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Airwave overload?
Addressing spectrum strategy issues that jeopardize U.S. mobile broadband leadership

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Executive summary

In 2011 we issued a paper highlighting mobile broadband's beneficial effects on America's economy.[1] In this new paper we suggest short- and long-range policy measures that could support the innovation and market-driven spectrum supply that allow the U.S. to lead in mobile broadband.

The U.S. benefits economically from its global mobile broadband leadership.

- The United States is the world's mobile broadband leader; a critical success factor has been government policies that relied upon market forces to optimize spectrum supply and use.
- In achieving global leadership, the United States became the world's innovation test bed for mobile broadband services and devices, which has contributed significantly to U.S. economic growth.

Our Mobile Communications National Achievement Index shows future U.S. leadership is not assured; other countries are aggressively promoting mobile innovation and development.

- Accelerated investment in 4G and related mobile broadband technologies is essential to maintain U.S. leadership and to reap the benefits of high-tech innovations that generate gross domestic product (GDP) growth and 21st century American jobs.
- We have developed a "Mobile Telecom Achievement Index" as a tool that tracks the state of countries' wireless sectors, enabling policymakers to evaluate America's standing compared to the rest of the world.
- The index follows the performance of a group of 20 countries that includes both established leaders and potential challengers from the developing world, using 15 indicators that measure end user benefits and the health of the wireless industry for each country.
- Each country receives an aggregate score based on benchmarking its standing in each area against the country with the highest score.
- This achievement index provides evidence of U.S. leadership in mobile broadband, but also suggests that the gap is closing as other countries aggressively pursue developments in this space – continued U.S. leadership is not assured given current trends.

U.S. mobile broadband leadership depends on maintaining a robust and adaptable wireless infrastructure, capable of offering new services and meeting growing demand.

- The rapid evolution and vitality of mobile broadband networks, in response to demand and supply signals, have enabled the exceptional performance of the U.S. ecosystem as a whole.
- Demand: Carriers seek to stimulate demand with mobile broadband offerings that respond to end users' needs at the right prices, in the right places, and at the desired level of quality.
- Supply: Carriers' ability to meet end users' needs depends on their ability to accommodate today's demand while serving as test beds for tomorrow's offerings.
- Industry configuration: End user needs are best met when the structure of the wireless industry combines choice and price competition with sufficient carrier scale to motivate and enable carriers to reduce costs, expand network coverage and capabilities, and invest in technology.

U.S. mobile broadband demand is rising at a tremendous rate and the surge is projected to continue.

- Demand for mobile services has accelerated, fueled by a multitude of innovative devices and an explosion in applications.
- Demand growth is likely to intensify as mobile broadband uses appear in a widening array of business and government segments; among the promising industry growth opportunities are automotive telematics, vehicle traffic management, and mobile healthcare (mHealth).

Carriers are expanding and upgrading their networks to keep pace with demand as government works to increase mobile broadband spectrum to 500 MHz by 2020.

- U.S. wireless carriers have extended their network capacity by deploying new generations of technology and building new cell sites.
- Congestion is also being countered by offloading traffic onto Wi-Fi hotspots, deploying small cells to complement traditional towers and cells, managing traffic demand, and sharing spectrum.
- The federal government has launched initiatives to make more spectrum available for use by mobile broadband, and to address issues such as local cell site approvals.

Despite efforts by carriers and government to augment network capacity, mobile broadband demand growth threatens to overwhelm the system.

- The popularity of bandwidth-intensive new mobile broadband data services is growing rapidly, meeting or exceeding projections in the National Broadband Plan.
- Carriers' network investments in next generation technology and additional cell sites are expanding network capacity, but demand is growing even faster.
- Solutions such as Wi-Fi, small cells, demand management, and spectrum sharing offer promise, but for now they can have only a marginal impact.
- The pace of government initiatives appears to be lagging in terms of what is required to reach the 500 MHz goal by 2020.
- Unresolved policy issues and uncertainties interfere with follow-through on spectrum initiatives.

Fundamental policy changes are required to avoid choking off the innovation that is responsible for America's global leadership in mobile broadband.

- To ensure that the United States does not become a victim of its own success, policymakers should consider measures that address not only the potential spectrum deficit but also the need for new approaches to spectrum management.
- Developing an official U.S. spectrum strategy could provide the opportunity to resolve policy ambiguities that hamper effective mobile broadband decision making.
- An approach that defines overall guidelines and relies on markets to work out economically efficient solutions is well suited to a changing and uncertain wireless environment.
- Treat the costs incurred in making sufficient spectrum available for commercial mobile broadband as investments with a return that is realized over time in the form of increased GDP, jobs, and tax revenue.
- A successful TV broadcast spectrum auction should be a top priority as a highly visible step toward meeting the 2020 goal of freeing up 500 MHz of spectrum for mobile broadband.
- Policymakers should consider expanding government funded or supported R&D efforts to explore the extent to which workable sharing solutions can help alleviate concerns about spectrum supply.
- Traditional auctions combined with viable secondary markets should continue to play central roles as effective mechanisms for distributing spectrum to users and uses with high-value potential.
- Allocating and assigning spectrum in large blocks based on technically driven criteria could alleviate constraints caused by the crowded, fragmented legacy spectrum zoning map.
- Principles-based license renewal reviews offer a means to ensure that license holdings and spectrum policies are aligned with changing technological and economic realities.

The bottom line

Governments around the world face challenges in managing a major transition in spectrum policy. Existing approaches are being overwhelmed. Technology advances are boosting demand for bandwidth-intensive new offerings. Multiple interests need to be balanced. To retain its global mobile broadband leadership the United States must not only head off a spectrum shortage but show the way in adopting a policy framework that can better meet the requirements of the 21st century marketplace. In this paper we have offered thoughts on how these issues can be addressed, and a set of metrics for monitoring the progress governments make as they compete to capitalize on the potential of wireless technology for the benefit of their economies and citizens.

The United States benefits economically from its global mobile broadband leadership

The United States is the world's mobile broadband leader; a critical success factor has been government policies that relied upon market forces to achieve sufficient supply and efficient use of spectrum.

In the last decade, the United States has become the world leader in mobile broadband. American companies excel at developing new mobile broadband services, devices, and applications for domestic and foreign markets. As shown in Exhibit 1, the United States ranks first in key measures such as advanced network technology coverage, subscribers using 3G and 4G services, mobile operating system (OS) shipments, mobile device sales, and application downloads.

Exhibit 1. U.S. global leadership in mobile broadband: selected comparisons

Mobile broadband market leadership indicators	U.S. position
Coverage with the latest generation network technology	Greatest number of people (186 million) and percent of population (60 percent) able to receive the industry's most advanced 4G services.[2]
Subscribers and market penetration	Despite having less than 6 percent of global wireless subscribers, the United States has more than 21 percent of global 3G/4G subscribers, at 164 million as of mid-year 2011. The United States also has 87 percent of global LTE subscribers.[3]
Mobile operating system shipments	U.S. companies dominate the smartphone OS market, owning more than three-fourths of the global market based on 2012 2Q sales to end users. The top two OS makers, Android and Apple, achieved 64.1 percent and 18.8 percent of global sales to end users, respectively, in 2Q 2012. Finland based Nokia owns the third-ranked OS, Symbian, and achieved 5.9 percent.[4]
Mobile device sales	U.S. companies produce close to 22 percent of all smartphones based on global 2012 2Q sales to end users. Two American companies, Apple and Motorola, are among the top 10 smartphone manufacturers globally – Apple is #2 at 18.8 percent and Motorola is #10 at 3.0 percent. The #1 manufacturer, South Korean company Samsung, achieved 29.7 percent.[5]
Application downloads	In the mobile applications market, Apple and Google have a combined 83 percent share of mobile app downloads globally.[6] An extensive community of developers supports each platform, with over 43,000 developers for the Apple App Store and over 10,000 for Google's Android Market.[7]

Government's contribution to this success has been to support the formation of a mobile broadband "entrepreneurial innovation ecosystem" populated by multiple entities, including wireless carriers, network equipment and handset manufacturers, operating system and application developers, cloud service providers, and consumer and business end users. The Federal Communications Commission (FCC) created the necessary conditions by auctioning large amounts of spectrum, removing spectrum caps limiting individual carrier's spectrum holdings, and permitting market forces to operate.

- From 1994 to 2000, FCC auctions tripled the amount of spectrum available for commercial mobile services.[8] These auctions are credited with prompting a 250 percent increase in investment and a 300 percent jobs increase in the mobile market.[9]
- In 2003, the FCC removed spectrum caps, making it possible for U.S. carriers to aggregate sufficient quantities of spectrum for the development of mobile broadband networks.
- The FCC permitted U.S. carriers to buy and sell spectrum, enabling more efficient allocation of available airwaves by allowing carriers with the greatest value-generation potential for the spectrum to purchase it from those that were less favorably positioned to use it effectively.[10]

In achieving global leadership, the United States became the world's innovation test bed for mobile broadband services and devices, which has contributed significantly to U.S. economic growth.

Government policy created conditions conducive to flourishing of private sector creativity, and U.S. companies have been energetic in seizing the opportunities available in an open market. The interactions of carriers, high-tech companies, and their customers resulted in an outpouring of 3G devices and services, and are now producing a similar surge of 4G offerings.

Patent generation is one indication of this phenomenon. By the first quarter of 2012, the United States was granting mobile patents at 2.5 times the rate of Europe. Mobile patents grew from less than 10 percent of all U.S. patents a decade ago to 20 percent today.[11]

Innovations hatched in the United States quickly move into international commerce. New offerings are introduced in the U.S. market, taking advantage of the advanced mobile communications infrastructure. After their launch, refinement, and validation, they are then sold abroad, expanding U.S. exports and contributing to GDP and job growth:

- **Smartphones (2007-2012).** Apple's iPhone and the iOS-based App Store revolutionized the mobile device market. The iPhone accounted for about 18.9 percent of global smartphone sales in 2011, and enabled Apple to capture an estimated 66 percent of global smartphone operating profit. U.S. dominance has also carried into the operating systems that enable these devices. The Apple iOS and Google Android operating systems were launched in 2007 and 2008, and quickly created a shift away from the operating system platforms of Nokia and Research In Motion. Only a few years later, in 2012 2Q, the Android and iOS platforms held a combined 82.9 percent share of sales compared to 11.1 percent for Nokia Symbian and Research In Motion.[12]

- **Tablets (2009-2012).** Initially launched in the United States, the tablet computer market is dominated by U.S. companies: Apple iOS and Google Android are atop the global operating system market for tablets, capturing 58.2 and 38.7 percent, respectively, of the market in 2011;[13] Amazon's Kindle Fire is the leading tablet in the Android-based market, capturing 54.4 percent of this category.[14] Tablets are now rapidly spreading worldwide to the benefit of these U.S. companies. In 2010, more than 50 percent of tablets were sold in the North American market. A market research firm projects that by 2014 sales abroad will expand to the point that sales outside North America will account for more than two-thirds of tablet shipments.[15]

- **e-Readers and e-Books (2007-2012).** Amazon pioneered electronic publishing with its Kindle and Kindle Store products, launching a new market in which global shipments of e-Readers amounted to 22.8 million units in 2011, an increase of 107 percent from a year earlier. Shipments are estimated to top 60 million units by 2015.[16] U.S. companies currently dominate the e-Reader market: As of first quarter 2012, Amazon's Kindle family of products captured approximately 56 percent of the market for devices used to read electronic books, with Kindle tallying 41 percent and Kindle Fire 15 percent, respectively, followed by the Barnes & Noble Nook at approximately 16 percent and Apple's iPad at 10 percent.[17]

- **Mobile applications (2010-2012).** Mobile applications developed (or now owned) by American companies, including Facebook, Google Maps, Skype, Apple iBooks, and Twitter, are all among the top 10 most commonly downloaded mobile applications in the world today.[18] Instagram is an example of the rapid growth of many U.S. app ventures. Based in California, Instagram launched in the App Store in October 2010. Less than six months later it was the most commonly downloaded application in the photography category in each of the 10 countries with the highest App Store usage (U.S., Japan, Italy, Germany, U.K., Australia, Canada, China, France, Korea). In April 2012 Facebook announced it would acquire the company for $1 billion in cash. Two days later it was the most popular app in the app store across all categories.[19]

- **Mobile chipsets (2007-2012).** Four of the five leading companies in the market for application-specific mobile phone semiconductors are U.S.-based, and in 2011 they accounted for more than 50 percent of this market by share of revenue. Qualcomm is the global leader, achieving 28 percent share. Other prominent U.S. companies in this fast-growing category are Texas Instruments at 8.9 percent, Intel at 7.4 percent and Broadcom at 6.3 percent.[20]

America's leadership in this field has produced significant benefits. A recent study cataloged some of the economic contributions of the U.S. wireless broadband industry:[21]

- Responsible for 3.8 million jobs, directly and indirectly, an increase of more than 200,000 over the past six years, accounting for 2.6 percent of all U.S. employment.

- Retained $146.2 billion in GDP in the United States and generated $195.5 billion in economic activity globally in the 12 months from July 2010 to June 2011.

- Now larger than the U.S. publishing, agriculture, hotels and lodging, air transportation, motion picture and recording, and motor vehicle manufacturing industries.

- At $195.5 billion, would rank as the 46th largest economy in the world,[22] and is generating economic activity across the mobile ecosystem through wireless and wireline operators, device and accessory manufacturers, device component suppliers, advertising and PR agencies, TV, radio, print, and Internet ad channels, network and other capital equipment suppliers, professional service providers, platform and component suppliers, mobile advertising networks, content suppliers, application and content stores, application developers, retailers and third-party dealers, and mobile virtual network operators.

Our 2011 report[23] provided estimates as to how the future contribution of 4G networks to the U.S. economy could differ depending on the extent to which the policy environment is conducive to carrier investments in the deployment of these networks. The time period covered was 2012-2016:

- **Baseline scenario.** U.S. carriers' mobile broadband investment could be on the order of $25 billion. This is consistent with a policy environment that is only mildly favorable toward 4G deployment. Under these conditions, U.S. companies could be vulnerable to incursions by foreign competitors capitalizing on aggressive efforts in their home markets to deploy 4G networks and develop 4G-based devices and services. Applying standard industry-specific multipliers, 4G networks could account for $73 billion in GDP growth and 371,000 new jobs.

- **Accelerated scenario.** Under conditions similar to what was achieved during the 3G rollout, carrier investment could double to $53 billion. This implies a scenario in which government policy is more supportive of private-sector initiatives. At this level of investment there is a much better chance that the United States would outpace other countries in deploying 4G networks and American companies could produce popular 4G-based devices and services before foreign competitors gain traction in markets here and abroad. Again applying standard industry-specific multipliers, 4G networks could account for $151 billion in GDP growth and 771,000 new jobs.

These figures are conservative, as is true of any analysis of mobile broadband's economic impact using the investment multiplier approach. This method focuses on the effects of spending by carriers, their suppliers, and the workers they employ – it is basically a look at the results within the telecommunications industry. The calculations do not include any of the benefits that flow from applying mobile applications to the rest of the economy. Moreover, the numbers do not reflect the social benefits that can accrue when minority groups, rural communities, and small businesses obtain access to mobile broadband; the U.S. economy becomes more fair and efficient as fewer individuals and businesses are at a disadvantage due to a lack of leading-edge broadband connectivity.

Regulatory policy is thus a significant factor in the development of 4G mobile broadband. An approach in which government focuses on creating conditions that are positive for the operation of market forces has made it possible for the United States to move into a position of global wireless leadership. The benefits flow not only to the U.S. telecommunications industry but throughout the American economy, and include providing products and services to markets abroad as well as serving the U.S. domestic market.

Our Mobile Communications National Achievement Index shows future U.S. leadership is not assured; other countries are aggressively promoting mobile innovation and development

Accelerated investment in 4G and related mobile broadband technologies is essential to maintain U.S. leadership and to reap the benefits of high-tech innovations that generate GDP growth and 21st century American jobs.

America's innovation and test bed leadership in mobile broadband is far from assured. Others are aggressively planning, investing in, and supporting deployment of advanced mobile infrastructure. Countries such as China, France, Germany, Japan, Singapore, and South Korea have adopted national broadband plans that include goals and policies designed to upgrade their wireless as well as wireline broadband platforms.[24]

Exhibit 2. Efforts to promote 4G deployment or advanced spectrum use: selected governments[25]

Government	Illustrative governmental actions
China	• A driving force behind the development of a competing version of LTE and is pushing to develop a supporting ecosystem that could give Chinese vendors a competitive edge • Providing R&D for a Chinese version of 4G wireless infrastructure • Coordinating large-scale LTE trials • State-owned banks financing the export of China's wireless technology • Funding cognitive radio research for wireless networks
European Union	• Supporting an initiative to develop cognitive radio systems through the introduction and promotion of real-time secondary spectrum trading and the creation of a new spectrum commons regime • Collaborating on standards and licensing to ensure pan-European standardization and spectrum allocations
France	• Made available 30 MHz of spectrum in the 800 MHz band and 70 MHz of spectrum in the 2.6 GHz band for 4G service • Mandated that 90 percent of the population will be covered by 4G by 2025, creating a large market for 4G services
Japan	• Identified 400 MHz of spectrum to reallocate for mobile broadband purposes • Supported NTT DoCoMo, the leading wireless carrier, with LTE field tests • Released revised version of Action Plan for Spectrum Reallocation in September 2011 that accommodates increased demand for 4G mobile radio communications by repurposing spectrum • Actively promoting the use of radio spectrum in a variety of social infrastructure applications, including public safety, marine multimedia, mobile telephony, and medical treatment
South Korea	• Actively field testing what has been rated the world's fastest LTE network • Providing funds to build a "mobile cluster" industrial zone to support LTE product development • Struck a deal to support Ericsson, a leading 4G network equipment vendor based in Sweden, with the development of a 4G R&D facility in the country
Sweden	• Deregulated market three years before the United States • Made the 2.6 GHz band available to carriers in April 2008 • Provided Ericsson an undisclosed level of financial support

In some cases, governments are playing a more significant role. Certain governments own shares in domestic telecom and high-tech companies. Some treat the success of their telecom and high-tech sectors as a matter of national industrial policy and offer assistance through means such as tax incentives, R&D funding, and end user subsidies in addition to directly supporting particular entities through their ownership role. Exhibit 2 provides illustrative examples.

With various degrees of governmental support, 347 operators around the world have committed to commercial LTE network deployments or are engaged in trials, technology testing or studies. Commercial service is already offered by 96 operators in 46 countries, and 292 operators have made firm commitments to commercial deployments in 93 countries. Another 55 operators in 11 additional countries are in pre-commitment stages.[26]

In the face of this activity and investment, the United States should not underestimate the competitive threat from abroad, particularly in a high-visibility area such as mobile broadband.

Why is continued global leadership important? Progressive generations of mobile technology have consistently offered a lower cost structure at higher levels of capacity, as well as advanced capabilities such as increased speed, reduced latency, improved security and advanced quality of service features such as prioritization by user or application. These price/performance and capability improvements, along with sufficient capacity and coverage, create the very type of leading-edge test bed environment that attracts investment, entrepreneurism, and high-technology jobs, which subsequently stimulates demand with innovative new products and services. Relinquishing America's leadership position to other countries risks a direct negative impact on U.S. economic contribution from the mobile industry. It could also create adverse indirect effects due to reduced U.S. ability to support the diverse set of industries that are increasingly reliant on today's mobile solutions, or are on the cusp of leveraging mobile data for tomorrow's growth opportunities.

An index that tracks the state of countries' wireless sectors would be a valuable tool for evaluating and anticipating America's standing compared to the rest of the world.

Continued mobile broadband leadership is an important driver of American competitiveness in the global economy. The U.S. position is being challenged as other countries establish the policies, advanced infrastructure, and network capacity to support and encourage business activity, consumer use, and global commerce in mobile broadband products and services. It would be helpful to establish an index that would provide a broad perspective on the status of factors that bear upon the strength and competitiveness of national mobile telecommunications sectors. This would furnish industry leaders and policymakers with objective readings on the relative positioning of countries whose performance is measured, along with performance trends over time.

We have developed a "Mobile Communications National Achievement Index" as a preliminary model for a tracking tool of the type that would fill this need.

To illustrate how a global index might look, we have constructed a Mobile Communications National Achievement Index that tracks country annual performance on a selected set of global competitiveness indicators. By monitoring a set of indicators of the type we have assembled, and understanding movements in country indices, industry leaders and policymakers can gain a clear, objective view of how the U.S. stacks up in the global mobile broadband marketplace, and can design plans and policies to leverage and protect areas of strength while developing strategies to address areas of relative competitive weakness.

This index tracks the trend over time of countries' relative performance with respect to 15 indicators that paint a broad picture of a country's mobile competitiveness. While any one indicator can be driven by a variety of underlying factors, the trend of the collective set provides a clear sense of the overall health and relative competitive strength of the mobile telecom industry within a given country.

The index follows the performance of a group of 20 countries that includes both established leaders and potential challengers from the developing world.

The countries were first selected based on the size of their information and communications technology (ICT) sectors. That initial set was then augmented with other countries that are demonstrating emerging ICT capabilities. In total, an index score was developed for each of 20 countries that could vie for the global mobile broadband leadership position over the next 10 to 20 years:

- Australia
- Brazil
- Canada
- China
- Denmark
- Finland
- France
- Germany
- India
- Japan
- Mexico
- Netherlands
- Norway
- Portugal
- Singapore
- South Africa
- South Korea
- Sweden
- United Kingdom
- United States

Other countries can be added in the future to extend the set of global index rankings.

The index consists of a group of mobile performance indicators that measure end-user benefits and the health of the wireless industry for each country.

In selecting the specific indicators to comprise the index, we followed two core principles:

- **Use objective measures.** To guard against bias, we chose to avoid subjective measures and instead focus only on indicators for which quantifiable data exists.
- **Select measures with good quality time series data.** Although absolute values determine relative global positioning among the countries, trends are arguably more important for understanding whether a country's policies and market dynamics are creating favorable conditions for advances in mobile broadband performance. We have included indicators for which there are good quality time-series data for the majority of countries.

By applying these principles we arrived at 15 indicators spanning the years 2004 – 2011. The indicators tracked in the index span user engagement, network performance and affordability, and industry ecosystem performance categories – each comprised of several sub-indices:

- **User engagement.** Measures such as mobile penetration per capita, advanced device penetration, mobile broadband penetration and voice usage.
- **Network performance and affordability.** Measures such as percent of population covered, data speeds and price per minute.
- **Industry ecosystem performance.** Measures such as carrier economic contribution, amount of carrier competition (Herfindahl–Hirschman Index), carrier capital investment, ecosystem patent generation, and share of wireless device sales.

An aggregate score is determined for each country based on benchmarking its achievement in each indicator against the country with the highest score.

To calculate a country's annual score for each indicator we applied a benchmarking methodology that compares each country's performance to the best overall score on each measure in that year. The highest performing country receives a 1 and all other countries receive a score less than 1 by dividing its performance by the performance of the highest performing country. This approach creates a relative performance measurement that is recalculated each year without effect from prior-year performance. It can also result in a country scoring lower in a subsequent year, despite making year-over-year progress, if that performance improvement was less than the market leader.[27]

After deriving individual country scores for each indicator, the scores are weighted to balance contributions from categories with multiple underlying indicators, then averaged into a single, overall country score.

This achievement index provides evidence of U.S. leadership in mobile broadband, but also suggests that the gap is closing as other countries aggressively pursue developments in this space – continued U.S. leadership is not assured given current trends.

The United States has significant advantages in the global contest for mobile broadband leadership – advanced infrastructure, an early lead in 4G deployments, a vibrant competitive carrier market, deep penetration of active user communities, and an extensive entrepreneurial ecosystem that has created many of the world's most compelling mobile innovations. These advantages are not easily replicated in other countries and are formidable obstacles for others to overcome.

As shown in Exhibit 3, overall country score trends in the Mobile Communications National Achievement Index indicate that the United States has indeed held a leadership position over the last several years. But after peaking around 2005 with relative strengths in voice usage, affordability, competitive balance, capital investment, and patent generation, the United States. proceeded to lose roughly three-fourths of its lead in a span of four years. This decline was driven by other countries' relative performance improvements in penetration per capita, affordability, voice usage, and capital investment. Also, the United States lagged in advanced device adoption. Simply put, the United States has lost ground as other countries and their governments make significant investments in developing and growing their mobile broadband capabilities and usage.

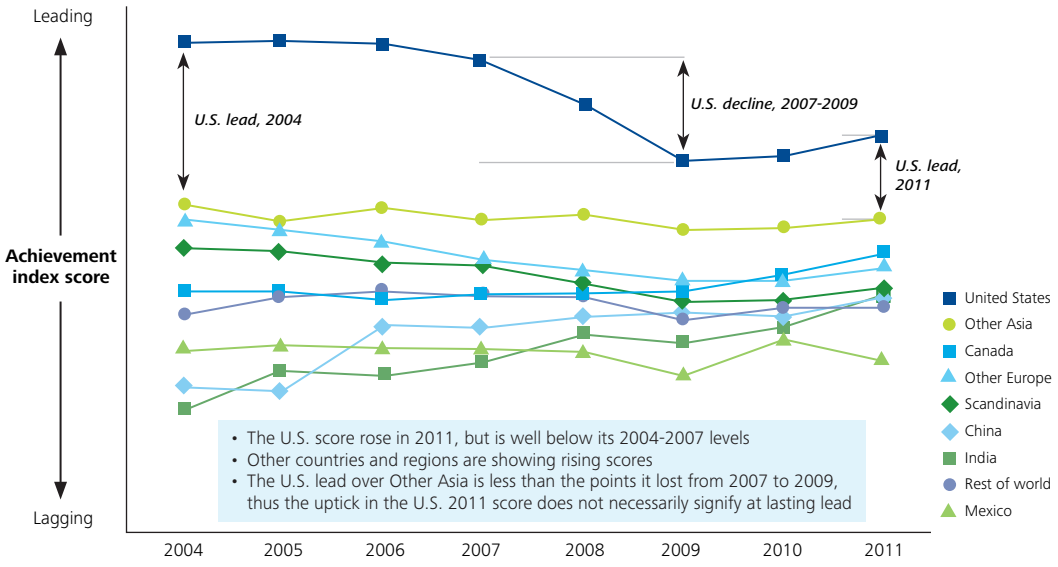
U.S. relative performance stabilized in 2009 and 2010, and ticked up slightly last year with modest improvements in several indicators. This could well have been the result of 3G and early 4G build-outs enabled by the 700 MHz spectrum auctions a few years prior. Despite its steep decline the United States has retained its lead, albeit with a margin that is much narrower than just a few years ago and less than the points it lost from 2007 to 2009. A U.S. stumble, such as a mobile broadband capacity shortfall, could allow other countries to close the now relatively narrow performance gap and overtake the United States within the next few years.

It is noteworthy that America's relative performance declined when the country was active in advancing mobile broadband – aggressively rolling out 3G, developing and deploying advanced smartphones, and laying the foundation for 4G services. In other words, it is not so much that the United States lost its intensity during this period of decline, but rather that the global competition got that much better. Japan, Korea, and Singapore have remained consistently strong competitors, while China and India have made steady gains over the last decade as rising challengers. These emerging mobile titans have built strong technology communities that benefit from government investment and support. The Scandinavian and Other Europe countries have generally fared well with their advanced infrastructures and high-use populations, and Canada has made significant gains in recent years as more advanced mobile broadband services have grown in the marketplace. All are viable challengers to U.S. leadership and well prepared to take advantage of a U.S. performance slowdown or misstep.

The significant lead the United States enjoyed in the mid-2000s may relate to the current strong showing of mobile ecosystem companies in the United States – the index could be a leading indicator of mobile ecosystem economic performance. If so, the lift from earlier investments and innovations may be diminishing and U.S. leadership across ecosystem industries could be increasingly challenged in coming years.

If the United States were to lose its leadership position, the opportunity costs would be manifested in foregone GDP, job creation, and tax revenue. Conversely, there would be substantial benefits from costs incurred to make sufficient spectrum available and otherwise promote U.S. mobile broadband to sustain U.S. leadership. As discussed in Chapter 1, the 4G investment scenarios we developed in 2011 indicate the implications of U.S. leadership in 4G over the period 2012-2016 could be on the order of $75 billion in GDP growth and 400,000 new jobs for the telecom sector alone.

Exhibit 3. Mobile Communications National Achievement Index ratings: selected countries and regions[28]



Note:
- Scandinavia includes Denmark, Finland, Norway, and Sweden
- Other Europe includes France, Germany, Netherlands, Portugal, and the United Kingdom
- Other Asia includes Japan, Korea, and Singapore
- Rest of World includes Australia, Brazil, and South Africa

U.S. mobile broadband leadership depends on maintaining a robust and adaptable wireless infrastructure capable of offering new services and meeting growing demand

The rapid evolution and vitality of mobile broadband networks, in response to demand and supply signals, have enabled the exceptional performance of the U.S. ecosystem as a whole.

The United States has moved into world leadership thanks to a virtuous cycle of innovative offerings, rising demand, and more investment. The cycle consists of several stages:

- Successive generations of mobile telecommunications technology have offered a lower cost structure at higher levels of capacity, plus advanced capabilities such as increased speed, reduced latency, and improved security. Technology advances also bring improved quality of service features such as network performance prioritization by user or application.

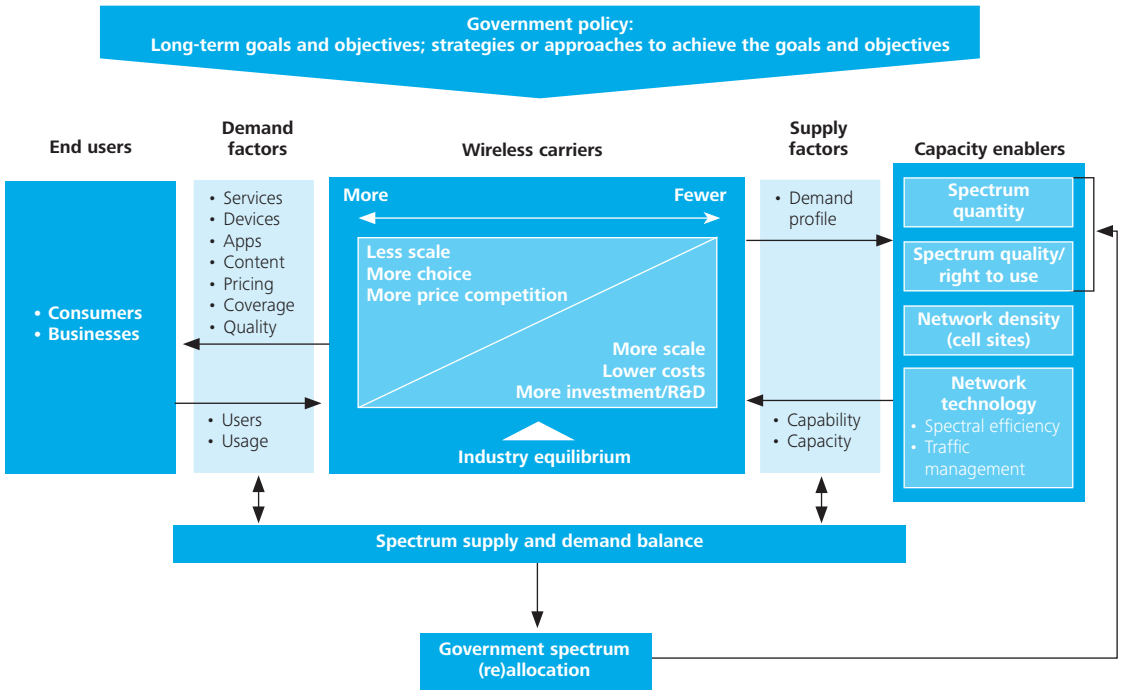
- These price/performance and capability enhancements, along with sufficient capacity and coverage, create the leading-edge test bed environment that attracts investment and entrepreneurialism.

- This in turn stimulates demand for innovative new products and services, and the positive market response promotes additional investment.

The vitality of the network segment of the ecosystem is crucial to maintaining U.S. global leadership in mobile broadband. Exhibit 4 depicts the network segment of the ecosystem.

The chart provides perspective on the functioning of U.S. mobile broadband networks within the framework of rules and regulations established by policymakers. It is therefore helpful to examine the elements of the system – the demand side consisting of end users and their consumption of mobile broadband products and services, and the supply side consisting of carriers, their networks, and their market offerings.

Exhibit 4. Mobile broadband dynamics



Demand: Carriers seek to stimulate demand with mobile broadband offerings that respond to end users' needs at the right prices, in the right places, and at the desired level of quality.

End users include consumers and businesses. They have needs involving goods, services, and information. Demand depends on how well carriers do at providing mobile broadband connectivity products and services that help meet those needs. The key demand stimulators are the products and services the wireless carriers offer, the prices they charge, the geographic area within which the offerings are available, and their performance along dimensions that matter to end users. As end users purchase and use mobile broadband products and services carriers receive signals as to the appeal of different offerings and the characteristics of the usage their networks must accommodate.

Supply: Carriers' ability to meet end users' needs depends on their ability to accommodate today's demand while serving as test beds for tomorrow's offerings.

Carriers' ability to generate new offerings and respond to end user demand depends upon factors that govern network capacity – the infrastructure's ability to handle traffic volume, the sophistication of the applications it can support, and the quality of its operation. These factors determine not only a network's ability to administer today's applications and traffic volumes, but also its viability as a test bed for tomorrow's mobile broadband offerings. The capacity enablers are:

- **Spectrum quantity:** the volume of radio frequencies allocated to wireless services by the FCC, and acquired by a given carrier, measured in megahertz.

- **Spectrum quality:** the suitability of the spectrum for the purpose intended. For example:
  - Lower frequencies tend to be better than higher frequencies for carrying mobile wireless signals long distances and for penetrating buildings
  - Larger, contiguous blocks of spectrum are easier to manage and allow greater efficiency of use than a patchwork of smaller ones
  - National allocations of the same frequencies enable simpler and lower cost nationwide operations than regional allocations that require a carrier and the associated devices to operate on and seamlessly transfer signals across multiple frequencies
  - Licensed spectrum that is dedicated to a particular network operator enables improved security and service management capabilities compared to unlicensed spectrum available for general public use.

- **Network density:** the shorter the distance between cell sites, the greater the amount of wireless traffic a carrier can handle with a given amount of spectrum. This is because cell sites with smaller radii serve on average fewer users for the same amount of spectrum capacity.

- **Network technology:** the more advanced the technology the greater is the network's ability to use spectrum efficiently and manage traffic effectively. For instance, LTE, a fourth generation technology, can be up to 96 times more efficient in its use of spectrum, measured in bits per second per Hertz, than GSM, a 2G technology.

A robust set of network capacity enablers will encourage a high level of demand stimulation, in turn leading to increased end user purchases and usage. This will stimulate further improvements in network capacity and capabilities.

There is another set of variables to consider, however, which is the configuration of the wireless industry.

Industry configuration: End user needs are best met when the structure of the wireless industry combines choice and price competition with sufficient carrier scale to motivate and enable carriers to reduce costs, expand network coverage and capabilities, and invest in technology.

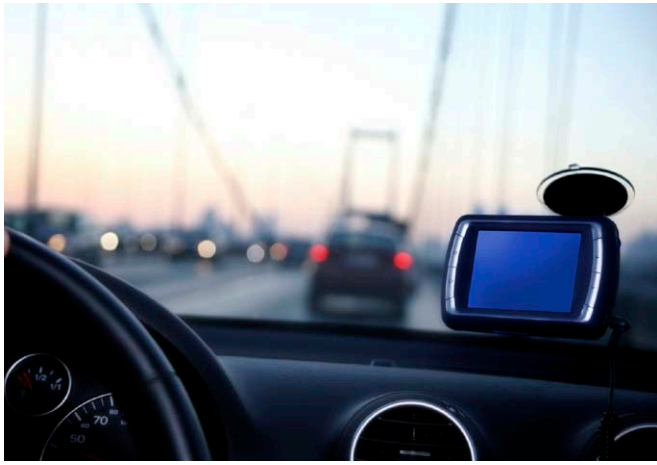
Where the carrier industry sits on a continuum between two industry consolidation extremes determines the nature of certain tradeoffs that affect the functioning of the network sector. The extremes are a low-consolidation situation in which there is a large number of small carriers, and a high-consolidation situation in which there is a small number of large carriers:

- At the low-consolidation extreme, end users have more choices among carriers, and carriers have a significant incentive to compete for increased market share. While this can often lead to aggressive price competition, the fact that carriers are smaller means they have less of the scale that enables the spreading of significant fixed costs across a high number of users, which limits how far they can cut prices. In addition, the relative lack of scale limits the amount carriers can invest in underlying capabilities and assets such as spectrum, network coverage and capacity, and the most advanced and efficient new technologies. That in turn curtails their ability to offer advanced products and services, and to further reduce prices.

- At the high-consolidation extreme, carriers have sufficient scale to spread fixed costs across a high number of users, reducing their per-unit costs and making it possible to keep their prices low. Likewise, large scale gives carriers the financial wherewithal to make substantial investments in spectrum, network coverage and capacity, and technology R&D that would lead to a more extensive, geographically expansive and technologically advanced array of offerings. However, there is less competitive pressure and thus carriers may be less motivated to invest their financial assets in the most advanced capabilities and offerings, and to keep their prices low.

The optimal location for the wireless industry is not at either of these extremes but closer to the middle. A midpoint location means end users are able to choose among multiple carriers and from a wide array of advanced, widely available, affordable offerings. Carriers are forced by competition to bring new and improved offerings to market as rapidly as possible, and they have sufficient scale to equip themselves with the spectrum, network coverage, and technology required to maintain optimal responsiveness to market signals. Importantly, the combination of scale and competition motivates carriers to pass scale savings to end users in the form of lower prices. This balance is thus critical for enabling a thriving market environment and ecosystem in which innovation with attractive pricing stimulates continued demand growth.

In the next sections we will examine the U.S. wireless market using this conceptual framework. First we will look at the state of customer demand. Then we will see to what extent wireless carriers are willing and able to provide the network facilities and offerings that align with current and potential market demand. Finally, we will offer observations regarding the decisions about maintaining America's global mobile broadband leadership confronting U.S. policymakers.



U.S. mobile broadband demand is rising at a tremendous rate and the surge is projected to continue

Demand for mobile services has accelerated, fueled by a multitude of innovative devices and an explosion in applications.

Globally, the wireless industry reached approximately 6 billion subscribers and over $1 trillion in revenues in 2011.[29] A little over a decade earlier, in 2000, global wireless subscribers numbered approximately 750 million.[30] This translates into a compound annual growth rate (CAGR) of 20.8 percent for subscribers and has exceeded even the most optimistic expectations. Moreover, the growth has been stimulated by demand for both voice and data services, leading industry analysts to expect that "by 2013 mobile phones will overtake PCs as the most common Web access devices worldwide."[31] Exhibit 5 summarizes the development of wireless technology over the past decade.

Exhibit 5. The critical developments of recent wireless technology generations[32]

	2G 2000 to 2006	3G 2007 to 2011	4G 2012 forward
Wireless penetration	38% to 77%	83% to 105%	105% to ?
Critical development	Digital wireless telecom in most people's hands	Faster download speeds enable development of mobile browsing and applications market	Mobility further embedded in daily life with technologies such as near-field communications. Shift from "best efforts" service to managed performance

America's entrepreneurial innovation ecosystem has performed well in making available products and services that appeal to wireless end users. As discussed in chapter 1, the United States leads the world in take-up of advanced devices and services. Exhibit 6 illustrates that this take-up has led to exponential growth in traffic: U.S. mobile traffic in 2011 was roughly 47 times the rate in 2000 and grew 74 percent over 2010.[33] Also in 2011, wireless penetration in the U.S. market reached 105 percent – more than one device in service for every man, woman, and child in the country. While other countries, particularly in Europe, achieved this milestone years earlier and now have penetration rates in the range of 140-160 percent, the U.S. milestone is notable in that it was achieved with a broader base of voice and data connected devices, suggesting a more diverse and dynamic industry.

Demand for mobile broadband services has never been stronger, and usage continues to grow vigorously as subscribers respond favorably to new devices and services. Exhibit 7 highlights the differences in the scope and magnitude of the U.S. industry since the turn of the millennium.

Driving this popularity and growth has been innovation in the sense of a new device or service that breaks existing tradeoffs involving performance and cost, i.e., the new offering provides more for less. It may be possible to obtain superior performance, but only at a higher price; it may be possible to pay less but only at a sacrifice in performance. A smartphone that offers a new combination of capabilities at a price competitors cannot immediately match is an example. There are also cases in

Exhibit 6. U.S. mobile traffic growth[34]

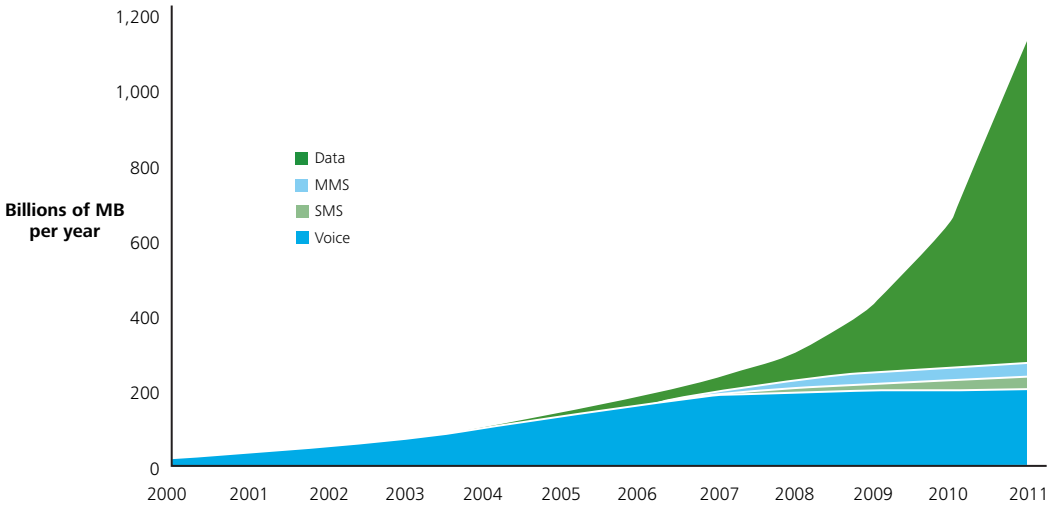


Exhibit 7. U.S. wireless industry evolution over the last decade[35]

	2000		2011	
	11 years of continuous change and growth			
Adoption	**Light**	• 34% penetration	**Heavy**	• 105% penetration
Usage	**Voice centric**	• Voice as primary application at 255 minutes per subscriber per month • Voice quality/coverage as primary purchase criterion • Per minute pricing plans define value	**Data centric**	• Voice usage 2.5X greater at 632 minutes per subscriber, but declining in favor of data • Data comprises 38 percent of total wireless revenue • Usage at 517MB per sub per month
Devices	**Feature phones**	• Competition based on form factor, reliability and voice quality • Low processing power and memory requirements	**Smart phones**	• 40 percent of the market is smart phone and emerging devices • Competition based on user interface, web access, application availability • PC-like processing and memory requirements
Uses	**SMS**	• Over 170 million SMS messages sent	**S/MMS and Apps**	• 2.3 trillion SMSs sent and 3.5 billion apps downloaded
Affordability	**ARPU and price per MB**	• $48.95 voice ARPU • $1.95 per MB	**ARPU and price per MB**	• $46.10 voice ARPU • $0.19 per MB

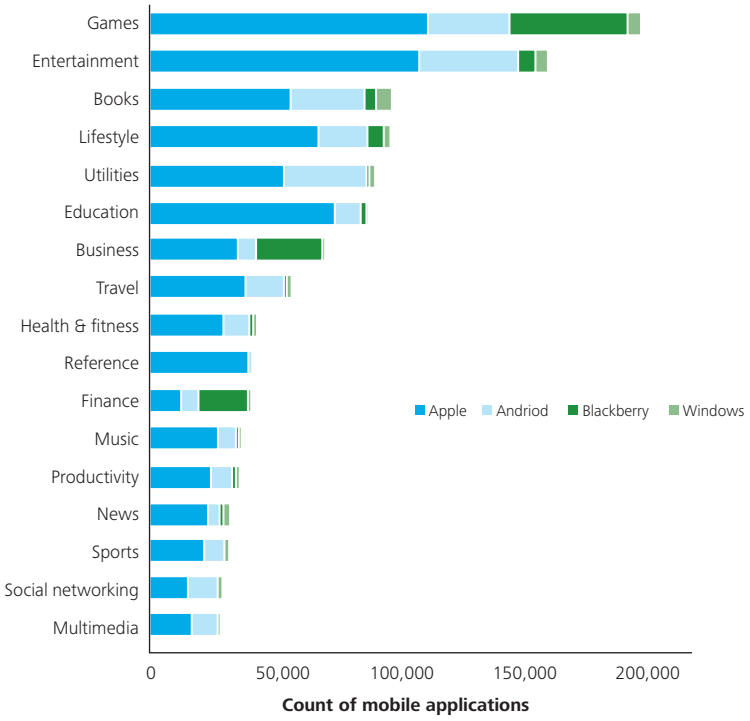
which evolving technology powers a new business model that challenges an entirely different market, as in the case of smartphones and PCs.[36] As mobile broadband devices and services break prevailing performance and cost constraints, they make it possible for similar advances in sectors where they are being used.

Such changes were first encouraged by the advent of data-enabled feature phones. The BlackBerry 5810, introduced in 2002, was the first BlackBerry device to supplement RIM's popular mobile e-mail and calendar features with the functionality of a mobile phone.[37] This combination of mobile voice and data functionality was an initial step toward mobile phones with ever broader sets of features, leading to more advanced smartphones, 3G mobile broadband services, and first-generation mobile user interfaces overlaid on existing Internet and business applications.

Growth further accelerated upon the emergence of mobile application ecosystems such as those for the iPhone and Android. This created a wireless infrastructure environment in which successful U.S. companies such as Facebook, Twitter, PayPal, and Skype led in offering mobile versions of their services. Another important factor has been the continued decline in the costs of mobile device processors, displays, and sensors, which enabled the development of more advanced smartphones, tablets, and other specialized mobile devices. The high-tech industry has now entered the stage where mobile solutions are not adapted from stationary precursors but are built from the ground up through the development of fully integrated devices and applications, better realizing the true potential of mobile broadband connectivity.

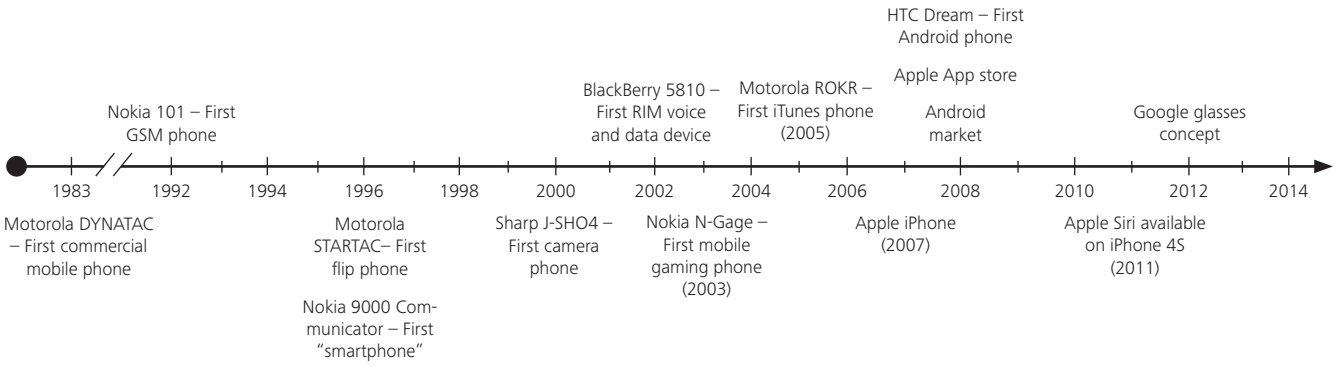
The rate and diversity of application growth underscore how mobile broadband devices and services have promoted vast demand for anytime, anywhere data connectivity. Mobile solutions are now embedded in nearly every walk of life and in every business sector, with roughly 1.1 million applications available on the market[38] and over 1,000 new applications being added on a weekly basis.[39]

Exhibit 8. Mobile applications available on the major mobile platforms[40]



The process continues – hardware price-performance ratios improve, network technology capabilities increase, and new offerings proliferate. For example, smartphones will increasingly be able to offer tracking mechanisms and sensors that, with user permission, can collect data about human behavior, physiology, activity, geographic movement, and even surrounding environments. By aggregating and analyzing this data companies are beginning to develop deeper and near real-time understanding of their customers through a variety of leading and lagging indicators, which in turn can lead to sophisticated applications and solutions to address and even anticipate customer needs. The traditional phone form factor is being challenged as well, with tablets becoming increasingly prevalent and glasses and other wearable devices coming soon.[41]

Exhibit 9. The evolution of mobile devices[42]



Demand growth is likely to intensify as mobile broadband uses appear in a widening array of business and government segments.

Beyond advanced personal communication devices, "machine to machine" solutions are also poised to deliver tremendous growth in applications across a broad swath of businesses and government organizations. Hundreds of specialized devices are now certified to operate on U.S. carrier networks to provide automated communications, remote sensing, and actuating solutions. These provide new capabilities, efficiency improvements, and data-rich insights, enabling companies across a variety of industries to drive top- and bottom-line growth and become more competitive in the United States and abroad:

- Progressive insurance customers who opt for usage-based insurance pricing plug a Snapshot device into their car's diagnostic port, typically near the steering column. Wireless transmissions from the device report on how often customers make sudden stops, how many miles they drive, and how often they drive between midnight and 4 a.m. Their driving profile determines the amount of discount they receive on the price of their insurance coverage.[43]

- The latest devices from TomTom, the satellite navigation provider, automatically tally traffic information from millions of users to set better routes for other drivers.

- Logistics firms such as UPS use mobile devices in their vehicle fleets not only to optimize driving routes, but also to provide live package tracking information for customers.[44]

- Smart Grid company Silver Spring Networks has installed tens of thousands of wireless smart meters to provide remote monitoring and reporting of utility network status and use.[45]

Some of the more promising industry growth opportunities are automotive telematics (connected car), vehicle traffic management, and mobile health care (mHealth):

Automotive telematics. The North American market for automotive telematics, which integrates wireless telecommunications and information technologies, is poised for tremendous growth over the next five to 10 years. After a modest start in the mid-1990s, the industry has steadily put new technologies, infrastructure, and partnerships in place. It now provides wireless services such as automatic collision notification and remote door unlocking for millions of subscribers. A 2011 study estimated that U.S. telematics unit sales – including both OEM installed and aftermarket – would rise to 13.1 million units in 2011, up 22.6 percent from 10.7 million in 2010, and climb to 32.3 million by 2017.[46] Another study estimated that by 2020 connected car services of some form will be in 90 percent of new passenger cars sold and contribute $600 billion in global revenue, cost reduction, or service improvement economic value.[47]

Due to its heavy use of intelligent sensors, devices and wireless communications, automotive telematics will be a leading candidate to migrate from older 2G and 3G network technologies to LTE networks that support both core vehicle management and in-car infotainment services. U.S. auto manufacturers are currently planning LTE-equipped vehicles for as soon as 2014,[48] and an LTE Venture Forum for Connected Cars, including BMW, Honda, Hyundai, Kia, and Toyota, is investing and promoting new ways to integrate LTE connectivity into vehicles and promoting the technology among automotive suppliers and application developers.[49]

Among industry analysts and car manufacturers opinions differ regarding the short-term pace of LTE adoption to support the connected car of the future, but there is consensus for a continued and increasing need for LTE levels of bandwidth to feed and support features. These include rear-seat video monitors, 3D navigation systems, surround-sound stereos, and other infotainment telematics applications that will be largely accessed through consumer smartphone devices installed in vehicles.[50]

Vehicle traffic management. The market for traffic management solutions and intelligent transportation systems is likely to see rapid growth in the coming years. With the number of cars on the road set to increase from 900 million in 2011 to 1.2 billion in 2020,[51] and the percentage of people living in cities expected to grow from 50 percent to 70 percent by 2050,[52] road congestion will be a far-reaching problem. To help meet the challenges implicit in this growth, state and local governments are looking for ways to minimize congestion and generate revenue through the deployment of intelligent transportation systems that include networked road signs, dynamic road tolling, and congestion-charging schemes. Many of these solutions have already been implemented in one form or another on a limited basis and by 2020 revenue generated by these systems may reach $100 billion.[53]

In addition to generating revenue, deployment of intelligent traffic management systems can help cities realize substantial efficiency gains through reduced congestion and improvements to living quality. One study from 2006 estimated that 5 to 10 percent of urban traffic, and up to 60 percent of small street traffic, is accounted for by drivers looking for parking space. As noted by Motorola:

> Traffic congestion costs money, imperils public safety and influences the family and social lives of billions of people. In 2003 in the United States alone, highway congestion cost over $63 billion in travel delays and wasted fuel. In international business, congestion affects the bottom line by affecting everything from inventory control to shipping to customer relationships. Finally, congestion and other roadway safety issues are partially to blame for traffic fatality rates that have begun rising again after years of decline.[54]

Intelligent transportation systems, enabled by wireless broadband data connections, have emerged as a promising set of technologies that can help address the congestion challenge. Over 3,000 companies are currently operating in the intelligent transportation systems space in North America, including major players such as Siemens, Telenav, and Magellan.[55] Citrix Systems, a cloud, networking, and visualization technologies company, recently moved into the space by acquiring Bytemobile, a mobile traffic optimization company.[56] This broad-based market participation has been elicited by expectations of strong revenue growth – forecasted to be as high as 41 percent between 2009 and 2015.[57] Subsegments identified as having particularly strong growth prospects are electric toll collection, video detection, and parking optimization. While wired versions of these systems have existed for some time, "comprehensive monitoring and management of large scale, widespread transportation systems have been hampered when only wired systems are in place."[58] Wireless broadband systems enable improvements in both the scope and effectiveness of intelligent monitoring systems, and could significantly increase innovation in this arena.

mHealth. The health care industry is approaching a potentially transformational shift enabled by mobile broadband capabilities. Mobile health services could significantly alter the current health care business model by creating opportunities to increase care provider efficiencies and productivity, improve diagnostics and treatment regimens, provide remote monitoring and diagnosis of patient conditions, increase access to specialized medical skills, and facilitate secure records transmission. The potential is significant:

- A dramatic expansion in patient historical health information, captured by mobile device sensors, for more accurate and semiautomated diagnosis of patient health
- A reduction in patient and practitioner travel for care, yielding both savings and safety benefits
- An increase in the number of patients that doctors and nurses can serve in a unit of time
- Expanded access to medical professionals – from local to global
- Equal access to specialized care for citizens in rural areas

Health professionals already rely heavily on mobile devices, with 81 percent of physicians owning smartphones and 38 percent using medical apps daily. One-third use smartphones or tablets to access medical records currently, and another 20 percent are expected to start using them this year.[59] Analysts are projecting that in the next several years mHealth solutions will advance beyond these types of basic physician aids to become one of the major growth opportunities in the global M2M marketplace. One research group estimates that the number of home monitoring systems with integrated communication capabilities will grow at a compound annual growth rate of 18 percent between 2010 and 2016, reaching 4.9 million connections globally by 2016. The number of these devices with integrated cellular connectivity has increased from 420,000 in 2010 to about 570,000 in 2011, and is projected to grow at a CAGR of 34.6 percent to 2.47 million in 2016.[60]

Another study estimates that the global health care cost savings and benefits of just clinical remote monitoring, a subset of total mHealth potential, could reach $350 billion by 2020.[61]

The federal government is supporting mHealth development through a range of initiatives. President Obama plans to create a technology innovators fellowship program "to pair top innovators from the private sector, nonprofits, or academia with federal government employees to collaborate on game-changing solutions that aim to deliver significant business results in just six months."[62] Two of the five target areas for this program involve health care and health care information technology.

Another program aims to expand the Blue Button program – a Veterans Affairs Department innovation – of text-based downloads of patient medical records. The "Blue Button for America" initiative aims to "develop apps and create awareness of tools that help individuals get access to their personal health records – current medications and drug allergies, claims and treatment data, and lab reports – that can improve their health and health care."[63]

The U.S. Department of Health and Human Services (HHS) is promoting the development of mobile technologies through its own programs – such as the Text4Health Task Force – and through the programs of various other health-oriented government agencies it supports. For example:

- The HHS Office of Minority Health has partnered with the American Association of Diabetes Educators, AT&T, and Baylor University to investigate the use of smart phones' secure video streaming by demonstrating live diabetes self-management education courses directed by clinicians and community health workers.[64]
- HHS has partnered with the White House to launch the Apps Against Abuse developer's challenge – a national competition that encourages the development of innovative applications that offer young adults a way to connect with trusted friends in real time to prevent abuse or violence from occurring.[65]

- At the National Institute of Biomedical Imaging and Bioengineering (NIBIB), researchers have developed "technologies for multimedia remote intraoperative monitoring systems capable of transmitting data, voice, and images over the Internet."[66] These technologies build on advances in mobile computing power and wireless communications, and have the potential to lead to substantial changes in the way doctors care for patients. Advances in these technologies can be particularly beneficial for patients with chronic illnesses and those that live in rural areas far from medical centers. The NIBIB has funded "development of sensor and microsystem technologies for point-of-care testing. These instruments combine multiple analytical functions into self-contained, portable devices that can be used by non-specialists to detect and diagnose disease."[67]

Carriers also recognize the mHealth opportunity:

- At a 2011 mHealth conference, Verizon Wireless announced that it will develop a new suite of digital health care products focused on treating and preventing chronic conditions such as diabetes and chronic heart failure.[68]

- AT&T's mHealth Solutions business unit is pursuing opportunities such as a remote patient monitoring service to help health care providers and payers more effectively manage chronic diseases and reduce hospital readmissions, and mobile connectivity for an application that collects, analyzes and delivers patient information for a pharmaceutical company trialing a new product.[69]

To enable this growth, telecommunications providers will need to provide sufficient mobile network bandwidth and capacity to connect care practitioners, medical institutions, and patients with capabilities such as high-volume data transport of medical records, high-resolution imaging and video streaming for remote consultations, and quick download of near-real-time medical information. These and other types of mHealth services call for sophisticated and advanced mobile broadband technologies such as LTE.[70]

Implications for future demand. Given the broad potential for mobile broadband growth in industry segments such as those outlined above, many analysts predict that U.S. mobile data use will continue its high growth rate as mobile data becomes increasingly embedded in U.S. society and an indispensable enabler within U.S. industries. Bullish industry forecasts expect enormous growth in mobile data traffic in the coming years with one report suggesting that "mobile data traffic will experience a 70% CAGR from 2011 to 2016" while another predicts a CAGR of 78% over the same time period.[71]

Globally and within the United States, mobile broadband demand is burgeoning. Technology advances are making it possible to introduce new products and services while holding prices in check. Consumers are responding favorably to offerings that incorporate anytime, anywhere use, particularly involving mobile data. Machine-to-machine solutions are also evolving and have the potential to transform the operations of many businesses and government organizations. Automotive telematics, vehicle traffic management, and mHealth are three examples of areas in which current activities and structures could be materially altered by mobile broadband and which in turn could produce further growth in usage. Meeting all this demand is a welcomed challenge, but one that could jeopardize America's mobile broadband leadership if it is not adequately addressed.

Carriers are expanding and upgrading their networks to keep pace with demand as government works to increase mobile broadband spectrum

U.S. wireless carriers have extended their network capacity by deploying new generations of technology and building new cell sites.

U.S. carriers are investing in their networks to increase capacity in an effort to accommodate demand while maintaining attractive pricing. Carrier investment since 2004 has increased total network capacity approximately 12.5 fold.[72]

The investments have brought about upgrades to next-generation, more spectrally efficient network technologies and the construction of cell sites to create denser network grids, especially in highly populated areas.

- **New technology rollouts:** The development and deployment timelines for new technology generations have been decreasing. Roughly eight years elapsed between the rollout of analog (1G) and GSM (2G). The move from 3G to 4G took about half that time.

- **Efficiency improvements:** Each generation of mobile technology from 1G to the current 4G has improved the traffic capacity efficiency of mobile spectrum use.

- **Cell splitting:** Carriers have more than doubled the number of cell sites over the past decade, partly for geographic coverage growth but also significantly for capacity expansion, substantially increasing the traffic-carrying capacity that is feasible with existing spectrum within a given geographic area.

Congestion is also being countered by offloading traffic onto Wi-Fi hotspots, deploying small cells to complement traditional towers and cells, managing traffic demand, and sharing spectrum.

Wi-Fi hotspots. A Wi-Fi hotspot is essentially a miniature wireless data network, with a range of several yards or more, that operates in unlicensed spectrum bands. These short range wireless networks can generally be deployed easily and cheaply and are typically connected to the Internet via a local wireline broadband network. Carriers have been actively pursuing a variety of means to enable and encourage mobile broadband users to connect their devices to Wi-Fi hotspots whenever available, thereby reducing the demand load on the licensed mobile network.

A hotspot acts as an unlicensed cell within a licensed cell, sparing the licensed wireless network from having to transmit a portion of traffic in the area. This is particularly effective when handling traffic from users with high data demand, such as video streaming, during peak use hours in high traffic areas. Users often benefit from this arrangement because they are moving their data usage off licensed carrier networks that typically have metered rates or monthly use caps.

Consumers often have a Wi-Fi hotspot in their home, connected to their DSL or cable modem service, or find similar data "hotspots" in coffee houses, libraries, campuses, malls, restaurants, airports, and other public locations. There are more than 114,000 publically available or pay Wi-Fi hotspots in the U.S. today, with growth projected at 45 percent CAGR[73] through 2015.

Wi-Fi hotspots are also widely deployed by enterprises for commercial private use, and carriers have invested in Wi-Fi deployments for the explicit purpose of mobile network traffic off-load in high traffic areas; AT&T alone owns over 33,000 Wi-Fi hotspots in North America and is planning to deploy many more to support surging growth in connections and data usage.[74] In 2011, AT&T increased its Wi-Fi network deployment by approximately 1,000 hotspots per quarter. Consumer connections to its Wi-Fi networks more than doubled over this time period and data uploads increased 550 percent.[75]

Although Wi-Fi hotspots today are data-only and have little ability to hand off communications from one hotspot to another if the user is on the move, the industry is working on a Wi-Fi 2.0 next generation technology that is designed to bring the ease of cellular roaming to Wi-Fi, enabling seamless user access and handoffs between networks when roaming.[76] Deployment of these enhanced hotspots over coming years can enable carriers to make greater use of unlicensed spectrum as a capacity complement to their licensed spectrum networks. For now, Wi-Fi is largely for off-loading traffic on behalf of stationary wireless users who stay within the range of a single hotspot.

Small cells. Carriers have also been working on heterogeneous or hybrid network solutions that involve a distributed network overlay of small cells, typically called "picocells", "femtocells," or "microcells," that handle mobile traffic within a much smaller coverage radius than traditional cells. These small cells are similar to Wi-Fi hotspots except that they are typically owned by the carriers as targeted overlays within the mobile broadband network to address specific capacity or coverage issues, and operate in the same licensed spectrum bands. By being designed into the mobile broadband network architecture and operating in the same licensed bands, these small cells enable carriers to move the wireless traffic onto wireline networks in many more physical locations, thus enabling the same spectrum bands to be "reused" many times over within a given geographic footprint. Furthermore, these cells offer improved capability over Wi-Fi hotspots by enabling carriers to offer higher quality service, voice communications, and seamless connectivity for end users moving from one cell to another. Carriers are currently experimenting with picocells, femtocells, and microcells in various locations such as homes, office buildings, and public locations to determine the commercial viability, operational feasibility, and economics of larger scale deployments.

Demand management. Carriers have sought to limit capacity constraints on their networks by optimizing the flow of traffic. Optimization can take a variety of forms, including improved data compression, adaptive video streaming to match device type, time shifting of traffic to off-peak hours, and empowering users to understand and manage their usage patterns. Some of these techniques offer greater promise than others, but collectively they are expected to provide incremental benefit in managing demand relative to the exponential growth rates that exist today.

Spectrum sharing. Spectrum sharing solutions allow multiple uses of the same spectrum ranges and may be promising options to increase future wireless capacity. There are different ways to share spectrum. One is geographic sharing – different users operate on the same frequency but use low-power devices with limited ranges; so long as the devices are not in close proximity the risk of interference is minimal. New technologies are increasingly supporting "dynamic sharing" or "opportunistic access." These allow a mobile device to sense or to query a database on which frequencies are being used and to move to a different, available frequency for communications. Frequency-hopping and smart-antenna technologies are currently of particular interest:

- **Frequency hopping:** Cognitive or software-based radio technology is able to scan or query a geolocation database for frequency bands or ranges that are shared with other users and types of usage for frequencies that are not currently in use. This enables the device to intelligently avoid capacity bottlenecks and the operator to carry more capacity within a given amount of spectrum. Importantly, it also gives mobile carriers access to more spectrum, such as spectrum currently allocated to federal agencies and departments, that otherwise would not be available for mobile broadband use for years, if ever.

- **Smart antennas:** Smart antennas with variable gain correct for certain inefficiencies by directing signals toward devices generating or consuming traffic. In effect this shrinks the cell site by only occupying the spectrum in the direct line of sight between the tower and device. As other devices consume traffic, they can share that same spectrum by also taking advantage of the directionally focused antenna.

Spectrum sharing, on a longer term basis and once proven, not only has potential to address the need for additional mobile broadband capacity, but private investments in these new technologies helps foster an expanded base of U.S. innovation should those technologies take hold with carriers throughout the world.

The federal government has launched initiatives to make more spectrum available for use by mobile broadband and to address issues such as local cell site approvals.

Spectrum reallocation. In March 2010 the FCC published a National Broadband Plan. Congress ordered that the plan be developed to ensure that every American has "access to broadband capability." The Plan characterizes mobile spectrum as a key enabler of national broadband interests. It defined measures for encouraging further development and use of this strategically vital national asset. Specific recommendations regarding spectrum were:

1. Provide greater transparency concerning spectrum allocation and utilization.

2. Expand incentives and mechanisms to reallocate or repurpose spectrum, including secondary market policies and rules to promote improved access to spectrum.

3. Make 500 MHz spectrum available for wireless broadband within the next 10 years and 300 MHz within five years.

4. Expand innovative spectrum access models, including unlicensed, TV white spaces and other unlicensed applications, and R&D that will advance the science of spectrum access.

5. Take additional steps to make U.S. spectrum policy more comprehensive, including an FCC and National Telecommunications and Information Administration (NTIA) joint road map to identify additional candidate spectrum for mobile and fixed wireless broadband use.

6. Increase the flexibility, capacity, and cost effectiveness of spectrum for point-to-point wireless backhaul services.[77]

In 2010 President Obama issued his own Memorandum with goals that are similar to the National Broadband Plan.[78] It instructs NTIA to coordinate with the FCC in making 500 MHz of federal and nonfederal spectrum available by 2020 for wireless broadband on an exclusive or shared basis, and directs NTIA to identify federal spectrum that could be used for this purpose. Since then NTIA along with interagency coordinating groups and outside advisors has prepared several reports on repurposing federal spectrum for commercial mobile broadband service.[79]

In February 2012 Congress passed legislation that included provisions relating to mobile broadband. The new law gave the FCC authority to conduct incentive auctions and established guidelines for using an incentive auction to free up TV broadcast spectrum for mobile broadband service. It also authorized creation of a Public Safety Broadband Network (PSBN), with funding from the broadcast auction and from leases to commercial mobile broadband users.[80]

The FCC plans to auction 120 MHz of TV broadcast spectrum and is working on the rules for the process. The commission intends to publish proposals regarding the auction process in the fall of 2012.[81]

The FCC has also made available for shared use the "white space" in TV broadcast spectrum and is revising rules and regulations that could impede broadband use in certain frequencies. The commission is likewise freeing up spectrum for wireless backhaul.[82]

Cell site approvals. The FCC has sought to reduce delays in gaining state and local government action on applications for cell site construction and modifications. In November 2009 the FCC adopted a Declaratory Ruling which, among other things, limited the time state or local zoning authorities have to make decisions on cell site applications. The limit (or "shot clock") for deciding on an application involving a collocation is 90 days and an application involving construction is 150 days. This ruling has had a limited effect on reducing the average time required to approve applications for cell site modification and construction.[83] The FCC issued a second ruling in February 2012 that stipulates automatic approval after a 90-day review period of cell site modifications that do not result in "significant" physical alterations to an existing installation.[84]

Despite efforts by carriers and government to augment network capacity, mobile broadband demand growth threatens to overwhelm the system

The popularity of bandwidth-intensive new mobile broadband data services is growing rapidly, meeting or exceeding projections in the National Broadband Plan.

The FCC's 2010 National Broadband Plan predicted that data demand in 2014 will be approximately 24 to 47 times that of 2009.[85] Actual demand over the past few years is tracking closely or even exceeding that forecast and others, reinforcing the point that continued significant network capacity expansion will be necessary to keep pace.

Exhibit 10. Latest demand forecasts relative to FCC National Broadband Plan assumptions[86]

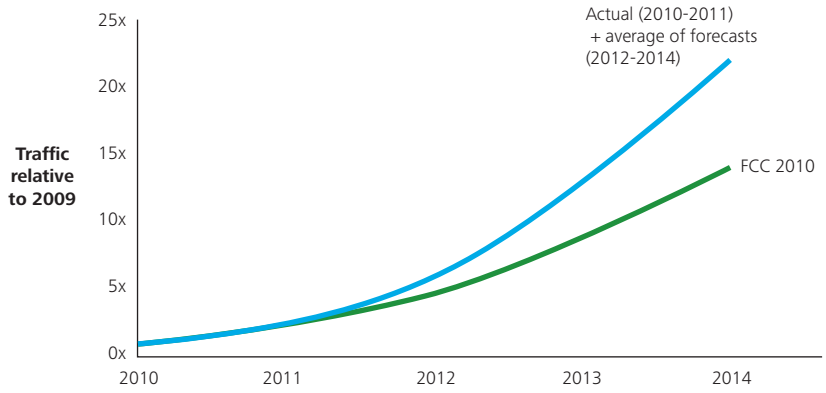
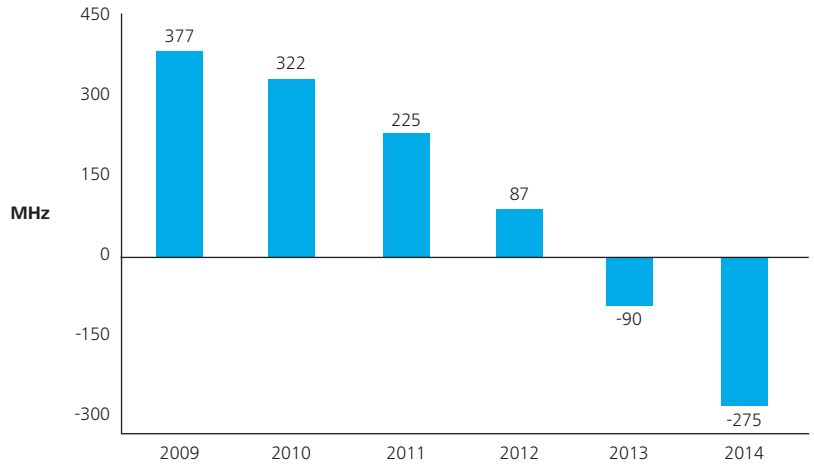


Exhibit 11. FCC forecast of U.S. spectrum surplus/deficit



As the Plan pointed out, this growth threatens to create a spectrum deficit if network efficiencies and new spectrum allocations do not expand capacity on a timely basis. So far it appears that supply increases are not keeping pace with rising demand.

Carriers have steadily multiplied their cell sites and upgraded technology, but the number of users per cell site has risen instead of fallen. Localities are taking longer to decide on cell site development proposals. Work continues on new technologies and capabilities such as microcells, demand management, and spectrum sharing, but realistically these will not mature into commercially viable, significant capacity management solutions in the near-term or midterm time horizon. The FCC is seeking to conduct spectrum auctions and prod localities to expedite their decision process but political and technical considerations are slowing progress.

As shown in Exhibit 11, given the current mobile broadband spectrum allocation of 547 MHz, the FCC estimates a spectrum deficit of 275 MHz by 2014, using "conservative assumptions about the market factors that affect spectrum need," and acknowledging that the output is "an aggregate national projection of likely spectrum needs, which is likely to mask differences across markets."[87] With demand growing as predicted or faster than assumed by the FCC, and with spectrum supply efforts to close the gap delayed relative to the National Broadband Plan schedule, the magnitude of the problem may be more significant than the FCC projected in 2010.

To put the estimated shortfall in perspective: A 50 percent shortfall in spectrum capacity was projected by 2014 relative to the currently allocated 547 MHz. Two years later the demand-supply imbalance has grown, meaning that the United States is facing a spectrum shortfall greater than 50 percent of current supply by 2014 unless immediate action is taken to remedy the demand-supply imbalance.

Carriers' network investments in next-generation technology and additional cell sites are expanding network capacity, but demand is growing even faster.

U.S. wireless carriers have achieved significant mobile broadband network capacity increases by upgrading to new generations of technology and are now in the process of deploying 4G on a nationwide basis. However, even as each new generation of technology delivers valuable improvements in spectral efficiency, it introduces functionality improvements that permit new uses and attract new users. The net result has been that the spectral efficiency increases have been more than offset by demand stimulated by the new functionality.[88]

Carriers have been deploying new cell sites but are experiencing challenging trends in terms of demand per site, site costs, site availability, and site construction cycle times.

- Adding cell sites has increased network density and achieved more intensive use of existing spectrum. But even as the number of cell sites more than doubled from 104,000 in 2000 to 253,000 in 2010, subscribers per cell have increased, from approximately 993 in 2000 to 1,144 in 2010.[89] After accounting for growth in demand per subscriber over the same period, demand per cell has grown more than 1,000 percent despite the doubling in cell count.

- Cell site construction and modification costs are significant, requiring extensive capital investment and ongoing operating costs for items such as power, HVAC, site leases, and maintenance activities. Development costs per new cell site have increased from roughly $215K in 2005 to $275K in 2011,[90] and are likely to continue rising as the cell site locations for capacity expansion are increasingly in the most densely populated and expensive urban areas.

- Carriers attempt to reduce these costs by collocating with other carriers on shared cell sites when possible. However, as cell site densities increase, lack of space on these sites is limiting the optimal placement of new antenna arrays, forcing carriers to seek alternate solutions such as "tenant improvement" sites like building walls and rooftops, and "street furniture" sites like sign poles, bus stops, street lamps, and billboards. These alternate locations often come with other challenges such as reduced coverage ranges due to height limitations and limited access to power and high-capacity backhaul.

- It can take years to deploy or upgrade a cell site. Under favorable conditions, particularly regarding local permitting and approvals, deployment of new technology on an existing site can typically be accomplished within a few months. New site construction may double that time. Deployment timelines for both situations can extend to several years in cases of more complex or challenging local zoning and regulatory situations.

Solutions such as Wi-Fi, small cells, demand management, and spectrum sharing offer promise, but for now they can have only a marginal impact.

Wi-Fi hotspots, picocells, and femtocells are promising options but care must be taken in projecting their ability to alleviate network capacity issues. None of these has yet been implemented at sufficient scale for a long enough period to determine when, whether, and to what extent they will offer cost-effective solutions to the mobile broadband transmission needs of carriers, enterprises, and consumers. Among the issues to consider:

Wi-Fi. Today's Wi-Fi installed base is not carrier-grade in that it has limitations with respect to security, handoffs for an end user on the move, and other capabilities consumers expect. Bringing Wi-Fi 2.0 into full operation will likely take substantial time and investment.

Small cells. The signal radius of a small cell is typically 100 feet. Covering a city block takes hundreds of access points. Each has to be powered and provided with backhaul Internet connections.

Spectrum sharing. Achieving workable sharing arrangements among carriers, government agencies, and others will likewise require an extended phase-in period and additional rounds of technology advances.

- Effective dynamic access requires users with complementary traffic, peak times, and payload profiles. Commercial carriers typically have similar usage characteristics; more promising are matchups between government and commercial users.

- The public safety subset of government users is not always a good choice for sharing with commercial users. The cellular network has very little unused capacity at the peak and the peak is broad. The commercial peak and public safety peak will often correspond – public safety activity tends to correspond with the cycles of community life. By the same token commercial use typically spikes along with public safety use during emergencies.

- Structuring a sharing arrangement involving public safety and commercial users can be complex. With respect to emergencies, for instance, there are questions as to what constitutes an emergency and who has the authority to declare when an emergency begins and ends. Rules governing commercial sharing with federal entities such as the Department of Defense or Department of Homeland Security are likely to be conservative, making it difficult for commercial carriers to plan on capacity from these shared resources.

- Carriers compete mostly based on network quality, and spectrum sharing affects network performance. Introducing spectrum sharing is inherently a sensitive proposition for carriers concerned about differentiation and competitive advantage. If spectrum sharing policy mandates that carriers share holdings equally, without consideration of which carrier can put the spectrum most rapidly to use, then carriers will naturally look to other methods to increase scale, namely consolidation.

- Before spectrum sharing technologies can have a material impact on capacity, carriers must upgrade both towers and end-user devices for tens of millions of customers. The capital expenditures and operating expense increases involved presumably will be passed along to end users at least in part, so time to achieve technical maturity and lower costs will likely be beneficial in managing the transition.

- In today's competitive environment, spectrum is central to how carriers design their networks. Spectrum holdings and the costs and opportunities involved in acquiring spectrum factor into capacity planning, capital investment, and demand management. Until rules are defined and technology performance is tested in a real-world environment, carriers and end users will be unable to benefit from additional capacity offered by spectrum sharing.

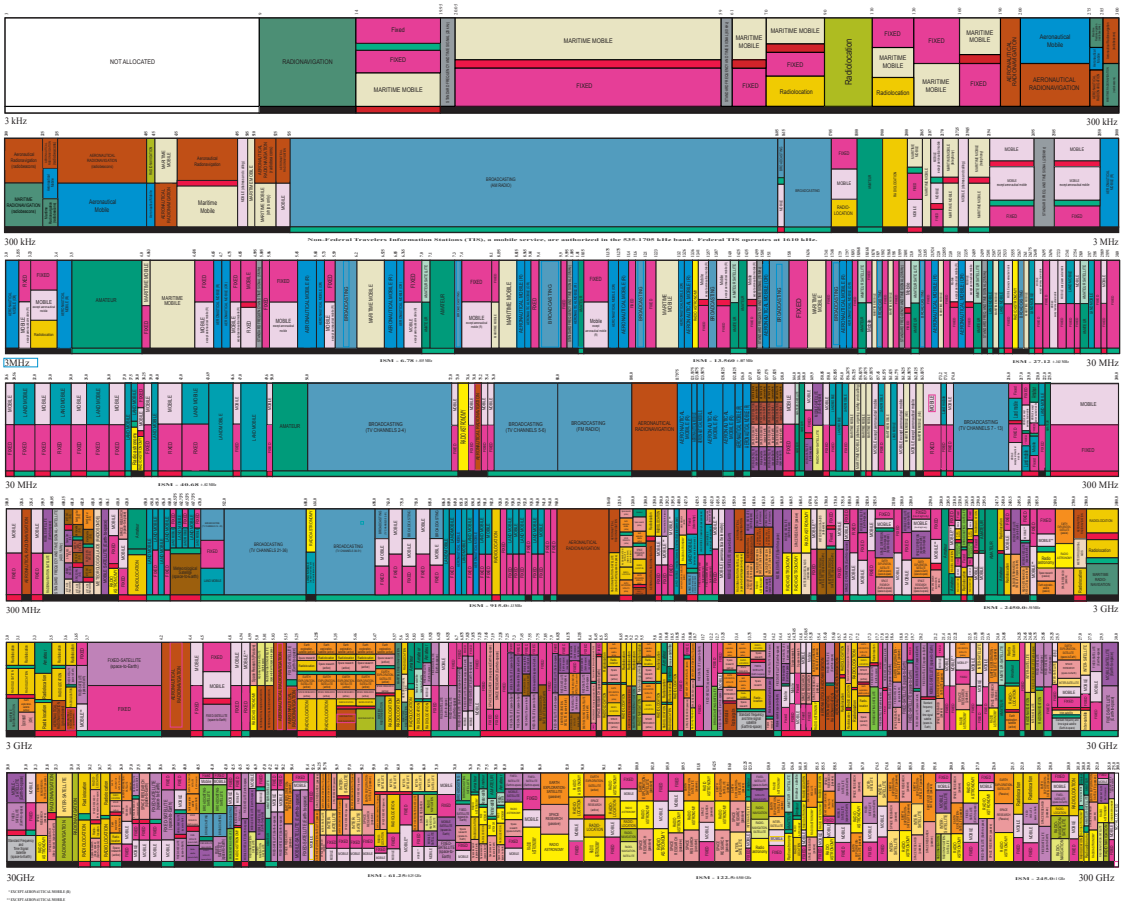
Collectively these facts imply that it will take years to establish the spectrum sharing technologies, infrastructure, policies, practices, and administrative mechanisms that will make it possible to know with any certainty the impact of sharing on commercial mobile broadband capacity.

Demand management methods are also promising but are only expected to slow the rate of demand growth, not fundamentally change the need for capacity expansion. In addition, demand management needs to be used carefully because it risks limiting the utility of some services and restricting the potential of emerging services. Carriers are conducting experiments and trials to determine savings potentials, validate technical feasibilities, and understand operational implications of deploying these more advanced capabilities on a widespread basis.

The pace of government initiatives appears to be lagging what is required to reach the 500 MHz goal by 2020.

The complexities involved in coordinating the use of spectrum by federal and nonfederal users described above are but one example of the reality that spectrum management entails not only technical challenges but also coping with the economic, legal, and political considerations that come into play when dealing with multiple competing interests. Exhibit 12 below is one way of illustrating the situation – the colored bars represent frequencies that have been allocated to various uses and users. Cellular spectrum occupies the frequencies between approximately 300 MHz and 3 GHz. Currently, about 16 percent of that spectrum is allocated to wireless carriers for providing cellular voice and data services. The remaining 84 percent is allocated to uses that include defense, government, scientific, satellite, and other uses. Modifying existing arrangements is no small undertaking, whether the issue is sharing spectrum, relocating incumbent users and granting spectrum to other users, altering allocation and assignment practices, or other such initiatives. Changes are inherently problematic and time consuming. Having said that, major changes are required if the U.S. is to preserve its mobile broadband lead.

Exhibit 12. U.S. frequency allocations[91]



Pursuant to the goal of making 500 MHz of additional spectrum available for wireless broadband by 2020, NTIA, in collaboration with the FCC and other federal agencies, prepared a plan and timetable that identify an initial list of candidate spectrum bands, outline steps to determine additional candidate bands, set a process to assess and evaluate their feasibility, and identify actions necessary to make that spectrum available for wireless broadband use within a decade.[92]

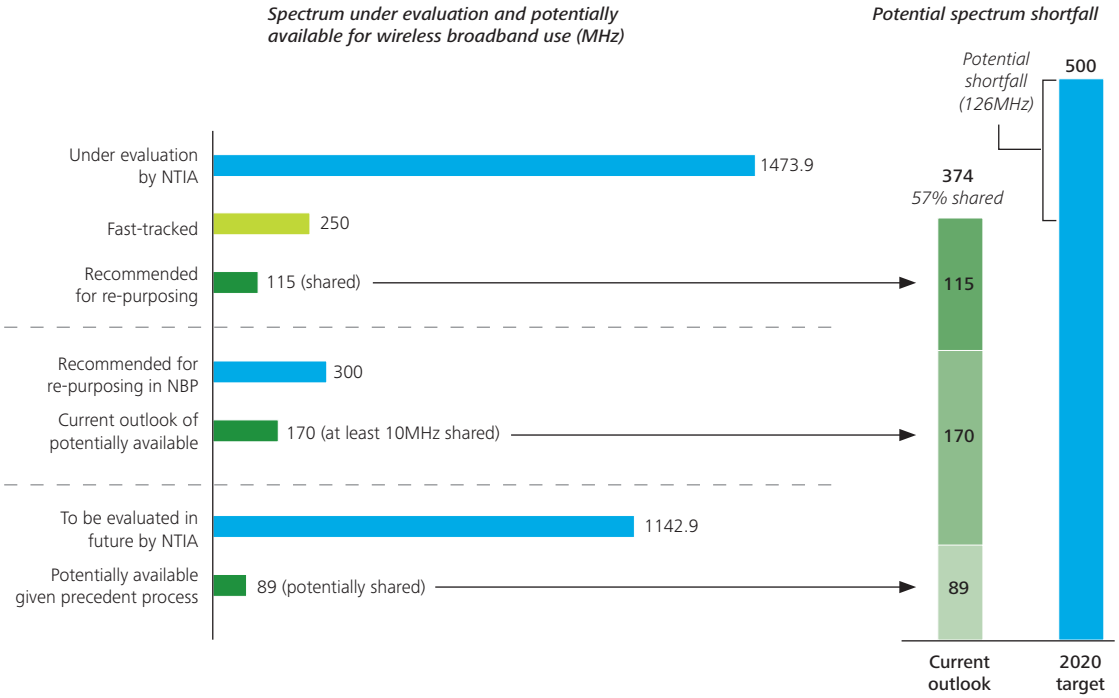
The plan and timetable identified approximately 2,200 megahertz of federal and nonfederal spectrum to be evaluated for potential wireless broadband use. NTIA, in collaboration with the FCC and other federal agencies, prioritized about 1,500 MHz of this spectrum for more detailed review and performed a "fast track" review of 250 MHz to determine whether any spectrum from this group could be made available for wireless broadband within five years. Of the 250 MHz of fast-tracked spectrum, NTIA has recommended that 115 MHz be made available on a shared basis for wireless broadband. Following this initial recommendation, and not including the federal spectrum required to be repurposed under recent legislation,[93] the affected federal agencies will conduct the detailed assessment and planning required to accommodate repurposing of their spectrum assignments, subject to available funding. The agencies will have up to eight years to process the recommended transition, after which any funds dedicated to the transition will revert to the Treasury. NTIA will continue to conduct reviews of additional blocks of spectrum through iterations of a process similar to that begun under the fast-track guidelines. About 1,150 MHz of spectrum not included in the initial fast-track assessment has been prioritized for future analysis and will be the starting point for subsequent rounds of evaluation.[94] Our extrapolation of the results of the fast-track evaluation process suggests that the next round of evaluation may result in a recommendation of about 89 MHz of additional spectrum in late 2013 to early 2014.

In addition to the spectrum under evaluation by NTIA, there are five bands previously under consideration by the FCC for wireless broadband use that were highlighted in the National Broadband Plan. These include: 120 MHz of TV broadcast spectrum, 90 MHz of mobile satellite spectrum, 60 MHz of Advanced Wireless Services (AWS) spectrum, 20 MHz Wireless Communications Services (WCS) spectrum, and 10 MHz of Upper D Block 700 MHz shared spectrum.

These bands offer 300 MHz of spectrum that may be available for wireless broadband use. Current estimates indicate that considerably less than 300 MHz, perhaps as little as 170 MHz, will actually be made available. Additionally, there are numerous complexities associated with repurposing each of these bands that may delay their conversion in the next four to five years. Historical precedent suggests that it may take six to eight years for any significant portion of this 170 MHz to actually be ready for redeployment in support of wireless broadband.

In sum, 204 MHz is a reasonable expectation of the amount of spectrum likely to become available through the first two rounds of the NTIA process – those most likely to result in spectrum available on the market before 2020. As shown in Exhibit 13, combining this amount with the 170 MHz of spectrum that may result from the prior FCC evaluations results in a total of 374 MHz. Thus there is a significant 126 MHz gap between the 500 MHz target and the amount of spectrum that can reasonably be expected to reach the market before 2020.

Exhibit 13. Government progress in identifying spectrum for mobile broadband[95]

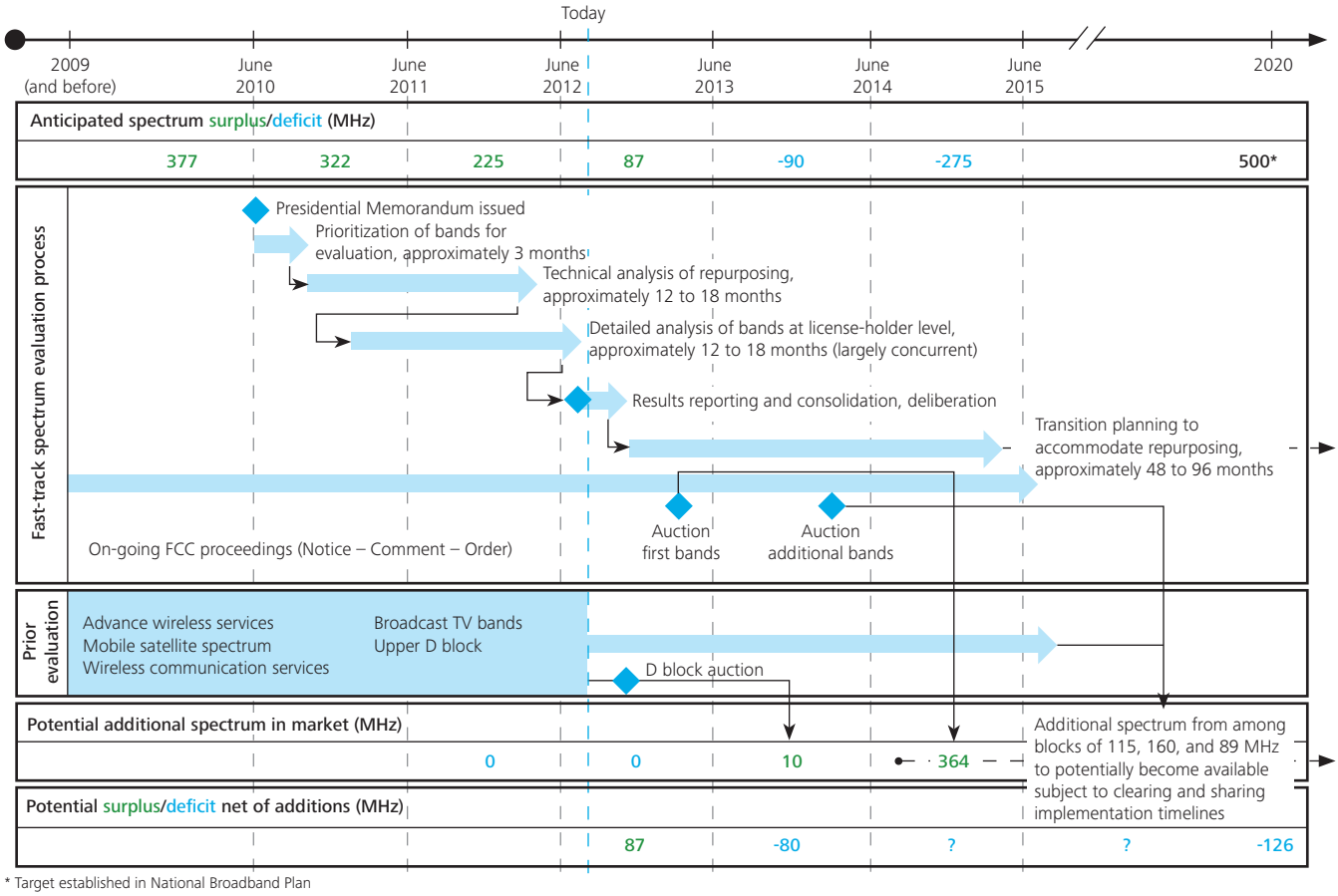


The FCC and NTIA periodically report on the status of the activities associated with their respective evaluation processes, but it is difficult to assess whether their collective efforts are on track or off track with respect to the NBP target. Our assessment, as shown in Exhibit 14, is based on the most recent available information and indicates that the process is behind where it needs to be.

Consequently the goal of making 500 MHz of additional spectrum available for wireless broadband use by 2020 appears to be at risk on two counts:

- There is a strong likelihood that even with the substantial amount of federal spectrum under consideration for clearing, the MHz eventually identified for repurposing will be insufficient compared to demand and the goal that has been set.
- Given the lengthy timelines associated with the NTIA evaluation process and the repurposing processes required for any bands identified by NTIA and/or the FCC, there is a significant risk of spectrum only being available for use in the marketplace significantly after the 2020 target date.

Exhibit 14. Potential timeline for mobile broadband spectrum additions[96]



* Target established in National Broadband Plan

Local cell site approvals. No major improvement has resulted from the FCC "shot clock" rulings designed to prevent undue delays when state or local government entities consider applications for cell site construction or modifications. Roughly 80 percent of applications are approved within two weeks or less,[97] but there are numerous examples of extensive delays or denials, often for high traffic areas with priority need for capacity upgrades. For example:

- **State A.** Collocation request. Initial decision was denied after 31 hearings and three years. Appeal took six more years.
- **State B.** New construction of a flush-mount antenna on a commercial building. Initial decision remains pending after four years.
- **State C.** New construction to cover a section of road with no mobile service. Initial decision attempted over seven years with 17 planning board meetings. Currently in court.
- **State D.** Application for new construction pending after three years.
- **State E.** Processing time of 30 months in some cases to approve new construction.
- **State F.** Application for new construction pending after two years.

Overall the time required to add cell sites has been lengthening. There are numerous examples of cities with lengthening cell site approvals across the country. For example, average approval times of cell site collocation applications have more than tripled in one major U.S. city between 2003 and today. These applications were typically granted within 15-30 days in 2003 and in 30-60 days in 2005, but today the average approval period is more than 90 days. In another city, average approval times for new construction have doubled from five months in 2003 to 10 months in 2007. Similarly, statewide average approval times for new construction in a midwest state have roughly tripled from two to three weeks in 2003 to six to eight weeks today.[98]

New local laws impact site approval times. For instance, some communities have adopted laws that require carriers to comply with separate zoning variance processes for all cell towers taller than 10 feet. That restriction impacts virtually all new construction applications.[99]

In addition to delaying and sometimes preventing network capacity expansion altogether, lengthy approval cycles create costs that are ultimately passed on to end users and limit carriers' ability to lower prices.

Economic analyses suggest that the United States risks undervaluing the role of infrastructure. Over the past 50 years U.S. investment in infrastructure such as roads, bridges, and water systems as a share of GDP has dropped by half to 2.4 percent.[100] The American Society of Civil Engineering has given the United States a grade of D in its "Report Card for America's Infrastructure."[101] It would be especially damaging to U.S. national economic interests if the difficulty in approving cell site construction applications foreshadows a similar decline in attention to mobile broadband infrastructure. As pointed out above, wireless networks are the equivalent of a test bed at the center of an innovation ecosystem that has the potential to increase GDP growth and create 21st century jobs for the United States. As with other forms of infrastructure, the initial expenditures can be viewed as investments with extended and significant returns.

The FCC's attempts to avoid cell siting delays now face a Supreme Court challenge. A group of Texas and California municipalities recently asked the U.S. Supreme Court to review an appeals court decision that sided with the FCC. Concerned about what they see as a federal intrusion into their zoning power, they contend that the FCC's shot clock rules exceed the authority Congress granted to the commission in the Telecommunications Act of 1996.[102]

The dispute between federal regulators and local governments over the proper interpretation of a section of the 1996 act provides a transition to another issue that jeopardizes timely action, which is the persistence of gray areas in American policies on matters relevant to the advancement of mobile broadband.

Unresolved policy issues and uncertainties interfere with follow-through on spectrum initiatives.
In crucial areas U.S. spectrum management is hampered by a lack of clarity or disagreement on important policy questions. Many of these involve matters of balance – not only federal versus local government responsibilities, but licensed versus unlicensed use, traditional auctions versus incentive auctions, federal versus nonfederal use, licensee interests versus government-defined national interests, incumbent users' interests versus the interests of newer users and uses, more competition to promote affordability versus more scale economies to promote investment, and continuity in spectrum management versus the potential benefits of updating and rationalizing the approach to spectrum allocation.

Spectrum policy is not unusual in presenting difficult questions, nor is it the only field in which changing technology and marketplace conditions make it challenging to draw lines and fix definitions. Nevertheless, ambiguities and contradictions complicate the task of promoting U.S. mobile broadband leadership. The following discussions highlight some of the issues that are shadowed by doubt about what policy is or should be.

Licensed and unlicensed use. Commercial mobile broadband spectrum has always been assigned through exclusive-use licenses. But with different types of spectrum sharing showing increasing promise, a debate has arisen as to the efficacy of exclusive licensing. The President's Council of Advisors on Science and Technology (PCAST) recently concluded that clearing spectrum for exclusive use is "not a sustainable basis for spectrum policy" and argued that "the norm for spectrum use should be sharing, not exclusivity." The NTIA administrator endorsed the PCAST report while the FCC chairman said he favored sharing as a tool to supplement rather than replace clearing for exclusive use.[103]

Traditional auctions and incentive auctions. For almost 20 years the FCC has used auctions to award licenses for commercial mobile service. However, the National Broadband Plan stated that "increasing spectrum availability does not necessarily imply a traditional spectrum auction," and characterized the traditional auction as a "backstop" for use "when a voluntary process has failed entirely."[104] The FCC asked Congress to consider granting it authority to conduct incentive auctions. As noted, Congress obliged.

Licensee rights and government's prerogatives. The FCC has the power to amend, revoke, or decline to renew a license under some circumstances. There is disagreement among legal experts as to the exact nature and extent of a licensee's rights and remedies, which is one of the reasons the FCC has elected to try to induce broadcasters to yield spectrum rights voluntarily.[105]

- The Communications Act of 1934 states that licenses permit the use of radio channels but do not convey ownership, and Congress has never changed that language.[106]

- Congress and the FCC have intermittently made major changes affecting licensees' interests, such as the introduction of competition into local telephone service markets and the changeover in TV broadcast technology from analog to digital.[107]

- However, some legal scholars argue that government policy has evolved from a model in which government allows private parties to use spectrum for government-defined public benefit purposes to one in which government treats spectrum licensees as private parties and encourages them to make investments they consider worthwhile. They maintain that government's discretion is constrained, if not by property rights then by rights that have much the same effect when it comes to modifying licensees' interests.[108]

Market's role. U.S. telecommunications policy is generally characterized as market-driven, with government's role limited to ensuring that competition is free and fair.[109] Overall U.S. mobile wireless policy has reflected this principle. Indeed, that was the approach that led to U.S. leadership in mobile broadband.[110] Nevertheless, the record also contains instances when government can be viewed as being overly prescriptive with respect to ends and/or means. There are two potential interrelated risks when the balance between market and government tilts in favor of government – that government decisions could be wrong and that execution could be flawed.[111] In the context of spectrum management the results can be reducing the efficiency of spectrum use or delaying deployment of infrastructure and devices:

- **C Block.** Legal challenges and auction rules related to the 1996 C Block auction of 30 MHz of spectrum resulted in the original buyers not building infrastructure for mobile services. Use of the spectrum was delayed by more than eight years.[112]

- **D Block.** The 10 MHz D Block in the 2008 700 MHz spectrum auction was subject to public safety use requirements and shared use. Stringent build requirements and lack of clarity on future shared use requirements resulted in no bids that exceeded the required minimum and have left the spectrum unused for four years.[113]

- **WCS.** 30 MHz of WCS spectrum auctioned in 1997 has sat unused for 15 years due to restrictions intended to protect adjacent bands from interference.[114]

- **EBS/BRS.** Fragmented licensing of the 194 MHz of EBS/BRS spectrum for two-way services in the mid- to late 1990s resulted in the original auction winners not building infrastructure. Companies with sufficient funds and capabilities to use the spectrum spent several years buying spectrum from the auction winners to aggregate nationwide coverage. Altogether 10 to 12 years elapsed before commercial services were deployed.[115]

Strategic clarity. The ability of the United States to keep pace with the explosion of mobile broadband demand is imperiled not only by unresolved issues on individual policy matters but also by the lack of a clearly articulated overall strategic framework for spectrum management.

One of the basic characteristics of U.S. spectrum management is divided authority. NTIA sets Executive Branch policy and manages federal spectrum while the FCC oversees nonfederal spectrum. The Government Accountability Office (GAO) has said that although the two entities have improved their communication, their differing perspectives and jurisdictional responsibilities "may pose a barrier to spectrum reform."[116]

The GAO has reviewed spectrum management at both NTIA and FCC and has noted opportunities for improving the performance of strategic planning. The benchmarks for the GAO findings are U.S. government standards for strategic planning, as mandated by the Government Performance and Results Act of 1993.[117] The standards have been defined by the Office of Management and Budget (OMB) and GAO. They state that strategic plans should identify long-term goals and objectives and then put forward approaches or strategies to achieve these goals and objectives. The standards likewise call for plan revisions approximately every three years.[118]

A 2011 GAO review of NTIA noted that the agency had produced only one of two strategic plans that the White House had ordered in 2003, and the plan it did develop was more a compilation of agency plans than a projection of federal spectrum needs. The GAO report said the plan did not discuss long-term goals or specify steps for achieving these goals. Additionally, the GAO report observed that NTIA did not maintain an ongoing process for refining and updating the plan.[119] When surveying experts and stakeholders as part of a review of the FCC's auction activities, the GAO found that more than seven out of 10 agreed that the FCC should provide a clear road map detailing future spectrum auctions, which the GAO said showed concern about uncertainty.

There are other indications of a desire for clearer spectrum strategy. A Senate bill would mandate development of a triennial national strategic spectrum plan.[120] Martin Cooper, mobile technology pioneer and Dyna chairman, has suggested that the FCC produce a national technology road map to improve the linkage between policy and technology.[121] The heads of four wireless and high-tech industry groups have written the President asking for "a commitment that identifies definitive bands and a specific implementable plan of action to provide regulatory certainty for investment."[122]

Fundamental policy changes are required to avoid choking off the innovation that is responsible for America's global leadership in mobile broadband

To ensure that the United States does not become a victim of its own success, policymakers should consider measures that address not only the potential spectrum deficit but also the need for new approaches to spectrum management.

It is apparent that there is nothing immutable about the lead the United States enjoys in our Mobile Communications National Achievement Index. Unless additional remedial measures are taken and policy ambiguities are resolved, U.S. capacity expansion will likely be insufficient to ensure adequate spectrum supply. Should U.S. wireless networks encounter capacity constraints, the advantages that superior infrastructure confer on the rest of the U.S. ecosystem would suffer. This would mean higher prices, rationing, or degraded service, and potentially all three, putting a drag on the U.S. economy. Competitors abroad would be able to gain ground in the development of products and services with appeal in global markets. Jobs and profits would be redirected away from the United States as the center for mobile innovation shifted overseas.[123]

Given the risk of a capacity shortage, it is critical that policymakers consider actions that could expedite the process of reallocating and licensing spectrum to meet the 500 MHz goal by 2020.

However, more fundamental efforts are required. U.S. spectrum policy is the product of 100 years of legislative and regulatory evolution. The current system has served U.S. national interests well, as illustrated by the country's current mobile broadband success. Nevertheless, to better position the United States to capitalize on the opportunities of the 21st century, policymakers should consider reforms that build on lessons learned, correct shortcomings, and take into account the implications of accumulating changes in technology and marketplace conditions. Exhibit 15 highlights the ideas we offer in this chapter for a broad-scale policy refresh.

Exhibit 15. Policy reforms for consideration

Strategic approach	Recommendations
Definition of an overarching spectrum management strategy	
Developing an official U.S. spectrum strategy could provide the opportunity to resolve policy ambiguities that hamper effective mobile broadband decision making.	• Define a strategic framework that offers a more clear-cut vision and direction for managing U.S. spectrum.
An approach that defines overall guidelines and relies on markets to work out economically efficient solutions is well-suited to a changing and uncertain wireless environment.	• Emphasize broad, overall goals and avoid specific, prescriptive formulations that may be based on assumptions that are overtaken by events. • Favor policies that leave to markets the task of determining how best to capitalize on opportunities and resolve challenges related to mobile broadband.
Treat the costs incurred in making sufficient spectrum available for commercial mobile broadband as investments with a return that is realized over time in the form of increased GDP, jobs, and tax revenue.	• Provide an overall business case for the national spectrum strategy in terms of an estimated return on investment. • When making decisions on individual projects such as relocations, auctions, and pilot tests, match the cost to the amount and timing of the payback rather than viewing it in isolation.

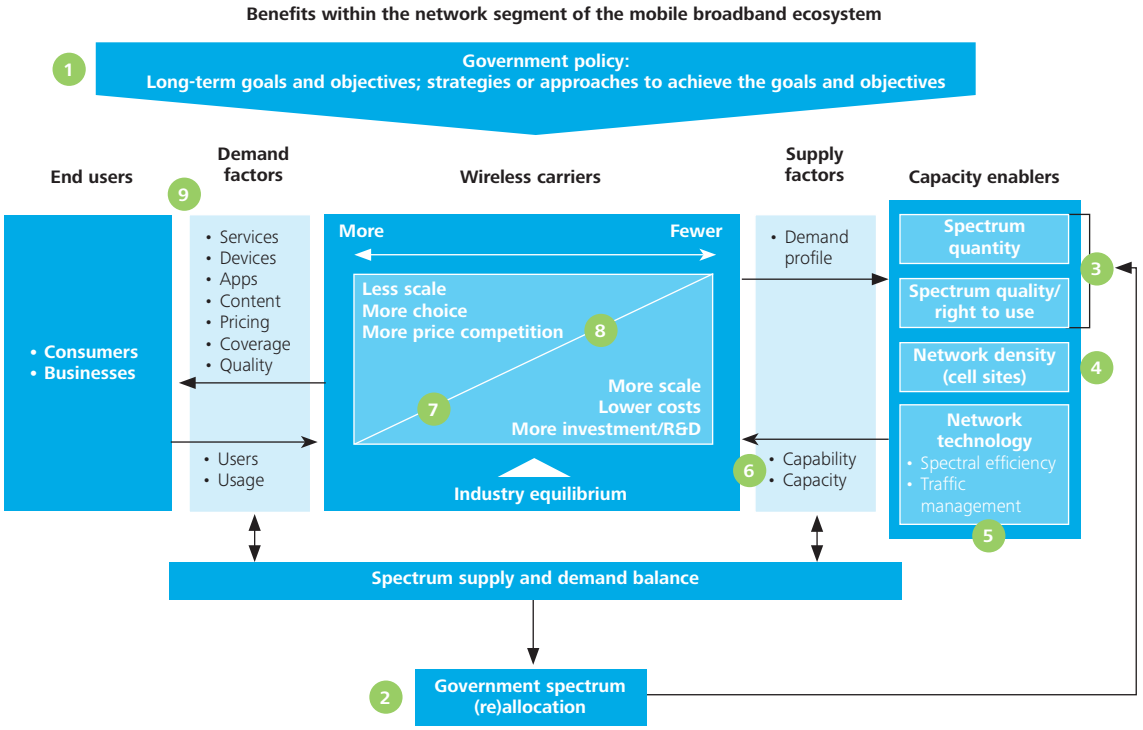
Exhibit 15. Policy reforms for consideration, cont.

Strategic approach	Recommendations
Policies and initiatives that merit special attention within the strategy framework	
A successful TV broadcast spectrum auction should be a top priority as a highly-visible step toward meeting the 2020 goal of freeing up 500 MHz of spectrum for mobile broadband.	• Identify means to ensure that the auction is completed on an expedited basis, such as giving broadcasters full information on all aspects of the auction and follow-up phases. • Define measures for streamlining and accelerating other reallocation projects needed to meet the 500 MHz goal by 2020.
Given the promise inherent in spectrum sharing, policymakers should consider expanding government funded or supported R&D efforts to promote the emergence of workable sharing solutions.	• Be clear that clearing spectrum for exclusive use remains the option of choice for promoting mobile broadband, but emphasize that spectrum sharing and other emerging methods deserve significant R&D support as complements and potentially replacements. • Support pilot-testing of spectrum sharing to gain experience that will shed light on its role in the government and commercial spheres. • Focus on higher-frequency bands for unlicensed uses, to avoid impinging on frequencies that are optimal for 4G LTE and 5G.
Traditional auctions combined with viable secondary markets should continue to play central roles as effective mechanisms for distributing spectrum to users and uses with high-value potential.	• Treat traditional auctions and secondary markets as the primary mechanisms for spectrum distribution, with incentive auctions as a potential complement to deal with special situations, guided by experience with the TV broadcast incentive auction. • Permit carriers to accumulate national and regional spectrum blocks tailored to their geographic and capacity needs. • Enforce build-out and non-interference rules along with other requirements to ensure that spectrum is used with maximum efficiency and timeliness in response to market demand.
Allocating and assigning spectrum in large blocks based on technically-driven criteria could alleviate constraints caused by the crowded, fragmented legacy spectrum zoning map.	• Shift to a new spectrum architecture involving large spectrum blocks both for experimenting with spectrum sharing and for benefiting licensed uses. • Permit large-scale carriers to accumulate more spectrum, balanced with measures that preserve the ability of smaller competitors to continue improving their spectrum positions. • Rely on the secondary market as the primary means for efficiently allocating spectrum to rural and disadvantaged carriers.
Principles-based license renewal reviews offer a means to ensure that license holdings and spectrum policies are aligned with changing technological and economic realities.	• Where other means have not brought about a shift from an existing spectrum use involving obsolete technology and/or minimal usage, hold an auction to determine the use that the market values most highly. • Preserve the predictability essential for investment and innovation by defining objective, transparent, and quantitative standards for deciding whether market access to the spectrum through auction is justified. • Use analogous methods keyed to the government context to ensure that existing use of federal spectrum is achieving sufficient benefit.

Timely government action on these topics could have a positive influence on the future of the U.S. wireless industry, ensuring that mobile broadband continues to contribute to national economic well-being, both as a service to end users and as a generator of GDP and job growth. Exhibit 16 identifies how the policy approaches we have suggested could produce benefits within the network segment of the mobile broadband ecosystem.

Exhibit 16. Benefits of government actions that address chronic policy issues and the near-term need for more mobile broadband spectrum

Strategic approaches	1 Clear decision making authority; strategy guidelines that eliminate policy gray areas	2 Expeditious and market-driven spectrum allocations, assignments, and transactions	3 Spectrum allocation and assignment that enables optimal network performance	4 Efficient spectrum use via means such as sufficient tower site supply	5 Increased R&D focused on improving mobile broadband technologies	6 Continued industry investment in technology and infrastructure	7 Right balance in industry configuration, e.g., decisions on merger proposals	8 Free and fair competition that allows markets to determine winners and losers	9 Market-driven development of new products and services
	Benefits to U.S. from needed policy actions								
Develop an official U.S. spectrum strategy	●								
Define overall guidelines and rely on markets	●	●	●	●		●	●	●	●
Treat costs as investments with return		●			●	●			●
Conduct a successful broadcast auction		●							
Expand spectrum sharing R&D			●		●				●
Rely on auctions and secondary markets		●						●	●
Allocate and assign spectrum in large blocks			●		●		●		●
Confirm value of licensed uses		●						●	●



Developing an official U.S. spectrum strategy could provide the opportunity to resolve policy ambiguities that hamper effective mobile broadband decision-making.

The U.S. government is working vigorously to meet the 2020 goal of making 500 MHz of spectrum available for wireless broadband. However, a variety of policy gray areas persist, which could create sufficient uncertainty to impede progress and slow desired investment.

As noted above, many of the policy issues involve matters of balance – federal versus local government responsibilities, licensed versus unlicensed use, traditional auctions versus incentive auctions, federal versus nonfederal use, licensee interests versus government-defined national interests, incumbent users' interests versus the interests of newer users and uses, more competition to promote affordability versus more scale economies to promote investment, and continuity in spectrum management versus the potential benefits of updating and rationalizing the approach to spectrum allocation.

Given the stakes involved in spectrum management in general, and with respect to mobile broadband in particular, it is important that government decisions and actions on subjects such as these have as their frame of reference a set of overarching purposes and strategies. This type of framework can provide an agreed-upon vision, direction, and principles, offering guidance when addressing a vital but volatile topic such as mobile broadband. Currently spectrum management goals and strategies for the United States can be found in major pieces of legislation, in Executive Branch directives and plans, and in regulatory decisions by the FCC. However, the lack of clarity on fundamental issues implies that these definitions and guidelines are not fully achieving their intended purposes.

Admittedly it is difficult to gain agreement on a new statement of vision, direction, and principles. Especially in the current political environment it is difficult to draw bright lines and settle differences cleanly.

Nevertheless it is increasingly important to do so in light of today's competitive international environment. U.S. economic leadership is increasingly being challenged by other countries, particularly China. And a key advantage China is said to have is the ability to make and implement government policies efficiently. The delays and uncertainties associated with the American policy making system are being compared unfavorably to what is depicted as the much more streamlined and orderly Chinese approach.[124]

For these reasons U.S. policymakers should consider whether existing spectrum management policy should be set within a framework that offers a more clear-cut vision and direction that in turn could better facilitate decisions and actions required to promote mobile broadband.

An approach that defines overall guidelines and relies on markets to work out economically efficient solutions is well suited to a changing and uncertain wireless environment.

It is apparent that governments around the world are encountering changes that raise the question whether approaches that sufficed over the past century are appropriate for the wireless marketplace that is now taking shape. However, the new marketplace is not yet in focus; its contours and dynamics are unclear. Spectrum sharing is a prime example – it seems likely that spectrum sharing will play an increasingly significant role, but it is still too early to tell how and how fast the technologies involved will develop, or what effect they will have. Policymakers are forced to simultaneously confront near-term challenges while attempting to facilitate the emergence of new technological and commercial models the attributes of which are not yet known.

The changeability of the wireless environment highlights the value of emphasizing broad, overall goals and avoiding specific, prescriptive formulations that may be counterproductive if they are based on concepts and assumptions that turn out to be incorrect. The objective is to define overarching purposes and strategies that reflect fundamental values and long-run interests, and which will therefore remain valid across a wide range of potential future circumstances. [125]

The question then becomes how to strike a balance so that government avoids specificity and coercion and yet has reason to believe the broad aims it does articulate will be attained. The U.S. experience with 3G mobile broadband supports the proposition that reliance upon market forces within certain boundaries and guidelines tends to produce positive results. Markets can be adept at finding economically efficient solutions despite – or even because of – turmoil.

Treat the costs incurred in making sufficient spectrum available for commercial mobile broadband as investments with a return that is realized over time in the form of increased GDP and tax revenue.
Any statement of spectrum management policy should set forth a vision as to how the cost of making spectrum available can be justified in terms of the returns on these expenditures over time. The costs should be considered infrastructure investments that have lengthy payback periods, but extensive returns. Further, the relevant metric is broader than simply the net revenue to the government from auctions; it extends to the returns from expanded economic activity, which include increased tax revenues. As explained in our 2011 report, investment in 4G mobile broadband over the period 2012-2016 can expand U.S. GDP between $71 and $151 billion, and account for between 371,000 and 771,000 jobs. And these figures are conservative since spectrum investment has beneficial effects not only in the telecom realm but also in sectors that leverage this infrastructure, such as automotive telematics, vehicle traffic management, and mobile healthcare (mHealth). Realizing the high-end economic benefits does require that the U.S. retain its global mobile broadband leadership position.

Further, when decisions are made on specific actions to implement the national spectrum strategy, such as relocating incumbent government spectrum users or pilot testing spectrum sharing, policymakers should require not only an estimate of the costs but also a broader business case that details the potential returns on investment and the payback period. This would make it possible to view the costs as being spread out over a period that corresponds to the realization of the benefits, in contrast to being treated as if they apply 100 percent when the expenditure is made.

A policy approach that recognizes the unique infrastructure aspects of spectrum and quantifies the potential returns and payback periods could help create sufficient momentum within both the private sector and government to help fund the costs of confronting technical challenges associated with making spectrum available on a timely basis.

Policymakers face many questions relating to both structure and substance when evaluating whether there is the need for a more complete and definitive policy framework concerning spectrum management. A variety of factors affect judgments about the need for enhanced guidance and what policies ought to be adopted. The following sections offer options for policymakers to consider.

A successful TV broadcast spectrum auction should be a top priority as a highly visible step toward meeting the 2020 goal of freeing up 500 MHz of spectrum for mobile broadband.
As also noted in the prior chapter, it is not clear that efforts are on track to meet the goal of making 500 MHz of spectrum available for broadband use by 2020, with an initial 300 MHz being cleared by 2015. An early test is the incentive auction designed to repurpose TV broadcasting spectrum.

Carrying out the auction is undeniably challenging, but concluding the process successfully and on a timely basis is crucial. Congress authorized the incentive auction mechanism, and the 120 MHz of spectrum it involves is a substantial portion of the total capacity that is to be converted to mobile broadband use – 120 MHz is 40 percent of the initial 300 MHz and 24 percent of the full 500 MHz. Moreover, the auction proceeds are to help fund the new national public safety mobile broadband network.

The incentive auction is thus a highly visible indicator of America's ability to increase the role of mobile broadband in both the commercial and public safety spheres. How this project fares can have a major impact on the momentum of the overall undertaking. Its successful conclusion is thus an example of a priority goal that could feature prominently in an overall policy framework.

Many suggestions have been made for ensuring that the plan for the incentive auction is implemented as intended on an expedited basis. These include:

- Promote auction transparency by resolving at an early stage questions about all phases of the reallocation project, including not only those that pertain to the conduct of the reverse and forward auctions but those concerning steps that follow the forward auction, such as the TV channel repacking and the award of licenses to winners of the freed-up spectrum.[126]

- As an extension of the previous point, put special emphasis on furnishing broadcasters with information on aspects of the process that affect their decisions about participating in the reverse auction, such as the retention of service areas by broadcasters that do not take part in the auction, the functioning of the broadcaster relocation fund, and measures to minimize service interruptions during the transition to new channels.[127]

- Assign high priority to the incentive auction and keep it under close scrutiny at the FCC, within the administration, and on Capitol Hill, ensuring that it remains on or ahead of schedule. This could include greater definition and dissemination of information about the timetable for the project and more frequent and detailed progress reporting.[128]

Although the incentive auction has a high profile and the addition of 120 MHz would be an important contribution to mobile broadband spectrum capacity, the effectiveness of that project by no means guarantees attainment of the 500 MHz goal by 2020. Many other spectrum segments must be cleared and reallocated as well. As indicated by the declaration in the PCAST report that spectrum clearing for exclusive use is not a sustainable long-term policy, the issues are numerous and daunting. Nevertheless, clearing spectrum appears to be the most productive means for delivering on the 2020 mobile broadband goals, given the relatively limited timeframe, the policies and programs now in place, and the current state of technology.

Accordingly policymakers should consider additional means to provide incentives and remove obstacles. Initiatives that have been suggested or that are in some stage of implementation include:

- Reorganize the agencies responsible for federal spectrum management to streamline decision making and improve coordination, for example by creating a Spectrum Management Team headed by the U.S. government's chief technology officer,[129] or by combining the spectrum management functions of NTIA and FCC into a single federal entity.[130]

- Make spectrum planning by government agencies more rigorous and systematic, for example by tightening requirements relating to spectrum planning and assignment and by requiring agencies to validate the data they submit for planning and review purposes.[131]

- Expand current efforts to increase the information publicly available regarding spectrum ownership and use, including the development of methods for ongoing measurement of the extent to which assigned spectrum is actually being used.[132]

- Create new incentives for federal agencies to clear and share spectrum, for example by making more relocation-related costs eligible for coverage by the Spectrum Relocation Fund and giving agencies more discretion as they decide how to meet their needs once they depart from their current spectrum.[133]

- Permit agencies to earn credit for being more efficient in their spectrum use, as measured by their ability to save amounts from their allocation of an artificial "Spectrum Currency" that could be traded for actual dollars."[134]

- Augment existing policies that oblige private-sector spectrum owners who do not put their spectrum to use within an appropriate period to either sell it, lease it, or find a partner who can build it out.[135]

Some of these suggestions could be accomplished via regulation; others might require legislation, such as expanding government agency relocation incentives. Legislation could be an effective means to underscore the importance of launching or accelerating certain activities. Further, timely decisions on appropriate initiatives or remedies would be more certain if there is consistent close monitoring of reallocation efforts and progress against plan by the White House, FCC commissioners, congressional committees, and other policymakers.

Policymakers should consider expanding government funded or supported R&D efforts to explore the extent to which workable sharing solutions can help alleviate concerns about spectrum supply.

Clearing spectrum for licensing to new users appears to be the most productive means for delivering on the 2020 mobile broadband goals, but spectrum sharing should also be part of the agenda. Unlicensed use within small cells is already making a contribution to more efficient spectrum use, and technology advances indicate sharing could play a much greater role as time goes on. It is important for the United States to be early and creative in testing and developing this option.

In terms of an overall policy framework, the proposition could be that clearing spectrum for exclusive use remains the option of choice for promoting mobile broadband, but spectrum sharing and other emerging methods deserve significant R&D support as complements and potentially replacements.

The recent legislation authorizing the PSBN permits commercial users to lease access as secondary users, and fees they pay are to help offset the cost of operating the network. As noted, developing a nationwide interoperable public safety network appropriate for mission-critical uses will be a complex undertaking;[136] how best to accommodate commercial users on this facility is thus a leading-edge challenge. Experience gained from this project can be valuable in the ongoing process of formulating viable spectrum sharing policies and practices.

The recent PCAST report offers a range of recommendations for encouraging spectrum sharing on federal government spectrum, and these ideas merit consideration by policymakers as a means of pilot-testing new concepts. Among the council's ideas are:

- Institute the new organizational framework under the federal chief technology officer and introduce the measures to incentivize agency cooperation with sharing initiatives as noted above.
- Define a large block of federal spectrum as priority frequencies for sharing and direct agencies to commence preparations for making them available for that purpose.
- Within the designated block of frequencies, experiment with the implementation of a new spectrum architecture of large blocks conducive to sharing.
- Establish a new spectrum access system modeled on the TV white space management system that would act as a central clearinghouse for registering users with access to the bands within its jurisdiction and issuing the conditions of use to which they are subject.
- Create three new categories of spectrum users – federal primary access, (legacy users that have top priority over other federal users and commercial users); secondary access users (federal or commercial users that warrant next priority); and general authorized access users (low-power, low-priority uses).
- Move from the traditional practice of basing sharing on frequencies, which is transmitter-focused, to an approach that takes into account a variety of factors that include device characteristics – including geography, time, economic priority, code modulation, and directionality.
- Set aside two bands of federal spectrum in which sharing would be permitted for low-power, frequency-agile devices.

- Experiment with short-term, lower-cost licenses for commercial users sharing federal spectrum.

- Designate a test city that can become a center for testing and developing new sharing procedures, technologies, and devices.

- Create a mobile testing service that can go to remote federal facilities to test the effectiveness of sharing approaches under consideration, as part of a public-private partnership with federal agencies.

- Create an advisory panel of industry executives to propose ways of sharing federal spectrum with commercial users.[137]

Initiatives of this type could increase the attention devoted to spectrum sharing within the federal government, encourage cooperation among government and commercial users, and furnish practical experience with sharing solutions. They could also provide policymakers with answers to questions regarding the role of spectrum sharing in avoiding frequency congestion, the magnitude of its contribution, and the timetable for its development.

Balances will need to be struck while encouraging spectrum sharing amid a general concern about mobile broadband spectrum supply. In making spectrum allocation decisions regarding unlicensed use, it is important to ensure that there is sufficient licensed spectrum across the standard bands required for 4G LTE, and that bands optimal for the next generation of mobile technology (5G) are not designated for other uses.

One solution might be to treat licensed spectrum as most appropriate for applications in which it is necessary to manage quality of service and unlicensed spectrum where best-efforts service is appropriate. However, that idea assumes an ability to predict future data usage in terms of application types, data intensity, and service management needs. Recent history shows this is difficult, if not impossible, to foresee. During the last decade expert forecasts failed to anticipate the popularity of smartphones, tablets, mobile data, and mobile video. Consumers unaware of coming technological advances assured pollsters they were lukewarm toward 3G applications they would soon embrace with enthusiasm.[138]

Consequently it would be unwise to allocate a significant additional amount of spectrum as unlicensed at the expense of prime licensed spectrum. A more prudent approach would be to focus on higher frequency bands for unlicensed uses, since they do not require the same propagation characteristics as licensed uses given the intentionally small coverage radii and the absence of a service management imperative.

Traditional auctions combined with viable secondary markets should continue to play central roles as effective mechanisms for distributing spectrum to users and uses with high-value potential.
Using traditional auctions and secondary markets is consistent with the principle of minimizing government involvement, and these mechanisms have established a favorable track record. The congressional grant of auction authority in 1993 has made it possible for the FCC to assign hundreds of megahertz of spectrum quickly and efficiently in the intervening years.[139] Secondary market transactions, including license transfers and leasing, have played a major role in further distributing spectrum. FCC data show that most cellular, broadband PCS, and AWS licenses have been transferred to different entities, including regional and smaller providers as well as large carriers. Many of those licenses have been partitioned or disaggregated, again transferring the spectrum to a wide range of entities of different sizes.[140]

Incentive auctions are a promising solution for dealing with situations in which spectrum clearing is particularly difficult, but the means for encouraging incumbents to yield their spectrum both increases the complexity of the process and gives government a prominent role. The repurposing of the TV broadcast spectrum can provide a useful case study regarding the advantages and disad-

vantages of the incentive auction. For purposes of an overall policy framework an effective approach could be to designate traditional auctions and secondary markets as the primary mechanisms for spectrum distribution, with incentive auctions as a potential complement for use in instances where spectrum clearing is unusually challenging and where there are substantial reasons for believing that a voluntary approach would produce better results.[141]

Relatively unfettered spectrum exchanges can permit the accumulation of national and regional spectrum blocks that permit carriers to establish spectrum positions more tailored to their own geographic and capacity needs. Recipients of national licenses should be allowed to disaggregate on a regional basis in the secondary market, which can enable regional carriers to improve their spectrum position while moving rural spectrum to those most willing and able to build mobile broadband capacity in rural areas. Moreover, this can permit the most efficient and immediate utilization of the spectrum, promoting low prices and adequate spectrum supply.

Policies need to ensure not only an adequate supply of spectrum but also that spectrum is used with maximum efficiency and timeliness in response to market demand. The FCC and NTIA can help ensure that spectrum made available is rapidly used by carriers in a manner that supports the principles of minimal spectrum caps and establishment of a robust secondary market. For instance, these agencies can issue defined build-out requirements that focus on a percent of population (versus geography) and create technology guidelines that prevent commercial or government entities from building infrastructure in a manner that renders it unusable for others or interferes with existing or future networks.

Allocating and assigning spectrum in large blocks based on technically driven criteria could alleviate constraints caused by the crowded, fragmented legacy spectrum zoning map.

The PCAST report recommends that rather than fragmenting spectrum into ever more finally divided exclusive frequency assignments, spectrum managers should develop large frequency bands.[142] The advisory council focuses on using broader bands for unlicensed use, but allocating broader swaths of spectrum applies equally well to facilitating the operation of licensed mobile broadband networks. An overall policy framework could therefore call for a shift to a new spectrum architecture characterized by large spectrum blocks both for experimenting with spectrum sharing and for benefiting licensed uses.

The principle favoring large spectrum blocks can further be applied to the assignment of frequencies to particular licensees. Stringent spectrum caps placed on large, national carriers could equalize network utilization across carriers at suboptimum levels and degrade the cost structure that has allowed carriers to hold prices relatively constant as data usage has exploded.

Large scale in the U.S. wireless industry has provided carriers with a cost structure that enables low prices and immediate reinvestment of profits to expand network capacity and efficiently use existing spectrum. Restricting certain players from access to newly auctioned spectrum could place it in the hands of carriers with existing capacity surplus and less incentive to build out immediately and/or less ability to add additional traffic to the newly allocated spectrum.

Making spectrum available to carriers that are most likely to put it to use in ways that benefit end users quickly can provide effective incentives for overall industry growth and innovation, and can help keep prices low. It is advisable to balance policies allowing large-scale carriers to continue accumulating spectrum with an assurance that their competitors – existing and new, regional and national – can continue to improve their spectrum position and alleviate potential future spectrum constraints.

Geographic restrictions can also be counterproductive. Nationwide frequencies/licenses facilitate planning and network deployment efficiencies. Previous spectrum allocations have led to complexity in network engineering and lower auction proceeds. For instance:

- 2006 AWS auction: the licenses were broken up into six blocks, designated A through F. Block A consisted of 734 Cellular Market Areas. Blocks B and C were each divided into 176 Economic Areas. Blocks D, E, and F were each broken up into 12 Regional Economic Area Groupings. Thus the government sought to award license for a total of 1,122 areas.

- The 2005 PCS auctions consisted of 217 licenses distributed across 24 different bidders

This is not to say that the division of spectrum into small units cannot serve a useful purpose. Some awards of regional licenses are appropriate to foster the deployment of mobile broadband networks in rural areas. A balance between regional and national spectrum license blocks is essential to provide for national-level economies while ensuring investment flows to rural and disadvantaged carriers. However, the secondary market should be the chief means for efficiently allocating spectrum to serve local needs.

These actions, executed correctly, can promote the balance between scale and competition that allows for continuing the consumer benefits of low prices and sufficient supply of mobile broadband. They can also help ensure that rural and disadvantaged communities receive sufficient mobile broadband coverage to support economic development, health care, and education.

Principles-based license renewal reviews offer a means to ensure that license holdings and spectrum policies are aligned with changing technological and economic realities.

One of the advantages of a free market is that it provides means for encouraging asset transfers when new circumstances cause a shift in measures of economic efficiency between existing and alternative users and uses. An important question is how to ensure that this type of check functions as it should in the realm of mobile broadband spectrum. For the sector to contribute maximum value to the U.S. economy and serve the public interest it is vital that changing technology and marketplace conditions have the appropriate impact on license holdings.

One means of promoting economic efficiency in spectrum holdings could be for the relevant government agencies to make periodic determinations as to whether a continuation of a license is economically efficient and in the public interest. In the case of spectrum used for commercial purposes the FCC could make this assessment when a license term approaches expiration.[143] In the case of government spectrum the assessment could be made by the NTIA at defined intervals. Where the decision is that the current use is not the most advantageous an auction could be held. This would permit a judgment by the market as to what use has the highest value for the U.S. economy and society.

In the government context, there could be situations in which an alternative to an auction might be preferable, for example if a specific spectrum segment is not of interest to commercial users, or in limited cases where the national interest requires that certain spectrum be reserved for government rather than commercial use. Should a mechanism such as the "Spectrum Currency" proposed in the PCAST report be developed it might be workable to stage a competition to determine whether the incumbent or another agency would hold the authorization.[144]

It would be crucial to establish clear standards for government decisions on spectrum rights retention, especially with respect to the private sector. If the policies governing these decisions were perceived as flexible or subject to differing interpretations the result would be uncertainty on the part of licensees and the financial sector regarding the security of rights to use segments of spectrum. In particular, it is important to avoid the impression that decisions on whether existing uses remain beneficial could be made according to standards that vary from one case to another or that such decisions could be made in an effort to achieve policy objectives that override market forces. This would chill investment and innovation – the opposite of what is intended.

Therefore, the standards would need to be objective and transparent, and with the emphasis on quantitative analysis rather than qualitative judgments. The inquiry would focus on how the existing uses and usage compare to alternatives. The presumption would be that a license renewal would be largely routine; so long as the secondary market is functioning efficiently there should be relatively few instances in which an existing use is not aligned with the true value of spectrum. The exception would be if, according to the defined objective standards, it is clear that the existing use and usage is less beneficial to the economy and society than one or more alternatives (with unambiguous definitions for determining if the difference is "clear.") In some circumstances a remedy could be removing use restrictions from a license to encourage new use or facilitate a secondary market sale, or conducting an incentive auction. Otherwise conducting a traditional auction might be the best solution. The incumbent would still have the opportunity to retain the license by bidding in the auction (or through an alternate, equivalent mechanism in certain cases within the government context).

Developing a process for conducting these periodic reviews could be undertaken as part of a larger initiative to clarify wireless license rights and obligations. As discussed in the prior chapter, there are currently uncertainties in U.S. policy on the legal rights and obligations of wireless licenses holders.[145] Accordingly, it could be constructive to articulate an approach that offers licensees the certainty they need to substantiate the value of their license and justify investments while clarifying government's authority to direct spectrum uses that best serve the public interest. This could include provision for providing some measure of compensation to incumbents who under certain circumstances incur losses on investments made prior to a change in or loss of a license.

Dispelling ambiguities and offering clear guidance in this area is challenging, but the need is acute. Particularly in a period of technology advances and competitive ferment, it is important to keep spectrum use aligned with the state of the marketplace. At the same time, uncertainty over the status and duration of a license or authorization could hamper investment, sales, leasing, and other beneficial activities. The policy objective is to arrive at a balancing of interests that injects a degree of market discipline without creating undue instability.

Lack of spectrum availability or policies that allocate spectrum in a manner that fails to reinforce industry health and consumer affordability will constrain the U.S. wireless industry and the associated ecosystem. Furthermore, there may be broader negative consequences across the U.S. economy due to the increasingly vital nature of mobile services for both consumers and businesses. The United States needs an expeditious process to resolve the unanswered questions in a manner that best addresses the needs of end users and supports ongoing U.S. leadership. Delay and actions that prevent efficient use of quality spectrum risk demoting the United States from the top rank in the Mobile Communications National Achievement Index to but one of many contenders; the opportunity costs will likely come in the form of diminished growth in jobs and GDP.

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Contacts

Craig Wigginton
U.S. Telecommunications Sector Leader
Deloitte & Touche LLP
+1 212 436 3222
cwigginton@deloitte.com

Dan Littmann
Principal, Technology, Media and Telecommunications
Deloitte Consulting LLP
+1 312 486 2224
dlittmann@deloitte.com

Phil Wilson
Director, Technology, Media and Telecommunications
Deloitte Consulting LLP
+1 214 840 7160
phwilson@deloitte.com

Dwight Allen
Director, Strategy Development
Deloitte LLP
+1 703 251 3625
dwallen@deloitte.com

Brett Haan
Principal, Federal Government
Deloitte Consulting LLP
+1 571 814 7380
bhaan@deloitte.com

Kevin Thompson
Senior Manager, Technology, Media and Telecommunications
Deloitte Consulting LLP
+1 312 486 2780
kethompson@deloitte.com

Christine Brodeur
U.S. Telecommunications Marketing Lead
Deloitte Services LP
+1 213 688 4759
cbrodeur@deloitte.com