twice as large as all the traffic that was carried on US mobile networks in 2011. Consumers will use more data, transmit and consume much more video of all types, operate more devices per capita, and utilize much more powerful devices than available today.

Even taking into account all types of technology efficiencies, from the introduction of LTE networks, to adding additional cell sites, to the creation of small cells to offload traffic more quickly to wired networks, antenna technologies, and improved network management technologies, it will not be enough. More spectrum is needed, and needed soon. Congress, the FCC, and the NTIA are already at work to find more spectrum, but much more work remains to be done. It's important that the Congress understand the dynamic growth occurring in this industry, and why public policy is critical to that growth. This Committee provides an excellent platform for making these connections more obvious to all.

Testimony

Good afternoon, Chairman Quayle and Ranking Member Edwards. Thank you for the opportunity to talk with you about the dynamic changes Cisco is seeing in the wireless economy.

Cisco is a San Jose based manufacturer of broadband networking equipment and services used by service providers, enterprises and consumers worldwide. Among other things, we produce advanced networking technologies used by mobile operators and are the largest manufacturer of Wi-Fi devices in the world. Cisco spends \$5.8 billion per year on research and development, which is 13 percent of our revenue. Cisco ranks eighth among U.S. companies in number of U.S. patents issued in 2011, with total of 8,600 US patents. Globally, Cisco earns \$43 billion in revenue, employs 63,000 people, and has relationships with 52,000 partner companies who implement Cisco technologies in their customer networks. From this description, you can see that Cisco's success is tied to innovation.

The explosive growth in the wireless economy is a global phenomenon. The U.S. technology sector has led that mobile broadband revolution. The U.S. is where global technology companies come to develop mobile broadband technologies. This is where the mobile app industry took root. This is where innovation is happening. It's creating thousands of new jobs fueled by access to spectrum. As this committee knows better than most, innovation in the private sector occurs when there is a market for entrepreneurs and innovators to sell their inventions. Spectrum tailored for use by mobile broadband networks is a necessary ingredient in the creation of that market. Without the market opportunity presented by additional radio spectrum for broadband, our country's technology leadership could stagnate and huge economic and social benefits may not be fully realized; without radio spectrum, the economic activity and investment in wireless broadband will gravitate to other regions of the world that are making spectrum available, such as the European Union and the AsiaPac rim.

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Understanding this story – and the role of a critical government-controlled input such as spectrum to the development of a vibrant wireless economy – is important. This hearing, and other activities sponsored by this Committee, are necessary in order to educate Congress about the vital role policy-makers play in fostering not just research and development or innovation, but jobs and global technology leadership.

Today's topic is the spectrum crunch. "Crunch" is a term intended to convey a shortage or scarcity of spectrum where demand exceeds supply. More poetically, "crunch" could also be the sound of your teeth gnashing when a call drops, your connection fails, the Internet fails to launch from your mobile device, or you can't send that important email. Cisco, as a technology vendor, sees evidence of the spectrum crunch all around us – from our analysis of traffic data and consumer usage, to the technologies our service provider customers are asking us to develop, to the activity we observe in the spectrum market.

This testimony discusses several topics related to the spectrum crunch: (1) Cisco's projections of mobile data traffic growth through 2016 demonstrating that we are very early in the transition to mobile broadband; (2) how consumers will experience the crunch; (3) the need for more spectrum; and (4) progress toward finding more spectrum. If more spectrum is not put into the hands of commercial operators quickly, then dropped calls, slower downloads, failed applications and more, will be a very common experience for consumers. According to the FCC, the first wave of these impacts could come as early as next year.

Because Cisco has to anticipate the networking needs of our service provider customers, including our wireless customers, Cisco invests heavily in understanding current traffic trends and projecting those trends forward. A few years ago, we decided to formalize this activity in the form of a publicly released

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report we call the “Visual Networking Index” which is available to you and your staffs at www.cisco.com/go/vni

Each February, we have been publishing a “Global Mobile VNI” tracking mobile broadband traffic worldwide and in individual countries such as the US. The results indicate that we are at an important pivot point in the wireless economy – we are early in the transition from mobile technology that supported voice and email to new broadband technologies that provide the full Internet experience from the palm of your hand. And as with any new technology, consumer usage is growing at an astonishing rate.

Our US mobile data forecast projects that the volume of data traffic on mobile service provider networks will increase 16 times from 2011 to 2016. That statistic represents a compound annual growth rate of 74 percent. That’s just a stunning growth rate. Here are several ways to try to grasp the significance of this growth.

- U.S. mobile data traffic will grow at a rate that is four times faster than U.S. fixed IP traffic from 2011 to 2016.
- The increment of growth in mobile data traffic from 2012 to 2013 will be twice as large as all the traffic that was carried on US mobile networks in 2011.
- By 2015, the pace of growth has gathered even more steam – just the increment of traffic growth between 2015 and 2016 is projected to be five times all of the traffic carried on US mobile networks in 2011.
- By 2016, mobile data traffic will be equivalent to four times the volume of the entire U.S. Internet in 2005.

What is causing mobile data demand to rise so steeply? Cisco has identified four big trends.

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First, consumers are receiving, and transmitting, more mobile data. In 2011, 4 percent of users were generating more than one gigabyte of mobile data per month. By 2016, 74 percent of users will be generating that much data each month. The average user in 2011 used 324 megabits of data a month. Roughly speaking, that's the equivalent of downloading 160 songs or 32 apps or 2 videos. In 2016, the average user will be consuming 4.2 gigabits a month or roughly 25 videos.

Second, the data that those consumers are going to be consuming will mainly consist of video in many forms – from YouTube, to video embedded in advertisements, to long form programming, and video “calls” which will become more frequent than they are today. Mobile video traffic will nearly double every year between 2011 and 2016, and by 2016, over two thirds (68%) of mobile traffic in the US will be video.

Third, more consumers are going to mimic the behavior of many of you on this committee, by owning and using more than one mobile device per person. In 2011, 8% of US subscribers used multiple mobile devices. By 2016, that number advances to 25% of subscribers. In addition, to multiple devices per person, mobile broadband will also support machine to machine connections – connecting not just people, but things. These machine to machine connections will be deployed into a wide variety of sectors – from energy supporting smart home energy meters as well as transmission and distribution networks, public safety supporting sensor networks and mobile video imaging, to healthcare such as home healthcare services. When we look at the total number of mobile connections that will be supported by operator networks, by 2016 there will be 726 million mobile connections for 348 million people in the US.

Fourth, the mobile devices themselves are changing, and driving new traffic demands on networks. Let me caution you that the changes in this part of our analysis remain highly dynamic and difficult to predict. Two years ago, Cisco did not even consider tablets to be a device category, and yet today these

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devices are too popular to be ignored. By 2016, the amount of annual U.S. mobile data traffic generated by tablets (145 petabytes) will be nearly one and a half times more than all U.S. mobile data traffic generated in 2011 (100 petabytes). Smartphones are having a huge impact as well, and by 2013 will become the most dominant device type responsible for mobile data traffic. Dominance of the smartphone as a device category continues to multiply through 2016, according to our projections. Moreover, all of these devices, regardless of category, become more powerful, placing new demands on networks. The average smartphone today uses about 200 megabits of traffic per month. By 2016, the device manufacturers will be selling smartphones that we project will generate 4,520 megabits per month. They will be smarter, faster, more fun, and there will be many more things that consumers do with their smartphones than we do today.

How good are these data points? As good as they were on the day in February when we released our most recent study. What Cisco has produced is a snapshot of a highly dynamic, fast growing market. That's why each year we update our data and learn new things. Our study relies on actual traffic data measurements from carrier networks, analyst reports and our own modeling. Since we began releasing the report, we have found that our projections of the current year have been accurate and slightly conservative – we underestimate what actually happened by a few percentage points.

With numbers as breathtaking as the ones Cisco is projecting, one logical question is – are we going to run out of spectrum? And what does that look like to the consumer? The answer is that the spectrum crunch will evidence itself differently by carrier (depending upon the spectrum licensed to that carrier and the technologies the carrier is using) and by geography. We can expect that in places like New York and San Francisco, where millions of consumers are competing for radio spectrum each time they use their devices, that once their carrier has released all available spectrum into that market, and the spectrum in use becomes congested, then consumers will experience the spectrum crunch in a broad

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way. This is already happening in a few major cities during rush hours for some carriers. Quality of service suffers – e.g., dropped calls and connections, inability to access the Internet, failure of a favorite app to load, and inability to send email. You probably have already had an experience like this – especially in places where there are many users trying to connect to the network simultaneously like at a ballgame or in a large traffic jam.

The Federal Communications Commission (FCC) staff, using Cisco's VNI data, projected in the fall of 2010 that the US needed to find 275 MHz of radio spectrum for broadband in five years to keep pace with the rising traffic demand. In their earlier-released National Broadband Report, the FCC estimated they would need 500 MHz of spectrum for broadband in 10 years (2020). The Administration embraced the 500 MHz goal in a Presidential Memorandum in 2010, directing the National Telecommunications and Information Administration to assist the FCC in finding 500 MHz of spectrum, including by identifying federal spectrum uses that could be moved to make way for commercial mobile use.

Progress is being made toward finding additional spectrum. Congress led the way with adoption of HR 3630 earlier this year, creating for the first time voluntary incentive auction authority that will allow the FCC to repurpose part of the television broadcast spectrum for mobile broadband. The bill also extended the FCC's regular auction authority and made important improvements to the Commercial Spectrum Enhancement Act governing the transition of federal spectrum to commercial use. Congress now needs to ensure that the FCC follows through on its grant of auction authority by conducting the voluntary incentive auction for broadcast spectrum as soon as possible. It will take several years for the FCC to complete its work. How much spectrum is actually cleared through this effort is unknown, but we do know that the best case scenario would clear 120 MHz, thus leaving us significantly short of the needed 500 MHz identified by the FCC and the Administration.

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The NTIA is also continuing its efforts to identify federal spectrum that can be repurposed to commercial use. NTIA just released its report on the 1755-1850 MHz band, evaluating the cost and challenges of relocating federal uses of that band to other bands. This 95 MHz of spectrum is of great interest because globally, the band is in use or in transition to mobile broadband. That's important for the technology sector because it means there is a global technology market opportunity. The NTIA report has signaled that relocating federal users will be difficult and expensive, and will take years. From the vantage point of future benefits to the economy, to jobs, and to consumers, we should not shy away from these difficult problems. Clearing as much of this spectrum as possible is an important way to meet consumer demand for mobile broadband and to keep the US at the forefront of technology leadership. We are hopeful that progress can continue to be made on transitioning this band.

In addition, the technology sector, for its part, is hard at work to try to help our service provider customers meet consumer demand until additional spectrum can be placed in service. Many technology companies are creating offerings to forestall congestion, and the service provider industry has been quick to implement them. One of the key innovations that are helping to address the spectrum crunch is offloading data from mobile networks onto Wi-Fi networks or other small cell technologies such as Femto cells. Let's look at an example using Wi-Fi. When a smartphone or tablet switches to a Wi-Fi network for data transmission, the spectrum used is not mobile spectrum, but entirely different radio spectrum known as unlicensed spectrum. When the mobile device you hold in your hand or on your lap communicates to a Wi-Fi router, data is transmitted back to the service provider using wired networks, not mobile wireless ones. Cisco estimates that today, almost half the data traffic generated at the edge of all IP networks is offloaded to Wi-Fi on a global basis. That offloading number will rise over time, but it's important to recognize – Wi-Fi cannot replace mobile spectrum. Wi-Fi is good for connecting your device when you are at home, in the office, at a public park, or a coffee shop, but it is not a useful technology when you are in a cab heading to the airport at 60 miles an hour.

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Across the technology industry, there is a broad range of innovations that are rolling out to help carriers cope with a shortage of spectrum. New chipset designs, new base stations and antenna technology, and new network management tools are a few of the offerings designed to wring more efficiency from available spectrum. This is being driven by customer demand – by service providers not just here in the US, but globally, who are experiencing the same problems. The push to deploy Long Term Evolution (LTE) networks (known as “4G”) is itself evidence of this trend, as LTE networks are much more efficient in carrying data traffic than prior network technologies. But despite increased efficiencies, the LTE networks currently under construction by AT&T and Verizon Wireless will not be enough by themselves to address rising demand. The carriers have said so, and so did the FCC in its fall 2010 study. Nor will the creation of additional cell sites be sufficient, as the FCC found in its study.

The Federal government is helping too. As part of HR 3630, Congress has directed the NTIA to consider opening more 5 GHz spectrum for unlicensed devices on a shared basis with federal systems. This is important because 5 GHz is the growth band for Wi-Fi technology. More access to shared spectrum here by Wi-Fi devices will help address the spectrum crunch since Wi-Fi is one of the technologies that enables mobile traffic to be offloaded onto fixed Wi-Fi connections. Industry is working very hard to provide technical inputs into NTIA’s first report, which is due back to this Congress in October. But this is not a silver bullet answer to the spectrum crunch problem either.

Will our technology improvement efforts be enough? Will the tech sector be able to generate efficiencies so great that additional spectrum is not required? No. Additional spectrum is needed. The growth in demand is simply too large and too sustained. Spectrum must be part of the answer, along with technology improvements. Network infrastructure companies like ours and the carriers themselves have repeatedly argued before Congress and the FCC that additional spectrum must be

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found because there is no technology or combination of technology solutions that is likely to be available to manage rising traffic demand using spectrum now available or in the pipeline.

Our nation is the leader in mobile broadband. The wireless revolution spurs the construction of new high speed wireless networks. It drives the manufacturing of chips, routers, network equipment, and mobile devices such as smartphones, laptops, and tablets. It creates business and consumer software, the development of app stores, and substantial growth in electronic commerce.

Mobility has been an important driver of jobs and economic growth, and it has the potential to generate hundreds of thousands more jobs if the federal government acts promptly to ensure that additional spectrum is made available to fuel future mobile broadband growth. It's important that the Congress understand the dynamic growth occurring in this industry, and why public policy is critical to that growth. This Committee provides an excellent platform for making these connections more obvious to all.

Thank you again for the opportunity to appear today. I look forward to your questions.

Chairman QUAYLE. Thank you very much.
I now recognize Dr. Subramanian for five minutes.

**STATEMENT OF DR. RANGAM SUBRAMANIAN,
CHIEF WIRELESS AND TECHNOLOGY STRATEGIST,
IDAHO NATIONAL LABORATORY**

Dr. SUBRAMANIAN. Chairman Quayle, Ranking Member Edwards—

Chairman QUAYLE. Is your mic on?

Dr. SUBRAMANIAN. Sorry. Let us try again. Chairman Quayle, Ranking Member Edwards, and Members of the Subcommittee, I want to thank you for the opportunity to testify before the House Science, Space, and Technology Subcommittee on Technology and Innovation.

I realize the importance of this topic, “Avoiding the Spectrum Crunch: Growing the Wireless Economy through Innovation.” I understand there is so much at stake for the future of the national economy and national security of this great Nation based on how we can handle this spectrum crunch today.

My name is Dr. Rangam Subramanian. I am the Chief Wireless Strategist at the Idaho National Laboratory.

In the interest of time I will discuss the key points in my written testimony.

As everyone said here, wireless spectrum is a limited natural resource just like gasoline. There is exceptionally high demand on this low supply, and there is little unallocated spectrum available for exclusive allocations.

However, wireless communication is a critical common technology track for all the key economic sectors in the future. It influences national security, emergency and first responder communications, smart grid energy infrastructure, electric vehicles and transportation systems, advanced manufacturing systems, medical devices, and so on.

So the demand for additional spectrum is not just restricted to the United States. Globally the European Union, Singapore, and China are all experiencing same issues, but they are also aggressively seeking innovative solutions and have established research testbeds that can be used by many people and innovations and patenting is rapidly growing there, which means is the United States behind in initiating this effort in a larger way. Perhaps is this an opportunistic moment for gaining global spectrum leadership and impacting the global economy?

Now, there are three key challenges to this solving the spectrum crisis and gaining global leadership in this country. Number one, there is a need for a national approach. It is important for the different national spectrum stakeholders to appreciate the crunch is for real and sharing primarily or repurposing in specific cases, especially with an emphasis on securing national security.

It is extremely important, both on the government side and on the industry side, and everyone has to work with the national agencies to identify spectrum bands for initiating research and experimentation in support of repurposing or sharing. Collaboration

is needed to build trustable, secure spectrum sharing technologies—including technologies for high-frequency operations.

The government has initiated some important efforts. The NTIA and FCC have been trying to work, identify suitable banks for spectrum repurposing or sharing and are also coordinating with several agencies. The recent *Middle Class Tax Relief and Job Creation Act of 2012*, H.R. 3630, has also identified specific bands for sharing and repurposing.

There are critical national efforts. For example, by the National Wireless Spectrum R&D Senior Group facilitating collaboration across the government agencies to develop an inventory of the research initiatives in the Nation, as well as the testing facilities. However, there is a long way to go in terms of realizing all the spectrum needed for the industry.

Challenge two, a strategy for accelerated spectrum-sharing technology development. Technology development is pretty much in infancy stage right now. There are research reports going around, but that is not in a deployable form. Stakeholders both from the government side and the industry need trust and security in spectrum sharing. Secure technologies, standardization, experimentation, and business models are extremely critical if sharing is to become successful.

The wireless carriers, equipment manufacturers, devices, and application vendors are not showing very keen interest in developing sharing technologies because it is not showing immediate return on investment.

Now, entrepreneurs have—the DOD labs have a limited portfolio of research other national laboratories have a lack of funding. The academic institutions have a lot of research going on but more on a theoretical basis. They do not have the necessary funding; for example, the NSF EARS program is lacking funding, and they do not have realistic national testbeds where they can go and really test it.

So this is a widespread problem across different research segments in developing the technologies right now.

Also, research on wireless cybersecurity is extremely critical. We have done this mistake with wireless security, and we cannot afford to do this going forward.

Now, secondly, standardization of the spectrum-sharing technology is in its infancy. There are limited efforts going on, one with the lack of technology, second with the understanding of the technology that experimentation and data sets are really important before you can standardize. So—that is a major problem. There are efforts by the International Telecommunications Union as well as by the Institute of Electrical and Electronics Engineers, IEEE. In fact, I was at a standards meeting yesterday talking on this topic. So we need this standardization effort to keep going on. It is extremely critical.

And one of the major impediments to spectrum-sharing technology innovation is the identification and creation of realistic outdoor testbeds where experimentation can be done. This is very clearly stated by the industry and academia during the second national workshop conducted by the Wireless Spectrum R&D Senior Group in January 2012, which I also happen to co-chair.

There are multiple Department of Defense wireless testing ranges that are primarily focused on operational testing and classification requirements. There are also smaller, non-DOD ranges, which are limited in their ability to enable real-world experimentation. And there are others in academia that are basically performing experimentation in unlicensed spectral bands using Wi-Fi, Bluetooth, and Zigby, which is not real life. We are talking about so many different bands and so many different kinds of applications which need to share the spectrum.

Now, since I was specifically asked by the Subcommittee to provide some details on the Idaho National Lab, I would like to provide a quick brief. Idaho National Lab has an 890-mile wireless range facility for supporting this national effort. In April 2011, after visiting the INL wireless experimentation facility, the National Wireless Spectrum R&D Senior Steering Group commented that, "The Idaho National Laboratory represents a unique opportunity for unfettered development and testing of advanced spectrum-using technologies in that Nation."

Chairman QUAYLE. Doctor, if you could wrap it up in 30 seconds, that would be great. Thank you.

Dr. SUBRAMANIAN. I will. Thank you.

Chairman QUAYLE. Thank you.

Dr. SUBRAMANIAN. I particularly note the existence of the wireless range of—and a strong research team working on related research, executing our nationally important experimentation. INL is making research investments on spectrum-related research, how a comprehensive national plan will help laboratories like INL.

Now, the third challenge, funding and collaboration support. The Nation is faced with the spectrum crunch, yet there is currently insufficient funding to accelerate development as well as experimentation. Without technologies to validate spectrum sharing trust and security, it is not possible to build the required government-industry support for collaboration.

The recently enacted H.R. 3630 bill has recommended specific spectral bands, but it also needs to be augmented with sufficient funding or proper funding to conduct research and experimentation.

In summary, the responsiveness of the Nation to the spectrum crunch challenge will have a significant bearing on economy growth and national security. The government has taken some important steps, but there is a long way to go in terms of a comprehensive national approach to spectrum sharing, accelerated technology development, and testing.

Thank you for the opportunity.

[The prepared statement of Mr. Subramanian follows:]

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Testimony of

Dr. Rangam Subramanian

Chief Wireless and Technology Strategist,
Idaho National Laboratory, Idaho Falls, Idaho

Before the

House Committee on Science, Space and Technology

Subcommittee on Technology and Innovation

On

**“AVOIDING THE SPECTRUM CRUNCH: GROWING
THE WIRELESS ECONOMY THROUGH
INNOVATION”**

April 18, 2012

Introduction

Chairman Quayle, Ranking Member Edwards, and members of the subcommittee, I want to thank you for the opportunity to testify before the House Science, Space, and Technology Subcommittee on Technology and Innovation. I realize the importance of this topic: "Avoiding the Spectrum Crunch: Growing the Wireless Economy through Innovation," and there is much at stake for the future national security and the economy, based on how the spectrum crisis is handled today.

My name is Dr. Rangam Subramanian. I am the Chief Wireless Strategist at the Idaho National Laboratory (INL), Idaho Falls, Idaho.

In my testimony today, I will address the following:

- Current status of the wireless spectrum situation in our nation
- Impact of limited wireless spectrum on America's global competitiveness
- The three major challenges to solving the wireless spectrum problem
- My role and opinions on the activities of the national Wireless Spectrum R&D (WSRD), Senior Steering Group (SSG) that was initiated by the White House, Office of the Science and Technology Policy (OSTP)
- The spectrum sharing research, experimentation, and demonstration capabilities at the INL supporting wireless innovation in the nation.

Current Status and Impact on Competitiveness:

Wireless spectrum is a limited natural resource. There is only so much spectrum available and yet the demand continues to grow. In fact, wireless communications is a critical common technology imperative that will greatly influence the growth of all key economic sectors, as well as our national security. Wireless spectrum crunch will impact the national defense systems, emergency and first responder communications, Smartgrid energy infrastructure, electric vehicles and intelligent transportation systems, advanced manufacturing systems, financial industry, medical devices, consumer electronic devices, and others. It is the increased use of the wireless spectrum for all these economic and defense sectors that is already causing "spectrum crunch"; it is starting to be felt by many Americans across the nation.

Statistics reflect the exponential growth of mobile devices and the resulting explosion in data traffic, or wireless spectrum usage. One of these statistics suggests that there will be 50 billion mobile connections globally by 2020, with the mobile multimedia data usage increasing by 60% per year. By 2016, the demand for commercial wireless spectrum usage in the United States is expected to see a 10-fold growth. To keep up with consumer demand, wireless industry in the United States has requested 800 MHz of additional spectrum. However, the Federal Communications Commission (FCC) in its National Broadband Plan, released in March 2010,

stated that there is little unallocated spectrum available for new exclusive allocations. Hence, one or a combination of the following is required: sharing spectrum, possibly repurposing spectrum usage to different bands enabled by efficient usage technologies, and research on high-frequency usage. The Spectrum crunch situation has forced the national priority call for spectrum technology innovation and experimentation.

The demand for additional spectrum is not restricted to the United States. Globally, the European Union, Singapore, and China are experiencing the same limitations; however, they are already aggressively seeking innovative solutions and developing technological patents that will solve their spectrum availability challenge and, importantly, further their market share in related industries. With appropriate government support through policies, a national technology development strategy, and funding, the United States can establish global leadership in this crucial area. This support will empower technical achievements, grow the economy, develop job opportunities and increase assurance of national wireless communications security.

NITRD WSRD SSG Support for Technology Development and Experimentation

In June 2010, the *Presidential Memorandum: Unleashing the Wireless Broadband Revolution*, was issued. This enabled the establishment of the National Information Technology R&D (NITRD) Wireless Spectrum Research and Development (WSRD) Senior Steering Group (SSG), in November 2010. The WSRD group represents 16 agencies and is chartered to assist the Secretary of Commerce in creating and implementing the plan to facilitate the research, development, experimentation, and testing required yielding innovative spectrum-sharing technologies. I am an active member of this group.

I believe the Wireless Spectrum R&D national steering group has effectively collaborated with the government agencies to develop an inventory of the research initiatives on spectrum sharing technologies being conducted by the government. The steering group also created an inventory of national test beds that can support technology innovation. Two workshops co-chaired by colleagues from the National Telecommunications and Information Administration (NTIA), National Science Foundation (NSF), Defense Advanced Research Projects Agency (DARPA), DOJ (Department of Justice), and I were conducted with technical experts and stakeholders from industry, academia, and government. These workshops were conducted to identify key gaps within the national R&D portfolio on wireless spectrum sharing innovation, to understand the nation's experimentation needs in these areas, and to identify research capabilities in industry and academia. I believe work of the SSG is critical to the nation and will continue to advance collaboration among the key government and industry stakeholders for advancing spectrum sharing innovation.

Key Challenges to Solving Spectrum Crunch

There are three key challenges to solving the spectrum crunch:

1. Need for a National Approach
2. Strategy and Technology Development
3. Funding and Collaboration Support.

A National Approach for Spectrum Sharing

One approach to spectrum sharing is to allow sharing based on real-world testing and evaluation in full-scale outdoor test beds—while meeting proper standards and protocols—to determine where sharing may feasibly occur in a secure and reliable manner without disrupting current applications. Through such an approach, immediate attention could be given to those frequency bands that are in high demand and resolve the inherent challenges of trust and security needed for different sharing models, such as government to government, government to industry, or industry to industry. Additionally, the requisite business models could be created to encourage further growth of the spectrum sharing approach.

Repurposing, on the other hand, also involves new hardware, software development and experimentation. But, because repurposing might only be a short-term solution, the risks of having to share spectrum in the long run remain. As detailed in the 1755-1850 MHz spectral band study released by the NTIA on March 27, 2012, it is expected to cost various agencies \$18.5 billion to repurpose government applications just for this 95 MHz band. Hence, besides research innovation and experimentation to exploit higher spectral frequencies for wider deployments, sharing spectrum wherever possible offers the best long-term path below the 4 GHz of commonly usable frequency spectrum.

Some of the most important governmental efforts in support of the spectrum sharing or spectrum repurposing opportunities can be summarized as follows:

- The NTIA and the FCC have been working for a few years to identify the most suitable bands for spectrum repurposing or sharing and repurposing, coordinating their studies with several agencies
- The recent Middle Class Tax Relief and Job Creation Act of 2012, HR3630, has also identified specific bands for sharing and repurposing, such as the 1675–1710 MHz, 1755–1770 MHz, 2025–2110 MHz, and the TV White Space. HR3630 has also requested studying very high frequencies for experimentation and potential deployment.

Strategy and Technology Development

Some of the drivers for technology development and a framework for R&D, standardization, and realistic experimentation are summarized below.

The wireless carriers, equipment manufacturers, devices, and applications developers are financially and competitively driven to show return on investment. This reality has left the cellular industry scrambling to find interim solutions, including offloading mobile data traffic using WiFi-like local area networking techniques to landline infrastructure where possible. As announced recently by the chief executive officer of one of the leading carriers, consumers are being forced to pay more for less, as evidenced with the removal of unlimited data plans for their mobile consumers.

Meanwhile, the equipment manufacturers are focused on supporting the deployment of the fourth generation, Long Term Evolution (LTE) technology by the leading national carriers and are not ready to invest in spectrum sharing R&D. Regarding academia, several institutions in the nation are working on various theoretical aspects of spectrum sharing research, modeling and simulation, and conducting evaluations in indoor laboratories. Some of the national laboratories are focusing on wireless technologies as they relate to sensors and other specific application areas. INL is primarily supporting DOD applications, spectrum sharing R&D, and testing to a limited extent, due to funding constraints. Research on wireless cyber security is a critical aspect that needs attention from the beginning. In the landline networks, cyber security issues were researched and understood long after large-scale deployment. Today the wireless security issues are not well understood. It is critical that there is both industry and academia focus on wireless spectrum sharing security research to better characterize the challenges, as well as to enable innovation and experimentation.

Another key component of a technology strategy is standards development. Standardization of technologies is in its infancy. In the telecommunications industry, it takes about 8–10 years for large-scale technology development, and that is after standards are established. For spectrum sharing technologies standardization, there are limited global efforts, including those being led by the International Telecommunications Union (ITU) and by the Institute of Electrical and Electronics Engineers (IEEE). National agencies are actively working on adopting broadband for customized applications, such as for public safety, the power grid, transportation systems, etc. These new applications and the associated unknown risks warrant realistic experimental testing and evaluation to standards-based protocols.

Experimentation in realistic outdoor test beds helps build credibility for all stakeholders and rule-making agencies. This was clearly stated by industry and academia during the second national workshop conducted by the national Wireless Spectrum R&D steering group in January 2012.

There are multiple Department of Defense wireless testing ranges that are focused on operational testing and classification requirements. There are also smaller ranges, which while they have

some utility, are limited in their ability to enable real-world test environments—some are close to the city and others, typically in academic institutions, are limited to indoor WiFi test facilities. What is missing is a facility that is isolated from urban and military congestion and provides users with a low radio frequency noise environment for conducting experiments on a range of equipment and devices in various spectral bands. INL provides such a facility as described later in this testimony.

Funding and Collaboration Support

The nation is faced with the spectrum crisis, yet there is currently insufficient funding to accelerate innovation and experimentation. Without technologies to validate spectrum sharing trust and security, it is not possible to build the required government-industry support for collaboration.

The recently enacted HR3630 represents progress by recommending spectrum sharing and repurposing study and analysis on specific spectral bands by the NTIA and the FCC. It is critical that appropriate funding be made available to include research and, full-scale test and evaluation based on applicable standards and protocols to make spectrum sharing a reality. Also, in this regard, designation of key facilities, such as national test beds or National User facilities, is much needed.

Spectrum Sharing R&D and Full scale Testing at Idaho National Laboratory

INL has established a research portfolio on multiple areas of spectrum sharing innovation such as dynamic spectrum access and white space sharing platforms, and wireless R&D related to SCADA devices and smart grid. Located on an 890-square-mile site in an isolated location, INL provides a very low noise environment for wireless R&D, Demonstration, and Deployment. The Laboratory has 2G (Second Generation)/3G (Third Generation) and WiMAX (Worldwide Interoperability for Microwave Access) carrier grade equipment, along with 60 miles of fiber optic links, 200 miles of roads, microwave, and satellite communications facilities. INL is an NTIA 7.11 licensed experimental station and is working with the FCC for commercial experimentation license. After visiting the INL wireless experimentation facility, the national Wireless Spectrum R&D Senior Steering Group commended that “The Idaho National Laboratory represents a unique opportunity for unfettered development and testing of advanced spectrum-using technologies.” INL is in a unique position to provide the bridge between the government, industry, and academia, and to accelerate and improve the quality of research and experimentation, and support the national standards, policy, and rule making organizations.

Summary:

The responsiveness of the nation to this spectrum crunch challenge will have a significant bearing on economic growth and national security. The government has taken some important steps to enable resolving the spectrum crunch issues, including the following:

- The FCC and NTIA are endeavoring to identify bands of spectrum for research purposes
- HR3630 ruling identifies specific wireless spectrum bands to share
- White House OSTP launching the Wireless Spectrum R&D Senior Steering Group to facilitate research, experimentation, and collaboration in the nation.

However, a comprehensive national approach towards spectrum sharing, accelerated technology development, establishment of national testbed facilities and appropriate funding support are needed. This will ensure developing solutions to solve the spectrum crunch issues, ensure future growth of the key economic sectors are not impeded by the lack of spectrum and help establish global leadership on spectrum sharing innovation.

INL, with its strong capabilities in wireless R&D and its full scale wireless test bed, stands ready to support this national initiative on spectrum sharing.

Thank you for the opportunity to testify.

Chairman QUAYLE. Thank you very much, and I want to thank all of our witnesses for their testimony.

Reminding Members that Committee rules limit questioning to five minutes.

The Chair will at this point open the round of questioning, and I recognize myself for five minutes.

Mr. Guttman-McCabe, in your testimony, you discuss how regulatory policies have a substantial impact on the ability for CTIA members to invest in new facilities and development of new technologies. Can you give us a sense of how these policies affect business decisions in the wireless industry, and also if you could, could you share specific examples of regulatory policies that could be particularly harmful to your industry's research and development?

Mr. GUTTMAN-McCABE. Certainly, and thank you, Mr. Chairman.

You know, the way we look at regulatory reform and regulatory issues is to sort of take a step back and take a 25,000-foot approach and say, you know, regulatory bodies should apply the physician's motto of first do no harm. There has been a lot of focus in the last couple of years about removing outdated or no-longer-applied regulations, and while that is beneficial, if you overlay then, you know, a half dozen new regulations and you take away regulations that weren't being in any way implemented or enforced, they are still is a net negative. And, you know, we represent carriers large and small, and when you look at, particularly from some of our smaller carriers' perspectives, when they have a dollar from a cap X budget, and it has to go towards implementing an FCC regulation or on the other hand it can go to moving towards LTE or upgrading their networks, you know, they have a finite budget. I mean, all of our members have finite budgets.

So when we look at regulations, we look at the cumulative impact of all of them, and there was an interesting memorandum that just came out from Cass Sunstein that actually said exactly that, that said you can't, while a regulation on its face may look logical, when you look at the cumulative impact of all of the regulations, that new regulation may, in and of itself, may not be logical.

And that is part of what we hope sort of Congress provides—a little oversight to the regulatory bodies is—is it is not just each individual regulation that at times may seem logical. It is the cumulative impact when you have finite capital resources. I think that is key.

And then from our perspective another one is just providing the environment for research and development investments, extending the R&D tax credit. It is a constant fight each year to try to extend it. We used to be number one in the world. We are 27th now.

Chairman QUAYLE. Okay.

Mr. GUTTMAN-McCABE. So that is an area where there could be great help.

Chairman QUAYLE. Okay. Thank you very much, and Ms. Brown, you state that without the market opportunity presented by additional radio spectrum for broadband, our country's technological leadership is going to really stagnate, and we could have huge economic and social benefits not fully realized.

How are the other regions dealing with this? How is the EEU and the Asia Pacific RIM, making spectrum available?

Ms. BROWN. Well, they had, in Europe, for example, they had the advantage of not having allocated spectrum, large swap of spectrum at 2.5 and have recently opened that more than 100 megahertz of spectrum, which given the timing by which they have released it is going to become immediately available for advanced mobile broadband technologies.

And similarly, there are similar sorts of actions in Asia Pact. Now, the reason I made that statement in my testimony is that because we have continually had radio spectrum in our pipeline for advancing technologies here in the U.S. This has become the locust. This country has become the place where these technologies are developed. Even global companies that are headquartered in Europe or elsewhere, they come here to do the development because this has been the center of mobile broadband and mobile technologies.

If we no longer have those market opportunities, our carriers are not able to advance, there are now plenty of spectrum opportunities in Europe and Asia Pact, and these development centers could migrate over time outside of the U.S., which would be a shame.

Chairman QUAYLE. Thank you, and with Cisco's Virtual Networking Index, the projects that the volume—projects that the volume of traffic on mobile service provider networks will increase 16 times—

Ms. BROWN. Uh-huh.

Chairman QUAYLE [continuing]. From now until 2016. How have Cisco and other technology companies increased deficiencies, improved technologies, and addressed rising demand through innovative research and development?

Ms. BROWN. So let me speak to Cisco and the tech sector generally. Through every layer and every corner of service provider networks, there are new technologies being deployed to try to address this right now. So from Cisco's perspective, network management technologies that enable to carriers to better balance their traffic loads so that they can spread the traffic out among cell sites. Cisco has also been at the forefront of Wi-Fi and Femto cell off-loading that many of the carriers are aggressively moving to try to get the traffic off the mobile spectrum and onto unlicensed spectrum.

But you can go on and on. The chips that manufacturers are producing, more efficient chip sets, the base station and antenna people are producing ever-more-efficient equipment. LTE itself is an example of a much more efficient technology than the 3G technologies that preceded it.

So it is going on at every level in every tech company that services service providers, mobile service providers.

Chairman QUAYLE. So we are making great progress, but as Mr. Bennett stated in his testimony, we are just not there yet in terms of being able to use overlapping spectrum for different communications.

Ms. BROWN. Right.

Chairman QUAYLE. Okay. Well, thank you very much, and before I recognize Ms. Edwards, I am in the middle of two other mark-ups just like many other people, so I apologize if I have to leave, and I want to thank you all for your testimony.

And now I recognize Ms. Edwards for five minutes.

Ms. EDWARDS. Thank you very much, Mr. Chairman, and thank you to the witnesses.

I just have one question because you all seem to indicate that we need to repurpose or reallocate spectrum for commercial use, and just as I was sitting here, I am a big Turner Classic Movie fan, and one of my favorites is "Pillow Talk" with Doris Day, the party line, Rock Hudson on the other end. And I can recall probably showing my age, recall us having a party line when I was growing up, and clearly we don't want to live in an age where if we are forced to share, then it means that it disrupts our ability to use and have broadband access when we want it and when we need it. We have become too accustomed to that kind of rapid access.

But what I am curious about and Dr. Subramanian notes in your testimony that repurposing is only going to be a short-term solution. It is not a long-term solution, and the risk of having to share a spectrum in the long run still remains.

And so my question is what is it that both the government and industry can do to ramp up technology and innovation in the sector so that, you know, in the meantime while we are reallocating and repurposing, which we have to do, that in the long run we are not going to find ourselves not just in a crunch anymore because we will have reallocated ad nauseam, but without the ability to meet the needs that all of us will have to expect rapid, up-to-the-moment information.

And so I wonder if you have some comments about that, about what the Federal Government can do and what the private sector needs to do to step up research and development around sharing technologies.

Maybe start with Dr. Bennett. Mr. Bennett.

Mr. BENNETT. Just Mr. Bennett.

Ms. EDWARDS. Okay. Well, we will make you a doctor later on, but we will start with Mr. Bennett.

Mr. BENNETT. Honorary degree. One of the first things that the government can do is actually focus on repurposing or redesigning government applications where government is actually an operator of networks as often in the case with the defense networks and several others. Those applications can be reconfigured to use commercial networks and also commercial networking technologies. In the Public Safety Network, we go part of the way there that we embrace a commercial technology, but we still retain the government's role as the network operator.

One of the things that is important to realize about this whole repurposing issue is that there is really no downside. Say we could all be completely wrong and there is no spectrum crunch, but there is no downside to acting on the assumption that it is real and updating the applications and replacing the equipment that was installed 20 years ago to run these applications a certain way with more modern equipment that takes more—better advantage of the technologies that we have right now.

Ms. EDWARDS. Thank you, and perhaps we can hear from Dr. Subramanian.

Dr. SUBRAMANIAN. First of all, I guess, in my personal opinion, we have started a little bit late on this whole spectrum crunch issue. Now, what this has led to is that there is hardly any spec-

trum to allocate now. So this means we need to devise methods for either repurposing or sharing before it can be a lucrative industry. And there are efforts going on as we talked about.

Now, on the industry front, carriers, the leading carriers as you all might know, they are already moving to unlimited data plans. If you are getting a new plan now, you've got to pay \$50 to get five gigabytes a month, and potentially because of this crunch. This has been very clearly stated by one of the CEOs of the carriers, that they don't have spectrum and are going to keep on increasing the cost of this. So the cost of the spectrum usage is going to increase. That is one thing.

The other thing they are also trying to do is using Wi-Fi or using Femto cell-like technologies to offload the traffic to landlines. So that is—it can go only so much, so far.

Now, if you look at the OEMs or the industry that is supporting the carriers, they are trying to build new advance or the next generation technology to optimize the efficiency of spectrum usage. So these things have to go on in parallel, and in my guestimate it takes at least about, you know, four to five years before technologies can be formed, tested, and deployed. So somehow the next four to five years the industry has to keep on making the small increments.

Ms. EDWARDS. So could we hear from, maybe, Ms. Brown? I mean, what is it that we could do that would, you know, sort of spur Cisco and, you know, others in the industry to ramp up their R&D capacity?

Ms. BROWN. Well, I think from the perspective of a manufacturer, there are already very strong profit motives in the private sector to engage in R&D in this area. Our customers are basically demanding that we create technologies that are going to enable them to be more efficient from a spectrum capacity. So I am not sure, from a private sector perspective, there is a stronger motive than that.

But there are things and there are, I think, things that the Federal Government can do, and there is a role for government here. So things like basic research of the type we heard from from NIST on cognitive radio, improving, as Richard Bennett said, improving federal radio systems, which were designed, many of them decades ago in a siloed environment where there was no thought given to being good neighbors from a spectrum perspective. And then as Dr. Subramanian said, test beds are important. One of the things we have learned from the very limited experience so far we have had in Wi-Fi sharing with federal radar systems, it is very important to develop a level of trust if you are going to have commercial and federal sharing spectrum. Both sides need to know that the investments they make and the services that they are offering are going to continue to happen when sharing starts. And it is things like test beds that enable you to build that level of trust.

So funding those sorts of activities as well is important.

Ms. EDWARDS. Thank you. My time has run out.

Mr. Chairman.

Chairman HALL. [Presiding] The Chair recognizes Mrs. Biggert, the gentlelady from Illinois, for five years—five minutes.

Mrs. BIGGERT. I don't know if I have got five years of questions. Thank you.

Chairman HALL. I made a mistake yesterday and cut a gentleman short and now I am overly generous.

Mrs. BIGGERT. Thank you, Mr. Chairman.

You know, I have got an iPad, I mean, whatever you call it, and a smartphone and an iPad and a Kindle. What is bothering me is particularly with this one, the Blackberry, I see everybody on the House Floor with them standing in the back, and I always ask them if they are talking to each other because nobody is talking anymore. I am really worried that the art of conversation is going to be gone. But we will see what happens with that.

And Dr. Subramanian, could you describe your work on NITRD? I am particularly interested in the Steering Group's role in coordinating and informing ongoing spectrum R&D activities across the government as well as identification of the shortcomings in the government's R&D portfolio with respect to the technologies that allow more efficient use of the spectrum.

Dr. SUBRAMANIAN. Yes. Thank you. Essentially, I think the first and foremost is to understand where is the national R&D money being spent, especially by the government agencies. And then to understand are there any national testing facilities that really exist that both the government and the industry can really collaborate and work together.

So on the first thing, we went to all the agencies—there are 16 agencies that are a part of the NITRD group—we went to all of them and said, hey, you know, where is your money going, including DARPA, NSF, DOD, DHS, all those, and where is your R&D portfolio going on, and they came up with a list of portfolio and a list of research that is happening. We did the same thing for testbeds, what are the testbed values, what are the features.

Then we coordinated two national working group meetings, one in Boulder last year in June and then one in Berkeley in January 2012. The first meeting we discussed the R&D areas that the government has been working on. We asked Industry, what are you working on? Is this all useful? And are there gaps that you want to do?

And then apparently it so happens that, you know, as I kind of alluded to in the testimony, that the industry is very focused on the near-term return on investments, especially on the spectrum sharing perspective.

So there are efforts going on on the government side, but there is a significant amount of research that needs to happen on sensing, policy, data processing, spectrum databases, and stuff—there is an extensive amount of research that needs to happen. And as Ms. Brown also mentioned, everyone said we needed a large-scale experimentation facility.

Mrs. BIGGERT. Okay. Thank you. Then what—and this is whoever wants to answer this question or all, what is the best strategy to ensure U.S. leadership in spectrum technology development and innovation?

Mr. Bennett.

Mr. BENNETT. Yeah. I think the best way we can win that race is to beat the other countries in investing and research, and basic

research is one of—is the thing that really ultimately drives all of this, and the United States used to have a wonderful position in basic research because we had Bell Labs, an institution that wasn't, had no parallel anywhere else in the world, and that is—Bell Labs, I mean, still exists in name, but it is not what it was.

And that gap in basic research funding really can only be filled by the government. The commercial sector is doing a great job on the applied research side, although they could use some help there, too, but fundamentally it is from the basic research we got to the standards committees, and from the standards committees we go to the commercial products. And so it really all begins with the research.

Mrs. BIGGERT. Thank you. Mr. Guttman-McCabe.

Mr. GUTTMAN-MCCABE. Congressman, if I may, I would also add, you know, I had the privilege of going to Dallas last week and met with six of our members, all who have R&D facilities in the Dallas area, and if we went back and looked, our members have about 87 labs in the United States doing R&D. So Ms. Brown talked about it. I mean, there is a lot of incentive on the private sector side to do this, but we do need to make sure that we make bringing spectrum to market a priority. If we do that, this will continue to be the hub for those R&D facilities. Almost every one of those companies is a multi-national company that has chosen to locate their R&D facilities here to bring those jobs, to bring those revenues here.

But it is sort of chicken and egg. Part of it is because we have led the spectrum position for quite some time, and we have managed to get the networks out there first, but there does need to be—we understand that sharing is a significant part of the equation, but there are other very developed countries like Germany and the UK and Italy and France, Japan that have standing armies and similar sort of environments that we do that are bringing hundreds and hundreds of megahertz of spectrum to market.

So our argument is we can't fall behind them or we will lose a lot, including the R&D test bed facilities that we have.

Mrs. BIGGERT. Thank you. Dr. Subramanian.

Dr. SUBRAMANIAN. There are two things I want to point out. If you look at the first generation and second generation of the wireless technology patents, the United States had more than 80 percent, which means we were really controlling the global supply chain.

But when you come to LTE, the United States has less than 40 percent of the patents and then there are an increasing number of patents in China as well as in Europe. So that is caution number one. There is a lot to be done.

The second thing is we asked the same question to the industry in Berkeley, hey, you know, what do you want to do, how can we help. The first thing they said was, identify the spectrum bands. This needs to happen. Second thing is bring those government agencies who are deploying the applications currently to the table so that we can collaborate and test in a common place.

So this needs to happen immediately, and I think the H.R. bill that has recently been released will definitely help in the right direction to go there.

Mrs. BIGGERT. Okay. Thank you, and I know this Committee always stresses basic science and research and continues to do that. I wish all of our Members would get the joke. Thank you.

Yield back.

Chairman HALL. The gentlelady yields back.

I recognize Ms. Bonamici from the State of Oregon for five minutes.

Ms. BONAMICI. Thank you very much, Mr. Chairman, and thank you, all of you, for your fascinating and important testimony, and I think I want to perhaps emphasize the importance.

I know, Ms. Brown, in your testimony you mention that Cisco did not even consider tablets to be a device category a couple of years ago, and I think that is pretty staggering now as we look around us, and it just shows how dynamic and ever changing the sector is.

So, and I understand that the future, even the near future, is pretty hard to predict, but a couple of you have mentioned in your testimony some emerging technologies that are on the horizon, and I know, Ms. Brown, you mentioned the machine communications. I had the pleasure of seeing a demonstration and hearing a discussion out at a fairly large Intel facility in my district, and some of the work that they are doing with medical technology is very, very promising, but really raises, I think, the issue of the need for more spectrum.

So can you talk a little bit more about, I know you mentioned that one example, other technologies and what that is going to mean for consumer demand just so we can figure out how much teeth gnashing there is going to be.

Ms. BROWN. Yeah. So our study that we release every year, the Visual Networking Index, is basically our attempt to look five years ahead and figure out what is going to happen on service provider networks from a traffic standpoint, what types of traffic are going to flow, what are the demands, and so on. And the purpose of that is so that Cisco can understand what we need to build, because it takes time to construct everything, and meet that demand three, four, five years out.

So as we get beyond the five-year time frame it becomes a little murky in terms of trying to project what is going to happen, but it is very clear from the evidence that we see today, which is from existing measurements of traffic of carrier networks today from analyst reports and from the kinds of things that are sort of on the cusp in the standards organizations and what is happening, that we are about to see a transformation of the mobile Internet from people to people to machine to machine, as well as people to machine and people to people.

So it is a huge transformation and a pivot point for the industry, and it is going to start happening over the next five years. So it is putting incredible demands on spectrum.

Ms. BONAMICI. Anybody else care to opine about looking into the future; what we can expect?

Dr. SUBRAMANIAN. Yeah. You know, if I may add to what you have been telling and Ms. Brown has been telling, let us take every economic sector, every key economic sector which is going to define the economic growth of this Nation. Let us talk about the energy sector, advanced manufacturing systems and all systems. The

whole energy grid for a significant time is going to be dependent on wireless.

Ms. BONAMICI. Right.

Dr. SUBRAMANIAN. Now, look at advanced transportation systems, electric charging, entertainment, safety—everything is going to become wireless. So now you can talk about advanced manufacturing systems and the Wall Street and the financial industry is going to be hit.

Now, you are talking about every economic sector, then you see the whole dependence of the economy, a significant technology dependence I should say, on wireless technologies.

Ms. BONAMICI. Thank you very much, and I wanted to follow up on the last set of questions and ask about—I know, Dr. Subramanian, that you mentioned the need, the demand is increasing not just here but in the EU and Singapore, China, and that they are aggressively seeking some innovative solutions. And I wonder if you could describe how our efforts compare, as we are attempting to address this crunch, and can we learn any lessons? I know that Mr. Bennett, you talked about the investment in R&D, but how do we compare, and can we learn anything from the, you said innovative solutions that are being pursued in other areas?

Dr. SUBRAMANIAN. Okay. Now, let us talk about the European Union. Now, the European Union has created a large-scale test bed where all the countries and all the vendors can have a common place. Now, you think about so many of these vendors supporting the ecosystem, having a common place where they are able to work and develop new technologies.

There are also efforts going on to measure the spectrum at different places and create a common database which can be used to deploy certain kind of architectures for spectrum sharing.

Similar efforts are on in Singapore. Singapore is trying to aggregate all the needs of the neighboring countries as well as its own. Now, what happens is they get the patents. So the more and more patents go out to the world, American economy starts paying a premium on these technologies, and you don't want that to happen. So that is the critical issue we are in right now.

Ms. BONAMICI. Thank you. I am going to yield back my time. Thank you.

Chairman HALL. Thank you. Thank you for yielding back.

The Chair recognizes Mr. Hultgren from Illinois for five minutes.

Mr. HULTGREN. Thank you, Mr. Chairman. Thank you all. I apologize. I have a busy afternoon. I have several different committees meeting and then other things, so I apologize I haven't been able to be a part of all this discussion but definitely appreciate you being here. This is a very important topic that we need to be talking about.

I just have a couple of questions.

First of all, I would ask if any of you have some thoughts on this. I know in Dr. Olthoff's testimony you described some of the work that NIST is conducting to improve emergency responder communications such as wireless systems, metrology program to measure distortions in difficult radio environments. This technology certainly will be very beneficial to public safety community.

I am curious as to whether you think this research would also be helpful in other commercial applications of wireless communication, and I just wondered if any of you have any thoughts about how this research could be used to help commercial communications.

Mr. BENNETT. If I could, there is a direct tie between any sort of test bed that we use to verify the validity or the robustness of an emergency communications system like that actually produces immediate benefits for the consumer, because we no longer really have—these technologies are no longer stove-piped the way they used to be.

In one of the comments that was made in connection with the White House's inquiry into the Public Safety Network, one of the public, one of the police chiefs I believe it was, made the comment that the average 16-year-old in the United States has better communications capability than the average policeman does. Well, there is a reason for that. The 16-year-old is using a system that was—that is the product of hundreds of billions of dollars of investment in basic research and R&D and chip development, as well as testing, whereas the average policeman today is using a system that was custom built for a relatively small market, you know, some time ago when the technology was just not as well developed as it is.

So there is a great benefit to standardization, which is why, you know, the standards bodies that developed, you know, the Wi-Fi standards and the 4G and LTE standards, that is where all the research comes together. So people all over the world are doing research. Everyone wants to be the next Qualcomm that has the patents on CDMA that have, you know, proved to be so valuable because they are universally deployed, and the test beds are part of the process to sort through the competing proposals and decide what the standard is going to be. I mean, we can't, we are not really in a position in the United States in commercial or government sector or anywhere else to really make our own decisions about technology.

Now, we pretty much have to go with the standards, because the arguments are so compelling.

Dr. OLTHOFF. The requirements for the Public Safety Network are so demanding, the ability to operate under the most severe environmental conditions, under conditions where the data load will be intense under really serious circumstances, the ability to be ultra-secure, the ability for literally thousands and tens of thousands of disparate organizations to utilize the same network, all of those are pushing us towards newer technologies and newer solutions, and all of those will inevitably lead to solutions perhaps unforeseen at this time that will be useful to the commercial sector.

Mr. HULTGREN. Mr. Bennett, if I can ask a quick question and get your thoughts with the expected massive increase in internet data transmission in the near future and also anticipated reliance on wireless technology, is it possible that broadband spectrum availability will constrain other computing technologies such as cloud computing, and what potential solutions are there to this problem?

Mr. BENNETT. Well, we need to solve the spectrum crunch, you know, once and for all, and I think the way that we do that is by—and I alluded to this in my oral testimony. It is also in my written statement. Development of technologies like spatial division, multiple access, and multiuser MIMO that allow multiple people multiple data streams to actually occupy the same frequency at the same time, and that pretty well, when those are fully developed, you know, there is no more spectrum crunch.

But it certainly is the case that the—by constraining the bandwidth that we have available for emerging applications like augmented mobile reality, which is directly related to the cloud, then the cloud can't really develop until the users of augmented mobile reality can exchange video streams with the cloud processing systems, and so, yeah, it is a crucial building block. I mean, application developers would use whatever spectrum is available, whatever bandwidth is available to them, they will use it. And if it is only enough for narrow band, fairly unimaginative applications, then that is what we will have.

Mr. HULTGREN. My time is up, but real quickly, just following up, Mr. Bennett, when do you think some of that might happen, some of that next advancement of technology? Any guess? I mean, is that in the next few years, is that the next decades?

Mr. BENNETT. I think we are going to start to see really dramatic changes probably within the next 10 years. It could be sooner than that. Network affects, it is really always difficult to take a revolutionary new technology and introduce it into the marketplace because there is so much momentum around the existing systems, but I would say as soon as five years and as—at worst case probably 20 to 30.

Mr. HULTGREN. Thank you all very much. I yield back.

Chairman HALL. The gentleman yields back.

The Chair recognizes Ms. Edwards for whatever time she wants to consume.

Ms. EDWARDS. Thank you, Mr. Chairman. He promised me five years, so you all will be here for awhile.

Just one question here, and it goes to a reference in Dr. Subramanian's testimony where he mentioned that the industry's focus on supporting the deployment of 4G technology and isn't ready to invest in spectrum sharing research and development, and I am curious as to what can be done to encourage more active involvement by industry in this area.

And it goes to another point that was made. I think Mr. Guttman, in your testimony, where you talked about focusing on repurposing and reallocation as opposed to other newer technologies around spectrum sharing, and I am just trying to get a handle on this question of what it means for the consumer, because if we reallocate and use as much spectrum as there is available and it is a finite resource, then at some point or other the consumer is like paying through the nose for data.

And that may not happen right now, but it is increasingly, and so I am trying to figure out what the incentive is for the industry to make investments in this existing technology, because it isn't just about the consumer demand, because I could imagine an environment where when none of the big carriers moves to invest,

where you would just say, well, you know, consumer demand, they pay more for what is available. What is then the incentive for the industry?

Mr. GUTTMAN-MCCABE. Sure.

Ms. EDWARDS. And so, Mr. Guttman, can you—

Mr. GUTTMAN-MCCABE. Yeah.

Ms. EDWARDS [continuing]. Help me with that?

Mr. GUTTMAN-MCCABE. Yeah. I think the clearest way to address this is almost to bifurcate the effort, to look at what can be done in the short term to address this conflict between supply and demand, and I think you would only need to look at the back row behind me. I am not sure they are still back there, but all those young folks when they first came in, I came in front of—right behind many of them through security. Every single one of them had at least one device.

And so what we are looking at, and I think Ms. Brown referenced this is what is in the pipeline in terms of spectrum resources, and there really isn't anything, and we are unique in the develop world in that sense. So we have got to focus on getting something in the pipeline now that is usable now.

And so when I talk about sort of real-time sharing or opportunistic use, I think everyone agrees that that is the long-term solution except for every panel I have been on in front of Congress, at the President's PCAs, everyone has said there is not a solution that is available or scalable yet.

And so how do we get to that, how do we bridge that timeframe between now and Mr. Bennett's five, 10, 30 years, and from our perspective it is let us focus again in the short term, having our government, you know, officials focus on repurposing the spectrum that is available. We looked at the broadcasters for every 100 megahertz that they use, 190 are not being used. So how do we drive efficiencies from that? How do we drive efficiencies from some of the government uses? There are microwave uses in bands that just do not need to be there.

So how can we drive out some of those efficiencies, bring it to market. At the same time you heard Ms. Brown say that they have every incentive to move to solutions that drive efficiency. When we were in Dallas last week, one of our largest manufacturers who is one of the largest in the world, said every single wireless solution that they have employed around the world was developed in the United States.

So I hope that the takeaway from here is not that the United States is not doing its part. That is why we are seeing multinational companies move their R&D facilities here into the United States. But there does need to be some focus on sort of some of the longer-term solutions. My point is we can't say that that is the gold standard now when it currently doesn't exist. It is a wonderful, absolutely necessary aspiration to get to it, and it will solve a tremendous amount of the problems, but once it is available, and there are people spending great deals of money on that.

Ms. EDWARDS. So, thank you, and because my time is running out, so I just want to be clear. From your industry perspective reallocate, repurpose for the short term, invest in the R&D and the technology and the development for the long term and so, Dr.—Mr.

Bennett, Dr. Olthoff, are we making enough of an investment in basic research from the Federal Government to support the long-term activities that have to take place in R&D?

Mr. BENNETT. Probably not.

Ms. EDWARDS. Just say it for the microphone. It is okay.

Dr. OLTHOFF. Certainly NIST has sufficient resources to be addressing the problems that we are working on right now, and the proposed initiative in the President's '13, budget will go a long way towards helping us address some of the new measurement needs that are being—all these new technologies we will be needing.

Ms. EDWARDS. Okay. Thank you very much. Thank you, Mr. Chairman.

Chairman HALL. The gentlelady yields back.

Mr. Lipinski, the gentleman from Illinois, for five minutes.

Mr. LIPINSKI. Thank you very much, Mr. Chairman. A quick question. The question that people I go home, people will want to know the answer to, is there going to be a point, maybe you feel like it is happening now, but is there going to be a point where the spectrum crunch causes a noticeable drop off in service? That is what—I talk about this at home, and people just want to know, okay, so what is it going to do to me? What am I going to—what impact am I going to feel?

So I just wanted to hear what any of you want to say about that. So, okay, let us start on the right side and go across.

Dr. SUBRAMANIAN. Yeah. I mentioned this some time back here. If you look at the major carriers, they have already removed the unlimited data plans. So at minimum now you have to pay \$50. I used to pay for my Blackberry \$29.99 for unlimited data plan from Verizon, and now if anyone wants to get a new data plan, you just get 5 gigabytes for \$50, and this is going to be increasing more and more.

Now, added to this, there is going to be quality of service issues, there is going to be dropped call issues, and things are going to go slow, and if this continues in 4 or five years, even to look at Facebook is going to be very difficult.

Mr. LIPINSKI. And that first part, is that a spectrum issue, or is that—well, if I had one of these companies, I could raise my prices, I would raise my prices. Is it that, or is it the spectrum issue?

Dr. SUBRAMANIAN. One of the major carriers has said it is a spectrum issue, and the government needs to act.

Ms. BROWN. Yes. It is a spectrum issue. All of the major carriers have discussed this in various respects, and the thing to understand about it is it is going to hit, the impact to consumers is going to hit, geographically it is going to be different and by carrier it is going to be different, depending on how much spectrum they have in the cupboard that they can bring out to address it.

So the major metropolitan areas, New York City, even San Francisco when I go back to Cisco's corporate headquarters in San Jose, when you are driving down the 101 to San Jose, it is very hard to get a connection that actually doesn't drop or have some issue with trying to get connectivity.

So we are already starting, sort of the early hints of it are here. The Federal Communications Commission said they think that we

are going to start seeing that more in a broad way next year if additional spectrum isn't found.

Mr. LIPINSKI. So is this something that is going to happen sort of slowly and just gets more and more aggravating and so—and that is something that is going to, unfortunately—

Ms. BROWN. Yeah.

Mr. LIPINSKI [continuing]. A lot of times up here on Capitol Hill we don't do anything until there is a crisis or a big sharp drop off somehow but—

Ms. BROWN. Yes.

Mr. GUTTMAN-MCCABE. Congressman, we coined the term “looming spectrum crisis,” in part to get the attention of you as leaders because—

Mr. LIPINSKI. Because you know that is the only way.

Mr. GUTTMAN-MCCABE. Exactly. I didn't say that, but that was—we tried to find a way to identify in a very succinct, very easy to understand way, and I think, again, I have spent an inordinate amount of time defending whether, in fact, there is a looming spectrum crunch or crisis, and I keep saying, you know, if this is a conspiracy, it is a global conspiracy because every country is addressing this issue, and when we talk about the area where we are falling behind, that is one area where we are falling behind. You look at the countries that I listed earlier, the closest one has a third of our population, you know, Japan. I mean, you look at Germany, the UK, Italy, France, South Korea. They have all identified hundreds and hundreds of megahertz. Some of them have brought it to market, and they have done it because they don't want to see that impact, they don't want to see carriers taking steps to try to drive down usage of their product, and they do want to see this explosion in verticals, whether it is M-Health or smart education or intelligent transportation.

I mean, we are seeing sort of the movement of wireless into so many sectors, and it is fantastic, and yet at the same time, it could be concerning if we don't begin to address both short and long-term this concern about the lack of spectrum in the pipeline.

Mr. BENNETT. The spectrum crunch hit San Francisco in 2007, when the iPhone took off and every hipster in town had to have one, and San Francisco has its unique policy where they really don't like to issue zoning permits for new towers, and so without spectrum, you know, it is, yeah, there is two solutions. Right. There is either more spectrum or more towers. And if you can't get the towers and you don't have the spectrum, then what happens is, you know, the hipsters can't have their iPhones. I mean, now that they—

Mr. LIPINSKI. Now you have hit the key here.

Mr. BENNETT. But now they have got Sprint so maybe, you know, maybe with Sprint and Verizon having the iPhone, you know, the people of San Francisco, some of them are hipsters but not all, will, you know, will be able to enjoy that.

Dr. SUBRAMANIAN. You know, personally, I don't think I would be very upset if I could not see the Facebook on my smartphone—my 11-year-old daughter might be—but I think the key point is this Nation has progressed. The economy has grown through innovation in various sectors and there is a fundamental dependency of

different sectors of the economy. For example, the Smart Grid, the advanced transportation systems, the medical systems, advanced manufacturing systems. They are all extremely different, dependent on wireless technologies, which means that job creation capability of this Nation is dependent on what is the spectrum usage and how effectively we can use it. So that is the fundamental problem.

Mr. LIPINSKI. Well, I am glad you brought it back to that because that—when we get down to it, we are talking about the convenience, and good, you know, devices are important, but the bottom line, the final bottom line is this is about, you know, economic growth.

So thank you very much, and I yield back.

Chairman HALL. The gentleman yields back.

I have just a brief something I would like to put in the record. The spectrum policy has been discussed at length this Congress, and there has been a dramatic increase in demand on spectrum in recent years, and to meet this demand there are those who argue the need for the new technologies and more efficient use of spectrum.

We also hear the argument from others that unleashing new spectrum through spectrum auctions is the solution to so-called, “spectrum crunch.”

An article appeared in the New York Times today and which highlighted these various opinions and detailed the issues surrounding spectrum use and the wireless economy.

I would like to ask unanimous consent that this article be put in, entered into the record, and without objection, it is so ordered.

[The information may be found in Appendix 2.]

Chairman HALL. And I will say now to you, nobody else here, don’t judge our interest and our appreciation of your appearance here today by empty chairs, because all these people have at least three places they ought to be right now, and we are thankful that they came and gave us as much time as they could, but we know you took time to prepare yourselves, and it takes time to give this testimony, and we are very grateful to you because you are helping us solve something that is almost insolvable.

I thank you for your valuable testimony and thank the Members for their questions, and the Members of the Committee might have some additional questions for you. We will ask you all to respond to those if you will, and the record will remain open for two weeks for additional comments and statements from Members.

The witnesses are excused. Thank all of you for coming. This hearing is now adjourned.

[Whereupon, at 3:32 p.m., the Subcommittee was adjourned.]

ANSWERS TO POST-HEARING QUESTIONS

ANSWERS TO POST-HEARING QUESTIONS

RESPONSES FROM DR. JAMES OLTHOFF

QUESTIONS FOR THE RECORD

THE HONORABLE BEN QUALYE (R-AZ)

U.S. House Committee on Science, Space, and Technology
Subcommittee on Technology and Innovation*Avoiding the Spectrum Crunch: Growing the Wireless Economy through Innovation*

Wednesday, April 18, 2012

1. What role will both the federal government and the private sector have in ensuring that the U.S. becomes/remains the global standards leader in spectrum?

Answer:

Maintaining global leadership in spectrum use and standards will require that both the government and the private sector continue to invest in a) new technologies that improve efficient use of the currently allocated spectrum, and b) new technologies that allow mobile wireless communications in previously unexploited spectrum, such as at 3.5 GHz and millimeter wavelengths. The federal government also plays an important role in spectrum standards development through its scientists and engineers, who contribute technical expertise and support through active participation in the international voluntary consensus standards process. Continuing support for such participation is critical.

2. What are the most pressing spectrum related research priorities for the next five, ten, and twenty years? What do you see as the "long-term spectrum solution?"

Answer:

- **The wireless telecommunications industry is doing an excellent job of squeezing out every last bit in the frequency bands below 5 GHz by use of innovations such as dynamic spectrum allocation, MIMO, and complex modulation schemes. It is anticipated that these wireless technologies will come to full fruition on a timescale on the order of five years or so.**
- **FCC Chair Genachowski has recently proposed accelerated development of "small-cell" systems in the 3.5 GHz frequency band. Small cells allow spectrum reuse, which can potentially go a long ways toward easing the spectrum crunch in the medium term (10 years).**

- **Wireless communications at millimeter-wave frequencies have some fundamental advantages that promise long-term solutions (>10 years) for solving the spectrum crunch:**
 1. **The bandwidth available at millimeter-wave frequencies is well over 30 times the currently available spectrum.**
 2. **The short wavelengths at millimeter-wavelengths inherently confine signals to a local area, which is an advantage in terms of spectrum reuse.**
 3. **Small highly directional antennas are well-suited to mobile applications and limit interference from nearby mobile units.**

NIST has recently launched research programs that support development of these technologies.

QUESTIONS FOR THE RECORD
THE HONORABLE LAMAR SMITH (R-TX)
U.S. House Committee on Science, Space, and Technology
Subcommittee on Technology and Innovation

Avoiding the Spectrum Crunch: Growing the Wireless Economy through Innovation

Wednesday, April 18, 2012

1. According to the National Association of Broadcasters (NAB), existing mobile phones are already equipped to receive local radio broadcasts, and new phones can easily be modified. Such a capability might come in handy to receive information during emergencies when people are unable to get cellular phone coverage. The NAB has asked the Federal Emergency Management Agency and other Federal agencies to explore this proposal. What are your thoughts on this proposal? Do you believe that the cost and benefit to the public of equipping mobile phones with free broadcast radio has merit over other proposals? What hurdles exist to implementing such a capability in mobile phones?

Answer:

In the event of an emergency, it is important to be able to broadcast an emergency message to many receivers simultaneously. This is a role that broadcast radio has filled for many years. The Federal Communications Commission (FCC), in partnership with Federal Emergency Management Agency (FEMA) and the National Oceanic and Atmospheric Administration's National Weather Service (NWS), is in the process of developing an enhanced Emergency Alert System (EAS) to benefit the public. EAS will be used by radio broadcasters, television broadcasters, and subscription media providers in similar fashion. Historically, mobile telephones have not served as receivers for one-to-many broadcasts. However, the newer standards include provision for "Cell Broadcast," in which emergency messages can be delivered to all mobile phone handsets in a region simultaneously. NIST has not been involved with the development of EAS, so technical questions would be more effectively answered by NWS, FEMA, and the FCC.



To: The Honorable Ben Quayle
Chairman, Subcommittee on Technology and Innovation
United States House of Representatives
Washington, DC 20515

Attn: Melia Jones

From: Richard Bennett
Senior Research Fellow, Information Technology & Innovation Foundation
Washington, DC 20005

Dear Chairman Quayle,

Thank you again for allowing me the opportunity to testify at your hearing on *Spectrum Policy for Innovation*. I found the hearing informative and hope the members did likewise. The following addresses the questions put to me in writing.

The Chairman asks:

1. What role will both the federal government and the private sector have in ensuring that the U. S. becomes/remains the global standards leader in spectrum?

First, the U. S. currently lags our European partners in spectrum available for mobile broadband, so our network providers are forced to over-invest in the bricks and mortar elements of their businesses – towers and related backhaul – and under-invest in research and development. Transferring 300 MHz or more from government use to commercial use will bring us to par with Europe or slightly above, allowing the private sector to spend more on R & D.

Second, a number of spectrum allocations have been made to commercial entities in the U. S. that no longer make economic or technical sense. The most glaring example is Over the Air TV. Most Americans now watch TV over cable and satellite services, so the massive allocation of spectrum to OTA TV no longer makes sense. The mobile networks have, on average, one hertz of spectrum per actual user, while OTA TV has closer to ten hertz per user. Broadcasters are reluctant to return their spectrum licenses to the FCC for fear they'll lose the "must carry" retransmission fees in the process. Congress and the

FCC can clarify a resolution to the “must carry” clause of the Cable Act that frees the obligation from the means of transmission.

Third, the U. S. can aggressively fund research through direct grants to research institutions and a permanent R&D Tax Credit.

Fourth, the U. S. must continue to lead the world in flexible use policies for spectrum, avoiding the trap that Europe set for itself by mandating the use of GSM for 2G digital cell phone service. Europe had to make additional allocations specifically for 3G, and once again for LTE. It’s much better to allocate large swathes of spectrum to an auction process that allows the market to determine the best technology for the spectrum. The technology moves much faster than the regulators, and it also corrects its own mistakes. This is not to say that there should not be unlicensed spectrum for wireless Local Area Networks such as Wi-Fi, Personal Area Networks such as Bluetooth, experimental Wide Area Networks using vacated TV White Spaces; there should, but for the immediate future the spectrum crunch is most severe in the licensed sector so it needs the most attention.

2. What are the most pressing spectrum related research priorities for the next five, ten, and twenty years? What do you see as the “long-term spectrum solution?”

Spectrum research falls into two general categories: A) Means for sharing network capacity within an operational network, such as Code Division Multiple Access (CDMA,) Space Division Multiple Access (SDMA,) scheduling systems, dynamic reallocation, modulation systems such as OFDM, and advanced coding systems, and cellular architecture advances such as LTE’s macro-cell, micro-cell hybrid architecture and developments in Internet Protocol (IP) use that support Quality of Service (QoS) for telephony and video conferencing; and B) means of coordination between operational networks such as Authorized Shared Access, the White Spaces database and similar approaches, and software-defined cognitive radios.

Intra-network efficiency and performance advances are most critical in the five year term, but inter-network coordination work may become important in the ten year horizon. Network technologists are free to develop inter-network coordination systems already, and have begun to do so in recent standards for Wi-Fi mesh (IEEE 802.11s) and TV White Spaces (802.22.)

Over the longer term, developments in modulation and coding will focus on the simultaneous use of common frequencies in adjacent locales without receiver impairment. This longer term technology holds the promise of relieving spectrum stress and ushering in smart antennas, but it’s currently very speculative.

It's doubtful that there will ever be an ultimate solution to spectrum sharing, however. It's helpful to regard every spectrum technology as amenable to improvement. This assumption will force regulators to design dynamism into the spectrum policy system, a very wise working assumption.

3. Please describe how industry shapes spectrum research and development. Specifically, how does spectrum-related research funded through non-federal means, including academic, commercial, and public safety sector sources trigger the creation of innovative new businesses and new applications that will transform Americans' lives?

Spectrum research begins in research institutions funded by public and private means, moves to simulation systems and test beds, and then advances to standards bodies such as 3GPP and IEEE 802 if it has merit. Standards bodies dictate the work of chip manufacturers, and they in turn produce the elements that go into smart phones and other wireless systems. Industry tends to spend its research dollars on systems that can produce financial returns in less than five years, for obvious reasons, while the academic sector is free to look further down the road. Academic research on cognitive radio has been ongoing for close to ten years and may yet produce dramatic benefits.

In the technology field generally, research and development on military, public safety, and aerospace systems has commercial spillovers. Military research on resilient networks lead to the development of packet switching, a vital part of the Internet and modern cellular networks. The heads-up displays now found in high-end automobiles began as elements of advanced fighter planes, and GPS was originally a military system.

Public safety has a list of applications it wishes to run over FirstNet, all of which have potential value to ordinary consumers. Public Safety is in a position to move the ball forward on the sharing of capacity with the private sector, to the mutual benefit of first responders and ordinary citizens.

We once stove-piped government and civilian uses of technology, which is appropriate enough when the research target is munitions and combat systems, but not in other cases. The need to communicate is a general human characteristic, so any system that enhances the ability to communicate in all scenarios is widely beneficial.

The Honorable Mr. Smith asks:

1. According to the National Association of Broadcasters (NAB), existing mobile phones are already equipped to receive local radio broadcasts, and new phones can easily be modified. Such a capability might come in handy to receive

information during emergencies when people are unable to get cellular phone coverage. The NAB has asked the Federal Emergency Management Agency and other Federal agencies to explore this proposal. What are your thoughts on this proposal? Do you believe that the cost and benefit to the public of equipping mobile phones with free broadcast radio has merit over other proposals? What hurdles exist to implementing such a capability in mobile phones?

I'm reminded of a famous statement by President Reagan: "Government's view of the economy could be summed up in a few short phrases: If it moves, tax it. If it keeps moving, regulate it. And if it stops moving, subsidize it." The desire to force manufacturers of smart phones to incorporate extraneous elements is an example of an unproductive subsidy. If the NAB is correct, smartphones already have this capability and there is no reason for government to force it upon them.

But the NAB is not correct, because most smart phones don't incorporate AM and FM radio receivers. Each receiver requires an antenna tuned to a specific range of frequencies, and the modern smartphone has limited space for antennas. Portable radios, in cars or otherwise, require separate antennas for AM and FM, for example, and smartphones typically include antennas for four cellular frequencies, two Wi-Fi frequencies, Bluetooth and GPS already. If consumers needed and wanted more reception capability in their smartphones, vendors would certainly provide it.

In California, where I live currently, we all keep earthquake kits on hand for times of disaster. These kits include drinking water, first aid, non-perishable food, radios, batteries, and sometimes generators. When I lived in Central Texas, we kept portable radios on hand in case of tornados, power failures, and hurricanes. Most of us have radios in our cars, despite the absence of any federal mandate, because we want them. There is no shortage of radios and no need for the NAB to seek this subsidy from the government.

One of motivations for the NAB's proposal revolves around a performance rights tax that would compensate creative talent for loss of income due to digital piracy. We at ITIF are strongly supportive of measures that would halt or reduce the piracy of creative work. Our report, "Steal these Policies: Strategies for Reducing Digital Piracy" (<http://www.itif.org/files/2009-digital-piracy.pdf>) is an important background element that helped shape the SOPA and Protect IP bills and our work was cited by members of the House Judiciary Committee several times during the SOPA markup. But we don't regard the radio mandate as effective.

In times of emergency, citizens require better two-way communication capability, which is best provided by the very robust and redundant cellular network.

Conclusion

I hope these answers are adequate, and remain open to providing additional information or clarification as desired.

Richard Bennett

Christopher Guttman-McCabe, CTIA – The Wireless Association®
 Responses to Questions for the Record of the April 18, 2012
 Hearing before the House Subcommittee on Technology and Innovation

Questions from the Hon. Ben Quayle

1. *What role will both the federal government and the private sector have in ensuring that the U.S. becomes/remains the global standards leader in spectrum?*

Response: CTIA believes that the federal government must foster an environment that allows U.S. companies to innovate and develop new wireless technologies that can be exported around the world. Two necessary ingredients for wireless innovation are an adequate supply of radio spectrum and financing for research and development. The government can help nurture this environment by ensuring that spectrum is allocated for the highest purposes, such as commercial broadband services, supporting R&D through both tax credits and stable, pro-investment tax policies, and by embracing policies that enable U.S. companies access to qualified workers by, for instance, granting conditional permanent resident status to foreign students who earn advanced degrees in a STEM (science, technology, engineering, or mathematics) field.

2. *What are the most pressing spectrum related research priorities for the next five, ten, and twenty years? What do you see as the “long-term” spectrum solution?*

Response: For now and the foreseeable future, the overarching challenge will be to accommodate consumers’ ever-increasing demand for more mobile data throughput. In order to meet this challenge, research must focus efforts on expanding the supply of usable spectrum for commercial applications – including both licensed and unlicensed – and, at the same time, increasing the efficient use of the existing inventory.

Near-term research efforts should focus on examining methods for clearing targeted federal government and television broadcast spectrum bands from “beach front” spectrum bands to make way for new commercial broadband services. Research is needed to determine how best to accommodate these incumbent governmental uses in other frequency bands or via commercial networks.

Nonetheless, it is difficult to envision an ultimate “long-term” solution to the current spectrum problem. As quickly as advancements are made, new challenges and demands will surely arise that require new solutions and developments.

3. *Please describe how industry shapes spectrum research and development. Specifically, how does spectrum related research funded through non-federal means, including academic, commercial, and public safety sector sources trigger the creation of innovative new businesses and new applications that will transform Americans’ lives?*

Response: The state of innovation in wireless services is extremely strong, and it has been funded in large part by non-federal means. In fact, CTIA has identified over 85 wireless-related R&D facilities in the U.S., many of which are affiliated with global companies that could locate anywhere but have chosen to locate in the U.S. because of our world-leading position in wireless technology. This world leading position has helped drive a virtuous cycle of investment in which, even during challenging economic times, the wireless industry has continued to invest tens of billions of dollars in providing consumers

Christopher Guttman-McCabe, CTIA – The Wireless Association®
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with new features and functionality as well as improved wireless performance. Consumers' growing appetite for a variety of mobile broadband services is driving competition and the need for greater capacity on broadband networks. This leads to investments in innovative new products to entice customers as well as investments to upgrade wireless broadband networks to meet customer needs. As noted in response to Question 1, the U.S. government can take steps to facilitate innovation, but it will ultimately fall to the private sector to make the investments necessary to create the new businesses and new applications that Americans increasingly expect and demand.

Question from the Hon. Lamar Smith

1. *According to the National Association of Broadcasters (NAB), existing mobile phones are already equipped to receive local radio broadcasts or new phones can easily be modified. Such a capability might come in handy to receive information during emergencies when people are unable to get cellular phone coverage. The NAB has asked the Federal Emergency Agency and other Federal agencies to explore this proposal. What are your thoughts on this proposal? Do you believe that the cost and benefit to the public of equipping mobile phones with free broadcast radio has merit over other proposals? What hurdles exist to implementing such a capability in mobile phones?*

Response: The use of the mobile platform to extend the existing emergency alert system was at the heart of Congress' work when it enacted the Warning, Alert and Response Network (or WARN) Act as part of the SAFE Ports Act in 2006. That legislation, which CTIA supported, set in motion that process that has led to the deployment this year of Wireless Emergency Alerts, which will enable commercial mobile customers to receive geo-targeted messages on their mobile devices warning them of an imminent threat to health and safety.

As a part of the WARN Act's implementation process, the Federal Communications Commission established the Commercial Mobile Service Alert Advisory Committee, comprised of more than 40 individuals representing tribal, local, state, and federal government agencies, communications providers, communications equipment vendors, multiple representatives of the broadcaster industry, consumers' groups, and other technical experts. In evaluating all of the potential technological options available for executing on the WARN Act's call for a mobile alert system, the CMSAAC considered and rejected the use of a number of technologies, including a NOAA Weather Radio, an FM-receiver, a paging chip, and a satellite chip, as a possible solution to enabling emergency alerting in commercial mobile devices. As the CMSAAC noted, there are a number of technical challenges which exist with using these non-native services in commercial mobile handsets, including providing an antenna that is not integrated with a wired headset and addressing power consumption.

With the CMSAAC having reached the conclusion – correctly, in our view - that FM is not appropriate for wireless emergency alerts, we view the inclusion of FM capability in wireless devices as something that must be driven by consumer preference and market forces. NAB appears to share this view, as NAB CEO Gordon Smith told the House Energy & Commerce Subcommittee on Communications & Technology, in response to a question posed by Rep. Marsha Blackburn at a hearing in 2011, that "NAB

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is not asking for a government-imposed mandate that mobile devices incorporate an FM radio chip.” NAB has repeated this position on its blog in a post titled “Radio-enabled cellphones: A voluntary approach to public safety,” available at <http://nabroadcasters.wordpress.com/2012/02/10/radio-enabled-cellphones-a-voluntary-approach-to-public-safety/>.

Additionally, even in the absence of any such mandate, there are more than 45 mobile phones with FM radio capability already available to consumers. To the extent that these devices perform well in the marketplace, it may be reasonable to expect additional FM-equipped devices to come to market. It is not reasonable, however, to imply that new phones can be easily modified or to expect all devices to be FM-capable. Furthermore, many consumers seem to prefer to use applications like Pandora and Spotify to access music and entertainment, since these services allow consumers to customize the material they receive, in contrast to “one-to-many” FM-radio programming where the content and format is dictated by the provider rather than the consumer. Consumers also have ready access to a significant number of NOAA Weather Radio and FM station broadcasts through streaming service applications such as iHeartRadio and WunderRadio.

RESPONSE FROM MS. MARY L. BROWN

QUESTIONS FOR THE RECORD
THE HONORABLE BEN QUALYE (R-AZ)
U.S. House Committee on Science, Space, and Technology
Subcommittee on Technology and Innovation

Avoiding the Spectrum Crunch: Growing the Wireless Economy through Innovation

Wednesday, April 18, 2012

1. *What role will both the federal government and the private sector have in ensuring that the U.S. becomes/remains the global standards leader in spectrum?*

The federal government has two important roles to bolster the US position as a global leader in spectrum technology: (1) create a pipeline of radio spectrum for advanced technologies, such as mobile broadband, so that spectrum supply helps the US market remain a center of commercial wireless innovation; and (2) support basic research that has potential to address advancements in radio technology, both in using spectrum more efficiently and in making more radio spectrum available. The private sector has two primary roles also: (1) fostering global technology standards that support advances in wireless technology; and (2) focusing commercial R&D efforts that can be implemented in the context of global standards.

2. *What are the most pressing spectrum related research priorities for the next five, ten, and twenty years? What do you see as the "long-term spectrum solution?"*

Short term: because commercial mobile broadband is rapidly becoming the dominant use for commercial spectrum, the short term critical path is to promote innovation that commercial broadband platforms (such as LTE) utilize spectrum even more efficiently over time through advancements in transmission technology, processing power, and other strategies, such as the use of small cells to offload traffic. These advances will largely be in the domain of private entities, including everyone from venture capital-funded start ups to large networking equipment companies. These involve complex existing standards-based technologies, and are not an area where government research is likely to produce noticeable gains. In the long term, advances in processing capability, transmission technology and a declining cost curve will push the industry toward more dynamic or flexible spectrum sharing technologies. This will occur gradually and incrementally, probably targeting bands with fixed uses first. Significant development work would be required to ultimately abandon the concept of "managed radio spectrum" that we utilize today in deploying mobile broadband networks. Basic research, funded by government, may have a role to play here. In addition, rational business models will need to evolve or emerge that make technology advances compelling to consumers.

3. *Please describe how industry shapes spectrum research and development. Specifically, how does spectrum-related research funded through non-federal means, including academic, commercial, and public safety sector sources trigger the creation of innovative new businesses and new applications that will transform Americans' lives?*

Global standards, supported by global spectrum allocations, best support commercial spectrum research. A growing, thriving global marketplace attracts funding because it presents an opportunity for return on investment. The mobile apps industry, a wholly new sector, exists because mobile broadband networks became powerful enough to support applications that consumers wanted to buy. And that occurred because hundreds of companies formed a consensus around global standards, enabling mobile broadband networks to be built.

QUESTIONS FOR THE RECORD

THE HONORABLE LAMAR SMITH (R-TX)
U.S. House Committee on Science, Space, and Technology
Subcommittee on Technology and Innovation

Avoiding the Spectrum Crunch: Growing the Wireless Economy through Innovation

Wednesday, April 18, 2012

1. According to the National Association of Broadcasters (NAB), existing mobile phones are already equipped to receive local radio broadcasts, and or new phones can easily be modified. Such a capability might come in handy to receive information during emergencies when people are unable to get cellular phone coverage. The NAB has asked the Federal Emergency Management Agency and other Federal agencies to explore this proposal. What are your thoughts on this proposal? Do you believe that the cost and benefit to the public of equipping mobile phones with free broadcast radio has merit over other proposals? What hurdles exist to implementing such a capability in mobile phones?

QUESTIONS FOR THE RECORD
THE HONORABLE RANDY NEUGEBAUER (R-TX)
U.S. House Committee on Science, Space, and Technology
Subcommittee on Technology and Innovation

Avoiding the Spectrum Crunch: Growing the Wireless Economy through Innovation

Wednesday, April 18, 2012

1. In your testimony, you indicate that Cisco projects a 16-fold increase in mobile data traffic from 2011 to 2016. Could you briefly describe how Cisco made this estimate?
2. How much do you imagine technology efficiencies and innovation will be able to slow the increase in pressure on spectrum usage, and how much will have to come from the government freeing up more spectrum?
3. You mention, in your testimony, the offloading of traffic to Wi-Fi. Are there any industry efforts underway to encourage users to switch to Wi-Fi when it is available? Are there any upcoming technologies that could result in additional offloading to preserve mobile data usage?

QUESTIONS AND ANSWERS FOR THE RECORD

Dr. Rangam Subramanian

Chief Wireless and Technology Strategist,
Idaho National Laboratory, Idaho Falls, Idaho

Before the

House Committee on Science, Space and Technology

Subcommittee on Technology and Innovation

On

**“AVOIDING THE SPECTRUM CRUNCH: GROWING
THE WIRELESS ECONOMY THROUGH
INNOVATION”**

May 25, 2012

QUESTIONS FOR THE RECORD
THE HONORABLE BEN QUALYE (R-AZ)
U.S. House Committee on Science, Space, and Technology
Subcommittee on Technology and Innovation

Avoiding the Spectrum Crunch: Growing the Wireless Economy through Innovation

Wednesday, April 18, 2012

1. What role will both the federal government and the private sector have in ensuring that the U.S. becomes/ remains the global standards leader in Spectrum?

Current spectrum crunch makes it imperative for both the government and the private sector to work together to address the issue. The specific roles to be played by each to ensure that the U.S. becomes/remains the global leader can be summarized as below.

Federal government:

- Define the national policy on future spectrum sharing or repurposing;
- Identify spectral bands for sharing and/or repurposing;
- Build national collaboration between the government, industry and the academia;
- Enable accelerated, realistic research and experimentation:
 - Develop a national roadmap prioritizing research
 - Fund accelerated and transformational research to develop trustable, secure spectrum sharing technologies and toolsets, which in turn, builds the vendor ecosystem;
 - Fund realistic, large-scale, outdoor wireless testing capabilities, to promote quality research and experimentation conducted collaboratively between the industry, government and academia.

Private Sector:

- Embrace the emerging reality of spectrum sharing;
- Support and fund spectrum sharing research and experimentation;
- Collaborate with the government on innovation and experimentation;
- Build spectrum sharing technology standards that can be deployed globally;
- Develop organic next generation, spectrum sharing technology eco-system;
- Develop innovative business models to continue growing a secure wireless economy and to enable the growth of other key economic sectors.

2. What are the most pressing spectrum related research priorities for the next five, ten and twenty years? What do you see as the “long-term spectrum solution?”

5 Years:

- (1) Spectrum Technology Research:

- Radio Frequency layer technologies, such as, broadband sensing devices, interference mitigation algorithms, chipsets with advanced fast signal processing technologies, antenna systems.
 - Network architectures, protocols, standards, spectrum databases, access and usage policies;
 - New business models to deploy next generation, disruptive technologies;
 - Cost efficient spectrum retooling for incumbent defense and other governmental systems;
 - Technology integration, interoperability experimentation and data analytics based on test results acquired through experimentation on realistic, outdoor national testbeds to enable effective standards and rule-making development;
- (2) Multi-disciplinary research and experimentation, applying wireless spectrum sharing technologies to public safety, critical infrastructure protection, energy, medical, transportation, advanced manufacturing, education and other economic sectors;
 - (3) Wireless end-to-end network security in a spectrum sharing environment;

Ten - Twenty Years:

The pace of technology development and usage prevent specific predictions for ten years and twenty years separately. However, the general long term research priorities will revolve around the following:

- (1) Spectrum Research
 - Next generation techniques and technology development for increasing spectral efficiency;
 - High frequency (beyond 5 GHz) research and enabling network architectures;
 - Cost efficient chipsets and devices for RF transceivers at high frequencies;
 - Advanced battery technologies and technologies for ultra-low-energy wireless networks;
 - Next generation secure protocols, devices and architectures for national defense, critical infrastructure protection, law enforcement and commercial use;
- (2) Research on transformational wireless applications in national defense, law enforcement, space communications, unmanned air space systems, advanced transportation networks and other major economic sectors;
- (3) Research on unified airborne and terrestrial communications.

Long Term Solution:

Spectrum is a unique natural resource, limited like oil, but available globally. However, there are alternate sources to generate energy, but wireless communications is limited to using the spectrum and constrained by the laws of physics applicable to various spectral bands. Hence, there is a no single long term wireless spectrum solution that can be applied globally.

Based upon the current state of research and technology, the near term solution will depend on sharing spectrum where appropriate, establishing new architectures for traffic distribution, optimizing bandwidth usage for content delivery and increasing spectral efficiencies through innovation. Continuous investments in research and realistic experimentation capabilities will both accelerate the innovation and improve the quality of the next generation technology and policy development.

QUESTIONS FOR THE RECORD
THE HONORABLE LAMAR SMITH (R-TX)
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According to the National Association of Broadcasters (NAB), existing mobile phones are already equipped to receive local radio broadcasts, and new phones can easily be modified. Such a capability might come in handy to receive information during emergencies when people are unable to get cellular phone coverage. The NAB has asked the Federal Emergency Management Agency and other Federal agencies to explore this proposal. What are your thoughts on this proposal? Do you believe that the cost and benefit to the public of equipping mobile phones with free broadcast radio has merit over other proposals? What hurdles exist to implementing such a capability in mobile phones?

First, while mobile devices can be designed to receive emergency broadcast information using over-the-top internet radio or use yet-to-be-implemented emergency cellular broadcast mode, functionality of this capability is dependent upon operational wireless infrastructure. This infrastructure can become inoperable during times of emergencies, rendering the cellular network capability unreliable. This happened for example during Hurricane Katrina. Furthermore, because wireless network infrastructure is extensively interconnected throughout the nation, an emergency event in one region can make wireless communications unavailable in multiple states. For this reason, embedding an FM radio capability in mobile phones provides a more reliable contingency plan for communicating emergency broadcasts. Second, in light of the spectrum crunch situation, enabling the FM radio feature in mobile phones can offload the FM radio traffic from the wireless network. This would also provide convenience and reachability both in urban and rural areas of the country, besides allowing integration of multiple devices.

The cost of equipping mobile devices with the proper hardware to enable these FM communications is at best on the order of a few dollars per mobile. Some of the chipsets used by the leading smart phone vendors in the United States are already FM hardware capable, requiring minimal software additions to make it operable. Hence, there are no technological hurdles to enabling this FM radio channel capability on mobile phones. There may be some business related concerns because of possibly diminished return-on-investment to some of the wireless ecosystem stakeholders as wireless data consumption through mobile internet radio usage is reduced by direct FM usage using mobile handsets.

In consideration of the ease and nominal costs to enable FM radio on mobile handsets, the relatively low overall impact to wireless service enablers, and the national importance in providing a reliable method of communicating emergency broadcast information, the cost and benefit equation favor adding FM capability to the handsets.

Appendix 2

ADDITIONAL MATERIAL FOR THE RECORD

CARRIERS WARN OF CRISIS IN MOBILE SPECTRUM: REPRINT FROM THE *New York Times*

Carriers Warn of Crisis in Mobile Spectrum - NYTimes.com

<http://www.nytimes.com/2012/04/18/technology/mobile-carriers-war...>

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April 17, 2012

Carriers Warn of Crisis in Mobile Spectrum

By BRIAN X. CHEN

AT&T, Verizon, T-Mobile and Sprint say they need more radio spectrum, the government-rationed slices of radio waves that carry phone calls and wireless data.

The wireless carriers say that in the next few years they may not have enough of it to meet the exploding demands for mobile data. The result, they ominously warn, may be slower or spotty connections on smartphones and tablets. They imply in carefully couched language that, given the laws of supply and demand, the price of cellphone service will soar.

It will affect "the services they're paying for because of the capacity issues," said Ed McFadden, Verizon's vice president for policy communications. "It potentially hinders our ability to meet consumer need."

But is there really a crisis? Some scientists and engineers say the companies are playing a game that is more about protecting their businesses from competitors.

Not even the inventor of the cellphone, Martin Cooper, is convinced that the wireless industry faces a serious challenge that cannot be overcome with technology. Mr. Cooper, a former vice president of Motorola and chairman of Dyna L.L.C., an incubator for new companies, says that claims of a so-called spectrum crisis are largely exaggerated.

"Somehow in the last 100 years, every time there is a problem of getting more spectrum, there is a technology that comes along that solves that problem," he said in an interview. Mr. Cooper also sits on the technical advisory committee of the Federal Communications Commission, and he previously founded ArrayComm, a company that develops software for mobile antenna technologies, which with he said he is no longer associated.

He explained that for carriers, buying spectrum is the easiest way for them to expand their network, but newer technologies, like improved antennas and techniques for offloading mobile traffic to Wi-Fi networks, could multiply the number of mobile devices that carriers can serve by at least tenfold.

Everyone agrees that data-guzzling smartphones and tablets are selling fast, and the wireless industry needs to keep up. Cisco, the networking company, published a study that shows mobile data usage more than doubled in 2011.

Cellphones are radios and their calls are carried on the electromagnetic radio spectrum just like an FM radio signal or a walkie-talkie. The F.C.C. divides up the spectrum by bands of frequency, under the theory that no one wants signals on certain frequencies interfering with one another.

The F.C.C. hands out licenses for each frequency band to entities like the military, TV stations, astronomy researchers and the phone carriers. Carriers now want some of the spectrum others have and are seeking approval from the F.C.C. to buy it at government auction or by buying licenses for it.

Verizon, the largest carrier in the country, has been on the hunt for more. It has been trying to buy wireless spectrum licenses from a group of cable companies, including Time Warner and Comcast. These transactions are being opposed by T-Mobile USA and some other smaller players in the wireless industry. AT&T's ill-fated deal to buy T-Mobile came about in large part to get more spectrum.

The F.C.C. believes that a combination of adding new spectrum and using new technologies will be needed to help the wireless industry evolve. "No single action is a silver bullet when it comes to meeting mobile capacity needs," said Neil Grace, an F.C.C. spokesman. "More efficient use of spectrum, new technologies, and unleashing new spectrum are all important parts of the mix."

Arguing that the nation could run out of spectrum is like saying it was going to run out of a color, says David P. Reed, one of the original architects of the Internet and a former professor of computer science and engineering at the Massachusetts Institute of Technology. He says electromagnetic spectrum is not finite.

Mr. Reed, who is now senior vice president at SAP Labs, a company that provides business software, explained that there are in fact newer technologies for transmitting and receiving signals so that they do not interfere with one another. That means separating the frequency bands would not be required — in other words, everybody could share spectrum and not run out.

The reason spectrum is treated as though it were finite is because it is still divided by frequencies — an outdated understanding of how radio technology works, he said. "I hate to even use the word 'spectrum,'" he said. "It's a 1920s understanding of how radio

communications work.”

Why, then, wouldn't carriers want to use these newer technologies that cause frequencies to not interfere? Because licensing spectrum is a zero-sum game. When a company gets the license for a band of radio waves, it has the exclusive rights to use it. Once a company owns it, competitors can't have it.

Mr. Reed said the carriers haven't advocated for the newer technologies because they want to retain their monopolies.

David S. Isenberg, who worked at AT&T Labs Research for 12 years before leaving to start an independent consulting firm, said the carriers have been deliberately slow with adopting more advanced radio technologies. He said that spectrum licenses come with obligations where carriers had to agree to serve the public interest, but those agreements have significantly weakened. “Their primary interest is not necessarily in making spectrum available, or in making wireless performance better,” he said. “They want to make money.”

Mr. Cooper, the inventor of the mobile phone, says that rather than give the carriers a few more slices of spectrum, he suggests requiring them to use newer technologies that amplify their networks.

He said that currently the technology with the most potential for carriers to use their networks more efficiently is the smart antenna. A traditional radio antenna on a cellphone tower spews energy out in all directions, but only a portion of it gets to the right phone, he explained. By contrast, the smart antenna would direct energy straight at the phones, and as a result, current spectrum would be put to more efficient use.

Fourth-generation LTE networks are supposed to adopt smart antennas, but most carriers haven't started installing these yet, he said. These new antennas will also start shipping in phones in the next two years, which would make even better use of the network, he said.

In interviews, representatives of AT&T, Verizon, T-Mobile and Sprint said new technology would not be enough to solve all their problems, and they said they would eventually need access to more of the nation's radio waves. “They're all Band-Aids, and you have to provide additional spectrum to deal with the wound to deal with the large capacity of bandwidth demands,” said Kathleen Ham, vice president for federal regulatory affairs of T-Mobile USA.

Mr. Cooper doesn't agree.

“Every two and a half years, every spectrum crisis has gotten solved, and that's going to keep happening,” Mr. Cooper said. “We already know today what the solutions are for the next 50

years.”