APPENDIX

EFFICIENCY GAINS AND CONSUMER BENEFITS OF UNLICENSED ACCESS TO THE PUBLIC AIRWAVES

THE DRAMATIC SUCCESS OF COMBINING MARKET PRINCIPLES AND SHARED ACCESS

MARK COOPER
SENIOR ADJUNCT FELLOW, SILICON FLATIRONS
UNIVERSITY OF COLORADO, BOULDER

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EXECUTIVE SUMMARY

Setting aside a few "garbage" bands in the spectrum for unlicensed use was a radically deregulatory policy that combined free market principles with shared access to a ubiquitous, essential resource. By allowing the public to use the radio spectrum on an unlicensed basis the FCC removed the biggest barrier to entry into wireless communications. Correcting a 100-year old public policy mistake unleashed a torrent of entrepreneurial activity, innovation and investment.

This paper shows that by every measure of economic performance – device shipments, users, usage, efficiency, value and innovation – the unlicensed model has equaled or exceeded the exclusive licensed model in the past decade. Simply put, without access to unlicensed spectrum, wireless broadband service would be much more costly and far less valuable. Consumers would buy less of it resulting in fewer jobs and less tax revenue.

Section II: By the end of 2010 there were thousands more devices certified for use in the unlicensed spectrum than in licensed spectrum. The number of users of unlicensed spectrum in the United States exceeded the number of users of exclusive licensed spectrum for broadband data purposes by 30 percent. The dramatic growth of users, uses and usage is not limited to mass market application, but is even stronger in business applications, where intensive intra-firm communications improve the efficiency of health care delivery, the electricity grid, inventory management and fleet monitoring.

Section III: Cellular broadband providers were offloading over one-third of their traffic into the unlicensed spectrum, with the expectation that that figure would grow dramatically.

Section IV: Avoiding the construction of over 100,000 cell sites, they avoided incurring annual capital and operating costs of over $25 billion. Instead the initial hop to the Internet was provided by Wi-Fi networks at less than one-tenth the cost.

Section V: Although unlicensed use is usually bundled with broadband service, all of the uses are also sold on a standalone basis. Valuing users and uses at those market prices puts the annual value of activity in the unlicensed space at over $50 billion.

Section VI: Counting standards, network technologies, devices and applications, I find substantially more innovation in the unlicensed space than the exclusive licensed.

Section VII: The challenges of continued expansion of mobile communications involve not only increasing quantities of data traffic, but also increasing diversity in the needs of different types of communications. The prospects for unlicensed spectrum to continue to play a critical and expanding role are great.

Section VIII: The unlicensed model succeeded because it is not free but allowed entrepreneurs to invest in products and services that people value. In order to utilize the unlicensed spectrum, device manufacturers must design, build and market devices that consumers buy. To induce consumers to do so, useful applications must be written and distributed. Hundreds of thousands of base stations must be deployed and consumers or service providers must pay for the transport of traffic to and from the Internet.

The unlicensed model succeeded because removing the spectrum barrier to entry decentralized decision making, deconcentrated investment, promoted an end-user focus, allowed user innovation and lowered transaction costs. This brought new and unique services to market, increased the value of broadband by extending it to new devices, and provided a lower cost, more efficient avenue to deliver data to consumers.

Section VIII: Ironically, the FCC, which fathered this remarkable success, has never studied it in detail. Predictably, the advocates of exclusive licenses have never come to grips with the remarkable success of the unlicensed model. Unfortunately, these gaps in knowledge now pose a threat to the future of mobile data communications. Without a proper appreciation for the vital importance of unlicensed to the success of wireless broadband communications, some policy makers are proposing a short-sighted spectrum policy that would strangle the future growth of the unlicensed model, by refusing to set aside additional spectrum for unlicensed use. This would be a huge mistake.

Making additional high-quality spectrum available for unlicensed use will grow the sector which will increase revenues because the complementary relationship between unlicensed and licensed increases the value of licenses and because cellular carriers will bid up the price of spectrum. The much larger wireless data sector that results will generate more economic activity and more general revenues.

Those who argue that unlicensed users should bid for spectrum in auctions ignore advantages of huge size, deep pockets, telecommunication experience and pre-existing networks that the dominant cellular providers have used to acquire 80% of the spectrum auctioned in the broadband wireless era. Those who holders of exclusive licenses will accommodate unlicensed through market transactions ignore the demonstrated willingness and ability of the incumbents to protect their market power.

Exactly 100 years ago Congress decided to give broadcasters exclusive licenses to use the spectrum and it has been clear for over fifty years that this approach is inefficient. Today Congress is threatening to repeat that mistake by slamming the door on the unlicensed model. In some ways, this would be an even bigger tragedy because Congress should know better and the stakes are much larger. Back in 1912, radio technology was new and primitive and there was little basis on which to consider alternative approaches. The demonstrated success of the unlicensed model provides a very strong basis to conclude that given access to spectrum with more attractive propagation characteristics, the unlicensed model will perform at least as well as the exclusive licensed model and the overall sector will perform much better, which of course, means more jobs and more revenue.

Congress should continue to put the public back in the public air waves and promote the mutually beneficial and complementary relationship between the licensed and unlicensed models. It should ensure that the TV white spaces are made available for shared use and that the unlicensed model receives no less than one-sixth of any future high quality spectrum (between 500 MHz and 1 GHz) that is cleared by relocating TV broadcaster. It was the FCC, the expert agency, that had the foresight to open the door to shared use in the broadband era, and the FCC should be authorized to make as much as one-quarter of any clear TV spectrum available for unlicensed use if that is proven to be in the public interest.

I. INTRODUCTION

EXPERIMENTS IN DEREGULATION

Over the past decade, the growth of mobile communications has been nothing short of remarkable.[1] Although wireline telephone service has been available for over a century and wireless voice became widely available in the late 1980s, globally the number of people who subscribe to wireless voice is four times the number of people who subscribe to wireline connections, with 80 wireless subscribers per 100 people worldwide in 2010.[2] In the United States, there are twice as many wireless subscribers as wireline telephone subscribers.[3] In fact, the penetration of wireline telephone service has begun to decline in the United States and globally.

However, the mobile communications revolution is now entering into a new phase, as new technologies make broadband Internet access service available with mobile devices like smartphones, laptop computers, tablets and other consumer electronic devices.[4] Today, more people subscribe to wireless broadband Internet service than wireline broadband Internet service, globally.[5] In the United States, wireless and wireline broadband service subscriptions are about equal, even though wireline Internet access has been available for a longer period of time.[6]

The mobile communications revolution has been built upon two very different and successful approaches to the management of spectrum that were made possible by a remarkable, U.S. led, real-world experiment.[7] In the early days of radio communications, policymakers chose to manage interference in radio transmission by granting an exclusive license to one user to transmit signals on specific frequencies, called bands, in a specific geographic area for a specific purpose. For three quarters of a century this approach led to the dominance of broadcasting in the commercial use of the airwaves. In the mid-1980s the Federal Communications Commission (FCC) altered the regulatory regime for access to spectrum and created the opportunity for dramatic improvements and changes in the use of spectrum for communications purposes. [8]

The FCC established the basis for two different approaches. Exclusive licenses were made available to allow new, two-way communications, and later, licenses were auctioned to the highest bidder.[9] The licenses were still exclusive, but the bidding and flexibility were intended to improve the utilization of spectrum by assigning the rights to those who were willing to pay the highest price. At the same time, the FCC identified some bands where there would be no licensee and interference would be avoided by the use of new technologies (spread spectrum) and restrictions on the amount of power devices could use. Anyone and everyone could transmit in these unlicensed bands as long as the devices obeyed the rules.

The original approach to interference management through spectrum allocation and the two new approaches have been described in a number of ways – command and control v. property

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[1]WSIS Forum, 2011, calls it a mobile miracle.
[2] ITU, 2011.
[3] FCC, Internet Service, 2010; CTIA, 2011.
[4] WSIS Forum, 2011, worries that the mobile miracle has not yet spread to mobile data.
[5] ITU, 2011.
[6]FCC, Internet service, 2010. Based on company financial statement, the number of cellular wireless broadband subscribers for year-end 2011 would be to close 100 million.
[7] Lemstra and Groenewegen, 2011, p. 4, "Moreover, the example set by the FCC in the assignment of radio frequency bands for use by radio LANS has been followed by assignments by national regulatory agencies in the countries of Europe and Asia, including Japan, South Korea, India and China, thereby creating a global market for Wi-Fi products."
[8] Wehrbach, 2002.
[9] The first two licenses were given to incumbent wireline telecommunications providers.

v. commons;[10] administrative v. tradable/flexible/market-oriented v. license exempt commons.[11] However, the simple labels do not do justice to the differences and similarities between the models. For example, it can be argued that the license-exempt approach is more market-oriented than the tradable/flexible exclusive licensed approach because it invites much greater entry and competition at the device and service levels. At the same time, the license-exempt model is far from a free-for-all, since the FCC certifies devices that must comply with very specific rules for their operation (in effect "licensing" devices rather than uses or users). Indeed, the FCC still administers the regime of rights enjoyed by spectrum users under both of the newer models.

The labels – with the intense ideological baggage they carry and rhetorical combat they inspire – are less important than the incentives the models provide and the economic performance that they achieve. [12] In fact, it can be argued that the labels have become a hindrance to clear analysis and policy recommendations. Fortunately, the theoretical/theological debate has been rendered moot by empirical reality. In a little more than a decade, the two institutional arrangements have come to stand side-by-side in remarkable balance and symbiosis.

THE UNIQUE SUCCESS OF THE UNLICENSED MODEL FOR BROADBAND COMMUNICATIONS

Although both of the new models have been quite successful, the success of unlicensed use was quite surprising. A June 2004 article in the *Economist,* written before exclusively licensed wireless broadband Internet access had achieved significant market penetration, captures the unique and powerful economic forces that created the initial success of the unlicensed use model.[13] The article identified a number of key developments in the unlicensed wireless space.

- By 2004, there was a high level of activity already taking place in the unlicensed use spectrum.[14]

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[10] Carter, 2006.

[11] Horvitz, 2007, p.1, "It is widely accepted today that there are three main approaches to radio spectrum management: The traditional "administrative" approach, in which a regulator decides who can use what frequencies for what purposes in what locations under what conditions: The newer "tradable/flexible/market-oriented" approach, in which those who are authorized to use spectrum are allowed to re-purpose or transfer some or all of their rights. Tenders or auctions are typically used for the initial distribution of rights. "License-exempt commons" in which any number of users are allowed to share a band with no right of non-interference and no right to cause interference."

[12] The debate between licensed and unlicensed spectrum frequently plays out, in footnotes at least (see e.g. Thanki, 2009), as a debate between two Nobel laureates in economics. On one side is Ronald Coase, whose 1959 essay highlighted the inefficiency of the licensing scheme at the FCC and is taken to be an argument for auctioning spectrum by neoclassical economists. On the other side is Eleanor Ostrom, whose work has demonstrated that efficient and effective non-property approaches to management of common pool resources are possible. Defenders of the unlicensed model claim Coase for their own, by arguing that a change in technology that significantly altered transaction costs could easily lead to a different conclusion about the relative merits of different institutional arrangements (Benkler, 1999, 2007; Ryan, 2005). The New Institutional Economics accommodates both possibilities by focusing on institutions as one, critically important element of economic structures, along with transaction costs and technology. As Douglas North (1990, p. 118) , another Nobel Laureate, put it, "Institutions provide the basic structure by which human beings throughout history have created order and attempted to reduce uncertainty in exchange. Together with the technology employed, they determine transaction and transformation costs and hence the profitability and feasibility of engaging in economic activity. (p. 118)." This is consistent with North's view that Coase's argument can lead to a fundamental critique of neoclassical economics (Douglas North, 1993, "It was Ronald Coase (1937 and 1960) who made the crucial connection between institutions, transaction costs and neo-classical theory; a connection which even now has not been completely understood by the economics profession. Let me state it baldly. The neoclassical result of efficient markets only obtains when it is costless to transact. When it is costly to transact, institutions matter. And because a large part of our national income is devoted to transacting, institutions and specifically property rights are crucial determinants of the efficiency of markets. Coase was (and still is) concerned with the firm and resource allocation in the modern market economy; but his insight is the key to unraveling the tangled skein of the performance of economies over time, which is my primary concern.")

[13] Economist, 2004, provides some early data. Lemstra, Hays and Groenewegen, 2011, provide more detailed and formal social scientific analysis.

[14] Economist, 2004, "Tens of millions of Wi-Fi devices will be sold this year including the majority of laptop computers. Analysts predict that 100m people will be using Wi-Fi by 2006. Homes, offices, colleges and schools around the world have installed Wi-Fi equipment to blanket their premises with wireless access to the internet. Wi-Fi access is available in a growing number of coffee-shops, airports and hotels too." Data on devices can be found in Lemstra, 2011a.

- The activity was driven by the close, complementary relationship that had developed between the adoption of broadband Internet access and the expansion of unlicensed use.[15]
- The level of unlicensed activity was particularly notable because the activity took place over spectrum to which experts had previously ascribed little value.[16]
- A self-regulatory approach to standard setting played an important role.[17]
- The broader significance of the success of the unlicensed use model and the prospects for further innovation it embodied were already notable.[18]

The contribution of the unlicensed use model to the wireless ecology in the period after 2004, when cellular broadband service based on exclusive licenses began to gain large numbers of subscribers, is equally impressive and continuing to evolve. It is driven by spectral efficiency,[19] deepening complementarity between licensed and unlicensed uses,[20] and the continual development of new arrangements that integrate the technologies and ownership models.[21]

PURPOSE: FRAMING THE ANALYTIC AND POLICY QUESTIONS

The dramatic developments in the wireless sector in the past decade and the success of the unlicensed model have been so swift and unexpected that their implications for policy have not been fully recognized. Ironically, the success of the unlicensed model has not been studied rigorously by the agency that made it possible. The counts of subscribers that are used to

[15] Economist, 2004, "Wi-Fi was boosted by the growing popularity of high-speed broadband internet connections in the home; it is the easiest way to enable several computers to share a broadband link… fee-based access points known as "hot spots" also began to spring up in public places." The importance of the transition to the home environment is noted in Lemstra, 2011b.

[16] Economist, 2004, "Wi-Fi seems even more remarkable when you look at its provenance. It was, in effect, spawned by an American government agency from an area of radio spectrum widely referred to as the "garbage bands." Technology entrepreneurs generally prefer government to stay out of their way: funding basic research, perhaps, and buying finished products when they emerge on the market. But in the case of Wi-Fi, the government seems actively to have guided innovation… [T]o open several bands of wireless spectrum, allowing them to be used without the need for a government license... was an unheard of move at the time… But the FCC, prompted by a visionary on its staff, Michael Marcus, took three chunks of spectrum from the industrial, scientific and medical bands and opened them up to communications entrepreneurs."

[17] Economist, 2004, "What ultimately got Wi-Fi going was the creation of an industry-wide standard… Inspired by the success of Ethernet, a wireline-networking standard, several vendors realized that a common wireless standard made sense too. Buyers would be more likely to adopt the technology if they were not "locked in" to a particular vendor product." Jacob, Lemstra and Hayes, 2011, describe the standard setting process.

[18] Economist, 2004, 'Wi-Fi's ultimate significance, then, may be that it provides a glimpse of what will be possible with future wireless technologies. It has also changed the way regulators and technologists think about spectrum policy. The FCC has just proposed that broadcast "whitespaces" – the airwaves assigned to television broadcasters but not used for technical reasons – should be opened up too. That is not to say that spectrum licensing will be junked in favour of a complete free-for-all over the airwaves. Jules Knapp, the deputy chief of the office of engineering and technology at the FCC, maintains that both the licensed and unlicensed approaches have merit." Roseel and Finger, 2011, examine the future of Wi-Fi within the constraints of current spectrum allocation.

[19] Rysavy, 2010b, p. 10, Cisco, 2011a, p.1, "Cellular carriers are looking for solutions to offload this data traffic from their cellular networks. Offloading data to hotspots is an economically attractive alternative because many carriers already operate a substantial number of hotspots;" Higginbotham, 2011, "Given the demand for data, this heterogeneous network is the future of mobile broadband, and could lead to lower operating costs and perhaps cheaper prices for end users."

[20] Cisco, 2011a,p. 1, "With the introduction of smartphones such as Apple's iPhone and Google's Android platform and the transition from a mobile voice to a mobile data model, more tier-one operators are taking a closer look at how to take advantage of the unlicensed spectrum and Wi-Fi as part of their mobile strategy. They are starting to realize that the operator with the best licensed **and** unlicensed strategy will deliver the most data service and the best mobile experience at the higher profit margin… Mobile operators would like to provide a user experience on Wi-Fi networks similar to that provided on 3rd generation networks. This means making Wi-Fi as easy to use as cellular and providing it with cryptographically equivalent mutual authentication and line-layer security."

[21] Higginbotham, 2011, "Japan's KDDI has seen the future of cellular service, and Wi-Fi has a starring role. The mobile operator will build out a Wi-Fi network composed of 100,000 hot spots and a WiMAX overlay that will take traffic off the cellular network when needed and will integrate seamlessly with the carriers exiting 4G network… What KDDI has done is take the jerry-rigged AT&T or Verizon approach to Wi-Fi, whereby a mobile operator provides access to free hot spots but relies on the user to do the work, and tossed it out the window. KDDI has brought Wi-Fi (and WiMAX) into its network and made it work together in a way that will proactively keep its cellular network less congested."

demonstrate the success of mobile communications and that receive the overwhelming attention of regulatory bodies and agencies focus almost entirely on cellular services offered by holders of exclusive licenses. The FCC publishes annual reports on the Commercial Mobile Radio Service market[22] and semi-annual reports on mobile and wireline broadband adoption,[23] but it does not produce any regular reports on the use or development of unlicensed spectrum. Indeed, it has never conducted a comprehensive, rigorous examination of the performance of the unlicensed sector. In a deregulatory age one of the most successful experiments in radical deregulation has received almost no analytic attention from the FCC.

Similarly, some leading analyses of spectrum policy have not come to grips with the success of the unlicensed model. For example, an analysis by Thomas Hazlett,[24] one of the most vociferous opponents of the unlicensed use model,[25] provides a case in point. He frames the analysis not in terms of whether unlicensed has succeeded, but whether it has reduced the case for exclusive licensed model.

> Here, the question is: Have advanced technologies, yielding enhanced opportunities for wireless activities to be coordinated by smart technology, reduced the case for exclusive spectrum rights? In a word, *no.*[26]

Hazlett then offers an "acid" test by which to evaluate ownership models.

> If technologies operating on unlicensed bands were actually disruptive to the logic of exclusive spectrum rights, market activity would show evidence of a shift in usage patterns. Wireless investment would migrate to unlicensed bands. That transition has not been observed. Moreover, the competitive threat posed by unlicensed applications would devalue licenses.[27]

This view ignores the possibility of positive complementarity between the two models. Writing in 2008, with data through 2006, it might have been possible to downplay the development of hot spots and extension of broadband, which allows unlicensed use to be a complement to broadband Internet rather than a competitor. However, with the growth of offloading of traffic from exclusive licensed to unlicensed spectrum, the central role of unlicensed spectrum cannot be dismissed.

This paper addresses the analytic challenge of measuring "market activity," "investment" and the "competitive" relationship between licensed and unlicensed spectrum with the full range of data from the first decade of broadband data delivery in unlicensed spectrum. The experience of the past decade makes it clear that the questions should be framed differently because of the complementarity between licensed and unlicensed spectrum.

First, we should examine the success or failure of the unlicensed model independently of the success or failure of the exclusive licensed mode. The first question should have been

- Have advanced technologies, yielding enhanced opportunities for wireless activities to be coordinated by smart technology, strengthened the case for unlicensed use models? And the right answer is an emphatic, *yes.*

[22] FCC, CMRs reports,
[23] FCC, Internet Access Services reports.
[24] Hazlett, 2008.
[25] Hazlett, 2001.
[26] Hazlett, 2008,pp. 120-121.
[27] Hazlett, 2008, p. 123.

The paper reaches that conclusion by using the measures demanded by Hazlett. The paper shows that, in fact, there **<u>has</u>** been a shift in market usage patterns. Investment **<u>has</u>** migrated. Complementarities between unlicensed use and exclusive use **<u>have</u>** increased the value of licenses. Examining the role of the unlicensed model in the overall success of the mobile data sector, the shows that in the delivery of mobile data the unlicensed use model has achieved success that equals or exceeds the exclusive licensed model by numerous measures of economic performance, including devices, users, usage, efficiency, innovation and economic value.

Second, with this evidentiary base, we can examine the implications of the performance of unlicensed for exclusive licensed spectrum. With the finding of complementarity between the two models, it can be argued that the case for exclusive licensing has been weakened by the performance of unlicensed use in the sense that, absent unlicensed use, wireless data would be more costly and less valuable and the sector would be less efficient and innovative. Consequently, the value of exclusive licenses would be lower without unlicensed spectrum.

Faced with a flood of traffic, the operators of networks based on exclusive licenses found it cost-effective to offload huge volumes of traffic onto the unlicensed spectrum. The solution advocated by the supporters of exclusive licensing to the ongoing spectrum shortage is to make more spectrum available on an exclusive basis. From a societal view, feeding the bandwidth hogs more spectrum is less efficient than making spectrum available for both models. In fact, based on the real world experience of the performance of the two models in the past decade, a good case can be made that unlicensed use has a stronger claim to spectral efficiency than exclusive licensed use. In this sense, with respect to the allocation of spectrum between the two models, it would "reduce the case for exclusive spectrum rights." However, the policy challenge does not have to be framed in that way. The policy question is not whether to choose one model; the policy question is how to support both to continue the dramatic expansion of the wireless data sector.

Filling this analytical gap is vitally important not only because unlicensed use has come to play such a large role in the wireless data space, but also because major decisions about the future of the exclusive licensed and unlicensed models are about to be made. The budget deficit debate in Congress threatens to undermine the future potential contribution of unlicensed spectrum because some policymakers are advocating auctioning all high-quality frequency bands (those between 500 MHz and 1 GHz that have been used by TV broadcasters) that come available to maximize short-term revenues without making any additional high-quality bands available for unlicensed use.[28]

The paper shows that focusing on short term revenues that would be raised by auctioning licenses, while ignoring the immense value that unlicensed spectrum creates, which would increase revenues much more than auction yields, is a mistake. It explains why failing to make more high-quality spectrum available for unlicensed use would severely constrain the development of the unlicensed use model, which would retard the development of the entire wireless broadband sector, stifle innovation, drive up consumer costs for service, reduce long-term growth and slow job creation. The net effect would be to lower federal revenues.

OUTLINE

To demonstrate this important policy conclusion, the paper offers answers to key analytic and policy questions.

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[28] *The Jumpstarting Opportunity with Broadband Spectrum Act of 2011,* required all spectrum that was cleared of broadcast licensees to be auctioned.

Has unlicensed use been successful in generating activity and creating value?

- **Section II** reviews the key role that unlicensed use has played in the remarkable success of wireless data delivery, showing that there is at least as much activity

Has unlicensed use improved the efficiency of and innovation in the wireless broadband sector?

- **Section III** estimates the contribution of offloading of traffic to the efficiency of the wireless sector by estimating the number of cell sites that cellular carriers avoided erecting by shifting traffic to unlicensed bands.

What is the value of activity in the unlicensed space?

- **Section IV** shows that the value of activity in the unlicensed space equals or exceeds the value of activity in the exclusive licensed space.

Has the unlicensed model stimulated innovation?

Section V presents evidence that the speed of innovation under the unlicensed equals or exceeds the speed of innovation under the exclusive licensed model.

What are the challenges facing the mobile broadband communications sector?

- **Section VI identifies** key challenges to the continued expansion of the mobile data sector as background for assessing the potential for unlicensed to continue to contribute to the sector. It looks beyond the projected increase in traffic flows, focusing on diversity of service needs and enhanced coverage.

What role can the unlicensed use model play in providing future wireless data service?

- **Section VIII** explains the success of unlicensed use in terms of the fundamental characteristics of the model and suggests that it can play an important role in the future of the wireless sector, if policymakers grant unlicensed access to higher quality spectrum.

Will auctioning spectrum provide the necessary spectrum for the unlicensed use model to continue to thrive?

- **Section VIII** explains the success of unlicensed use in terms of the fundamental characteristics of the model. It then discusses the reasons why auctioning all spectrum will not result in making adequate spectrum availability for unlicensed use to expand. It concludes with recommendations for policies to ensure adequate spectrum is available to preserve the unlicensed option and the diverse, balanced development of the wireless communications ecology.

II. ACTIVITY

The unlicensed model has succeeded in supporting a large amount of economic activity in the wireless broadband space by bringing new and unique services to the market, increasing the value of broadband service by extending it to additional devices, and providing a lower cost, more efficient avenue to deliver data to consumers. Frequencies reserved for unlicensed use have come to support two broad categories of activities. Mass market activities involve widely available end-user-oriented activities including extension of broadband data transmission within the home/office and use of commercial hot spots. Unlicensed use bands have also become an important intermediate input used by businesses to support and improve their operations. These include the offloading of cellular traffic onto unlicensed spectrum to increase the efficiency of cellular service and the intensive use of intra-firm wireless communications by non-telecommunications firms and the "tagging" of things that are tracked in machine-to-machine (M2M) communications to manage their flow more efficiently.

THE RAPID EXPANSION OF THE UNLICENSED SECTOR

Devices

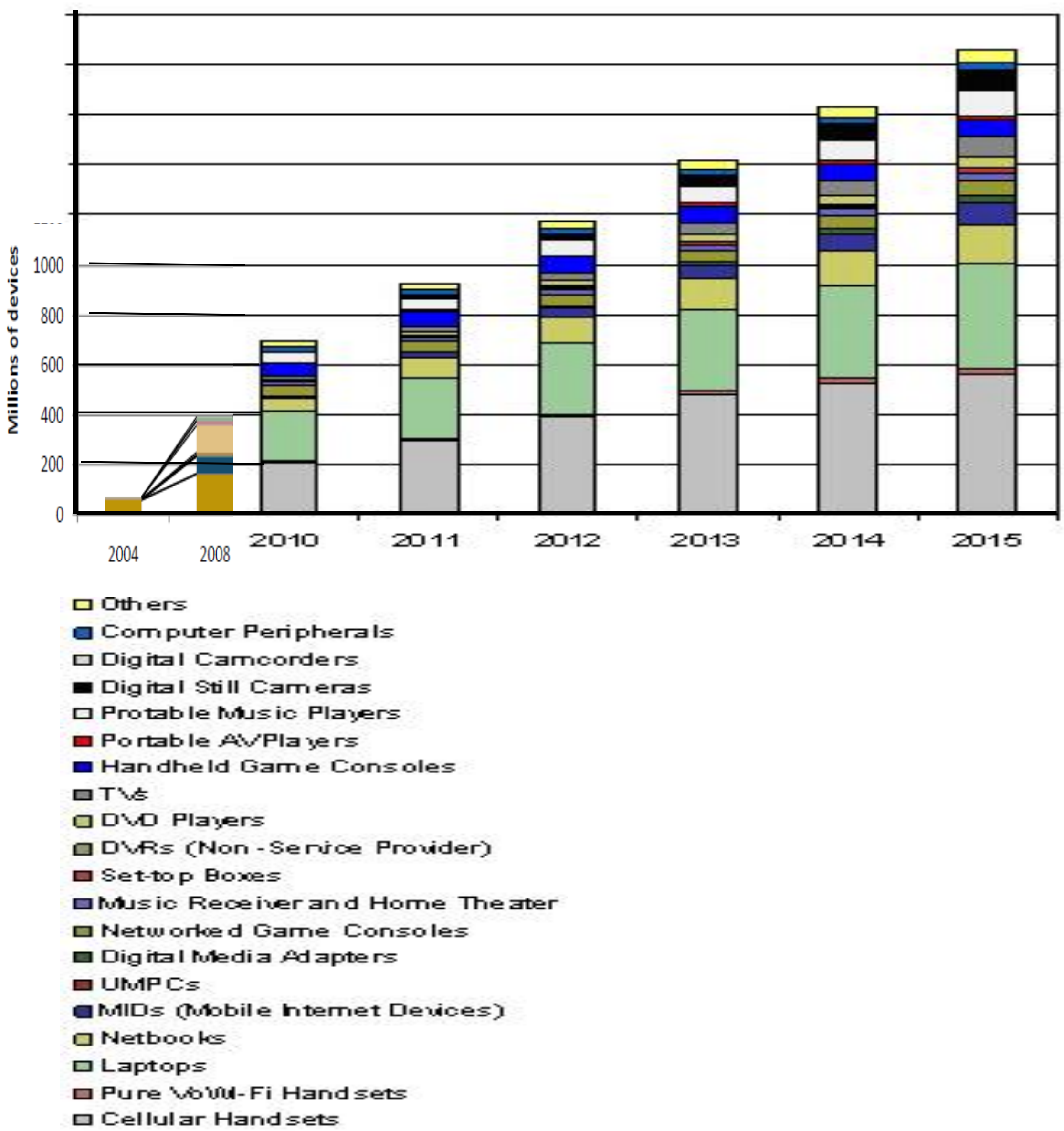
Devices are the focal point of the unlicensed model, whereas cellular service providers, who rely primarily on exclusive licensing, focus on subscribers and subscriptions. This distinction introduces some complexity into comparing the models. The complexity is compounded dramatically by the fact that one of the primary uses of unlicensed spectrum is to extend fixed broadband to mobile devices and by the fact that cellular providers bundle access to unlicensed in their wireless broadband offerings. The two have become thoroughly intertwined.

The standard to support broadband devices in the unlicensed use bands was adopted in the United States in 2000. By 2004, there were 2,000 devices certified to operate in the unlicensed use bands subject to the 802.11 standard, which was 20 times the number of devices that had been certified for use in cellular licensed bands.[29] By 2007, there were over 3,500 devices certified for to operate in the unlicensed bands.[30]

As Exhibit II-1 shows, global shipments of devices were expanding rapidly over this period. From the "tens of millions" of devices sold in 2004 globally, as noted by the *Economist,* the market is approached 800-900 million sold in 2010-2011.[31] That is a compound annual growth rate approaching 50 percent. Since the life of a device is more than a year, the number of devices in use is probably in the range of 1.5 to 2 billion globally (assuming a two-year life). Moreover, the shipment of Wi-Fi capable devices is projected to double in the next five years.[32] Additionally, Wi-Fi functionality is being deployed in almost two dozen different types of devices and a growing number of devices (especially smartphones) are dual mode devices.[33] Thus, the distinction between licensed and unlicensed-capable devices is shrinking dramatically.

[29] Snider, 2006.
[30] Lemestra, 2011c, p. 135.
[31] Lynn, 2011; Flaherty, 2011b.
[32] Flaherty, 2011b. Research and Markets, 2011, projects a higher rate of growth of Wi-Fi enabled devices in the U.S. than globally.
[33] Dual mode devices are about 40% of cellular devices (Portio Research, 2011) and one-third of shared use devices (Flaherty, 2011b).

EXHIBIT II-1: SHIPMENTS OF WI-FI CAPABLE DEVICES



Sources: Nick Flaherty, "Consumer Wi-Fi Drives Global Growth: Wi-Fi chip shipment to surpass 770 million in 2011?, up 33%," *The Embedded Blog,* May 26, 2010; Richard Thanki, *The Economic Value Generated by Current And Future Allocations of Unlicensed Spectrum,* Perspective, 2009. The underlying data in both cases is InStat. The exhibit is pieces together from published graphics.

The U.S. numbers are a little different. The United States accounted for one-quarter of global shipments of Wi-Fi enabled devices in in 2005, estimated to decline to one-fifth in 2007-2010.[34] U.S. cellular shipments were approximately 150 million Wi-Fi enabled devices per year in the years between 2007 and 2010. Looking at the numbers of devices shipped, and assuming a two year life for devices, the number in use in the United States would be 300 million. Given the rapid spread of

[34] King,2007.

dual mode smart phones and other Wi-Fi enabled mobile devices, the share of Wi-Fi enabled devices in total broadband wireless connectivity devices appears to be well over half.[35]

Users

Estimating the number of users of unlicensed spectrum is difficult not only because there is no centralized organization that charges for use, but also because the cellular providers who do charge have been bundling use of unlicensed spectrum into their paid services. Because the cellular operators control which spectrum is used in many cases, consumers may not even know when they are using unlicensed spectrum.

Globally, there are about 1.3 billion subscribers to wireless broadband service and a little over half as many wireline broadband subscribers.[36] The total wireline and wireless subscribers would be about 2 billion. However, a substantial number of those who subscribe to wireline broadband also subscribe to wireless broadband, so the total count of unique users would be smaller.

At the end of 2010, the FCC put the number of wireless broadband subscribers at 84 million, with an equal number of wireline broadband subscribers. However, there is a substantial overlap between the universe of wireless and wireline broadband subscribers in the United States. The Current Population Survey for October 2010 indicates that approximately two-thirds of wireless broadband subscribers are also wireline broadband subscribers, but the unit of analysis is the household, rather than the individual.[37] In a mid-2011 study, ComScore.com estimated that there were 116 million Wi-Fi users.[38] In subsequent analysis for year-end 2010, we use an estimate of 110 million Wi-Fi users.[39] Thus, disregarding overlap, the number of subscribers at the end of 2010 is as follows: 110 unlicensed users, 84 million broadband wireline and 84 million broadband wireless.

The percentage of all mobile data users who are unlicensed spectrum users can be estimated in two ways. If we count unique users of broadband (taking overlap into account) then unlicensed users would be over 90 percent of unique broadband users.[40] On the other hand, arguing that unlicensed spectrum and exclusive spectrum users are thoroughly conflated by the bundling strategy of cellular service providers and that the line between wireless and wireline subscribers is blurred by dual mode devises and extension of wireline broadband, we might include in the denominator of the fraction all broadband subscribers. Viewed in this way, users of unlicensed spectrum would be equal to almost two-thirds of the total.[41] This is consistent with the share of devices discussed above.

[35] Dediu, 2011, cites a Nielsen finding that 43% of the phone in use in the United States are smartphones. Nielsen, 2011, for the third quarter of 2011 gives a figure of 44%. Adding tablets and notebooks into the analysis, smartphones account for about 70% of the mobile data devices. Hence dual mode devices account for over two thirds of the mobile connectivity devices.
[36] ITU, 2011.
[37] CPS, 2011, Figure 4.
[38] Comsource.com, 2011.
[39] Examination of quarterly SEC reports by the top four cellular carriers indicates that wireless carriers added about 6 million subscribers through mid-year 2011. Assuming that these all involved dual mode devises, subtracting this six million from the ComScore.com estimate yields a total of 110 million.
[40] The calculation is 110 million unlicensed users compared to ((84 million * 1, 33 broadband users = 112 million) + a small number of unlicensed only users).
[41] The calculation is 110 million unlicensed users compared to (84 million wireless broadband users + 84 million wireline broadband users = 168 million).

Thus measured by devices and users, unlicensed use appears to be a major contributor to broadband activity, with a share equal to or greater than that of cellular wireless broadband subscribers.

MASS MARKET USES OF UNLICENSED SPECTRUM

Extending Broadband

The key applications that drove early Wi-Fi adoption as described in the quote from the *Economist* were the extension of broadband internet connectivity to a number of devices and access to hot spots.[42] Within the home or business of a broadband subscriber, the ability to use Wi-Fi to extend the broadband service to all capable devices is ubiquitous because the spectrum is available for unlicensed use.[43] Anyone with a router can distribute the signal over a short range. The sale of routers has sustained a compound average growth rate over 30 percent for almost a decade.[44]

At present the major broadband Internet access providers, whether wireline or wireless, view Wi-Fi as a way to extend their broadband service to a host of devices.[45] They advertise the advantages of in-home mobility that Wi-Fi provides and they market wireless hot spot devices for personal use.[46] Just as modems quickly became a standard feature of desktop computers, Wi-Fi capability became a standard feature of any mobile device.[47] For example, in announcing a major deal to sell its spectrum to and enter into a joint marketing venture with Verizon, the President of Comcast Cable chose to highlighted it Wi-Fi strategy – "These agreements, together with our Wi-Fi plans, enable us to execute a comprehensive, long-term wireless strategy and expand our focus on providing mobility to our Xfinity services".[48]

The extent of home networking is difficult to pin down because home networking is generally bundled as an extension of broadband service. Once a signal is delivered into the home, the service provider who is paid for that signal does not measure its distribution to other devices because that distribution does not contribute to the congestion on the delivery network, nor does the use increase revenues. It is safe to say it is ubiquitous.

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[42] *Meraki*, 2011, It took more than a decade for mobile devices to overtake fixed devices in Wi-Fi deployment, which highlights the "extension" function of Wi-Fi. "Between 2010 and 2011, mobile platforms overtook desktop platforms in percentage of Wi-Fi devices."

[43] Vonnagy, 2010a, "Consumer Wi-Fi has an immediate and substantial value proposition for consumers. It is a **gateway technology** that increases consumer adoption of many other technologies that have value to people. It allows them to access the Internet while on the couch or in bed; stream music from one room to another; it creates portability and flexibility for home offices, allowing people to move to another portion of the house. It's value to consumers is tremendous, largely because it gives people freedom to interact with the Internet and consumer content in the place and the method they choose. It breaks down barriers and allows people to interact on the web on their terms."

[44] Research and Markets, 2011b, *Global Home Networking and Broadband CPE Outlook through 2012.*

[45]Comcast, 2011, "Wi-Fi is used to provide a high-speed wireless connection within a limited area (in tens of feet) like a home, office, or coffee shop. Wi-Fi is commonly referred to as a Local Area Network (LAN) technology. XFINITY Internet 2go Metro (4G) service is based upon a 4G mobile broadband technology called WiMAX. WiMAX provides mobile broadband network across a much broader coverage area than Wi-Fi. WIMAX is commonly referred to as a Wide Area Network (WAN) technology, due to its ability to provide a much broader coverage area; e.g., covering most a metro area, where available."

AT&T, 2011b, DSL: "Stay connected at home and on the go. Built-in wireless home networking capability included. Our Residential Gateway is powerful enough to virtually eliminate wireless dead spots and safeguard against outside access of your Internet connection. Also includes four Ethernet ports for wired LAN connections. AT&T Wi-Fi—email, watch streaming video, listen to music, and much more—all on the go. Includes access at home and on-the-go to the entire national AT&T Wi-Fi Hot Spot network, at no extra charge. ‡ ‡Access includes AT&T Wi-Fi Basic. Wi-Fi enabled device required. Other restrictions apply. See www.attwifi.com for details and locations. Use of Wi-Fi at home will count toward your AT&T high speed Internet usage allowance."

[46] Nadel, 2011.

[47] Vos, 2011, "carriers showed a strong and renewed interest in Wi-Fi as they look to build affordable capacity and coverage to augment their cellular networks, offer mobile data offload services and deliver fasters and more reliable Wi-Fi services."

[48] PRNewswire, 2011.

Hot Spots

Another unique aspect of the unlicensed use model has been the growth of hot spots.[49] Here again, measuring the extent of activity in the unlicensed space and comparing it to the exclusive licensed space involves complex considerations. On the one hand, one can argue that hot spots and cell sites provide the initial connectivity for end users. On the other hand, accessing hot spots over unlicensed spectrum is presently a very short range form of connectivity. However, to a significant degree, the difference in reach of unlicensed reflects the allocation of spectrum to the various models and the rules that have been applied to avoid harmful interference. Comparing hot spots to cell sites as connectivity points may be an apples to oranges comparison today, but that reflects a policy choice. The result is not immutable. Because the current distribution of capabilities reflects prior policy choices, they should certainly not be seen as "proof" that the future distribution of capabilities and functionalities must be similar to the past.[50]

Within the constraints of past policy choices, unlicensed connectivity has flourished. The frequencies set aside for unlicensed use are suited to short-range transmission, which was conducive to businesses offering access to a hot spot as an inducement to patronize the establishment. Just as bars find it effective to give away salty snacks to attract customers, a host of commercial enterprises have come to view free Wi-Fi as an invitation to customers to enter and linger.[51] Community hot spots at universities, government buildings and libraries were a second major area of activity that was supported by the allocation of spectrum and the rules. Later, the cellular carriers began to promote hot spots of their own. They advertise Wi-Fi access as a selling point in their mobile broadband offerings and support hot spot development. T-Mobile claims to support 45,000 hot spots globally.[52] AT&T claims 29,000 U.S. hot spots and access to 190,000 globally with roaming.[53]

Comparing cells sites and hot spots may be apples-to-oranges, but an analysis by HBSC from early 2010 compares hot spots and cell sites operated by major cellular service providers in a number of developed nations. HSBC argued that hot spots and cell sites are different forms of initial connectivity for the reasons noted above. However, the study shows a great deal of connectivity in both models, and the analysis was conducted before the biggest increase in offloading. Focusing on major wireless service providers only, with data through year end 2009, the ratio of hot spots to cell sites varied widely, from zero in Italy to five in Korea. In the U. S., counting only Verizon, AT&T and T-Mobile it stood at 0.4. Stated in another way, hot spots were

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[49] "A **hotspot** is a site that offers Internet access over a wireless local area network through the use of a router connected to a link to an Internet service provider. Hotspots typically use Wi-Fi technology. have come to refer to a number of different services." http://en.wikipedia.org/wiki/Hotspot_(Wi-Fi). Access to the Internet can be made available under a wide range of conditions. Public hot spots are referred to as locations where commercial establishments make access available to any member of the public either for free or for a fee. Community hotspots are available to all members of a community (e.g. universities). Cellular carriers use hot spots to deliver broadband traffic to their subscribers sometimes by controlling which spectrum (the exclusive licensed spectrum or unlicensed), sometimes allowing the subscriber to make that decision. There are two other approaches that are not generally included discussion of hot spots, but they do not differ a great deal from what is generally referred to as a hot spot. Some cellular carrier sell the right (and equipment) to set up personal hot spots. When consumers use a router to distribute broadband data to devices in the household, it is not generally referred to as a hot spot. Thus, there are four broad categories of hot spots – public, community, corporate and personal, which may be available with or without a fee, Since much hot spot activity is unbilled, use is highly decentralized, and under the control of different entities, it is difficult to measure the level of activity, even in the aggregate, with any precision.

[50] Benkler, 2011.

[51] Vonnagy, 2010b, "Wi-Fi hot spots have long been a staple of cafes and bookshops, but will see increasingly broad adoption among other retailers looking to provide a mechanism for customer engagement while in store where they have the most influence at the product location. Wi-Fi will serve as a foundation for mobile commerce and marketing applications due to its pervasive presence in consumer smartphones and the lack of adequate 3G/4G cellular data network coverage within many brick-and-mortar facilities."

[52] T-Mobile, 2011.

[53] ATT, 2011.

already almost 30 percent of the available initial connectivity hops for these three carriers.[54] The flood of data caused by mobile broadband was in its early stages, but the wireless carriers were already relying on unlicensed spectrum to provide a significant share of initial connectivity. In the year after the study AT&T increased its U.S. hot spots by 50%, Verizon embraced hot spots for its 4G network,[55] and KDDI in Japan launched a plan to quadruple the number of hot spots in that nation. The ratio would grow dramatically in the short-term for these service providers. There were also already a large numbers of hot spots operated by other, non-wireless providers.[56]

INTERMEDIATE INPUTS

Offloading Cellular Traffic

The unlicensed use model was successful even before cellular broadband Internet access had gained much traction in the marketplace but when cellular broadband became widely used, unlicensed use moved to the center of the mobile communications revolution because unlicensed access allowed more efficient use of scarce radio spectrum. In a sense, the most important intermediate input use of unlicensed spectrum is the offloading of traffic from the cellular network to the unlicensed space.[57]

Cellular providers simply could not handle the huge quantity of traffic that mobile Internet access generated without making massive investments in their own infrastructure.[58] Network operators found it less costly to offload traffic to bands reserved for unlicensed use than to build more towers and/or increase the number of cells in their networks.[59] Use of Wi-Fi devices to deliver data in the bands reserved for unlicensed use is such an attractive approach to utilizing spectrum that over one-third of the Internet bound mobile data traffic carried by the cellular licensed wireless carriers is offloaded to the unlicensed use bands and the percentage is expected to grow over the next decade.[60]

AT&T was the first of the major U.S. cellular service providers to embrace Wi-Fi. In the two years after AT&T embraced Wi-Fi in an effort to provision connectivity with the launch of the iPhone, its Wi-Fi connection grew four times as fast as cellular wireless industry messages.[61] In the three years that AT&T has been reporting hot spot connections, they have increased at an average, compounded annual rate over 270% and the rate of growth has been increasing or stable.[62]

ComScore.com estimated that 37 percent of smartphone traffic was offloaded by cellular carriers by mid-2011. While smartphones have increased their market share, other devices like

[54] The calculation if as follows hotspots = (.4/1.3) *100 = 100%.
[55] Goldstein, 2011; Maisto, 2011.
[56] http://www.hotspot-locations.de/?newlang=english
[57] Chapin and Lehr, 2011, p. 10, "In offloading, mobile devices remain registered on their home network, but when appropriate, transfer data for specific applications via the offload network. Normally mobile devices have a separate radio chip enabling them to communicate via the primary network and the offload network at the same time, which is a key difference from the roaming model. For example, smartphones are able to receive a phone call via a 3G network while transferring data over a Wi-Fi network. There is a strong synergy between infrastructure sharing via an offload network and spectrum sharing… Thus, there is much more spectrum available for the offload network than would be available for a CMRS class network capable of supporting roaming."
[58] Wirelesse2e, 2011.
[59] Juniper Research, 2011.
[60] *Wirelesse2e, 2010*,"Last 8-10 years have shown that Wi-Fi is the superior choice even with the very limited 2.4 GHz band. We estimate 30-40 % of wireless traffic is already carried over Wi-Fi in developed world where the wired infrastructure is more readily available. Majority of this offload is at home and this traffic grows to be a larger segment of overall traffic. Real Wireless/Ofcom report predicts at-home use will reach 58% of total traffic by 2013. When the office use is added, the total opportunity goes up to 85% of overall traffic."
[61] Cristi, 2010.
[62] Solsman, 2011; WNN, 2010.

tablets, laptops and consumer electronics still represent half of the Wi-Fi enabled devices sold. These other devices consume six times as much data and rely on Wi-Fi for a much larger share of their transmission (over 90 percent).[63] If these non-smartphone devices represent one-third[64] to one-half of all devices,[65] then unlicensed use spectrum carries about 80 percent of the traffic.[66] These estimates do not fully take into account business applications, which can make very intensive use of unlicensed use spectrum.

Intra-firm Communications and the Internet of Things

The intermediate use applications of unlicensed use bands are more varied and emerging, but they are still a substantial sector. Projections show that this application group will become widespread, with tens of billions of devices connected wirelessly in the decade ahead.[67]

> The Internet and wireless communications services have grown in recent decades into mass market infrastructure. Their on-going convergence holds the promise of a pervasive communications fabric that is always and everywhere accessible for everyone and everything that wants to communicate. With such a capability comes the prospect of widespread automation and real-time control of real-world systems, or equivalently, the cyber-real world convergence.[68]

> The Internet is growing up and lifting its gaze… the protean Internet technologies of computing and communications are rapidly spreading beyond the lucrative consumer bailiwick. Low cost sensors, clever software and advanced computing firepower are opening the door to new uses in energy conservation, transportation, health care and food distribution.[69]

Benkler (2011) considers a broad range of applications and focuses on the market shares between unlicensed use and exclusive licensed use models. He considers applications that fall into the two broad categories used here. In the mass market category, which Benkler calls mobile broadband, he reaches conclusions about the amount of activity that are similar to those set forth here.[70] In the intensive internal business category, he examines the unlicensed use and exclusive licensed use technologies being used in applications like smart grids and health care. The machine-to-machine/RFID applications involve asset management, access control, mobile payments and fleet management. As shown in Exhibit II-2 with the exception of fleet management, Benkler's

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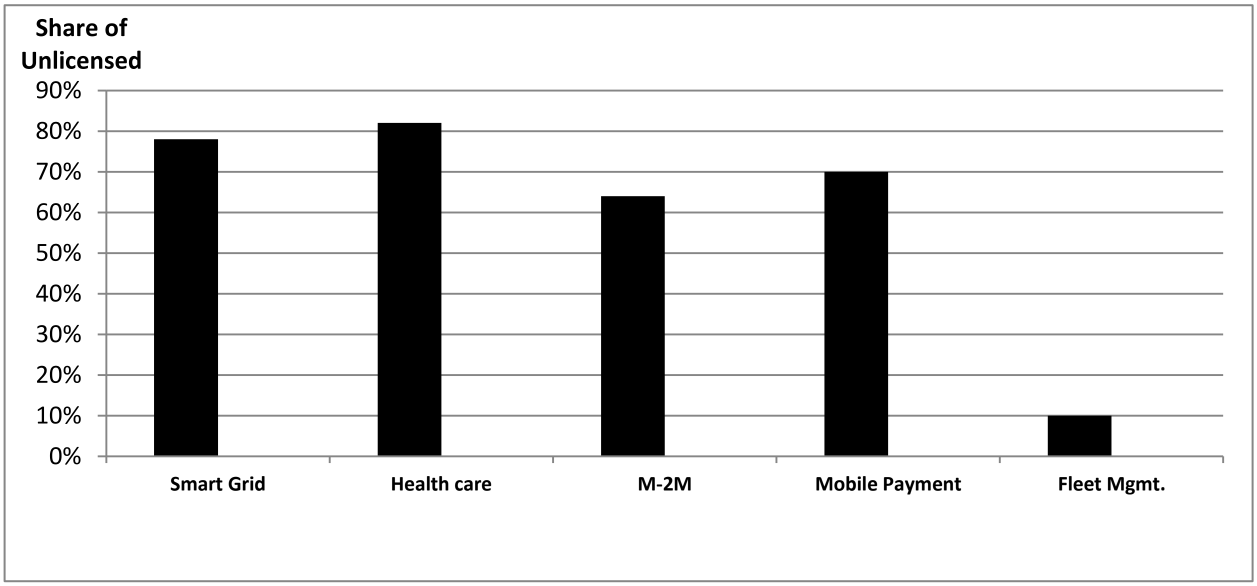
[63] Comscore.com, 2001, p. 6.
[64] ComScorce.com, 2011, p. 10.
[65] Wireless Broadband Alliance, 2011.
[66] The calculations are as follows:
For each category of device Multiply I x II x III = Device weighted cellular traffic.
For each category of device Multiply I x II x IV = Device weighted Wi-Fi traffic.
Sum cellular traffic
Sum Wi-Fi share traffic
Wi-Fi share = Wi-Fi weighted traffic/(Wi-Fi weighted traffic + Cellular weighted traffic)

Device Share	I Market Weight	II Data Weight	III Cellular Share	IV Wi-Fi Share	V=I*II*III Cellular Total	VI=I*II*IV Wi-Fi Total	VII= (VI/(VI+V))*100 Wi-Fi %
50/50 case							
Smartphone	.50	1	.63	.37	.315	.185	
Laptop/Tablet	.50	6	.10	.90	.3	2.7	
Total					.615	2.885	82.4
65/35 Case							
Smartphone	.65	1	.63	.37	.41	.241	
Laptop/Tablet	.35	6	.10	.90	.21	1.89	

[67] Rysavy, 2011a, p. 3, give the 10 billion figure. Portio, 2011, puts mobile payments alone at 1 billion connections by 2016, while Harbor, 2010, puts M2M connections at half a billion by 2014.
[68] Chapin and Lehr, 2010a, p.1,
[69] Lohr, 2011.
[70] Benkler, 2011, pp. 5-8

conclusion is overwhelmingly clear; the major of activity is taking place in the unlicensed use bands.

EXHIBIT II-2: SHARES OF UNLICENSED SPECTRUM IN INTERMEDIATE INPUT ACTIVITY



Sources and Notes:

Intermediate Inputs: Yochai Benkler, *Unlicensed Wireless vs. Licensed Spectrum: Evidence from Market Adoption,* 2011. Richard Thanki, *The Economic Value Generated by Current and Future Allocations of Unlicensed Spectrum,* Perspective, 2009, provides dollar estimates for health care and tagging in the retail sector.

Because the services are bundled and comingled, some measured, some not, some billed and some not, apportioning activity or, as we shall see in Section IV, value between them is inevitably imprecise. In fact, the take away from this analysis should be that the use and value are thoroughly interwoven and interdependent. Indeed, one author finds that as much as 80 percent of end user traffic that flows on the networks operated by cellular broadband carriers who have embraced unlicensed spectrum reaches the consumer with an initial Wi-Fi hop.[71]

[71] Iluna, 2011,"Generally speaking, those operators that have aggressively embraced a Wi-Fi offloading strategy, such as PCCW and AT&T Mobility, estimate that about 20 percent of their overall data traffic is riding over Wi-Fi networks…. and it's likely that another 60 percent is landing on home Wi-Fi networks now that the operator has instituted tiered data plans."

III. EFFICIENCY

THE IMPLICATION OF OFFLOADING FOR EFFICIENCY

In the case of the cellular embrace of Wi-Fi, necessity is the mother of acceptance.[72] The reliance on Wi-Fi is much more than just a convenience; it represents a fundamentally different approach to provisioning initial connectivity that some analysts believe is the inevitable long-term solution for wireless broadband communications. The key to the efficiency of offloading traffic onto unlicensed use spectrum as implemented by the FCC is the fact that all unlicensed use spectrum is available to all users all the time. This has the effect of making more available to every user, as long as interference is effectively controlled by the rules of sharing.

> Operators are already using Wi-Fi for effective data offload on their 3G networks. This is an excellent application of Wi-Fi because the technology can deliver much higher throughput in small coverage areas to more people than is possible with cellular technologies. Not only is there more unlicensed Wi-Fi spectrum available than the amount of spectrum licensed to any individual cellular operator, but since coverage areas are much smaller, frequency reuse is much higher, and thus there is more bandwidth available to each subscriber.[73]

Evaluating the impact of offloading of traffic involves a counterfactual analysis. What would the network have looked like if offloading had not been available as a strategy? Conceptually, the answer is simple. The wireless providers delivering high speed data service would have had to build many more cell sites, shrinking their size to support the huge increase in data flows. The industry would have been less efficient – the cost of service would have increased and demand decreased. How much difference would it have made? Broadly speaking, with one-third or more of the traffic being offloaded, the answer is, it would have made a big difference.

Providing a more precise answer involves assumptions, as suggested by Exhibit III-1. Exhibit III-1 shows the key data on subscriptions in two ways to highlight the analytic challenge. The top graph in Exhibit III-1 shows the number of cellular subscriptions and cell sites. Viewed in this way, the number of subscribers increased by over 85 percent from the end of 2004, when they started adding broadband service, until the middle of 2011. The number of cell sites grew at about half that rate.

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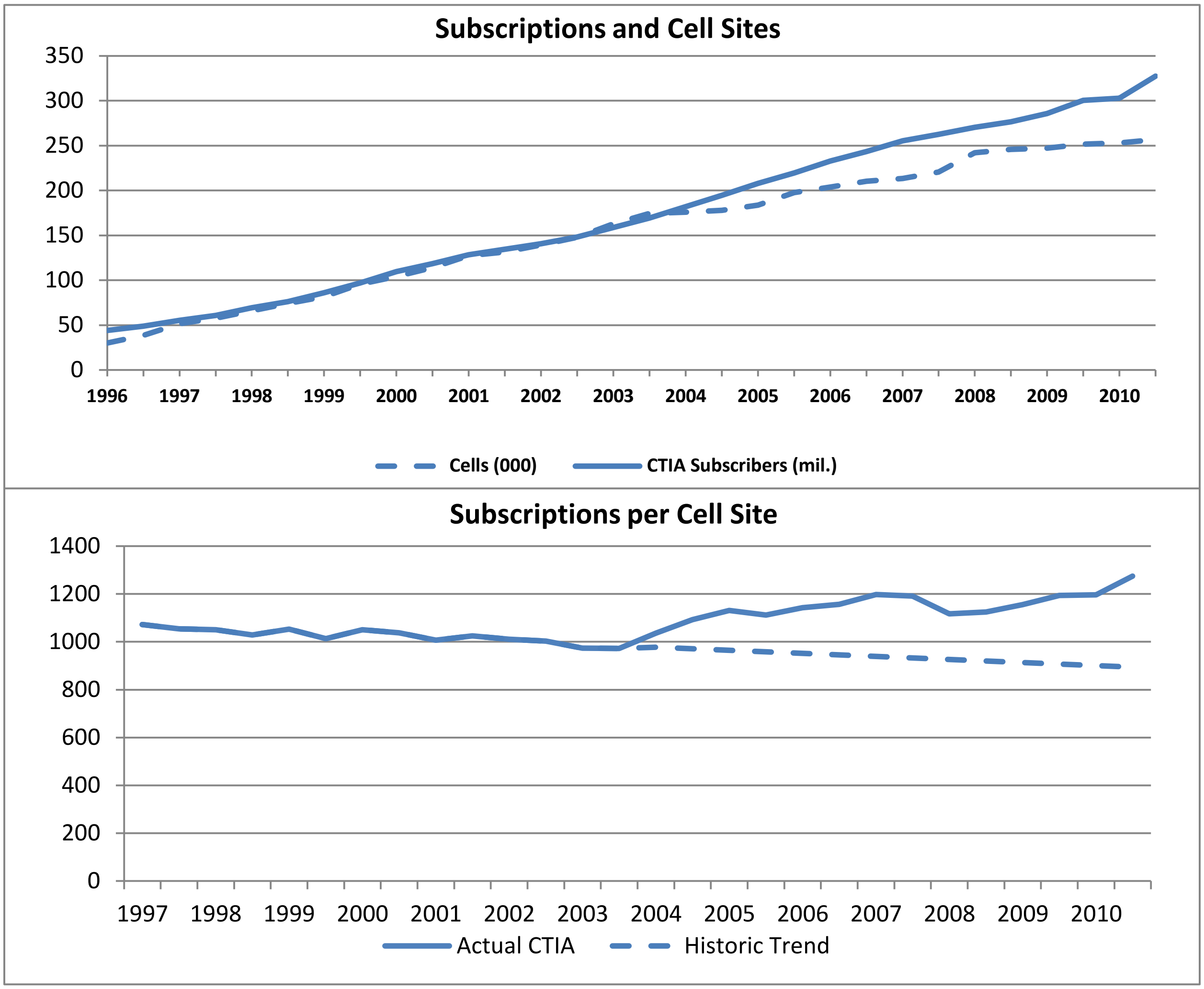
[72] Iluna, 2011. "[O]ffloading smartphone mobile data traffic onto Wi-Fi networks is becoming a key network requirement for operators around the world as they grapple with heavy data traffic. But interestingly enough, those operators that have embraced the offload concept have difficulty quantifying its ability to reduce 3G network congestion or solidly demonstrate its cost advantages. They just know it works…the effectiveness of offloading for PCCW and other operators is difficult to measure primarily because the data traffic doesn't all end up in the same place. It may bounce between the Wi-Fi connection and the 3G connection and end up terminating on the 3G network again. Moreover, operators cannot simply look at smartphone traffic traveling over Wi-Fi networks and conclude that the traffic would have moved over 3G had the hotspot not been available. The accessibility and the growing number of Wi-Fi enabled smartphones tends to drive up traffic on Wi-Fi networks. Not only does data traffic increase on Wi-Fi networks, but analysts say it drives up traffic on 3G networks as well." Wi-Fi has taken away congestion but generated more usage. But still, you need it," "Wi-Fi offload will become a crucial part of an operator's network. ... It would be challenging for operators to carry everything on their networks. "Wi-Fi causes people to use things they may not have otherwise," he said. "It may be generating more traffic, but it's likely taking more of that traffic off 3G. Wi-Fi offload is going to continue being part of the solution."

Woyke, 2011, "It would seem there is a relatively simple solution to the wireless data deluge faced by mobile operators: shift the traffic that is tying up their networks to Wi-Fi hotspots whenever possible… Wi-Fi is available and represents a cheaper alternative to cell connections… Forbes has learned that three of the four largest U.S. carriers are testing technology from Tel-Aviv-based startup WeFi that lets them point subscribers' smartphone to private and public Wi-Fi networks whenever practical.

[73] Rysavy, 2010b, p. 7; Lamberth, 2011, "White Space and the Internet of Things," *MSolve Partners Newsletter,* September 2011. TV stations and cellular network operators used their spectrum the most with 50-90% and 30-50% utilizations respectively on average. The rest of spectrum bands were occupied 25% of the time, or less, with 18 of the 32 bands studied averaging less than 10%. These results are similar to SSC's 2005 study finding similar low spectrum occupancy rates in Chicago and New York."

EXHIBIT III-1: GROWTH OF SUBSCRIPTIONS AND CELLS



Source: CTIA Semi-annual Industry Survey, 2011

The bottom graph in Exhibit III-1 shows the number of subscribers per cell site over this same period. It shows a sharp break in the trend even using the CTIA count of subscribers. The number of subscribers per cell site had declined steadily until the end of 2004, but then began to rise markedly. If the historic trend had continued, by 2010 there would have been 25 percent fewer subscribers per cell site. The analysis of the count of cell sites and subscriptions underestimates the burden that was being placed on the network. Broadband data subscribers use a great deal more bandwidth and the growth in the number of broadband subscribers in the past half-decade has been substantial. The need for cell sites and the resulting shortfall was much greater than the count of subscription indicates.

QUANTIFYING THE EFFICIENCY GAINS

This analysis highlights the fact that the estimate of the shortfall in cell sites hinges on the question of how broadband subscriptions affect the need for cell sites to handle their traffic. Since broadband subscribers and voice subscribers share some plant, it might be argued that adding broadband subscribers only increases the need for cell sites at the margin. On the other hand, broadband subscribers generate traffic that is several orders of magnitude greater than voice subscribers. From this perspective, one might argue that the marginal increase in cell sites to serve them is greater than the average. In other words, the addition of broadband pushes cellular wireless into a region of the supply curve that involves rising marginal costs.[74]

Perhaps the cellular providers thought that the new technology that used spectrum more efficiently would allow them to meet demand with fewer cells. In the period in which offloading became a prominent feature of the wireless broadband ecology, i.e. ten quarters from year-end 2008 to mid-2011, the industry added 15,000 cell sites. In the ten quarters preceding the offloading period, when the industry began to roll out wireless broadband service, the cellular providers added three times as many cell sites. The hope that new technology would be able to handle the flow of traffic proved incorrect, given the dramatic increase in data flow that came with broadband service.

By one estimate, users of smart phones, the most common connectivity device for accessing unlicensed use bands, generate over twenty times the traffic of the user of a standard handset ant tablets, the second most common type of connectivity device, generate over 100 times as much data.[75] The spectral efficiency gains of the new technologies being deployed to provision wireless broadband are in the range of 2 to 4 times, which are paltry compared to these increases in use. The historical trends of declining subscribers should have accelerated, not ended as these new services were rolled out.

Hallahan and Pena argue that service subscribers who use voice and data require almost 1.9 times as many cells, on average (2.1 times as many in rural areas, 1.8 times as many in suburban areas, and 1.7 times as many in urban areas, where the roll out of wireless broadband was most rapid over this period). Exhibit III-2 shows an estimate of the implications of offloading traffic by estimating the number of cell sites that would have been necessary to adequately provision the network. In order to just maintain the historic decline in subscribers per cell site, the cellular providers would have had to add 109,000 additional cell sites. Weighting wireless broadband subscriptions at 1.8 times other subscriptions (the suburban average); they would have had to add 130,000 cell sites.[76]

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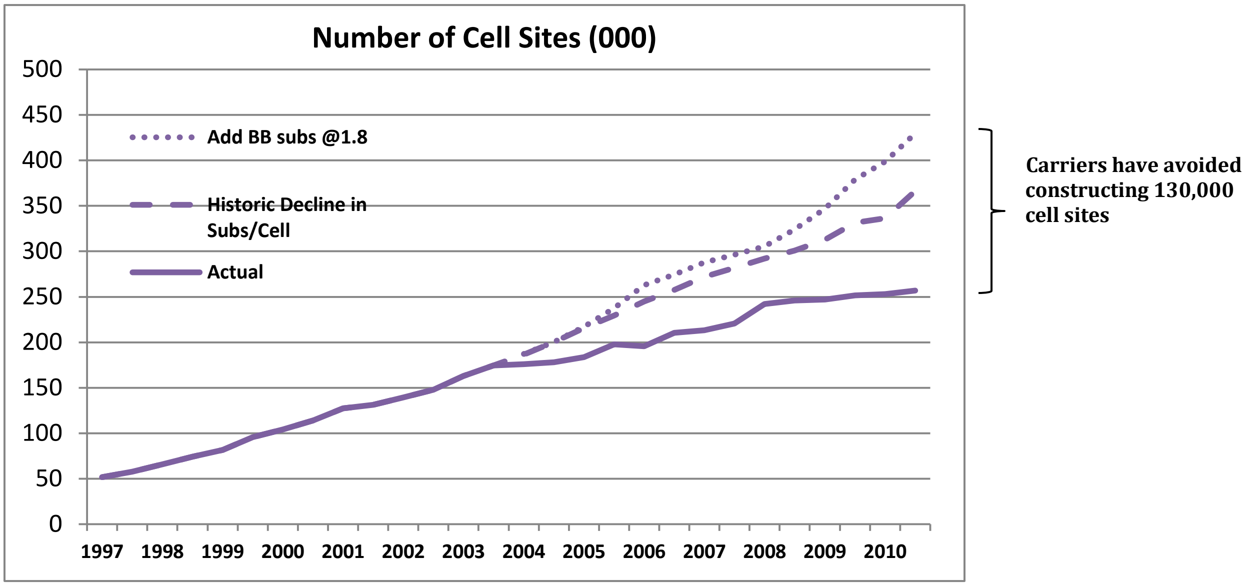
[74] Cooper, 2011, before 2004 there were very few mobile broadband subscribers and by 2008 AT&T, which had exclusive distribution of iPhones, was engaging in substantial offloading, It can be argued that a successful mobile sector required either many more cell sites or offloading of traffic onto unlicensed spectrum. The continued growth of mobile broadband appears to require both, given the amount of traffic that subscribers generate.

[75] Rysavy, 2011c, based on Cisco, 2011a; Leigh, 2011.

[76] A study by Dineen (2009) for HSBC suggests a similar level of need for additional cell sites, absent offloading. He constructed three scenarios. In the base case, without increasing cell density, the industry has a shortfall of capacity by 2012. The network is overwhelmed by the combination of more data subscribers and higher rates of data usage per subscriber. In the increasing cell density scenario, the industry is just barely able to keep up with demand until 2015 by increasing cell density by 35 percent. In the third scenario, he assumes both increasing cell density and 20% offload of traffic on unlicensed spectrum. The industry has more than adequate capacity. Dineen's analysis underestimated the growth of wireless data users by 50 percent. By 2011 cellular wireless broadband providers were already offloading almost 40 percent of their traffic. The network was under more pressure than Dineen projected, nevertheless his analysis provides insight into the number of cell sites that would be needed. Using the higher growth rate of data subscribers, but the same data usage rates, without offloading, the network would fall into deficit in 2010-2011 and 2011 usage already exceeds 2012 levels. The projected increases of cell densities in 2011 (23%) and 2012 (27%) needed to keep up with demand imply increases in the number of cell sites of 127,000 and 136,000 respectively. The earlier estimate of 130,000 cell sites seems reasonable.

EXHIBIT III-2:
EFFICIENCY GAINS THROUGH REDUCTION IN THE NUMBER OF CELLS



Notes and Sources:

130,000 cell sites derived by using capacity needed for a voice and data subscriber at 1.8 times the need for a voice-only subscriber based on the suburban estimate of Ryan Hallahan and Jon M. Peha, *Quantifying the Cost of a Nationwide Broadband Public Safety Network,* Carnegie Mellon University, Research Showcase, September 1, 2008. Richard Dineen, *The Capacity Crunch: What Can Mobile Telecoms Operators do as "Moore's Law Mobile" Breaks Down?* HSBC, December 8, 2009, estimates increases in cell density necessary to keep up with data traffic growth showing a deficit, without offloading by 2011. The rate of growth of broadband subscriptions exceeds his assumed growth by 50 percent. His projected increase in cell density needed to keep up for 2011(23%) and 2012 (27%) without offloading imply the need for 127,000 to 136,000 more cells.

Adding 130,000 cell sites to a network that previously spent 20 years to reach 256,000 sites would have been an immense challenge. It implies adding about twice as many cell sites in a shorter period than the industry had ever achieved. In Exhibit III-2, the rate of increase in cell sites needed to keep pace with demand after 2008 is greater than anything that had been achieved in the previous decade. It is safe to say that without offloading, the industry would have been smaller and service would have cost much more.

While one can debate how to count the broadband subscribers and how to price the cell sites, the exhibit makes it quite clear that the deployment of cell sites slowed dramatically in late 2008. In the ten quarters between December 2008 and June 2011, the industry added 15,000 cell sites. In the ten quarters before December 2008, the industry added 64,000 cell sites – over four times as many. The drop-off in the addition of cell sites coincided with the offloading of traffic onto the unlicensed use spectrum.

IV. VALUE

As we have seen, it is difficult to pin down the number of users and the amount of usage in the unlicensed space because of the complementarity of the uses of unlicensed spectrum and licensed as well as wireline broadband and the lack of attention to the usage of unlicensed spectrum. In the two previous sections we have presented best estimates of the economic performance of the unlicensed space in terms of physical quantities. Valuing that activity poses another layer of challenges and complexity. In this section we offer estimates of value based on the estimates of physical quantities. We take a similar approach to the estimation of value, finding real world referents for the value of the activities.

DEMAND -SIDE

Cellular providers bundle and manage access to unlicensed use bands in their wireless broadband offering so the value of access to exclusive licensed and unlicensed use spectrum is comingled. However, several of the major cellular service providers and some independent companies sell Wi-Fi access on a standalone basis. Monthly subscriptions run in the range of $10 to $20 and session charges are in the range of $2 to $8,[77] while daily fees at hotels, where Wi-Fi is not free, run $10 - $15.[78] Cellular providers sell the ability set up private hot spots for $15 to $30 per month. [79] Given that the price of a broadband data plan for a cellular wireless service is in the range of $20 to $50 per month and access to unlicensed spectrum is bundled in that price, these offerings suggest that the value of access to exclusive licensed and unlicensed use service is similar. At $20/month with 110 million users, the value would be over $26 billion per year.[80]

These estimates do not include hot spot activities, whose value could be substantial. For example, AT&T reported hot spot connections at an annual rate of about 1.2 billion in late 2011. While AT&T has been the most aggressive in using Wi-Fi for offloading, it only accounts for a fraction of the total traffic to hot spots, since so much hot spot traffic involves "unbilled" access in commercial establishments and community applications. Thus, AT&T's one-third share of broadband wireless subscribers probably overestimates its share of hot spot connections. With per session charges in the range of $2 to $4, it would be extremely conservative to put the value of hot spot connectivity at $10 billion per year and growing.[81]

AT&T and Verizon, the two largest retailers of wireless broadband service report that their wireless data revenues nearly doubled between 2008 and 2010, from $21 billion to $38 billion.[82] Since they represent about 70 percent of total mobile data traffic,[83] it is reasonable to put wireless data revenue at $55 billion.[84] Assuming 37 percent of the traffic is offloaded, this would suggest that offloading is carrying traffic that results in revenues of about $20 billion. This amount will grow dramatically in the years ahead. Recent predictions of a flood of video traffic moving onto wireless networks also predicts that Wi-Fi traffic will equal fixed Internet traffic and account for

---

[77] Web site visits to Boingo, AT&T, Sprint and T-Mobile.
[78] Web site visits and Clausing, 2011, Mailone, 2011.
[79] Nadel, "2011. "The Big Three national networks charge between $15 and $30 a month (on top of your data place fees) for allowing you to tether a notebook or tablet to you phone. Mobile hot spot technologies can access both exclusive licensed and shared use bands."
[80] An average of $20/month would reflect a combination of monthly subscription values at $10-$20, single monthly buys (up to $50/month) daily buys at $10 and session buys in the range of $2-$8.
[81] The calculation is as follows: ATT count of 1.2 billion times 3 = 3.6 billion connections at average value per session of $3 ($2+$4/2) = $10.8 billion.
[82] Based on 2010 annual reports.
[83] FCC, 15th Annual Report on CMRS
[84] Higinbotham, 2011a.

three times as much traffic as cellular licensed wireless Internet traffic in half a decade.[85] Milgrom, et al. use a similar estimate of the total value of data traffic, but attributes 50 percent to unlicensed use for a value of $25 billion.[86]

The estimate of the value to mass-market users is generally embedded in billed services and not actually billed on a stand-alone basis. They are grounded in quantities and revenue flows that are observable in the marketplace for a small set of end-uses (defined by broadband connections). They indicate unlicensed use generates as much value as exclusive licensed. Others have attempted to estimate more aggregate measures of value or consumer welfare.

Thanki estimated the consumer surplus associated with in-home Wi-Fi was between $4.3 and $12.7 billion.[87] The estimate rests on the assumption that there were 38 million Wi-Fi users in the United States. The range of values results from a low end assumption that Wi-Fi accounts for 10% of the value of broadband, while the high end results from the assumption that 30% of the value of broadband results from Wi-Fi. The per monthly value is in the range of $9.50 and $27.60, which is in the range of the charges for standalone Wi-Fi. The 30% figure is consistent with the offloading of traffic. Thanki pointed out that he expected those figures to rise dramatically by 2014, perhaps increasing six-fold, if the increase in the number of devices was taken into account. Moreover, there are many other activities that end users engage in. [88]

In fact, in just two years, the number of Wi-Fi users has increased dramatically and is already about three times as high as when Thanki made his estimate. The earlier estimate of 110 million is close to three times the figure used by Thanki and the offloading of traffic has grown dramatically since his estimate as well. With three times as many subscribers, a range of values based on Thanki's per user estimates would now be $13 billion to $38 billion. Moreover, given the increase in traffic since Thanki's estimate and the increase in offloading, it is likely that his estimate that Wi-Fi accounts for 30% of the total value of broadband is a quite conservative estimate for today. Thus, the $38 billion figure is a conservative estimate for the current market. With offloading at 37%, the value would be $74 billion. This is a consumer value figure for total in home Wi-Fi usage. Some of it is explicitly bundled in broadband packages; much of it is not billed.

Thanki also provided two examples of the value of intermediate inputs – intensive wireless communications in hospitals that rely on unlicensed use spectrum and the use of RFID chips in the retail clothing sector. These two are forward looking analyses that are examples of the possible application of unlicensed spectrum technologies. He estimates costs savings in the range of $12 to $24 billion. Many other sectors could achieve similar savings. Benkler discusses the activity in this space in terms of market shares[89], not the value of output, but his discussion suggests that the activity in many areas is as robust as it is in the two discussed by Thanki. Thus, the $24 billion is a low estimate of economy-wide value.

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[85] Roetgers, 2011; FCC, 2010

[86] Milgrom, et al., 2011.

[87] Thanki, 2009, p. 27.

[88] Thanki 2009, p. 27, "This analysis only accounts for the value that consumers might place on the ability to use broadband wirelessly. However, there are a number of other uses for a home Wi-Fi network. These include online gaming using consoles, the ability to stream rich media content and large files around the home and increasingly that of home automation and smart metering applications. Furthermore, many of the applications increasingly being downloaded and used on smartphones are restricted for use only over Wi-Fi networks, so as not to overburden cellular carriers' 3G data networks. Therefore these results are likely to represent a strict lower bound for the value of Wi-Fi in homes. This analysis also does not capture a more structural effect, that the shift of the PC market towards laptops and the convenience they bring has also been facilitated by the availability of Wi-Fi."

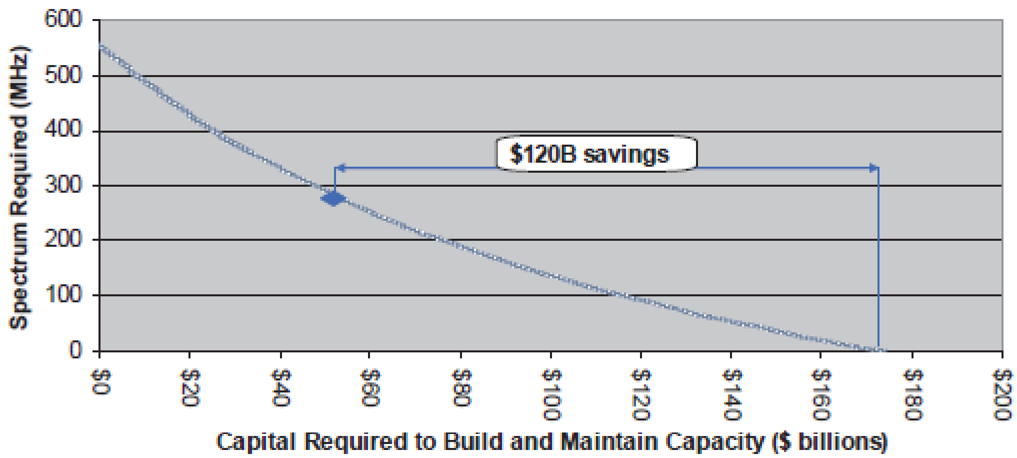
[89] Benkler, 2011.

SUPPLY-SIDE

Valuing the efficiency gains discussed above requires us to put a price tag on 130,000 cell sites that were avoided by offloading. The FCC has recently provided a framework with which to do so. In assessing the prospects for provisioning cellular networks to meet future demand for wireless broadband service, it hypothesized an indifference curve between capital investment and spectrum. Cellular providers could add capital – i.e. increase the number of cell sites – or use more spectrum and fewer sites. The FCC analysis describes the implications of Exhibit IV-1 as follows:

> The blue diamond represents the point on the indifference curve corresponding to the … site growth assumption… This represents capital investment by the mobile broadband industry of $54 billion in addition to the 275 MHz of additional spectrum. The curve implies that if no additional spectrum is released, the cost to build enough capacity sites to handle the demand will be $174 billion. The difference between these costs represents the value created by additional spectrum in 2014, which is $120 billion. [90]

Exhibit IV-1: Capital vs. Spectrum Indifference Curve - 2014



Source: Federal Communications Commission, *Mobile Broadband: The Benefits of Additional Spectrum,* OBI Technical Paper No. 6.

The exact same logic can be applied to unlicensed use spectrum. To the extent that cellular providers have substituted unlicensed use spectrum for investment in cell cites "these costs saved represents value created" by the use of unlicensed spectrum. The FCC used a cost per cell site of $500,000. This is the same cost used by Hallahan and Pena. While the FCC considered lower costs, a case can be made that the cost of that many cell sites, particularly concentrated in urban areas where traffic is heaviest, is too low. Building sites for a large number of cells (130,000) becomes more and more difficult and expensive to construct, especially in high density urban areas, where they are needed most. [91] Fiber backhaul costs increase, as well.[92]

---

[90] The FCC estimates of cell sites needed to meet demand in next half decade assumes the average growth rate of the period of adoption of broadband, but this rate of growth was far too low to support the expansion of traffic, absent the availability of shared use bands.

[91] Rysavy 2010a, p. 7, "Moreover, a critical problem is that in most urban areas, the ability to add additional towers is very limited, either due to the fact that carriers already have reached capacity in terms of the number of cell sites that an area can support from a practical implementation perspective, or because local zoning restrictions make it unrealistic to add sufficient towers to provide relief."

[92] Chapin and Lehr, 2011, p.5," The primary competitive strategy to cope with insufficient spectrum holdings is thus to split cells, which means building new cell sites that infill existing covered areas. This improves the spatial reuse of existing spectrum allocations and increases capacity. Unfortunately this strategy increases infrastructure costs per square kilometer covered. Another effect

The capital expenditure for 130,000 cell sites would be $65 billion based on a cost per cell of $500,000. Converting this to an annual charge at a cost recovery factor of 20 percent yields an annual cost of $13 billion. Operating costs would go up as well. These are generally put at 20 percent of capital expenditures.[93] Thus, the 130,000 cell sites would result in annual costs of $26 billion. Moffett (2011) has recently provided estimates of the cost of deploying a Wi-Fi network for an incumbent broadband wireline network operator. He models the incremental cost to a cable company in a large urban area, Cablevision in New York. Scaling Moffet's estimate up to the 120 million homes passed in the United States, the capital cost would be about $7.5 billion. Using the same cost recovery ratio of 20%, the annual capital recovery would be $1.5 billion. Operating costs scale up to $.5 billion. The order of magnitude cost advantage of Wi-Fi (one-thirteen the cost of adding cells) provides a compelling explanation for the decision to offload so much traffic into the unlicensed spectrum.

There are two take-aways from this exercise. First, there is no doubt that the cellular providers saved a great deal of money by offloading traffic. That cost would have shown up in consumers' bills. Second, as suggested by the efficiency analysis above, the long-term solution to the traffic problem must involve a mix of approaches to first mile provisioning. Just adding more cell sites will not do get the job done. There is not enough space to keep adding cell sites in these numbers in urban areas where the vast majority of end-users reside. Thus, this range of the projected need for cell sites, absent offloading of traffic, big as it is, may be too low. At a minimum, it reinforces the observations offered above that the unlicensed use spectrum must be a core element of the future industry if data transmission is to grow at anywhere near the rate it has in the past, not to mention the extremely high rates that have been projected of the future.

THE VALUE OF UNLICENSED ACTIVITY IN PERSPECTIVE

To put these estimates in perspective, with 84 million subscribers at year-end 2010 paying on average of about $40 per month, the total monthly revenue for wireless broadband would be about $40 billion per year. Since Wi-Fi is bundled, part of its value reflects the value of Wi-Fi access. Moreover, the estimates of value calculated above involve consumer cost, consumer surplus and producer surplus. Therefore, it becomes difficult to compare the values precisely. However, Thanki's observation seems appropriate: "Using only a fraction of the spectrum, the value derived from unlicensed usage may even become comparable to that generated by licensed usage as the number of unlicensed applications continues to proliferate"[94] That prediction has probably already come to pass.

Exhibit VI-2 depicts this discussion of value in several ways. The top graph provides two estimates of value for end-users. One estimate is based on the value that appears to be bundled in the monthly bills for broadband service. We estimate the value of unlicensed activity by pricing the amount of activity at the level for which it could be purchased on a standalone basis. We show the value of offloaded traffic as 37 percent of the total value of wireless subscription, which is the minimum estimate of offloading. The second set of estimates in the top graph is consumer surplus

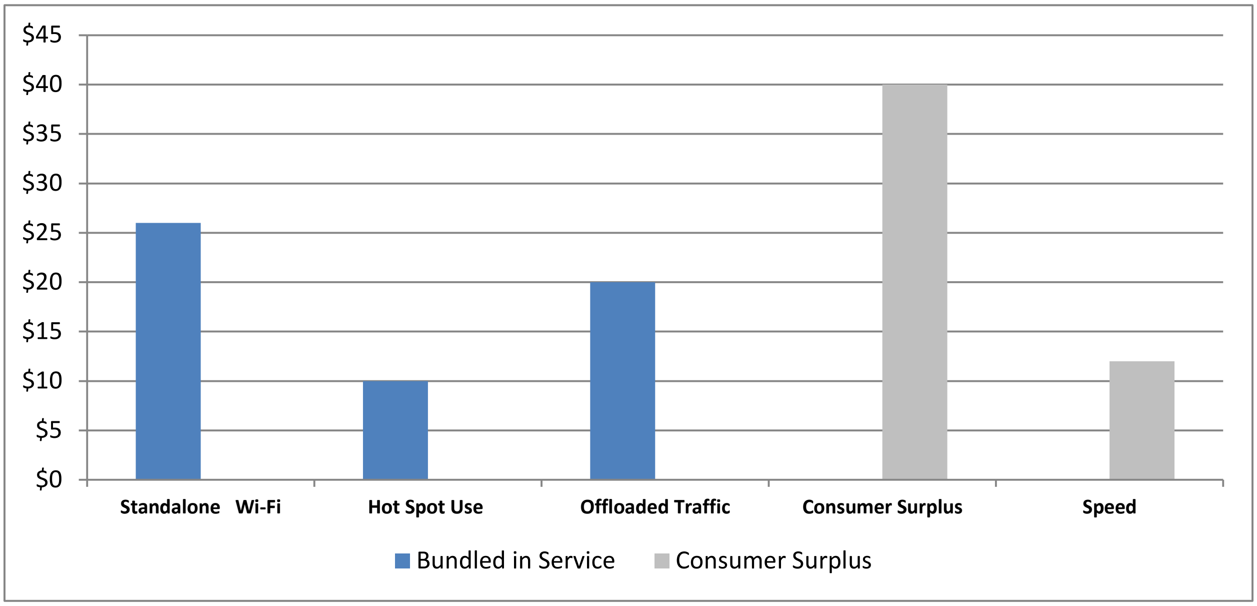
increasing infrastructure costs is the high backhaul requirements of the base stations for high-grade mobile broadband service. In most markets, fiber optic backhaul is required to provide the envisioned mobile broadband quality of service. Thus there will need to be significant investment in fiber plants supporting the base stations."

[93] Hallahan and Pena, 2008.

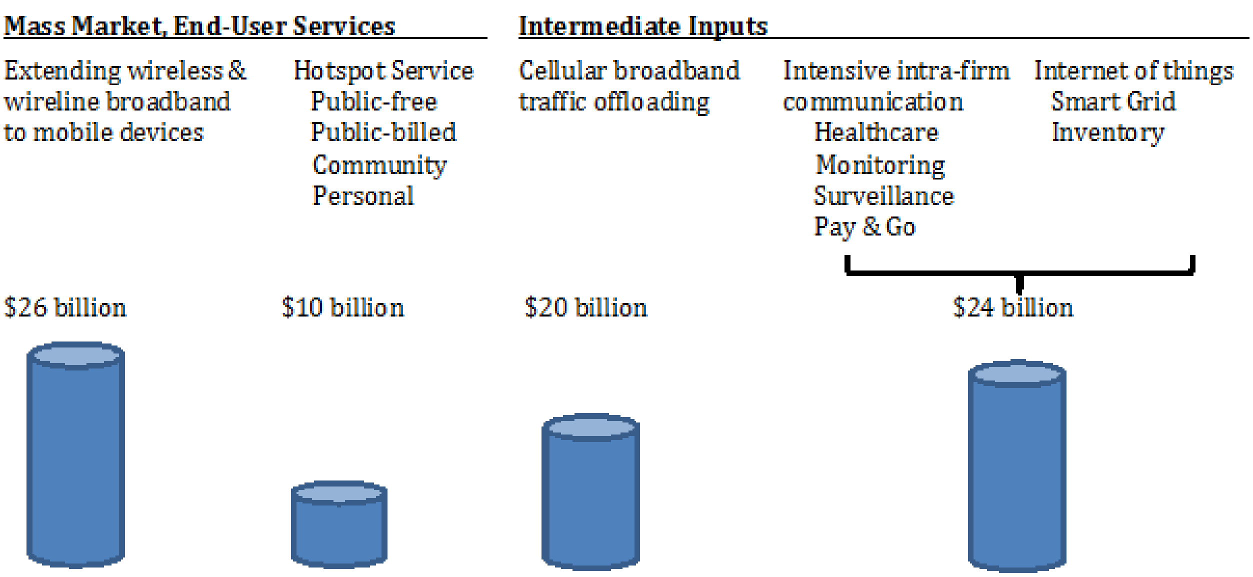
[94] Thanki, 2009, p. 35.

EXHIBIT IV-2: ANNUAL VALUE OF ACTIVITY IN UNLICENSED SPECTRUM (YEAR-END 2010: BILLION)

Mass Market, End-User Value and Surplus



Across Services and Functionalities



Sources and Notes: Wi-Fi standalone value is calculated as 110 million users are $20 per month value based on charges for standalone Wi-Fi services (as advertised in web sites of Boingo, AT&T, T-Mobile). Most cellular providers bundle Wi-Fi with cellular broadband subscriptions. Hot Spot Connectivity estimated by scaling up AT&T 1.2 billion per year to 3.6 national total valued at average per session charge of $3. Consumer surplus is from Richard Thanki, *The Economic Value Generated by Current and Future Allocations of Unlicensed Spectrum,* Perspective, 2009 (adjusting his 30% scenario for the current level of broadband subscribers). Speed is from, Paul Milgrom, Jonathan Levin and Assaf Eilat, *The Case for Unlicensed Spectrum,* October 12, 2011). Intermediate Inputs from Richard Thanki, *The Economic Value Generated by Current And Future Allocations of Unlicensed Spectrum,* Perspective, 2009 and Yochai Benkler, *Unlicensed Wireless vs. Licensed Spectrum: Evidence from Market Adoption,* 2011.

There is certainly overlap between the estimates and the consumer surplus numbers include a significant amount of value that is not reflected in the purchase prices of the underlying services. Nevertheless, a figure of $50 billion per year in 2010 seems reasonable for the value of activity in the unlicensed spectrum and that figure is likely to grow dramatically in the near term, as more data flows.

A figure of $50 billion, based on the price/use of services would give unlicensed spectrum a major role in the broadband data space. Monthly charges for wireline broadband average slightly less than $50 per month. In other words, monthly subscription charges for both wireline and wireless total are somewhat less than $100 billion. Since unlicensed adds value to both of those underlying services by extending them to mobile devices, as well as creating unique value in other services, one could conclude that unlicensed is at least an equal partner in the overall value of the broadband data space.

V. INNOVATION

In order to deliver all the services discussed above and carry the immense amount of traffic that has been offloaded onto unlicensed use bands, a great deal of technology had to be developed and deployed in a short period of time. This goes to a fundamental focus of economic policy – the ability of a model to stimulate innovation. There has been an intense debate over which model, licensed or unlicensed, is better at innovation for over a decade. Measuring innovativeness is at least as challenging as measuring the value of economic activity in a space where no centralized organization is charging for it, but it can be done by comparing what innovations have taken place and how significant they are.

In fact, Faulhaber and Faber, two vigorous opponents of the unlicensed use model, have argued that the exclusive licensed model fosters innovation, arguing as follows:

> In spite of this scarcity of spectrum, carriers have been able to utilize this resource with ever-increasing efficiency to offer more voice services and more recently data service over mobile phones.
>
> Innovation in the core network therefore can be conceived as *increasing spectral efficiency.* Increased spectral efficiency is manifest as increased capacity to make voice calls and increased speeds by which our phones access the Internet, download our e-mail and allow us to watch video on our handsets, based on the very limited resources of spectrum...
>
> Innovation in core networks often takes the form of standard-setting, as new means of using the carrier's spectrum must be accompanied by new devices, and device manufacturers must have standards to which they build their handsets or else they won't work on the network. Therefore, we often see core network innovation manifest in an alphabet soup of protocol initials: CDMA, GSM, WiMax, 3G, 4G, EV-DO Rev A, HSPDA, UMTS, and LTE, to name a few.[95]

STANDARDS AND DEVICES

The authors then present a table including technologies that enhance "System Spectral Efficiency of Selected Network Standards" sourced from Wikipedia. As shown in Exhibit V-1, it is an impressive list. However, Wikipedia also provides a list of standards developed for the unlicensed use model under the 802.11 protocol. It is just as impressive, if not more so.

The authors also identify the development and sale of devices as an indicator of innovativeness, listing two dozen that have been deployed. The list involves more adoption than innovation, mostly individual examples of existing technology adopted by a series of companies. Most of the devices were dual mode, so that to the extent it tells us something about innovation, it provides evidence that both models work.

Devices are the focal point of the unlicensed use model as implemented by the FCC, so we should expect it to have a large advantage in this measure of output. Exhibit V-1 reinforces the conclusion that the unlicensed use model stimulates at least as much innovation in the device space. Devices were discussed above in terms of certification and an overall count in the United States. The Wi-Fi Alliance lists thousands of devices available from hundreds of companies in a dozen different categories. While some of the larger manufacturers produce devices for both the unlicensed use and the exclusive licensed space, there are hundreds of smaller companies that

[95] Faulhaber and Farber, 2009, pp. 8-9.

serve only the unlicensed use market. [96] The categories of devices in the unlicensed column represent hundreds of companies and thousands of devices.

EXHIBIT V-1: INNOVATION IN UNLICENSED USE AND EXCLUSIVE LICENSED USE SPECTRUM: STANDARDS AND DEVICES

EXCLUSIVE LICENSED USE

Standards Released

2G – GSM 1993

2.75G- GSM+EDGE
3G – CDMA 2000
3G – 1x EV-DO Rev A
3G- WCDMA
3.5g – HSPDA
WiMAX – IEEE 802.16
4G – LTE

Major Handsets Launched

6/29/07 AT&T Apple iPhone
11/19/07 VZW LG Voyager
4/1/08 Sprint SamsungInstinct
7/10/08 Apple iPhone 3G
7/11/08 AT&T HSDPA iPhone 3G
9/23/08 T-Mobile Android G1
10/21/08 AT&T Samsung Epix
11/4/08 AT&T Blackberry Bold
11/20/08 Sprint HTC Touch Diamond
11/21/08 VZW Blackberry Storm
2/24/09 AT&T Matrix Pro
2/26/09 VZW LG Versa
3/2/09 Sprint Palm Pre
4/1/09 MetroPCS Samsung Finesse
7/13/09 VZW & Sprint Blackberry Tour
9/21/09 Cellular South HTC Hero (Android)
EOY 2009 LG Watch Phone

Sources:
Gerald R. Faulhaber and David J. Farber, *Innovation in the Wireless Ecosystem: A Customer-Centric Framework* (2009) for exclusive license standards major handset launches; Wi-Fi Alliance, Wi-Fi Certified Products, http://www.wi-fi.org/certified_products.php for Wi-Fi-enabled devices

UNLICENSED USE

IEEE 802.11-1997: WLAN standard originally 1 Mbit/s and 2 Mbit/s, 2.4 GHz RF and infrared (IR) standard (1997),
IEEE 802.11a: 54 Mbit/s, 5 GHz standard (1999
IEEE 802.11b: Enhancements to 802.11 to support 5.5 and 11 Mbit/s (1999)
IEEE 802.11c: Bridge operation procedures; included in the IEEE 802.1D (2001)
IEEE 802.11d: International (country-to-country) roaming extensions (2001)
IEEE 802.11e: Enhancements: QOS, including packet bursting (2005)
IEEE 802.11g: 54 Mbit/s, 2.4 GHz standard (backwards compatible with b) (2003)
IEEE 8702.11h Spectrum Managed 802.11a (5 GHz), European compatibility (2004)
IEEE 802.11i: Enhanced security (2004)
IEEE 802.11j: Extensions for Japan (2004)
IEEE 802.11k: Radio resource measurement enhancements (2008)
IEEE 802.11n: Higher throughput improvements using MIMO
IEEE 802.11r: Fast BSS transition (FT) (2008)
IEEE 802.11w: Protected Management Frames (September 2009)
IEEE 802.11y: 3650–3700 MHz Operation in the U.S. (2008)

Examples of Certified Wi-Fi-Enabled Devices: (Hundreds of companies/Thousands of Devices)

Networking Equipment - Access Point/Router
Access Point for Home or Small Office (Wireless Router) Enterprise Access Point, Switch/Controller or Router Mobile AP
Networking Equipment - Gateway
Cable, DSL or Other Broadband Gateway (Integrated Home Access Device)
Consumer Electronics - Cameras
Digital Still, Portable Video, Networked Web
Consumer Electronics - Audio Devices
Digital Audio - Stationary (speakers, receiver, MP3 player)
Digital Audio - Portable (MP3 player)
Consumer Electronics - Video Devices
Set Top Box, Media Extender, Media Server
Display Device (eg. television, monitor, picture frame)
Consumer Electronics - Gaming Devices
Game Console or Game Console Adapter
Gaming Device - Portable
Consumer Electronics - Storage and Servers
Media Server or Media Adapter
Network Storage Device (networked hard drive)
PCs and Computing Devices - Adapter Cards
External, Internal Wi-Fi Adapter Card
PCs and Computing Devices - Computers and PDAs
Laptop Computer, Ultra-mobile PC, PDA
PCs and Computing Devices - Printers
Printer or Print Server (includes scanner and fax)
Voice-Capable Devices - Phones
Phone, dual-mode (Wi-Fi and cellular)
Phone, single-mode (Wi-Fi only)
Smartphone, dual-mode (Wi-Fi and cellular)
Smartphone, single-mode (Wi-Fi only)
Other
Barcode Scanner

[96] Wi-fi alliance, web site.

NETWORK TECHNOLOGIES AND APPLICATIONS

Faulhaber and Faber also list a series of announcements of roll outs of technologies by individual carriers. One-third of the listed "innovations" are announcements about technology that will be adopted, rather than actual adoption or innovations. There are fifteen entries but only four technologies. These are simply the standards listed in Exhibit III-3 being deployed by cellular carriers.

A systematic comparative look at network technologies and applications reinforces the conclusion that the unlicensed model has performed at least as well as, likely better than, the licensed model (as shown in Exhibit V-2). Thanki provides a comparative analysis of the timing of major technology deployments and introduction of applications Once again, it is clear that the unlicensed use model is at least as effective as the exclusive licensed model. Thanki defines the innovations in applications as follows:

> Incremental innovation involves small steps, something that is a minor improvement to an existing solution. Small steps have taken Gillette from one razor blade, to two, three and now five glades.
>
> Radical innovations take big steps, creating major improvements that are often very different to existing solutions. Cloning 'Dolly" the sheep qualifies as a radical innovation – it was a first and it was certainly a breakthrough.
>
> Revolutions happen when groups of these innovations can together cause a huge, far-reaching impact. The computing revolution was achieved because of thousands of new technologies including the microprocessor, the telephone and the television. Globalisation, the Human Genome Project, and the Lunar Landing would not have been possible without it.[97]

EXHIBIT V-2: INNOVATION IN UNLICENSED AND EXCLUSIVE LICENSED SPECTRUM: TECHNOLOGIES AND APPLICATIONS

	EXCLUSIVE LICENSED USE	UNLICENSED USE
Network Technologies		
Digital Spread Encoding	1991	1988
Spread Spectrum	1995	1988
OFDM	2006	2001
MIMO/Adaptive Beamforming	2008	2004
Applications:		
Radical	Precise global positioning	Precise urban positioning Real-time location
	Wide area networks	Local area networks/wireless broadband
	Satellite based Communications	Novel wireless connectivity (critical device monitoring, monitoring and control in adverse environments) Automatic building control Wireless sensor networks
Incremental	Mobile TV	Personal area networks/Cable replacement (computer mice, keyboards, printers, head sets, headphones
	Services, texting, picture messaging, video calling, secure mail	Contactless payment Supply chain improvement
	Data over broadcast Networks (subtitling & video text)	Consumer electronics (Wi-Fi radio, STBs Identification (RFID - Humans, Animals, Goods) Remote controls

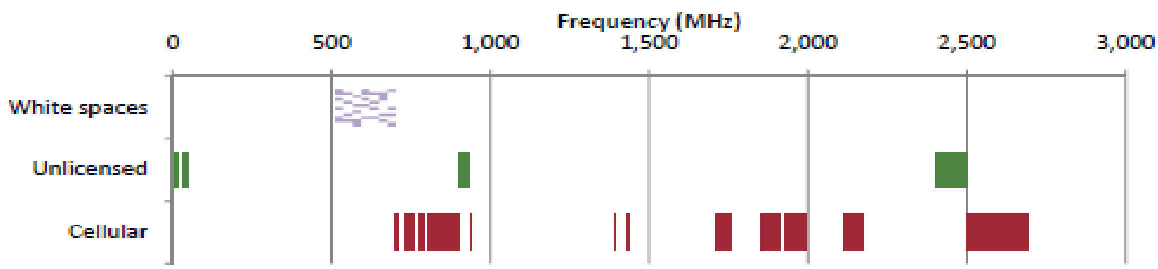
Sources:
Richard Thanki, *The Economic Value Generated by Current and Future Allocations of Unlicensed Spectrum,* Perspective, 2009, pp. 37-39).

[97] Thanki, 2009, p. 38.

MAKING THE MOST OF SCARCE SPECTRUM RESOURCES

Interestingly, Faulhaber and Faber point out that the cellular industry has achieved its success "in spite of a scarcity of spectrum."[98] Compared to the amount of spectrum used by broadcasters that complaint rings true. However, compared to the amount of spectrum set aside for unlicensed use, it does not, certainly not with respect to high-quality spectrum. Exhibit V-3 shows the relatively small amount of spectrum in the 500 MHz to 1 GHz range set aside for unlicensed use. Even up to 3 GHz, the challenge of "spectrum scarcity" has been much greater for the unlicensed use model than the exclusive licensed model.

EXHIBIT V-3: COMPARISON OF SPECTRUM AVAILABLE FOR LICENSES AND UNLICENSED BELOW 3 GHZ



Source: Richard Thanki, *The Economic Value Generated by Current and Future Allocations of Unlicensed Spectrum,* Perspective, 2009, pp. 37-39).

The opportunity to share white spaces is depicted differently in the graph because the users who will share the white space do not occupy the entire broadcast spectrum. The sharing users are required to give deference to the licensees and in major metropolitan areas, they may be limited to just a couple channels. Moreover, even this limited opportunity is very much at risk based on proposals pending in Congress.

The paucity of spectrum made available for wireless, communications, particularly unlicensed use, has become a potentially critical constraint on future expansion of activity and the ability of the economy to generate trillions of dollars of value discussed in Section IV.

Thanki's description of the success of unlicensed underscores the dramatic difference in the success of unlicensed, given the immense amount of activity taking place in "narrow slivers" of spectrum.

> [W]e saw the wide uses to which unlicensed applications are being put in the consumer, commercial, industrial, educational, healthcare and governmental sectors. In each of these sectors there are thousands of equipment manufacturers and system integrators creating new products and services, and thousands of buyers exploring new ways in which they can use wireless devices. This market interplay is the origin of the innovations in unlicensed spectrum…
>
> This level has been achieved in a short-time scale. It has been less than 25 years since the FCC permitted the use of communications devices in unlicensed ISM spectrum. Furthermore, this innovation has taken place in a limited amount of spectrum…. The substantial levels of economic benefit and innovation that are delivered by unlicensed usage of spectrum… has been largely achieved using narrow slivers of low frequency spectrum, or larger allocations of higher frequency spectrum. However, there is no larger allocation of spectrum for unlicensed usage between

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[98] Faulhaber and Farber,2009, p. 8.

100MHz and 1GHz, spectrum which has excellent characteristics in its ability to carry broadband data and in its ability to penetrate walls and other obstacles using low transmit power. This may have adversely affected the development of longer-range, more reliable and ultra-low power unlicensed applications requiring high data rates[99].

[99] Thanki, 2009, p.44.

VI. FUTURE PROSPECTS AND CHALLENGES

THE POTENTIAL VALUE OF FUTURE MOBILE COMMUNICATIONS

Given that there is a substantial potential increase in penetration of mobile broadband and numerous applications that have only begun to penetrate the marketplace, there would appear to be a great deal of potential expansion in the sector. In fact, there is a broad consensus that the potential value is immense.

Consider the view of a group of broadcasters, led by Sinclair, a broadcaster that probably holds more exclusive licenses to high-quality spectrum than any single commercial entity. Their proposal implicitly admitted that TV broadcasting is an inferior use of the spectrum.[100] They estimated that repurposing the spectrum could result in additional economic activity of more than one trillion dollars over a 15-year period.[101] They want the federal government to allow them to take on the role of landlord. They will rent the spectrum out to other users and pass a small fee – 5 percent – back to the government.[102]

Advocates of auctioning spectrum for exclusive licenses argue that auctioning 120 MHz of high-quality spectrum would generate about $40 billion. [103] They also argue that the value spectrum yields to exclusive licensees is 10 to 20 times larger than the price they will pay for it at auction.[104] This suggests value to the cellular carriers of $400 to $800 billion. The FCC wants to make 2.5 times that amount of spectrum available, which suggests potential value in the range of 1 to 2 trillion dollars. This estimate of the value of spectrum in excess of the price it would fetch in auction is corroborated by another calculation that these authors make, one which provides into the current policy context. The high quality spectrum that is the target of the current bandwidth frenzy of the cellular providers is all subject to broadcast licensing. Current proposals to auction that spectrum envision paying the broadcasters to move their signals. By using new technologies that are more efficient in the use of spectrum, they can deliver the same service with less spectrum, which will free up spectrum for repurposing. The economic cost of moving the TV broadcasters is put at $1 billion.[105] The transaction cost of getting the broadcasters to agree to move, to buy out their licenses, is put at $15 billion.

Europe has witnessed an interesting debate over how to capture the potential value of high quality spectrum. Two equipment manufacturers (who expect to sell a lot of network equipment) have argued to EU regulators that allowing exclusive licensees to manage the sharing of their spectrum (which they call Authorized Shared Access) would increase the output of the spectrum by over $100 billion per year. [106] Over a 15-year period, the value would be just over $1.5 trillion. Advocates of unlicensed have countered by proposing two new approaches to utilizing the

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[100] Miller, 2011.

[101] The initial estimate indicated a stream of value of about $2.5 trillion over 15 years. The estimate was later cut in half for political reasons (Miller, 2011, Jessell, 2011). The plan was prepared by Rajiv, 2011.

[102] Whether they should be the trustees of this value and play the landlord role is unclear, to say the least. Broadcasters have no particular organizational competence to perform the role of wireless landlord. They do not develop, deploy or manage two way communications technology, not to mention manage a complex space with multiple technologies. If anything, they have been thoroughly hostile to the sharing of spectrum and their resistance to change has delayed the availability of high-quality spectrum for decades. The have a conflict of interest, since they have a financial interest in an incumbent line of business that they would want to protect. They do not have a direct customer relationship; they sell advertising not subscriptions or service. They did not acquire the spectrum in the marketplace – they were given the spectrum in beauty contests. Their only claim to being the rent collectors is that they are the incumbent tenants, who occupy the space rent free.

[103] Bazelon and Jackson, 2011, p. 2.

[104] Bazelon and Jackson, 2011, p. 2

[105] Bazelon and Jackson, 2011, p. 1.

[106] Qualcomm, Nokia, 2011. Similar arguments have been made in the UNIITED STATES without the estimation of value.

broadcast spectrum –make more spectrum available to unlicensed spectrum through sharing (along the white spaces model, which has been authorized, but not yet implemented) and dedicate 50 MHz of cleared spectrum entirely for unlicensed use.[107] The unlicensed advocates estimate that the value created by dedicating high quality spectrum to unlicensed would be over $110 billion per year. This argument puts the value of spectrum close to $1.7 trillion over a 15-year period. They appear to put the value of increasing additional spectrum for exclusive licensed at slightly less than half of what Qualcomm and Nokia do. [108] Therefore, in their view unlicensed spectrum will generation twice the value that exclusive licensed spectrum will. This is consistent with the earlier analysis.

It is safe to say that the stakes are huge.

THE CHALLENGE OF PROVISIONING THE WIRELESS FUTURE

The challenge ahead lies in making the most efficient use of spectrum –carrying as much data as possible, maintaining quality of service, and making such service affordable. The challenge involves both the continuing growth in the quantity of data and a dramatic increase in the variety of data and consequent need for different quality of service.

Growing Diversity of Service Needs

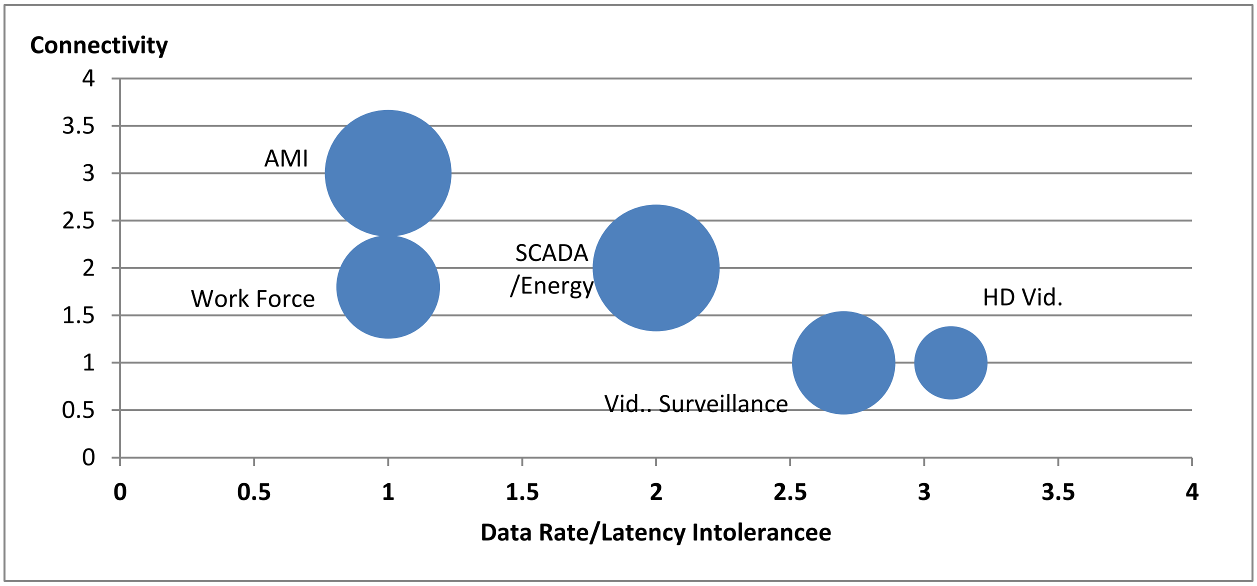
The challenge of delivering wireless data as usage expands will be made more complex by the fact that different types of communications place different demands on the network. Variety creates complexity. However, it may also alleviate some of the traffic flow problems because different types of communications place less demand on the network. Key conditions that vary across applications identified in the literature involve latency, connectivity, coverage and bandwidth at affordable costs, as shown in Exhibit VI-1. As shown in the top graph, using a simple three point scale (low, medium, high) for three communications characteristics for five broad types of intermediate input services suggests the complexity of the emerging communications space. For example, at one extreme, advanced metering tolerates a low data rate/hi-latency, needs low cost radio technology, and does not need a high level of connectivity. Video applications have the opposite set of requirements. Affordability is defined by the interaction of the cost and value.

The bottom graph reproduces a two dimensional analysis of mass market applications that yields a similar view of the terrain of demand. The bottom graph focuses on mass market applications according to bandwidth needs and congestion tolerance. E-mail and gaming are polar opposites in this categorization.

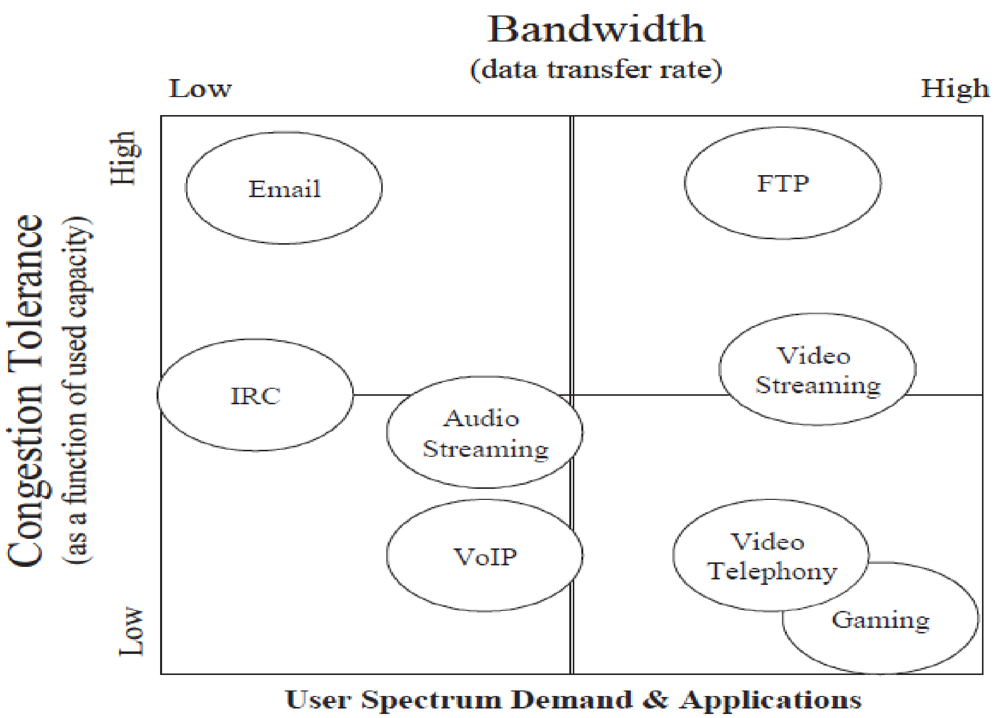
A detailed analysis of the diverse characteristics is not critical to the task of evaluating the future contribution of unlicensed use. The discussions recognize the complexity of the communications ecology that is emerging and that unlicensed use is likely to have a significant role in the future because it is better suited to provide important functionalities to support several of the configurations of demand characteristics. IAs long as spectrum policy does not bias the outcome by favoring one approach at the expense of the other, both would expand to meet growing demand. Moreover, by offering both models the opportunity to expand the amount of activity is likely to be higher and efficiency greater.

[107] Forge, Horvitz and Blackmun, 2011.
[108] Forge, Horvitz and Blackmun, 2011.

Exhibit VI-1 Diversity in Service Needs
(size of circles measures sensitivity to device costs)



Sources: Guzelgoz, et al. emphasize Data Rate/Latency – i.e. low data rate, high tolerance for latency; Chapin and Lehr, 2011, emphasize cost i.e. need for low cost; Benkler, 2011, emphasizes connectivity, i.e. need for Connectivity;



Source: Mark M. Bykowsky, Kenneth Carter, Mark A. Olson and William w. Sharkey, *Enhancing Spectrum's Value Through Market-Informed Congestion Etiquettes,* February 2008.

Enhancing Coverage

Complementarity will be necessary to solve the problem of geographic coverage [109] by evolving new institutions to deal with interference.

- Cellular service providers must shrink cell size, which means moving the base stations closer to consumers. [110] They will not get close enough to deliver the exaflood of data directly to the consumer over their licensed spectrum, however. The amount of data flowing in unlicensed spectrum is likely to rise.
- Users of unlicensed spectrum will have to find ways to ensure quality of service as their reach expands. The unlicensed use model will have to exercise greater control over interference with rules that place greater limits on what people can do (controlled access or managed commons), or with some limits on the number of users.

Exhibit VI-2 conceptualizes the geographic space of the wireless future. It suggests how access to spectrum in the 500 MHz to 1 GHz range could dramatically improve the performance and expand the scope of the unlicensed use model. Holding power constant and allowing Wi-Fi technology to operate at different frequencies affords it better coverage, or higher capacity. The bulk of end-user activity at present takes place in the 2.4 GHz spectrum and affords it a limited coverage. Use of 5 GHz (and perhaps higher) bands will allow higher capacity that can support new applications or improve the performance of existing applications, but it does not solve the problem of the limited range imposed on the unlicensed use model by its exclusion from higher quality spectrum. Using the TV white spaces[111] example, access to higher quality spectrum[112] would more than double the coverage. [113] Hot spots could become "Hot Zones or Oases."[114] In areas

[109] Chapin and Lehr, 2011, p. 21, "The move to smaller cell sizes that is driven, in part, by spectrum scarcity, makes infrastructure sharing between dedicated and unlicensed (range restricted) spectrum easier. It is important to note that cell density does not need to increase to the point that unlicensed bands can be used to reach any mobile device. Unlicensed spectrum can be used for mobile devices that are close to the infrastructure antenna, with dedicated CMRS spectrum used to reach mobile devices that are further from the antenna. The cell density merely needs to be reduced to the point that a substantial fraction of mobile users are within range of the unlicensed band from an infrastructure antenna, in order to provide significant offload."

[110] Chapin and Lehr, 2011, p. 32, "A key driver of the need for increased sharing among CMRS operators is the need to shrink cell sizes. Smaller cell sizes enable efficient spatial reuse of spectrum and support lower power operations, as well as a number of other technical options such as network MIMO. Lower power operation has many benefits, including ameliorating concerns about any potential health risks. Moreover, lower power operation facilitates the sharing of spectrum. There are multiple reasons for this, including the fact that it provides better range matching between licensed and unlicensed spectrum and the technology for frequency agility is more advanced and affordable."

[111] Lamberth, 2011," In the UNIITED STATES and U.K. TV white spaces occupy positions low on the frequency map meaning that the signals penetrate building better, travel farther and cover larger areas than higher-frequency signals. TV white space transmissions can carry as far as 10km/6.2 miles, which is more than 100 times better than Wi-Fi operating range of 100 feet indoors and 300 feet outdoors. Data throughput rates are in TV white space spectrum are high… Because of these attributes, the U.S. Congress and FCC call TV white spaces "Wi-Fi on steroids" and "super Wi-Fi" (even though white space devices do not conform to IEEEs 802.11 Wi-Fi standard)…. One of the thorniest problems is that white spaces aren't available in the same amount or on the same channels everywhere… Because white space availability is generally better in rural areas, the first white space solutions are to be offered for sale may be skewed toward solutions that benefit these communities, such as pubic broadband services. "

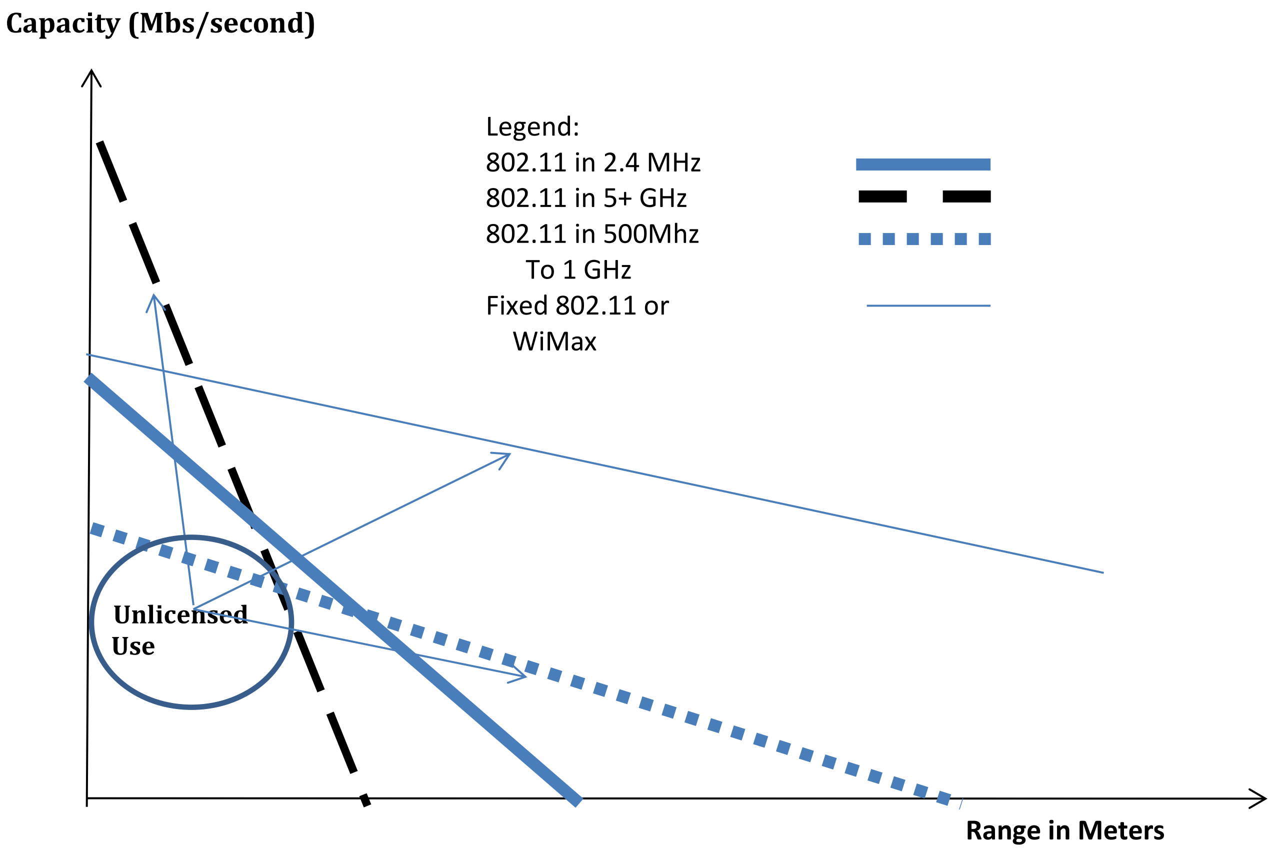
[112] Lamberth, 2011, "TV white spaces are available to anyone on an unlicensed basis, similar to Wi-Fi. That means any device can use the spectrum so long as it complies with a set of rules that prevent it from interfering with licensed users, wireless microphones and other white space devices. These rules present some fairly steep technology requirements: white space devise must function at restricted power levels, use adaptive power control to ensure they are radiating at the lowest level possible, know where they are, and connect to the Internet in order to access a geotagged spectrum availability database. In both the UNIITED STATES and U.K., proposed requirements that would require white space devices to sense and avoid other signals on the channels they're using were dropped based on technological feasibility, timing and cost, though both regulators would prefer this approach should it become feasible in the future. "

[113] Thanki, 2009, also presents a calculation of the difference that having access to high-quality spectrum would make in increasing the coverage of 802.11g devices. At the power level allowed by the sharing rules, the coverage is tripled by having access to higher quality spectrum. Coverage is much greater in rural areas because of fewer obstacles, but even in urban areas the difference is considerable. Given the high cost of providing rural areas with broadband Internet access, making this spectrum available for shared use would be particularly important in these areas.

[114] Benkler, 2011.

where the current exclusive licensed frequencies are unused, it would be possible to use more power to increase the capacity and coverage of Wi-Fi in fixed applications. WiMax would operate in this space as well, but it requires greater control of interference, which has given rise to a hybrid, lightly licensed model.[115]

EXHIBIT VI-2: THE POTENTIAL COVERAGE AND CAPACITY GAINS FROM ACCESS TO HIGHER QUALITY SPECTRUM



Sources:

These estimates are a representation of the general gain in capacity and reach based on Richard Thanki, *The Economic Value Generated by Current and Future Allocations of Unlicensed Spectrum,* Perspective, 2009 and Dirk Grunwald, *How New Technologies Can Turn a Spectrum Crisis Into a Spectrum Opportunity,* February 2011. The precise degree to which the range and capacity are increased depends on the amount of spectrum made available and the rules of use.

As coverage expands, interference management becomes more challenging. The solution lies at the institutional level. Expanding range requires additional measures to prevent

[115] The distinction between unlicensed with stronger rules for preventing interference and lightly –licensed blurs as they meet. Wikipedia defines lightly licensed as follows: "In June 2007 the FCC issued final rules for a novel "light licensing" scheme in the 3650-3700 MHz band. Licensees pay a small fee for a nationwide, non-exclusive license. They then pay an additional nominal fee for each high powered base station that they deploy. Neither the client devices (which may be fixed or mobile), nor their operators require a license, but these devices must receive an enabling signal from a licensed base station before transmitting. All stations must be identifiable in the event they cause interference to incumbent operators in the band. Further, there is a requirement that multiple licensees' devices are given the opportunity to transmit in the same area using a "contention based protocol" when possible. If interference between licensees, or the devices that they have enabled, cannot be mediated by technical means, licensees are required to resolve the dispute between themselves." http://en.wikipedia.org/wiki/IEEE_802.11y-2008.

interference, which can be provided in a number of ways including a mix of known technology and policy,[116] and the innovation that can be expected once the barrier to wider coverage is removed.

The past success of the wireless data sector is remarkable and the potential future benefits are bright, but the challenges are great too. The irony is that the wireless sector has been so successful over the past decade that the debate has shifted 180 degrees. It started from a situation in which analysts had to fight to convince policymakers that an immense amount of value was being wasted in spectrum that was locked into static broadcast applications; but we now have arrived at a situation in which there is so much potential use and value that we face a perpetual "spectrum crunch." Traffic growth has been so great and is likely to remain so rapid that there inevitably will be a series of "spectrum crunches," even if more bands are made available to exclusive licenses.[117]

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[116] Chapin and Lehr, 2011, p. 7, "Below a threshold cell size, network MIMO techniques become feasible.a/ a/ Most users are familiar with the new class of WiFi routers that use 802.11n MIMO (Multiple Input-Multiple Output) technology. This is implemented on each wireless router by using three antennas to take advantage of multipath to disentangle the desired signal from noise, and thus improve system performance. Similar strategies can be employed by integrating the signals from multiple networked base stations to enable network MIMO, if cell size is small enough that mobiles are in range of multiple base stations at the same time. In addition to expanding capacity, network MIMO provides benefits to reliability (because of path diversity and redundancy), coverage (dead-spot elimination), and data rate. p. 17, "By the term *controlled access unlicensed band* we refer to the general class of unlicensed allocations made in recent years." In the "original" unlicensed bands… an unlicensed device can transmit at any time as long as no interference occurs to protected users…. More recent unlicensed bands preserve the property that any device can use the band without exclusive licenses, but they have placed increasingly strict requirements on unlicensed transmitters. These requirements have been necessary to protect incumbents from interference since the new unlicensed allocations have been carved out of partially used spectrum bands."

[117] McBride, 2011, "Technologies and Strategies for the Mobile Broadband Capacity Crunch," (May 13, 2011), Traffic growth is just too great. Spectrum capacity will run out (and/or services will suffer), costs of continual expansion of core network and backhaul capacity will undermine operator profitability. Operators are all juggling with the need to divert non-essential traffic off of their networks in order to protect the performance and throughput of these vital assets. Offload is seen as the answer… the immediate future… of identifying and selecting specific types of traffic, content and even devices, creating new paths – outside the operator networks core – for access to and delivery of content. Further down the road, it is all but inevitable that the mobile data network will become a fully distributed environment that behaves like the Internet today, with no central core."

VII. THE MULTIPLE ROLES OF UNLICENSED SPECTRUM IN THE WIRELESS FUTURE

Advocates of both the unlicensed use and exclusive licenses models are busy developing analyses that explain the likely direction and parameters of change. These analyses are intended to demonstrate that, given access to more spectrum, each model can make a major contribution to the expansion of the sector. The lesson that emerges from the analyses is that both models can expand substantially and the mutually beneficial and peaceful coexistence of the two the models should be preserved and enhanced.

THE INGREDIENTS OF SUCCESS

In order to ensure that future policy preserves and promotes the opportunity for the unlicensed model, it is important to identify the factors that have enabled the model to succeed. The success of the unlicensed model rests on two sets of factors – traditional economics and systemic diversity.

The unlicensed model succeeded because it is not free but allowed entrepreneurs to invest in products and services that people value. In order to utilize the unlicensed spectrum, device manufacturers must design, build and market devices that consumers buy. To induce consumers to do so, useful applications must be written and distributed. Hundreds of thousands of base stations must be deployed and consumers or service providers must pay for the transport of traffic to and from the Internet. The unlicensed model succeeded because removing the spectrum barrier to entry decentralized decision making, deconcentrated investment, promoted an end-user focus, allowed user innovation and lowered transaction costs. This brought new and unique services to market, increased the value of broadband by extending it to new devices, and provided a lower cost, more efficient avenue to deliver data to consumers.

Traditional Economic Factors

From the point of view of traditional economic analysis, compared to exclusive licenses, the unlicensed model is extremely, even radically, deregulatory.[118] It captures what would be externalities with respect to licensed approaches.[119]

- The unlicensed model removes the spectrum barrier to entry, which is the primary obstacle by allowing anyone to transmit signals for any purpose, as long as the devices used abide by the rules.[120]
- Removing this barrier to entry removes the threat of hold up, in which the firm that controls the bottleneck throttles innovation by either refusing to allow uses that are not in its interest, or appropriating the rents associated with innovation.[121]

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[118] Hovitz, 2007, p. 4, Market forces obviously operate in license-exempt bands even without spectrum pricing – through equipment purchase decisions by countless individuals at the retail level and through manufacturers' product development and marketing decisions at the wholesale level. Regulatory criteria for equipment type acceptance constrain these forces – though not as much as license conditions limit the choices of purchasers, designers and producers of radio equipment for licensed use. In that sense, license-exempt bands are arenas for more creative competition among equipment vendors and service providers than the licensed bands."

[119] Milgrom, et. al. 2011, p 2, [T]he primary benefits of unlicensed spectrum may very well come from innovations that cannot be yet be foreseen. The reason is… that unlicensed spectrum is an enabling resource. It provides a platform for innovation upon which innovators may face lower barriers to bringing new wireless products to market, because they are freed from the need to negotiate with exclusive license holders."

[120] Horvitz, 2007.

[121] Milgrom, et al., 2011, 13.

- It lowers the hurdle of raising capital, by eliminating the need for a network and focusing on devices.[122]
- It fosters an end-user focus that makes innovation more responsive to consumer demand; indeed, it allows direct end-user innovation.[123]
- It de-concentrates the supply of services compared to the exclusive licensed model, especially for high bandwidth services which tends to result in a very small number of suppliers, particularly in lower density markets.[124]

Unlicensed spectrum lowers transaction costs. If the rules are written leniently, many people will be able to transmit for many purposes. If the rules are written well, interference will be avoided. The FCC's approach to setting aside spectrum for shared use exhibits several characteristics that accomplish the task of managing the common pool resources in a light handed manner. [125]

- The use rules were simple and established an easy set of conditions with which devices had to comply.
- They did not require intensive, continuous monitoring and coordination.
- There were no membership rules. Anyone could enter and use the shared resource.

Systemic Diversity

Beyond these traditional economic factors, the unlicensed model creates a much more diverse sector. Diversity has come to be recognized as a uniquely important characteristic of economies and economic systems because it reinforces desirable economic traits of the system.[126] Diversity creates value, enhances innovativeness and builds resilience, as well as promoting other social values like pluralism. Diversity is created by three systemic characteristics – variety (the number of firms), balance (market shares of firms) and disparity (the differences between the firms). Adding an additional cellular service provider may increase variety and may improve balance if the new provider gains market share, but it does not increase disparity. The diversity that a different ownership model introduces into the communications ecology provides the uniquely significant benefit of introducing a different perspective that is ideal for enhancing diversity.[127]

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[122] Lemstra and Groenwegen, 2011b, p. 373, "Multiple product vendors and, later, service providers have been seen to be willing to invest in the development of products and service to exploit the unlicensed part of the RF spectrum." One could argue that this is the result of the return on investment largely being based on the sale of Wi-Fi equipment, and not on the exploitation of a service requiring complementary and deep investment in the creation of a network infrastructure, as is the case in mobile cellular communications."

[123] Von Hipple, 2005, has emphasized the importance of user innovation. Cooper, 2006, discusses the importance of end-user innovation and local knowledge in collaborative production in digital product spaces, including Wi-Fi and mesh networking.

[124] The intensity of the debate over ownership models is equaled or exceeded by the intensity of the debate over whether the dramatic increase in concentration of the cellular service sector has resulted in the abuse of market power. Cooper, 2011b, shows that economies of scale and scope and industry concentration have both typified the decade of development of wireless broadband, making it difficult, if not impossible, to disentangle the two.

[125] Cooper 2005, applied the framework developed by Ostrom to mesh networks, discussing the eight sets of rules that have been identified. The FCC boiled the management challenge down to primarily one set of rules – position rules that define what users of the resource are allowed to do. Milgrom, et al. (p. 14), describe the FCC approach to shared public use spectrum as a "managed commons. " In fact, it has succeeded because it relies on as little management as possible to get the job done.

[126] Stirling, 2000, Benhamou, et al., 2009.

[127] It is important to note that the benefit of diversity in ownership models in the digital age is not limited to the example of spectrum reserved for or made available to shared use by the public. In fact, we find a similar outcome across a number of areas of the digital economy. Cooper, 2006, analyzes several examples. In software development, proprietary and open source software have both grown side-by-side. Sometimes they reinforce one another, as in the extensive support provided to open source projects by proprietary software firms. Sometimes they compete, as in the rivalry between Microsoft, Apple and Linux in operating systems or

ALTERNATIVE ROLES

Complementarity

The expansion and nimble integration of unlicensed use technologies with exclusive licensed models has played a key role in the development of broadband data service. It is likely to continue to play a vital part in promoting an efficient solution to the long-run challenge of provisioning mobile data services.[128] Unlicensed use of frequencies is one of the key technologies that provide a platform that makes much more intensive use of spectrum.

> Wi-Fi is becoming increasingly more effective as a broadband access solution for the following reasons: The IEEE 802.11n provides for extremely high throughputs (maximum 6000 Mbps theoretical rate), high spectral efficiency, extended range, multi-band support, and operating flexibility in trading off between distance and throughput. Wi-Fi can be deployed at lower cost than most alternative technologies, especially in environments where little wireline infrastructure exists. Time to market is also faster. Maturing operator-class Wi-Fi equipment has the sophisticated functionality needed to work in these challenging RF environments… New equipment enables flexible deployment. Examples include mesh operation and Wi-Fi based point-to-point communications for backhaul.[129]

> Unlike traditional services where dedicated connections are provisioned, broadband services can leverage unlicensed connections that are 'virtualized' according to principles developed for Internet- and Web-based network technologies. Tremendous performance gains and capital efficiencies can be achieved with intelligent scheduling and bandwidth management techniques…

> Notable innovations are particularly focused toward enabling low cost platforms for small cells, software defined radio configurations, and automated configuration and provisioning management. Many of these innovations capitalize on technical capabilities derived from the Internet.[130]

The two ownership models can expand to deliver these functionalities along two dimensions –geographic and organizational. While convergence is frequently used to describe this process, convergence has taken on a connation that implies networks inevitably compete and replace one another, but the relationship between licensed and unlicensed use of spectrum entails a great deal of complementarity, co-existence. Complementarity and functional specialization are likely to continue to be central features of the wireless broadband ecology, although competition may increase as well. Networks based primarily on exclusive licenses will continue to perform

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Apple and Android in the mobile operating system product space. In the desktop computing product space, the PC open platform and the Apple closed platform have existed side-by-side for decades. When the smaller, closed platform ultimately supported the larger open platform it gained substantial market share, creating more balance. In the production and distribution of content, peer-to-peer networks exist alongside hub-and-spoke networks and are used to alleviate congestion on or efficiently manage the resource of those networks (Cooper, 2011a). The real world experience during the past quarter century (which is roughly the first quarter century of the digital revolution) strongly supports the conclusion that diversity of business models **and** ownership approaches creates an environment that stimulates economic growth and dynamic innovation. While collaborative production based on non-property exploitation of common pool resources has long coexisted with the private exploitation of resources, the two ownership models tended to occupy very different spaces and the collaborative model has played a much smaller role in industrial society. Digital technology seems to be supporting a broader role for collaborative production. Digital technologies enable the embodiment of knowledge in silicon chips, which facilitates the decentralization of intelligence and promotes distributed innovation. Digital communications dramatically lower the cost of communications, which enhances coordination as a result. The digital revolution has fostered the convergence of areas in which the two models can exist side-by-side and expanded the role of collaborative production.

[128] Wirelesse2e, 2010, "In summary, choice for the wireless network executive is not a simple bifurcation between spectrum and additional cell-sites." Instead a multi-pronged approach is the advisable path: Deploy the technology advances (spectrum efficiency), Make spectrum purchases to plan for traditional macro, micro cell deployments for dense urban, urban and rural coverage, Identify hotspots (those 3-4% of sites that will carry 30-40% of total network traffic) and find ways to use dense Wi-Fi deployments to off-load traffic, Work with device manufacturers to promote the adoption of higher orders of MIMO for 802.11n and the use of 5 GHz band."

[129] Rysavy, 2010b, p. 10.

[130] Marshall, 2011.

better by integrating unlicensed spectrum,[131] but services that rely primarily on unlicensed may expand as well.

Rivalry

While we have seen and expect future complementarity and functional specialization, we should not dismiss the possibility of rivalry as well. At a minimum, exactly where the line between the services will be drawn is an open question that should be decided in the marketplace, not determined by policies that decide the outcome by allocating spectrum to one model and not another.

A leading Wall Street analyst of the communications space has recently described two possibilities that are emerging in the marketplace that rely on the ubiquity of unlicensed spectrum-based Wi-Fi.[132] For cable operators, he sees the continuing extension of broadband as the driving force behind the adoption, as we have noted above.[133] He also sees the potential for a full purpose wireless service to develop that relies primarily on Wi-Fi. A link to cellular wireless would be maintained for voice, not broadband data. The key factor in this hybrid model is the increasing density of Wi-Fi.

> Earlier this week, we wrote about even more disruptive opportunity made possible by Wi-Fi. A start-up named Republic Wireless is now beta testing an unbelievable $19 per month unlimited plan for voice, video and data. The plan is made possible by the emerging ubiquitous availability of Wi-Fi. Republic's modified LG *OPimus* Android smartphone defaults to WiFi… even for voice service. Importantly, the service *does include* full ("unlimited") cellular capability whenever WiFi *isn't* available (via an MVNO arrangement with Sprint). That positions Republic as a credible replacement for higher priced plans (including, those, ironically, from Sprint). This kind of service would be a natural fit for cable. Inside the home, it would leverage the customer's own WiFi network (that is, their cable broadband connection). At work, it would leverage their employer's network. At malls and restaurants and city centers, it would leverage the Wifi network increasingly being built by Comcast, Time Warner Cable and Cablevision. The customer would only need a traditional cellular network in a car."[134]

Benkler places this potential direction of development into the current policy context, as discussed in the next chapter, by noting that access to higher-quality bands could greatly enhance the ability of the unlicensed model to provide seamless coverage, thereby bringing the superior entrepreneurial and innovative forces of the unlicensed model to bear with greater force on future services.

> [I]f Congress does empower the FCC to move broadcasters so as to make it easier to deploy new uses of wireless technologies, it becomes possible to use that change to permit open wireless devices to transmit in some of the cleared frequencies, rather than auction all of the cleared frequencies for exclusive use. A dedicated band in which only open wireless devices would operate, rather than on a shared basis as with white spaces, would allow the development of devices with longer range and higher power. These would be constrained not by the sensitivity of older, less sophisticated services like broadcast, but only by what new devices specifically built for open

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[131] Chapin and Lehr, 2011, p.28,"operators who segregate their traffic may be better positioned to take advantage of dedicated unlicensed spectrum to supplement their overall capacity needs. "

[132] Moffet, 2011.

[133] Moffet, 2011, p. 3, "If there is an opening for cable operators in the wireless industry, it is far more likely to be in offering WiFi than in offering LTE… Their strategy is to give away WiFi service for free. They've made wireless a *feature.* The strategy actually makes sense. They rely on free spectrum and low cost WiFi equipment. They leave it to consumers to foot the bill for equipment (i.e. The Wi-Fi chips that are already build into iPhones and iPods and laptops), meaning there's little or no subscribe acquisition costs."

[134] Moffet, 2011, pp. 3-4.

wireless use can bear. The primary potential benefit of such new devices would be increased area coverage, particularly in built environments. By increasing coverage, these devices could make the kinds of nomadic access we already see from open wireless strategies more seamless. In other words, a dedicated band in these lower frequencies could provide precisely the capabilities that could fill in the primary weakness that current open wireless strategies exhibit because of the regulatory constraints that the protection of licensed services imposes on them—continuous coverage. It would allow open wireless strategies to fulfill the requirements of ever-more time- and space-sensitive applications.

More basically, open wireless strategies have exhibited rapid innovation, filling services that only a few years ago would have been considered to require licensed exclusivity. The freedom to operate and innovate, by anyone for any purpose, that permission to operate without a license provides has allowed the kind of distributed, diverse innovation we have come to associate with computers and the Internet, more than the innovation model of more centralized models.[135]

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[135] Benkler, 2011, pp. 19-20.

VIII. POLICY IMPLICATIONS OF THE SUCCESS OF UNLICENSED SPECTRUM

The past two decades have demonstrated that the effectiveness of ownership models is an empirical matter. Unlicensed spectrum has proven to be at least as effective as, and probably more effective than, exclusive licensing in preventing interference/congestions, incenting investment and stimulating innovation and economic activity. Even the holders of exclusive licenses who use it for cellular communications have recognized the immense value of unlicensed use spectrum and have relied on it to lower their own costs and expand their service offerings. The success of unlicensed use and the strong complementarity between the unlicensed use and exclusive licensed models supports the conclusion that spectrum should be made available for both models. Public policy that fails to allow for both models to expand is likely to reduce the output of the spectrum. Therefore, assuring that adequate spectrum is set aside for unlicensed use should be a goal of public policy.

The immediate question confronting policy makers is – are auctions a good mechanism to achieve that goal? The answer is no – "Any such auction would be decisively biased against unlicensed uses, even in cases where the unlicensed uses would be far more valuable than the licensed ones."[136]

LARGE, INCUMBENT CELLULAR PROVIDERS DOMINATE AUCTIONS

Auctions are certain to result in little, if any, spectrum being allocated to the unlicensed use model.[137] Given the history of spectrum auctions in the United States, they will fail to address the problem of the market power of the incumbent cellular providers and fail to reflect the externalities and transaction cost efficiencies of unlicensed use spectrum. Opponents of setting aside spectrum for unlicensed use have put forward a highly implausible model in which groups of companies interested in exclusive licenses are pitted against groups of companies interested in unlicensed spectrum.[138] Such a contest would be totally one sided, loaded in favor of the group pursuing exclusive licenses.

Looking at auctions in the last decade and subsequent mergers and acquisitions, two-thirds of all spectrum auctions ended up in the hands of the top two companies (see Exhibit VIII-1). The top four firms have acquired 80 percent of the spectrum. Post-auction mergers, acquisitions and joint ventures have increased the concentration of control of spectrum. Here it is important to recognize that the marketplace would put virtually all of the auctioned spectrum in the hands of the dominant incumbents through auction, merger and acquisition in less than a decade if regulators do

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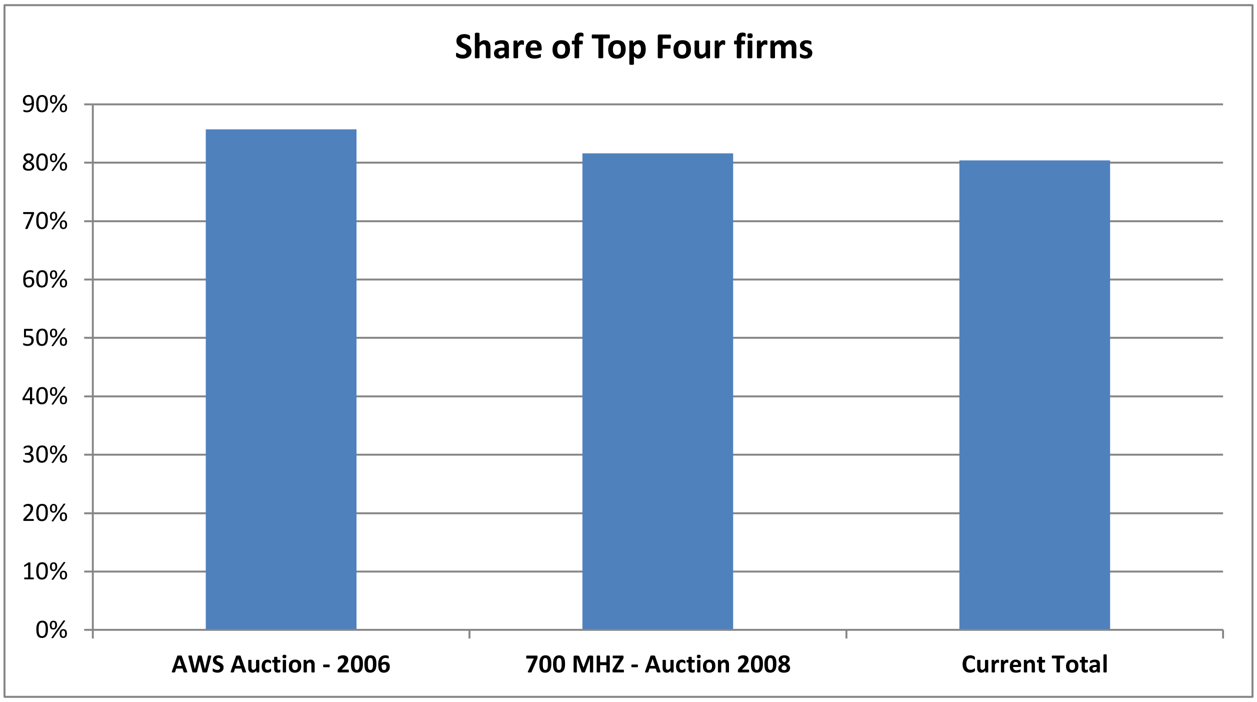
136 Milgrom, et al., 2011, p. 26.

137 If public policy is to reflect economic reality, it must reflect the fact that the two models are effective solutions to the coordination problem. Economic analyses or public policies that assume exclusive licenses are superior to shared use spectrum are simply wrong. The suggestion that auctions can be configured to yield the "socially" optimal amount of shared use spectrum has been thoroughly criticized. First Rose argues that the game theoretic outcomes that demonstrate the superiority of auctions are based on biased assumptions about the ability of institutional models to manage interference and congestion. The dice are loaded, so to speak, by the assumption that the exclusive license model is one that is assumed to work best in managing interferences. Rose, 2011, p. 9, "The game, bluntly put, and rigged in such a way as to make unlicensed spectrum simply a spurned modality of licensed spectrum.,,, do these games and etiquettes resemble anything which empirically obtains in the world? The answer has to be no." In fact the past decade has shown that, if there is anything, the shared use model has proven more adept at managing interference and congestion, Rose, 2011, p. 5, "This is particularly pertinent if the advantages of digital technology – which allow the possibility of intelligent devices and modes of user interaction which make spectrum far closer to a non-rivalrous than a rivalrous good – hold….This is particularly tragic because the reasons for which auctions, arguably promote efficiency for licensed spectrum do not apply to unlicensed spectrum. In fact, just the opposite applies. Milgrom et. al., 2011, argue that the distribution of incentives and resources of bidders do not reflect reality. The small number of large cellular license holders has resource and organizational advantages in the auction process that bias the outcome of the auction in their favor at the expense of the large number of much smaller beneficiaries of shared use spectrum. License holders have an incentive to overbid for spectrum to keep it out of the hands of potential competitors. Shared use beneficiaries face obstacles that lead them to underbid, or prevent them from bidding altogether.

138 Bykowsky, Olson, and Sharky, 2008,

not stop the process. Whether or not the proposed acquisitions are allowed to close by regulatory authorities, they make it clear that the largest incumbent cellular operators thoroughly dominate the exclusive licensed space.

EXHIBIT VIII-1: AUCTIONS INCREASE CONCENTRATION OF EXCLUSIVE LICENSES



Source and Notes:

Top 4 firms are Sprint-Clearwire (Joint Venture), AT&T, Verizon, and T-Mobile. Current shares are from Federal Communications Commission, *Fifteenth Report In the Matter of Implementation of Section 6002(b) of the Omnibus Budget Reconciliation Act of 1993 Annual Report and Analysis of Competitive Market Conditions With Respect to Mobile Wireless, Including Commercial Mobile Services*, WT Docket No. 10-133, June 27, 2011. Auction shares are from FCC Auction Database, year shown is the completion date. Total spectrum available for broadband is from Coleman Bazelon, Charles L. Jackson, and Giulia McHenry, "An Engineering and Economic Analysis of the Prospects of Reallocating Radio Spectrum from the Broadcast Band through the Use of Voluntary Incentive Auctions," *Telecommunications Policy Research Conference,* September 19, 2011, Table 4 based on Potential Supply.

Incumbent cellular service providers are likely to be the big winners in auctions for spectrum for several reasons.[139] Incumbents

- have deep pockets,
- already possess communications infrastructure,
- concentrate demand and decision making,
- are primarily telecommunications companies, and
- have a strong incentive to bid to foreclose competition.[140]

[139] Cramton, et al., 2011 p.1. Most spectrum auctions, however, are held in a… complex environment. In particular, a common asymmetry in the auction is the distinction between an incumbent and an entrant. The incumbent has existing customers, network infrastructure, and spectrum; the entrant does not.

Indeed, in the context of auctions of spectrum in a communications sector that has become highly concentrated, the cellular service providers have an incentive to keep competition out. By denying spectrum to potential or actual competitors, they increase their own ability to extract the rents that flow from their market power.

> Unfortunately, an auction that awards the spectrum to the bidders with the highest values may not assure efficiency because of the bidders' private values for the spectrum may differ from social values as a result of market structure issues. For example, an incumbent will include in its private value not only its use-value of the spectrum but also the value of keeping spectrum from a competitor. Effective policy must recognize competition issues in the downstream market for wireless services…
>
> Moreover, the incumbent can potentially limit entry, and hence competition, by purchasing additional spectrum that would otherwise go to the incumbent… part of the willingness to pay in the auction for the incumbent comes from the value of deterring entry, which is bad for overall efficiency for the standard market power reasons and may be bad for the dynamic evolution of the service if the threat of competition is necessary to speed up build out and development of new technologies.[141]

The push by incumbent cellular network operators to prevent the FCC from imposing any conditions on the auction of spectrum, coming after the failure of past auctions to stimulate competition and amid vigorous efforts by the incumbent wireless carriers to obtain more spectrum through mergers and acquisitions shines a bright light on the effort of the incumbents to deny additional high quality spectrum for the unlicensed model. The unlicensed space has long been the most competitive area of the wireless market and, as we have seen in the discussion of future development, it may be the last hope for meaningful competition in the broadband space.

> The reason we prefer allocating the spectrum as dedicated unlicensed is this provides a well understood model for ensuring open and non-discriminatory access to the resource – not just for incumbents but potential future entrants. Preserving the option for future entry helps ensure that the bottleneck resource (spectrum) is not cartelized so as to limit competition (and thereby, also hampering prospects for innovation).[142]

As the debate over spectrum auctions has unfolded, the facade of concern about revenues has been pierced by several issues that raise alternative explanations. For example, the steadfast opposition of the dominant incumbents to allowing the FCC to design auctions to ensure they have a procompetitive impact highlights the market structural aspects of the debate.

> Wireless Competition Bureau Chief… said the agency's two major "sticking points" with the GOP bill are restriction on the FCC's ability to "foster competition in the market" and to decide how much spectrum should be dedicated for "unlicensed" use.[143]

AUCTIONS WILL NOT MAKE SPECTRUM AVAILABLE FOR UNLICENSED USE

Cellular providers will certainly not take care of unlicensed use spectrum. In the context of an auction to allocate exclusive licenses, it is highly unlikely that if the winners are in the cellular communications business they will act in a manner that reflects the value of the two models. It is

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140 Milgrom, et al., 2011, p. 13, identify a foreclosure premium that incumbent license holders may pay – bidding prices up to keep potential competitors from entering the market – "[A]uction theory tells us that the type of mechanism used to allocate spectrum, if they work well, will tend to maximize industry profits, and one expects industry profits to be higher with more concentration."

141 Cramton, et al., ppo.1…2..

142 Chapin and Lehr, 2010 p. 27.

143 Dailywireless.org, 2011.

highly unlikely that licensees will allow access to the exclusive licensed spectrum that they have obtained in an auction in a manner that is as unfettered as under the unlicensed use model. The behavior of the incumbent occupants of spectrum strongly suggests that license holders do not share easily or well. Having bid for spectrum, winners are not likely to then set aside the spectrum for unlicensed use.[144] They will have a strong economic incentive to exclude "free riders" and charge for use of "their" spectrum. Access will be "authorized" and costly. They are certain to encumber access to the spectrum, charging for its use, resisting applications that might compete with their core businesses, seeking rents from new applications that do not compete, etc. Thus, they will create the problems that setting aside spectrum for unlicensed use is intended to solve. They will become gatekeepers, recreating and exploiting the spectrum barrier to entry the unlicensed access removed.

Pitted against this small group of large, specialized communications companies is an ill-defined and diverse set of companies and end users that may use unlicensed spectrum for a small part of their overall economic activities.

> An advantage of open access, service neutral, unlicensed bands is that there seem to be innumerable applications which were not predictably lucrative enough to justify the cost of securing a license, but which proved valuable in the aggregate once they existed… So it is highly desirable to have space in the radio frequency spectrum for mass market experiments. Many see an analogy with the Internet: the ability to release new content and applications to a potentially global audience at relatively low cost and without difficult authorization procedures seems to stimulate creativity and new business activity like nothing else.[145]

Those who benefit from unlicensed use spectrum are unlikely to be able to win at auction for several reasons.[146]

- Diffuse and unforeseeable future benefits mean that potential users will undervalue unlicensed public use spectrum.
- The public is not likely to be eligible to bid and the transaction costs of enabling public bidding would be staggering.
- Each individual, non-telecommunications company that might bid will be self-interestedly short sighted, unable to see the potential future value.

[144] Lamberth, 2011, "Even though the FCC has already approved unlicensed use of TV white spaces, several members of the U.S. congress proposed auctioning access to TV white spaces during the summer's debt ceiling debates. While the legislators are hoping for a financial windfall to help close the U.S. budget gap, industry insiders wonder why anyone would pay for non-exclusive access to intermittently-available spectrum.

[145] Horvitz, 2007, 4.

[146] Milgrom, et al., 2011, p. 3, "What makes such ideas untenable is that too many of the beneficiaries – future innovators and consumer in the case of unlicensed spectrum – are difficult or impossible to identify at the time of the auction… ignorance about who the future individual users will be or what their value will be cannot justify overlooking those users and values, as would surely happen with such an auction (2)… "While allowing market forces to determine the allocations between licensed and unlicensed might superficially appear to be an attractive option, it is not a practical alternative. Auction markets work best when one can identify the relevant bidders in advance, bring them to auction, inform them what is for sale, and motivate them to bid…. (p. 25) [T]here is a diverse and emerging group of devices that use and benefit from unlicensed spectrum… Even the group of existing beneficiaries is too large and diverse to be identified, informed and motivated to bid, particularly when individual beneficiaries cannot expect their bids to have any effect on the outcome. And without knowing how many other users there might be or how much interference might arise, they would be unable to make realistic estimates of value…. Moreover, the importance of innovation to capture the full benefits of unlicensed spectrum would make it even more implausible that beneficiaries of unlicensed spectrum could be assembled. For potential innovators who may use unlicensed spectrum, the main problems are that they are numerous, their identities are unknown; their participation is costly, making it hard to bring them to auction; and the very nature of innovation makes their information about future benefits unreliable."

- Because of the decentralized nature, it is highly unlikely that the army of potential users can band together to claim the spectrum at auction, or that the auctioneer can aggregate their bids to set aside spectrum.
- The hospitals, libraries and universities that have been blanketed with Wi-Fi and other unlicensed spectrum applications are very unlikely bidders, as are the infinite array of enterprises that will benefit from RFID applications.[147]

It is interesting to compare the companies who have been offered up as potential future bidders for unlicensed use spectrum to the telecommunications giants who have and are likely to bid for exclusive licenses.[148]

- Many of the companies in the unlicensed use category did not exist when the unlicensed use spectrum model was first implemented in 1985 (Google, Skype, Frontline, Yahoo, Ask.com Cisco, Juniper Networks Panera Bread).
- Many did not exist when the spectrum auctions began. It is exactly these unforeseeable beneficiaries whose interests are not taken into account an auction.
- The only company that was primarily a telecommunications company has gone out of business (Frontline).
- Others have bleak futures (Yahoo).
- Those that have been around for a long time (e.g. Marriot, Starbucks) are in a completely different line of business.

On the other hand, the telecommunications giants who are identified as likely bidders (AT&T, Verizon and T-Mobile)

- have been around from the beginning,
- have dominated the auctions in the wireless data era, and
- are, on average, ten times the size of the members of the group of presumed bidders for unlicensed use spectrum.

If the asymmetry between incumbents and new entrants who are in the communications business is a problem, as noted above, that problem is greatly magnified when firms that are not in the communications business at all are required to put a value on communications service.

In short, economic analysis that purports to show that spectrum auctions could be designed to meet the needs of the unlicensed use model are based on two sets of assumptions that are contradicted by reality. They incorrectly assume that exclusive licensed spectrum is better equipped to manage interference and to maximize economic value. They also incorrectly assume that the auction represents a level playing field between the beneficiaries of exclusive licensed use and unlicensed use spectrum.

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[147] Lamberth, 2011, "Worse, the proposal would allow a single bidder to swoop in and outbid the total of all other bidders for white space access. In that case, the single bidder would gain an exclusive license to use white spaces, effectively killing public and community access to white spaces."

[148] Bykowsky, Olson, and Sharky, 2008,

MAKING SPECTRUM AVAILABLE FOR UNLICENSED USE WILL REDUCE THE DEFICIT

Given the success of the unlicensed use model and the potential benefits it could provide in the future, the best argument for making spectrum available for unlicensed use in the context of the budget deficit debate is that it is likely to decrease the deficit in the long term for the following reasons.

- First, if the supply of spectrum for exclusive licenses at auction is reduced, the cellular providers will bid up the price of the spectrum that is auctioned. Given the fact that the cellular service providers have declared a "spectrum crisis," it would be reasonable to assume that they will bid up the price substantially.[149]
- Second, because licensed and unlicensed have strong complementarity, the availability of unlicensed increases the value of licenses.
- Third, the expansion of economic activity associated with the spectrum set aside for unlicensed use generates tax revenues[150] at a higher tax rate than exclusive licenses because the purchase price of the spectrum is not claimed as a business expense.[151]

Providing precise quantitative estimates of the impact of auctioning spectrum is difficult. The Congressional Budget Office "scores" it in the range of a few billion dollars at most, after the costs of clearing the spectrum are taken into account. If the failure to make high-quality spectrum available for unlicensed use reduces the output of the sector by ten percent, (a low estimate given the extremely important role that it has played to date) the loss would be $100 billion or more over the next decade and federal revenues would be reduced by tens of billions of dollars.[152]

CONCLUSION: AVOIDING ANOTHER 100-YEAR MISTAKE

This year marks the 100 year anniversary of the initial decision to give exclusive licenses to individuals to use the spectrum. The problem with such an approach is that, over time, as technology changes, the ability to use the spectrum changes and improves. What were the most valuable uses at one moment, or even the only technologically feasible uses, may no longer be the

[149] Milgrom, et al, 2011, p. 23, "First, the reduction in the supply of spectrum is likely to increase the per unit price. If the aggregate demand for licenses is relatively inelastic… would by itself, actually increase the revenue that can be expected from a given auction. We are not aware of convincing estimates of the aggregate demand for licensed spectrum. Bulow, Levin and Milgrom (2009), however, have pointed out that in large spectrum auctions; the overall revenue tends to reflect the aggregate budgets of the participants. To the extent that telecommunications firms allocate budgets for spectrum purchases that are relatively insensitive to changes in available spectrum, and tend to spend their budgets at auction, changes in the available spectrum will have only modest effect, if any, on government revenue."

[150] Milgrom, et. al., 2011, p. 23' "A second point is that complementarity between licensed and unlicensed spectrum can lead to a situation where unlicensed spectrum applications increase the demand for licensed spectrum applications and lead to higher license prices."

[151] Milgrom, et al., 2011, p. 2, Another goal in many auction setting is raising revenue. A pro-efficiency argument for maximizing revenues is that substituting auction revenues for revenues raised through distortionary taxes saves dead-weight loss of those taxes. Yet, maximizing revenues often conflicts with the goal of creating a competitive market for wireless services. First, reducing the amount of available spectrum would typically increase auction revenue, but restrict the development of wireless services. Second, selling the rights to be a monopolist can raise much more revenue than selling license to many competing providers, to the detriment of post auction competition and efficiency."

[152] These observations are supported by an analysis of social surplus under the conditions in the wireless market as described throughout this paper. In the absence of the complementarities available with unlicensed spectrum, demand is lower and becomes more elastic because of more churn. In the absence of efficiencies associated with unlicensed spectrum, costs rise more rapidly at the margin since the costs of reducing congestion increase). Total output declines. However, auction revenues are essentially unaffected in the short-term by making spectrum available for unlicensed use since the reduction in supply increases bid price, offsetting the reduction in quantity. The producer surplus remains about the same but the consumer surplus is reduced. Long-term general economic activity is reduced significantly because of the large decline in consumer surplus. Total social surplus declines by about as a result of the reduction in available unlicensed use (consistent with current offloading). The vast majority of the reduction in total social surplus comes in the form of a reduction of consumer surplus.

best use of spectrum. The holders of licenses hesitate to give them up, even if they were never intended to be permanent exclusive licenses. Thus, choosing regimes to allocate spectrum to users and uses tends to be very "sticky;" once they are made they are difficult to change. For at least fifty years, it has been recognized that the original scheme for licensing spectrum in the United States is no longer efficient.

The fact that the transaction costs of scrapping the old system (bribing the broadcasters to move) are fifteen times the transformation costs of moving to a new system (implementing technologies to repack the spectrum) is testimony to the power of incumbent quasi-property right. The amount of money that will be paid to the broadcasters is larger than the impact the disputed conditions would have on the auction revenues, yet, there is no legal reason the ransom should be paid. It is not unnecessary to pay the ransom.[153]

Ironically, Congress is threatening to make another 100 year mistake by favoring one ownership model to the exclusion of another. Exercising it independent expert judgment, the FCC set aside several small slivers of spectrum that became the basis for the remarkable success of the unlicensed model. The key to the success was removing the spectrum barrier to entry and combining free market principles with shared access to a bottleneck essential facility. Some members of Congress want to prevent the FCC from exercising that judgment in the future. They propose to recreate the barrier to entry by requiring that all spectrum be auctioned, which guarantees that none will be made available for the continuing expansion of the unlicensed model.

A plausible case can be made that the spectrum should be split equally between the exclusive license and the unlicensed public use models. However, because the unlicensed use model exploits spectrum so much more efficiently, it can thrive on less than half. Today, exclusive licensing occupies five times the spectrum in the 500 MHz to 1GHz frequencies as unlicensed use. If none of the next 120 MHz to be auctioned is made available for unlicensed use – exclusive licenses will have the use of ten times as much high-quality spectrum. This imbalance will distort the development of the sector and will fly in the face of the demonstrated ability of an open access model to avoid interference and therefore promote communications in a much more consumer-friendly manner.

The second 100-year mistake will be an even bigger tragedy because Congress should know better. Back in 1912, the radio industry was new, the technology was primitive and there was little basis on which to consider alternative approaches. Today, the demonstrated success of the unlicensed use model provides a very strong basis to conclude that given access to spectrum with more attractive propagation characteristics, the unlicensed use model will perform at least as well as the exclusive licensed model, and the overall sector will perform much better. If legislation fails to make more spectrum available for unlicensed use, it will truly be a tragedy of the Congress.

- Policy makers should ensure that the proposal to allow shared access to TV white spaces is implemented.
- Policy makers should ensure that unlicensed model has access to a share of the high-quality spectrum that is not smaller than it has today – one-sixth.

[153] None of the TV broadcast licenses are permanent. All of them will expire in the next decade. None of the TV licenses were acquired at auction. They were all granted to the broadcasters, at no cost, before auctions were adopted as the approach to allocating spectrum. Instead of paying broadcasters to return licenses they were given for free; policy makers could require them to bid for those licenses when they are up for renewal. If they reject the offer of a no-cost relocation, they should be required to participate in the auction. The broadcasters are not likely to win the auctions because their core competence lies in an inferior use of the spectrum.

- The FCC should be empowered to allocate up to one quarter of future spectrum that comes available for unlicensed use, if unlicensed use continues to prove to be effective at utilizing the spectrum without interference and at stimulating innovation.

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