The Importance of R&D in Improving Federal Spectrum Systems

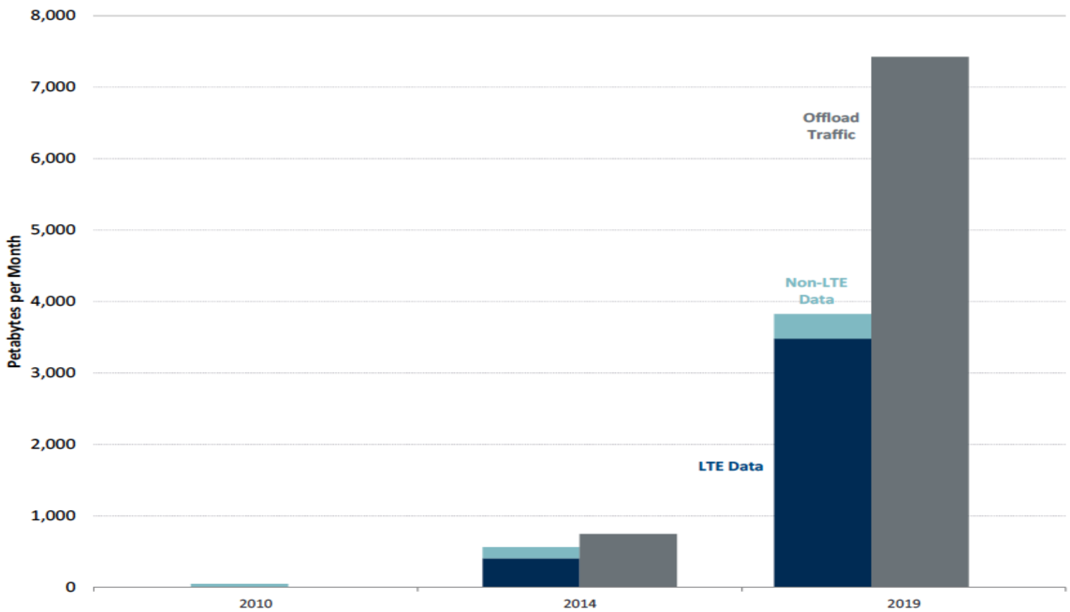
Jeffrey H. Reed
Willis G. Worcester Professor and Founding Director of Wireless@Virginia Tech
Bradley Department of Electrical and Computer Engineering
Virginia Tech
reedjh@vt.edu

Thank you Chairman Walden, Ranking Member Eshoo, and Members of the Subcommittee for inviting us to appear before you today. I share your goals of putting more spectrum into productive commercial use to facilitate economy growth and innovation. The federal government though its policies can make a tremendous difference in our ability to develop and apply wireless communication technologies to achieve these goals.

My goals for this presentation are to address the key trends and emerging technologies affecting spectrum management, and to discuss how we can utilize R&D to accelerate the process of making more spectrum available for commercial use to address the rapid increase in demand for wireless services.

As we all know, the number, usage and bandwidth demand of wireless devices is growing at a rapid rate. The increased use of smart phones, particularly for video communication, has propelled the need for more bandwidth (spectrum) to support these devices and their applications. This is dramatically illustrated by, Figure 1, developed by Cisco, which projects a 7 fold increase in wireless data between 2014 and 2019. Data traffic growth will significantly increase demands on both licensed technologies such as LTE, and unlicensed technologies such as Wi-FI. The Internet-of-Things, enabled by wireless technologies is at the cusp of rapid expansion and it promises not only to greatly increase wireless traffic, but also change the characteristics of that traffic. To handle this demand, licensed and unlicensed technologies will be augmented by the new technology of spectrum sharing, which will manage the interference between various devices.

Figure 1: Projection of capacity needs. 7x increase between 2014 to 2019.



Source: Substantial Licensed Spectrum Deficit (2015-2019): Updating the FCC's Mobile Data Demand Projections, Coleman Bazelon and Giula McHenry, Brattle Group, June 2015. Last accessed 10-4-15 http://www.ctia.org/docs/default-source/default-document-library/bazelon_mchenry_spectrum-deficit_2015-06-23.pdf and based on data presented in Cisco reports, Feb. 2015.

Impact of New Wireless Technologies

Advances in wireless technologies have brought significant new benefits to national defense, government services, and economic development. For this discussion, I will focus on the benefits to economic development. There are two categories of benefits. The first category comes from the direct development of technologies that constitute the wireless systems. The second category comes from indirect economic benefits that occur from the deployment and use of these systems.

The first category of benefit, for example, the creation of the hardware that forms the cellular infrastructure network, has diminished in the US. There was a time when major cellular infrastructure providers primarily developed and manufactured wireless technology within the US. Companies such as Motorola (now part of Chinese corporation Lenovo) and Lucent (now part of French corporation Alcatel) were key US players. Today there are no major US-based (or even North American with the demise of Nortel in Canada) base station provider. Furthermore, very few cell phones are made in the US. The US still designs cell phones and in some cases produces chips that enable smart phones, but compared to ten years ago, we have experienced a major decline in manufacturing of cellular infrastructure. So this is the bad news.

However, there is good news to share. Innovation is healthy in the US. Major equipment manufacturers have significant R&D facilities in the US. These facilities are the source of high-skill and high-wage jobs. For instance, the creation of applications, operating systems, and software defined infrastructure has progressed very well in the US. iOS (Apple's mobile operating system which powers the iPhone) and Android are US products. Furthermore, the US is pioneering the development of spectrum sharing technologies, which has been enabled by the federal government and the regulatory community's interest in investigating and experimenting with new and novel approaches that enhance spectrum utilization. We are seeing an emerging ecosystem to support spectrum sharing, which I am confident will be a major technology component of 5G.

The second category of economic benefit comes from deploying and using the technologies. Certainly the US has been a leader in the early deployment of these wireless technologies and consumers have been able to reap the benefits of the associated economic efficiency. The early deployments of LTE as well as the early mass deployments of Wi-Fi are examples where the US has led the world. Reaping productivity gains using these new technologies is perhaps the most important economic benefit and there is much more to come in the way of new and innovative applications. It is these new applications that will continue to drive the need for greater amounts of spectrum and greater spectrum efficiency.

New applications of wireless technologies will bring all sorts of productivity gains and improvements to quality of life. Examples include connected cars that are self driving and that provide vastly improved safety; augmented reality that will help us to learn and perform complex tasks by superimposing computer generated images on our field of view (what I like to call just in time learning); ambient intelligence that will follow us and predict our needs; and telemedicine and wireless healthcare which promises to keep aging Americans to continue living in their homes safely, compensate for cognitive decline, and serve as one avenue for reducing the burden on the nation's healthcare system. These applications will be wireless enabled, and will of course need spectrum to support the data communication requirements. Hence the exponential growth curve in wireless data will continue for many years to come. If the US is to be a leader in the development and use of these technologies, we need the spectrum resources that will enable these applications. The phrase “build it and they will come” certainly applies to wireless technology. Build a solid spectrum management infrastructure, and the applications and services based on this infrastructure will come.

There are new technologies that will help in managing spectrum needs of the future. Small cells – miniature base stations are certainly one key technology. Small cells are very localized cellular technology that can reside in your home or office and provide low interference to others. The result is that these small cell can be densely packed and provide services to many users. Small cell technology has been developing along with automated deployment tools so that small cells become “plug-and-play,” requiring little set up effort and virtually no maintenance. Using higher frequencies is another way that we can improve bandwidth availability to users, but this approach does have its limitations since at higher frequencies radio waves tend to behave more like light and are subject to being blocked by objects in the environment, thus limiting coverage. Although higher frequency systems have a role in the future for supporting high-data rate systems, better use of lower frequencies is the best approach for providing bandwidth for wireless services for the near term.

Two of the most interesting and promising technologies for more effectively using lower frequencies are spectrum sharing and software-based infrastructure. Spectrum sharing takes previously allocated spectrum and allows new users to co-exist with legacy users through coordination. We are seeing spectrum sharing applied to AWS-3, the recently auctioned cellular band, and Citizens Broadband Radio Service (CBRS) at 3.5 GHz. These technologies are very important in allowing spectrum policy to rapidly adapt to match the demands of new users and applications while accommodating legacy users of that spectrum. In the case of AWS-3, service providers will be able to get access to the spectrum they paid for quickly. However, because of the long lead time necessary for federal users to transition to other bands, there will be delays and disruptions in some regions and frequencies that federal users have not vacated.

In the case of 3.5 GHz the sharing regime is more complicated. We still have protection of legacy federal users like that of AWS-3, but we also see a prioritization of spectrum access for the commercial users. An auction is used to grant priority access to some users (for a limited time) while lower priority access (General Authorized Access or GAA), similar to unlicensed devices, is granted without an auction payment. If the spectrum isn’t being used then a GAA device may use that spectrum. The authority to use the spectrum is granted by a database. You can think about the management of this spectrum like checking out a library book. That library book is available for loan and can be recalled when needed.

We are seeing some interesting business models develop from an adoption of a more sophisticated approach to spectrum sharing. In this case access to the spectrum is essentially rented and while service providers are expected to take advantage of this, non-traditional service providers can gain access to guaranteed spectrum without spending enormous amounts of money for a license. Anyone can obtain access to this spectrum. This spectrum use is different than that of unlicensed; it provides assurances of availability to those Priority Access users. Also the 3.5 GHz band is an international LTE band and hence it is feasible to obtain low cost LTE hardware from a mass market. It is likely we will see the establishment of private LTE networks that can serve a variety of industries such as transportation, healthcare, and manufacturing. This is a fundamental paradigm change in wireless communications that is being pioneered in the US, and will no doubt be applied in other parts of the world that are facing similar issues with spectrum availability.

Software defined infrastructure is another emerging technology area, which is different, yet complementary to spectrum sharing. This technology area is a combination of emerging technologies such as Software Defined Radio, Software Defined Networking, Network Virtualization Function, and Distributed Antenna Systems. An elementary way to view these combined technologies is that the infrastructure consists of antennas where the received signal is digitized, sent over fiber to a cloud infrastructure that can process the signal and implement the network functions in a flexible and dynamic fashion. So what are the implications of this technology on spectrum management? Such functionality will make spectrum sharing more cost-effective and add flexibility and scalability to deal with dynamic behaviors of incumbent, priority and general access users. It will also potentially remove some of the barriers that have prevented federal systems from interacting with other federal systems or from sharing spectrum with commercial systems. Federal operators who have been reluctant to cede control of their networks will find the ability of this technology to customize commercial services to their needs very attractive. Furthermore, the incremental costs associated with supporting new users and additional bands are minimized since most of the incremental cost will be in renting additional fiber and cloud resources. Since the network resources are common, coordination to support spectrum sharing is easier.

The Role of R&D to Speed the Availability of Spectrum

I applaud rapid movement in the policy arena that has allowed for the introduction of new technologies and spectrum management techniques. However, good policy must be grounded within sound engineering principles and hence R&D should lead policy decisions. While I am very optimistic and encouraged by recent and rapid policy changes, we could be doing a better job in providing a solid technical foundation to support policy decisions.

The recent AWS-3 auction is an example where upfront R&D could have made the process better. Granted the auction did produce sizable revenue for the Treasury, which is surprising given technical uncertainties surrounding the transition. There was and still exists, a great amount of uncertainty of how the federal legacy users and commercial users will co-exist. Technical issues involving sharing spectrum with airborne platforms, and the aggregate interference levels to military systems caused by numerous wireless devices, are still unanswered. How well commercial systems, using their advanced interference rejection, will be able to contend with interference from military systems is not clear. These are fundamental questions that should have been addressed well before the auction, but one must wonder if the federal government would have netted substantially more proceeds if these risk factors had been removed from the auction? Could a few million in R&D before the auction improved the value of that spectrum? Oddly, these R&D issues still have to be addressed, but now are being done after the auction.

The situation is similar for spectrum sharing in the 3.5 GHz band, where there was a fundamental lack of knowledge about the propagation characteristics of this band as the rule making progress began. The initial proposed rules for this band excluded large swaths of the country's population centers for shared spectrum use because of the lack of channel knowledge resulting in overly conservative interference protection zones (areas) in which commercial use of this band is excluded. Eventually this issue was resolved, for the most part, but this lack of technical data slowed the policy makers and hence slowed the transition of this band. The old adage "time is money" is certainly true for deployment of spectrum for commercial use and the economic benefits it brings.

These observations lead me to a set of specific recommendations given below.

Specific recommendations

1. *Prepare in detail for transition of bands, before any final decision is made for that transition.* Funds invested in this preparation are a small price to pay for speeding up the overall process of spectrum transition, even if that transition proves infeasible. For example, better preparation might have shaved a year off the transition of the AWS-3 band. The interest on $40B over a year would have dwarfed the small R&D costs needed to expedite that transition.
2. *Allow spectrum relocation funds to address the overall problem of transitioning federal spectrum, not just a specific band that has already been auctioned.* It is

counterproductive to everyone's best interest to narrowly constrain the use of these funds. It slows down the transition process for commercial use, and introduces unnecessary risk. For example, I understand that OMB has scored R&D funding for AWS-3 in a manner that is tightly constrained to only support AWS-3 transition. I don't know enough about the budgeting process to recommend fixes for this problem, but I do know that it is a pervasive issue preventing us from understanding the complete depth of transitioning users to other bands

3. *R&D incentives can help industry find solutions to government transition problems.* If companies are incentivized by R&D funds, they will use this knowledge to create products that will reduce risks of transition, and could even improve capabilities for the legacy spectrum users. If a government entity sees that the technology exists to supports their transition process, and that in the end the transition will give them better capabilities than before, then they will be much more likely to engage in the transition. In the end, industry can play an important role in transitioning spectrum to more productive use.
4. *Approach risk-assessment with realism.* Avoid falling into the trap that spectrum sharing techniques are not perfect and can in some instances cause interference to legacy users. No communication system has ever been immune to interference. Risks versus rewards need to be pragmatically assessed. Moreover, the ongoing improvements in cost, complexity and performance of wireless hardware and signal processing technologies enable the use of new methods for removing that interference. Many of these methods, developed by the defense and intelligence sectors over the past thirty years, change the paradigm of what's possible.
5. *Incentives can build support from the legacy spectrum users, but the "devil is in the details."* Thought needs to be given to metrics for assessing what and how much

incentives should be given for what [and how much] concessions. Furthermore, how those incentives are distributed within federal organizations make a difference in how cooperative the elements in those organizations will be with the transition. The organization's policies, and the benefits it receives from the transition, need to be clearly articulated throughout the organization.

6. *Build trust and transparency through collaboration between federal and commercial users, starting at early stages in the transition discussion.* If both federal and commercial users understand the problems resulting from the transition process, and how they have arisen, then they are more likely to work together to quickly solve those problems. Classification restrictions and export control issues of legacy federal systems are manageable though established processes and they should not be allowed to be a barrier that limits effective communication between federal and commercial sectors.

Conclusion

It is difficult to overstate the importance of good spectrum management on economic development. Establishing the right spectrum policies encourages innovation to happen here in the US, putting us in the leadership position to develop and deploy these new technologies. Policy changes should happen quickly to respond to demands of greater wireless traffic and to take advantage of new technology opportunities, but policies based on solid technical principles from upfront R&D are essential. This will require (1) continued research into spectrum sharing; (2) an R&D strategy that anticipates future needs more than we have seen in the past; and (3) active and frequent communication between all stake-holders including industry, researchers, policy makers, and incumbent spectrum users (both commercial and federal users).