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Solving the "Spectrum Crunch:" Unlicensed Spectrum on a High-Fiber Diet

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Foreword

By Fernando R. Laguarda, Time Warner Cable

The growth of Wi-Fi consumer demand is beginning to overwhelm existing unlicensed spectrum allocations. The cable industry has invested heavily in the deployment of more than 150,000 Wi-Fi access points across the country, with more being deployed every day. In addition to individual company deployments, five cable providers teamed up in 2012 to provide reciprocal wireless broadband access using unlicensed spectrum for each other's subscribers nationwide. Studies calculate the annual contribution of the unlicensed wireless sector to the economy to be between $50 and $100 billion.

Wi-Fi also expands the reach of cable broadband service and provides benefits to the broader community, including emergency response following SuperStorm Sandy in the New York/New Jersey area, and large public events like the Democratic National Convention in Charlotte, North Carolina. As deployment of Wi-Fi has expanded, usage has increased dramatically. In December 2012, the number of unique users accessing our network grew by over 720 percent, and data consumption per user grew by over 100 percent, compared to December 2011. Devices per user and average minutes per session have also increased. Our experience confirms that user demand for ubiquitous Wi-Fi coverage will continue to grow.

In this report, Michael Calabrese, Director of the Wireless Future Project at the New America Foundation, describes this trend in more detail and makes the case for balanced spectrum policy to address consumer appetites for mobile, data-intensive applications. Taking advantage of the technical attributes of wireless networks and the robust capacity of wireline networks, as noted in an earlier Research Program essay by Dale Hatfield,* Calabrese proposes a path forward on spectrum policy for the FCC. This report makes a compelling case for the importance of unlicensed spectrum as a component of federal spectrum policy supporting advanced digital communication needs.

It is generally agreed that the preferred frequency range for wireless RF communications used in the access portion of the network lies in the span of roughly 300 MHz to 3,000 MHz (3 GHz). The 2.4 GHz band relied upon for Wi-Fi to date has become increasingly saturated. Wi-Fi accounts for an estimated 80 percent of all traffic from smartphones, tablets and other consumer electronic devices. In the U.S., more data is carried over Wi-Fi than any other Internet path. A recent study estimated the 2.4 GHz band could be exhausted by the end of 2014. Meanwhile, next-generation gigabit Wi-Fi is currently not possible in any unlicensed frequency band suitable for Wi-Fi deployment in the U.S. today due to FCC rules. The 5 GHz band is particularly well-suited for continued deployment of outdoor cable Wi-Fi with existing standards, but new gigabit Wi-Fi standards allowing for increased throughput (meaning shorter transmission times, less battery consumption and a better customer experience) depend on access to 160 megahertz channels, which are not provided for under current FCC rules.

We hope this report stimulates debate and encourages a thoughtful policy discussion. As always, we look forward to your comments and feedback.

*Dale N. Hatfield, "The Challenge of Increasing Broadband Capacity," *The Future of Digital Communications: Technical Perspectives* (also appears in *63 Fed. Comm. L. J.* 43, 2010).

Introduction

The most encouraging contradiction in telecommunications policy today is the gap between claims of a "looming spectrum crisis" for mobile carriers and the reality that consumers rely increasingly on a relatively small amount of unlicensed spectrum to satisfy their exploding demand for streaming video, music and other applications on mobile devices. Consumer demand for bandwidth-intensive apps is outstripping the capacity of mobile carrier spectrum and infrastructure.

Six short years ago, before the iPhone, virtually all mobile device traffic was routed over a carrier's exclusively licensed spectrum and through cell towers and other carrier-provisioned infrastructure. Today, less than two-thirds of smartphone data traffic—and less than 10 percent of iPad data—are traversing carrier networks. The rest is transmitted a very short distance, at low power, over unlicensed spectrum, and into a wireline network that the end user (or an employer or a wireline ISP) has already provisioned. The share of mobile device traffic offloaded over unlicensed spectrum onto residential and business wireline networks is likely to surpass two-thirds over the next several years as the cable industry and many telcos continue to knit together millions of indoor and outdoor Wi-Fi access points.

This paper describes this trend, and argues that a balanced policy that prioritizes both more licensed *and* unlicensed spectrum will be needed to achieve a wireless future of pervasive connectivity at affordable prices. From a consumer perspective, the traditional distinction between wireline and wireless networks will increasingly blur. The devices may be mobile, but consumers are increasingly using data-intensive applications within Wi-Fi range of a wireline connection that is cheaper, faster and fairly soon will connect and hand off seamlessly as well. Because more than 80% of mobile device use is not truly *mobile* (in a car, on the go), but rather *nomadic* and often indoors (at home, at work, in a café or other public space), the vast majority of wireless data use can be offloaded over Wi-Fi or other very small cell technologies.

As fiber and other high-capacity wireline networks become more widely available, the ability of mobile devices to transmit data short distances over shared spectrum into less traffic-sensitive wired networks can replace the "spectrum crunch" with wireless bandwidth abundance. The key policy obstacle to this positive outcome is progress on the FCC's effort to open the most underused bands of spectrum—particularly federal spectrum and portions of the mostly empty TV band—for unlicensed sharing.

Note: The views expressed are those of the author and not necessarily those of Time Warner Cable or the Time Warner Cable Research Program on Digital Communications.

The Untethered Consumer: Internet Everywhere

As smartphones with PC capabilities and wireless modems become more ubiquitous and gain access to faster 4G and advanced LTE networks, total wireless data consumption will continue to increase geometrically. The most recent Semi-Annual Survey by CTIA, the wireless industry association, reports that U.S. wireless data traffic during 2012 totaled 1,468 billion megabytes (MB), a 69% increase over 2011 and more than three times the 388 billion MB in 2010.[1] Smartphone users increased their average data consumption by nearly 50 percent over this same period.[2] This trend is global. As consumers upgrade from narrowband cell phones to broadband smartphones, tablets and wireless modems in laptops, Ericsson predicts that mobile data traffic worldwide will grow twelvefold by the end of 2018.[3] Cisco's annual Visual Networking Index ("VNI") similarly projects that global wireless data traffic increased by 70 percent during 2012 and by 2017 will be 100 times the volume of traffic in 2009, when smartphone and tablet use began to proliferate.[4]

This explosive growth in wireless data demand shows few signs of slowing. Just as cell phones became far more numerous than landline connections, it seems likely that nearly all consumers will want wireless connections to the Internet on a variety of mobile devices. In the U.S., smartphone penetration reached 50 percent this year and one in five households (22%) owns a tablet.[5] This suggests we are at most halfway through a transformation to mobile Internet access. Mobile carriers are also in the process of extending considerably faster 4G coverage nationwide. As networks and devices support higher-resolution screens and higher-bandwidth applications, users will increasingly try to do everything on their mobile devices that they do on their home PC. And as high-capacity 4G networks and smartphones become pervasive, significant numbers of consumers will be tempted to "cut the cord" and rely solely on a single mobile broadband subscription for personal Internet access.[6]

Although today's focus is personal applications, such as mobile video calling and photo-sharing, wireless machine-to-machine communication (M2M) will also mushroom as costs decline, with predictions of 50 billion connected devices within a decade.[7] Applications including energy and environmental monitoring and controls, mobile health care, the connected home, and intelligent transportation systems will integrate wireless connectivity into an expanding Internet of Things. Demand for M2M connections over cellular networks is projected to grow substantially, with ABI Research projecting that it could increase 10 times to $35 billion in global sales by 2016. However, as a recent economic study observed, while M2M connections will grow exponentially, "at least 95% to 97.5% of all connections will use license-exempt [unlicensed] technologies."[8]

The overall impact of ubiquitous connectivity is enormous. A May 2013 study by the McKinsey Global Institute examined 100 disruptive technologies and ranked the mobile Internet number one, with an estimated global economic impact of $3.7 to $10.8 *trillion* by 2025 (nearly double the impact of the second most valuable technology: the automation of knowledge work).[9] The implications of this trend for innovation and economic competitiveness led the FCC's National Broadband Plan to recommend the reallocation of an additional 500 MHz of spectrum by 2020 in the prime frequencies below 3.7 GHz. Legislation in 2012 granted the FCC incentive auction authority to reallocate TV band spectrum from broadcasting to mobile carrier licenses—and mandated an auction of several other bands as well.[10] However, even with these increases in exclusively

licensed spectrum, inherent limitations on the capacity of the current carrier business model suggest that greatly expanded use of unlicensed spectrum for Wi-Fi traffic will be necessary to absorb projected demand, ensure consumers higher-speed connections, and promote innovation in M2M connectivity more broadly.

"Spectrum Crisis:" Why Mobile Carriers Can't Keep Pace

There are a number of reasons why relying primarily on a business model dominated by auctioning exclusively licensed spectrum and facilitating carrier-provisioned infrastructure (e.g., cell towers, fiber backhaul) appears unsustainable without a more balanced policy that also provides expanded access to unlicensed and other small cell, band-sharing policies.

First, there is a looming limit to the number of frequency bands below 3 GHz that can be reallocated, by auction or otherwise, to exclusively licensed use. Every frequency band is assigned to some use—and efforts to reallocate underutilized bands for exclusive licensing have proven to be slow and expensive. There appears to be no economically or politically feasible path to clearing 500 MHz for auction and exclusive licensing within five to 10 years, let alone the 800 MHz requested by CTIA, the wireless industry association.[11] While the National Broadband Plan's headline goal is 500 MHz, the Plan could identify only 280 MHz of non-Federal spectrum suitable for repurposing to mobile broadband. The remainder would need to come from clearing bands currently occupied by Federal government operations, most of which are military and radar systems. NTIA, however, concluded last year that there are few if any Federal bands that can be cleared for auction. Federal agencies argue they need more spectrum, not less, or that it would be too costly or disruptive to relocate their systems within a five-year or even in some cases a 10-year time frame.[12] For example, after an intensive, year-long agency/industry working group process focused on reallocating the Federal 1755-1850 MHz band, the Department of Defense concluded it could accept transitional sharing and eventual repurposing of only the bottom 25 megahertz.[13]

A second reason that the traditional carrier business model cannot keep pace with consumer demand is the imperative for spectrum frequency reuse over increasingly small areas. Martin Cooper, leader of the team at Motorola that invented the first mobile phone, has calculated that frequency reuse is responsible for roughly 64 times more improvement in total wireless utilization over the past 45 years than any improvement attributable to making more spectrum available.[14] Mobile carriers invest enormous capital to add cell sites and base stations that reuse spectrum over smaller areas. But there are practical limits to how close carriers can bring their transmitters and backhaul to the individual consumer. According to industry survey data, during the most recent two-year period, total cell sites increased less than 20% (from approximately 253,000 to 302,000), while total wireless data traffic increased 375% (from 388 to 1,468 billion megabytes of data).[15] As demand for mobile data increases, the industry's cell site bottleneck is a very real constraint and cost that limits the spectrum efficiency of the dwindling number of prime frequency bands that can be auctioned for exclusive use.

A third obstacle to depending on exclusively licensed spectrum to meet surging demand is competition policy. AT&T cited the need for more spectrum licenses as its principal reason for acquiring rival carrier T-Mobile in 2011—a bid that was rejected by the Justice Department's Antitrust Division. MIT economist William Lehr and DARPA technologist John Chapin have argued that the supposed spectrum shortage stifles competition and encourages industry consolidation by raising costs for deploying competitive 4G broadband.[16] They surmise that it will be "impossible" to maintain current levels of competition simply by allocating more exclusively licensed spectrum.[17] Moreover, a shortage of spectrum for mobile broadband encourages monthly data caps

and higher prices that inevitably deter consumption of high-bandwidth services and stifle wireless innovation.

Wi-Fi to the Rescue: Offloading Mobile Device Traffic

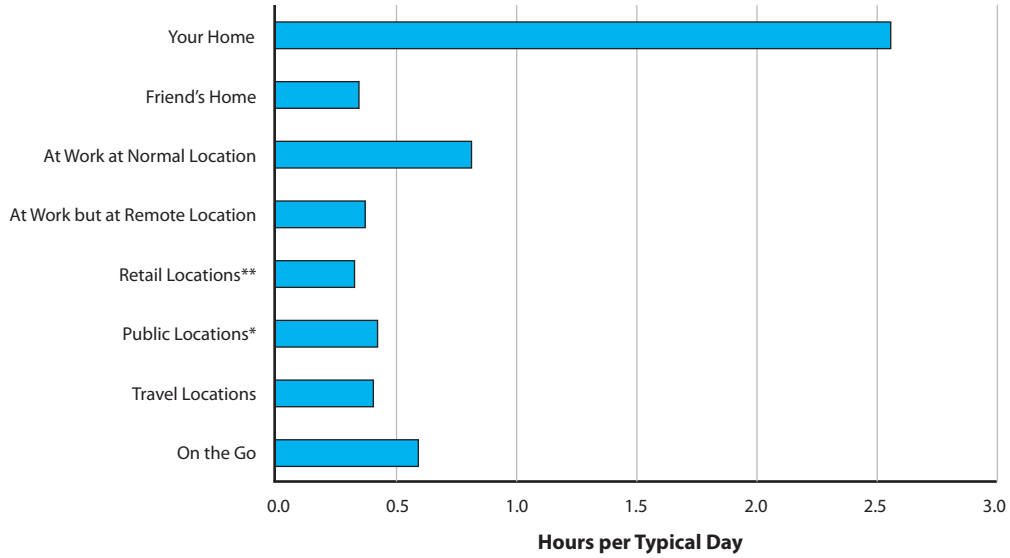
In short, there is simply not enough exclusively licensed spectrum to meet the rapidly rising demand for wireless data, to sustain a competitive market, and to keep prices at an affordable level. Major mobile carriers are increasingly coming to grips with this reality. The Wireless Broadband Alliance, a global industry group, reports that Wi-Fi offloading has become an industry standard as "18 of the world's top 20 largest telcos by revenue have now publicly committed to investing in deploying their own Wi-Fi Hotspot networks."[18] The industry is shifting steadily toward what it calls heterogeneous networks (HetNets)—i.e., a combination of licensed and unlicensed infrastructure—in order to meet their customers' insatiable demand for data while keeping costs down. Alcatel-Lucent forecasts an increase of "87 times [the current] daily traffic on wireless networks" over the next five years, with 50 percent of that traffic on cellular networks "while the remaining 50 percent will be offloaded to Wi-Fi."[19]

One of the many proven benefits of unlicensed spectrum is that it facilitates spectrum frequency reuse over very small areas (a home, business, or school). Ruth Milkman, chief of the FCC's Wireless Bureau, stated recently that the aggregate capacity of the world's Wi-Fi networks "is 28 times greater than the capacity of the world's 3G and 4G networks, which use licensed spectrum."[20] Because of its efficiency and low cost, Cisco's Virtual Networking Index projects that unlicensed spectrum will carry as much IP traffic to and from consumer devices as wired lines by 2016—and five to 10 times as much data as mobile carrier networks.[21] As Sprint explained in an FCC filing last year, Wi-Fi "gains its efficiency and speeds in part because it only needs to use radio transmission for a very small portion of the end-to-end route taken by data traffic. The vast majority of the route is along the less traffic-sensitive wired network."[22]

Since most video and other high-bandwidth applications on mobile devices are used either indoors or outdoors within range of a wired local area network, widespread availability of Wi-Fi operating on *unlicensed* spectrum is the single most important factor in mitigating the "spectrum crunch." It is critical in this regard to distinguish between truly *mobile* data demand (on the go) and *nomadic* data demand (indoors or outdoors near a wired connection). Cisco's Internet Business Solutions Group (IBSG) conducted a survey last year of more than 1,540 U.S. individual and business users of mobile data devices. The Cisco survey found that mobile devices, including smartphones, are used primarily at home and work—and overwhelmingly in locations with wired networks that either do or could easily offer Wi-Fi offload. "While two-thirds of people still use their devices on the go, the world of mobile devices is changing from a 'mobile,' on-the-go world (average usage of 0.5 hours per typical day) to a 'nomadic' world dominated by the home (2.5 hours)," Cisco stated.[23] As Table 1 shows, users report that two-thirds of their usage is at home or work, with only 10 to 15 percent being "on the go" or outside of retail and public locations that are increasingly wired for Wi-Fi access.

Wi-Fi is becoming ubiquitous in all the places where users typically use high-bandwidth applications, such as video streaming, video calling, gaming and web browsing. Among these, video is driving overall demand and most of that traffic is migrating to Wi-Fi. Verizon reports that already at least 50% of its mobile traffic is online video, a share the company projects will increase to two-thirds of all mobile broadband traffic by 2016.[24] Video traffic is projected to keep growing by an average of 60% annually over the next five years, according to the Ericsson Mobility Report.[25] Happily, video is perhaps the most nomadic of wireless device applications. Surveys of user behavior show that nearly

Table 1. Average Daily Mobile Device Usage by Location



Q33. In a typical day, for how long do you use your mobile devices in each of the following locations?

N=varies
** Public – e.g., stadiums, parks, schools*
*** Retail – e.g., stores, restaurants*

Source: Cisco IBSG, 2012

85% of video on mobile devices is watched at home (50%), at work (15%), or at other indoor locations (20%) where Wi-Fi networks are or could be available. Only 15% is watched outdoors or "in transit."[26]

As a result, analysts estimate that despite the ongoing rollout of 4G LTE services, offloading to Wi-Fi will continue to grow, rising from roughly 35 percent today to as much as 60 to 70 percent of the total traffic that would otherwise be on 3G and 4G networks by 2015.[27] Juniper Research projected this year that 63% of the data traffic generated worldwide by smartphones, tablets and feature phones will be transferred onto the fixed network via Wi-Fi and femtocells by 2015.[28] With overall data traffic on mobile handsets and tablets expected to increase to the equivalent of seven billion Blu-ray movies by 2017 (90,000 petabytes), carrier macro networks will only be capable of carrying about 40 percent of it.

Consumers Prefer Wi-Fi, Reducing Carrier Costs

This massive redirection of mobile device traffic onto fixed networks over unlicensed spectrum is being driven not merely by necessity, but also by consumer preferences. Now that Wi-Fi is integrated into nearly all mobile devices—and available in an increasing share of homes, offices and public places—consumers are actively choosing to use it as an alternative to their carrier's macro cell network. Surveys show that increasing numbers of both individual consumers and business users prefer Wi-Fi for reasons of both cost and quality.

For example, the Cisco IBSG survey noted just above found that among both individual consumers and business users, 50% of tablets, laptops and eReaders are connecting exclusively through Wi-Fi.

Table 2. Preferred Network Access: Wi-Fi or Cellular Network?

Attribute	Mobile/Cellular	Wi-Fi	No Difference	N*
Lowest Cost	20%	56%	24%	746
Speed of Network	18%	58%	24%	800
Best Reliability	31%	46%	23%	794
Best Performance for My Applications	27%	46%	27%	759
Best Coverage	46%	35%	19%	792
Most Secure	34%	35%	31%	753
Easier to Use	29%	40%	31%	821

* Don't Knows removed from sample.

Q38. Thinking about Wi-Fi and mobile/cellular networks, which type of wireless network do you think offers the most desirable performance or features in each of the following areas?

Source: Cisco IBSG, 2012

"Given a choice, more than 80 percent of tablet, laptop, and eReader owners would either prefer Wi-Fi to mobile access, or have no preference," Cisco concluded. "And, just over half of smartphone owners would prefer to use Wi-Fi, or are ambivalent about the two access networks."[29] The Cisco surveys found users are choosing Wi-Fi over mobile connectivity for reasons of cost, "because it doesn't impose data-usage caps or reduce their mobile data plan quotas."[30] But the primary reason for choosing Wi-Fi "is that respondents find it much faster than mobile networks." And since Wi-Fi traffic travels over the underlying (and nearby) *wireline* network, that speed differential may only increase as more and more homes, businesses and retail outlets upgrade to fiber optic or other high-speed connections of 100 mbps or more.

Of course, individual and business users are not the only beneficiaries of Wi-Fi offload. When consumers offload mobile device traffic over Wi-Fi, it translates directly into reduced costs for carrier-provisioned infrastructure and licensed spectrum capacity. Cisco IBSG concluded in a study that "mobile operators can reduce their radio access costs by at least 25 percent (in most cases) by selectively incorporating Wi-Fi into their network architectures and operations."[31] A 2012 study by Consumer Federation of America economist Mark Cooper found that Wi-Fi offloading, in addition to reducing the spectrum needed by U.S. carriers, also reduced the infrastructure costs of cellular broadband service by roughly $20 billion per year, "which is a substantial savings in a market with annual revenues of $70 billion."[32] Mobile carriers simply do not have either the capital or spectrum to carry their customers' Wi-Fi traffic onto their own network.[33]

Hybrid Networks: Three Models Emerging

The implication of these trends is that rising consumer demand for data on mobile devices can be most efficiently met by offloading most data traffic onto wired local area networks (such as home or business Wi-Fi connections), rather than relying on transmission over exclusively licensed spectrum to carrier-provisioned infrastructure. If sufficient unlicensed spectrum is available, an increasing share of mobile device traffic will be transmitted just a very short distance, at low power, over shared public spectrum, and into a wireline connection that is either the end user's or part of an offload network managed by a wireline (e.g., cable company) or wireless ISP. Under either scenario, both spectrum reuse and backhaul will increasingly be more cost-effective at the edge of the network, closest to end-users and subject to their control (or, more practically speaking, determined on the fly by software in their device).

Cellular carriers—relying as they do on a necessarily limited amount of exclusively licensed spectrum, and shouldering the capital costs for centralized infrastructure—will continue to serve as the "quality of service provider." Consumers will happily pay for remote coverage, for needed mobility (connectivity on the move), or for the transport of latency-sensitive applications (voice). But they will increasingly seek to avoid paying a wireless carrier or other intermediary to transport the bulk of their mobile data over the publicly owned airwaves when a far more cost-effective and spectrum-efficient alternative is to transmit a short distance over unlicensed spectrum into a wireline Internet connection that is already provisioned.

Massive deployments of Wi-Fi access points on unlicensed spectrum by wireless and wireline carriers are supplementing—and increasingly supplanting—self-provisioned private Wi-Fi as a way to make Internet access ubiquitous and more affordable. Three general models are emerging for the use of small cell unlicensed offload to ease the "spectrum crunch" due to exploding demand for untethered broadband use.

Model One: Carrier-Provisioned Hotspots and Hot Zones

Mobile carriers worldwide are embracing the benefits of Wi-Fi offload and doing so to a far greater degree than in the United States. A case in point is Japan's NTT DOCOMO. Despite an extensive 3G network and burgeoning deployment of LTE service, the company has been rapidly expanding its Wi-Fi hotspot network. NTT DOCOMO announced that it will have between 120,000 and 150,000 operational Wi-Fi hotspots by March of this year, up from just 8,400 one year earlier.[34] On a far larger scale, China Mobile has deployed more than two million Wi-Fi access points and carries a reported 70 percent of its customers' total data traffic over Wi-Fi.[35]

The world's largest carrier-operated data offload network is in France, where Free Mobile's phone customers have access to more than four million residential Wi-Fi hotspots created by Free's wireline parent, Iliad, which opens up the home wireless routers it installs for its wireline customers.[36] Free Mobile has been able to offer a far less expensive mobile service by offloading a large share of its mobile device traffic over Iliad's fixed network.[37]

Although cellular carriers in the U.S. have appeared ambivalent about embracing Wi-Fi offload or small cell band-sharing more generally, there are signs that even the two largest carriers with the best spectrum holdings (AT&T and Verizon) will follow the global trend. AT&T Wireless gives its customers free access to more than 32,000 company-deployed Wi-Fi hotspots and an increasing number of "hot zones" that blanket congested areas, including Times Square and stadiums such as Chicago's Wrigley Field, with a mesh network of Wi-Fi coverage. AT&T's network deployment has focused on popular retail, hospitality and sporting venues, including Starbucks and McDonald's, where it finds that customers congregate and demand fast connections. Consumers made 2.7 billion connections to AT&T's Wi-Fi network during 2012, double the number during 2011 and more than 25 times as many as in 2009. More important, the total data traffic tripled to 5.2 billion megabytes during 2012. Verizon similarly maintains a network of Wi-Fi hotspots in certain high-traffic locales (e.g., airports, convention centers), but it is far smaller than AT&T Wi-Fi and not promoted.

Model Two: Metro Wi-Fi Extensions of Wireline Networks

A similar but more extensive set of Wi-Fi networks have been built out by cable and other *wireline* ISPs as part of an "Internet Everywhere" strategy that extends customer access to the Internet and to subscription content. The earliest and most extensive leveraging of unlicensed spectrum to untether access to fast wireline networks was pioneered by Spanish telecom FON. The FON model was initially premised on consumers agreeing to become a *Fonero* by voluntarily sharing access to their own Wi-Fi connection in exchange for receiving access to every other participating subscriber's access point. This permits subscribers to get Internet access on a nomadic basis across large portions of western Europe. FON now has the world's largest Wi-Fi consortium, with more than eight million hotspots that are increasingly provided free to subscribers by major wireline telecoms that include the BT Group (British Telecom), Vivendi's SFR (France), ZON (Portugal), Belgacom (Belgium) and, launching in 2013, Deutsche Telekom (Germany).

By far the largest aggregation of hotspots is in the U.K. British Telecom is aggressively expanding its BT Wi-fi, the new name for BT OpenZone, which is free to customers and (it claims) far faster than 3G mobile connections. The wireline telco adapted FON's technology to broadcast an open Wi-Fi connection from more than five million home and business customers.[38] BT gives each customer a wireless router (a "Home Hub") that enables both a private and a public Wi-Fi network, each with a separate SSID. Subscribers have the option to opt out, but very few do because they value the ability to connect at not only five million hotspots across the U.K, but an additional 3.5 million in the other countries participating in the FON consortium. Connecting is quick and easy, since BT customers use automated login technology standardized through the global Wireless Broadband Alliance to tunnel through BT's core network to the public Internet. And since BT is such a prevalent wireline provider in U.K. cities, the map of BT Wi-fi hotspots shows a nearly seamless cloud of free wireless coverage in many neighborhoods and congested retail areas, including more than 500,000 in London alone.[39] Non-BT subscribers can purchase access for as little as 90 minutes or as long as 30 days.

In the U.S., a consortium of the nation's largest cable companies—Comcast, Time Warner Cable, Cablevision, Cox and Bright House—have rapidly built out a network of more than 150,000 hotspots that blanket large portions of the New York, Philadelphia, Los Angeles, Chicago and other major metro areas with a shared Wi-Fi network.[40] These extensive metronets give cable subscribers the ability to access content away from home over the mobile device of their choice. Each company deploys its own network, but using a common authentication software it recognizes and

grants reciprocal access to the subscribers of each company in the consortium. The CableWiFi® Alliance is expanding rapidly. Comcast alone has expanded its XFINITY WiFi network from 5,000 to 55,000 public hotspots since the beginning of 2012.[41]

Unlike BT Wi-fi and France's Free Mobile, which focus their coverage on residential neighborhoods, the CableWiFi® platform has been deployed primarily outdoors in very heavily trafficked commercial districts and civic spaces. For example, Time Warner Cable (TWC) invested over $15 million to deploy 12,000 Wi-Fi access points throughout the Los Angeles area, including along the streets in the La Brea downtown shopping and entertainment district, UCLA and major marinas and harbors.[42] Overall, TWC projects that it will double its total number of Wi-Fi access points to more than 30,000 by the end of 2013.[43] TWC reports that during 2012 the number of unique users on its Wi-Fi network grew by more than 700% and that data consumption per user more than doubled.[44]

It also seems likely that as in London or Paris, U.S. residential areas with concentrations of cable Internet subscribers will also become clouds of Wi-Fi connectivity. On June 10, on day one of the 2013 Cable Show, Comcast announced a "neighborhood hotspot initiative" that will turn millions of customer cable Internet connections into shared Wi-Fi hotspots using a dual-use wireless home gateway. Like the FON and BT Wi-fi model, the subscriber's wireless home gateway will broadcast two Wi-Fi signals over unlicensed spectrum: one password protected for the private use of the home subscriber, and the other a neighborhood XFINITY WiFi network signal open for shared access by other Comcast Internet subscribers.[45] Since Comcast is the nation's largest wireline broadband provider, with more than 20 million subscribers clustered in particular geographic areas, the initiative could quickly leverage unlicensed spectrum to put clouds of connectivity over a dozen or more major metro areas.

As cable metronets extend Wi-Fi access beyond the home, they directly increase the size and share of total mobile device traffic offloaded from carrier networks into local wireline connections via unlicensed spectrum. Although the CableWiFi® platform is intended primarily as a subscriber amenity, non-subscribers can purchase day passes. Public access to cable Wi-Fi on both a free and a pay-as-you-need-it basis is also expanding as an increasing number of small business customers sign up to broadcast their cable Internet connection as a consumer amenity.

Model Three: Fully Integrated HetNets

A third mobile device offload model will allow wireless providers to integrate seamless access to "carrier-grade" Wi-Fi networks, enabling seamless connections and hand-offs between unlicensed and licensed bands. Wi-Fi could relieve carrier congestion and conserve spectrum to a far greater degree if subscribers did not need to manually discover, select and access each hotspot. A combination of automatic authentication and hand-offs between the core network and Wi-Fi could allow consumers to maintain their video call or other Internet session as they move from an indoor (nomadic) Wi-Fi, or other small cell network, to the wide-area macro network. Since consumers would not necessarily realize (or care) which part of the network they are on, some industry experts expect that certain attributes of mobile networks—such as security, billing and centralized network management—could be applied to Wi-Fi offload as well, promoting both quality of service and monetization of what today is primarily consumer-provisioned Wi-Fi offload.[46]

Industry standardization efforts, such as the Wireless Broadband Alliance's *Next Generation Hotspot* and Wi-Fi Passpoint Certification initiatives, aim to bring a "cellular-like" experience to Wi-Fi, with automatic SIM authentication, security and seamless roaming across potentially

global confederations of carrier-grade Wi-Fi networks.[47] A number of major carriers outside the U.S. are deploying these hybrid network technologies. PCCW, which is Hong Kong's leading integrated broadband service provider, has upgraded its entire network to support automated SIM authentication and switchovers to Wi-Fi offloading when available. As noted above, China Mobile has deployed more than two million Wi-Fi access points and is implementing seamless access between its 3G and Wi-Fi networks, also using SIM authentication. The Swiss carrier Swisscom is experimenting with a data card that enables devices (initially notebooks) to maintain an Internet session during a seamless hand-off between 3G and Wi-Fi networks.[48] And although U.S. carriers have not yet moved to truly integrate Wi-Fi or other small cell offload networks, one upstart carrier—Republic Wireless—is reversing the traditional business model by offering subscribers very inexpensive and unlimited smartphone service that relies principally on Wi-Fi, including for calls, while using leased access to Sprint's nationwide mobile network as a backup where Wi-Fi is not available.

The Prospects for More Unlicensed and Shared Spectrum

A second seeming contradiction in telecommunications policy today is the gap between claims of a "looming spectrum crisis"[49] and the reality that only a fraction of the nation's prime spectrum capacity is actually used even in the most congested urban areas. These two propositions are not actually contradictory. There is little question that mobile data demand and the need for more spectrum by wireless carriers are both growing rapidly. At the same time, actual spectrum occupancy measurements show that even in extremely high-demand areas such as Manhattan and downtown Chicago, less than 20 percent of the frequency bands below 3.1 GHz are in use over the course of a typical business day.[50]

Spectrum policy is a situation of scarcity (of exclusive licenses) amidst abundance (of unused capacity). All of the lower-frequency spectrum best suited for mobile broadband services has been assigned over the years for other purposes, with broadcasters and the military holding by far the largest shares. The FCC itself recently acknowledged that although its efforts have focused primarily on clearing bands for "traditional, exclusive licensing uses . . . it has become increasingly clear that such efforts alone will not suffice to meet the growing demand for commercial wireless spectrum."[51]

It is also increasingly clear that spectrum efficiency and consumer welfare would be optimized by hybrid networks that carry most mobile device traffic over short distances, at very low power, using virtually unlimited unlicensed and shared spectrum capacity within and between wireline local area networks. To achieve pervasive connectivity at affordable prices, policymakers need to promote a balanced combination of small cell spectrum strategies in parallel with continued efforts to increase exclusively licensed spectrum for wide-area mobile coverage. This will require more licensed and more unlicensed spectrum in frequency bands with a variety of propagation characteristics.

Unfortunately, despite the many proven and rapidly growing benefits of Wi-Fi, the sole unlicensed band with both relatively wide, contiguous channels and decent propagation—the 2.4 GHz band—is becoming heavily congested in densely populated urban areas. Although unlicensed bands and Wi-Fi protocols promote intensive sharing and small cell reuse, as mobile devices proliferate and consumers do more video streaming and video calling, more open access to shared public spectrum will be needed—and not only at high frequency ranges (above 5 GHz) that limit use to indoor or line-of-sight uses.

Currently the FCC has three active regulatory proceedings that propose to expand unlicensed access to spectrum in frequency bands with a variety of propagation characteristics:

FCC Proceeding One: Implementation of the TV Band "Incentive Auctions" Mandated by Congress in the 2012 Spectrum Act

Local TV stations will be given an option to give up either all or half of their broadcast channel in exchange for a share of the auction revenues collected from mobile carriers bidding to acquire exclusive licenses. While this will convert some of the best "beachfront" spectrum to licensed use,

the reorganization of the TV band also creates an opportunity to ensure that there is at least 30 to 40 megahertz of TV band spectrum available for *unlicensed* use in every market nationwide.

At present, the majority of TV channels are not used for broadcasting. And although the FCC recently began permitting unlicensed use of many vacant TV channels, there are few if any unlicensed channels in the biggest cities, including New York, L.A. and the San Francisco area. As part of the incentive auction process, the FCC is considering whether to designate needed guard bands and what are currently channels reserved for wireless microphones and radio astronomy for low-power unlicensed use. By setting aside a substantial minimum amount of unlicensed "white space" channels in big cities as well as rural areas, the FCC will facilitate markets of national scope and scale for the incorporation of this superior spectrum in devices along with other unlicensed bands with less favorable propagation characteristics.

FCC Proceeding Two: A Larger Increase in Open Access to Shared Spectrum

This increase would result from the FCC's proposed *Citizens Broadband Service* in a very underused band (3550-to-3700 MHz) used primarily by the military for offshore naval radar and satellite earth stations. In its report and recommendations last year, the President's Council of Advisors on Science and Technology (PCAST) identified this band as the best opportunity for opening a grossly underutilized Federal band for shared licensed and unlicensed use on a small cell basis conducive to Wi-Fi offload technologies (as well as machine-to-machine innovation). The FCC's proposal would protect Federal incumbents from interference and provide "priority access" to one-third of the band for quality-of-service use. In addition, the Commission proposes "general authorized access" across the entire band for unlicensed devices. To avoid interference with licensed incumbent and priority access users, unlicensed users would be required to check their location periodically with a Spectrum Access System database designed to protect licensees. The PCAST concluded that by relying on an automated database, on spectrum sensing, or on a combination of both, it is now technically feasible to dynamically share most of the very underused frequency bands and turn spectrum scarcity into abundance.

FCC Proceeding Three: Expand Unlicensed Spectrum Access in the 5 Ghz Band, a Higher-Frequency Band

Although this spectrum does not propagate well through walls, bad weather or over long distances, because most of the 5 GHz band is already shared with military and FAA radar systems on an unlicensed basis (using spectrum sensing technology), the FCC's proposed 195 MHz expansion will permit channels several times wider than today's Wi-Fi at 2.4 GHz. These wide channels enable very high-capacity wireless throughput over short distances and will be capable of speeds up to 1 gigabit per second using the newest 802.11ac Wi-Fi standard.[52] Video routing and outdoor point-to-point backhaul are among the most immediate uses. At the same time, trends in wireless technology suggest that higher-frequency and wider-channel bands will be increasingly useful as both complements and substitutes for the more spectrum-scarce licensed carrier networks, just as the 2.4 GHz Wi-Fi band is today.

Recommendations

The unlicensed economy has become central to the positive impact of both wireless and wired Internet access on innovation, job creation and economic growth more broadly. The initial and most obvious benefit of unlicensed spectrum has been Wi-Fi networks that permit many different users—at home, at work, or in a hotspot location—to share a single wireline Internet connection. More recently, as described above, an increasingly valuable use has been to offload larger and larger portions of the data traffic generated by the rapid uptake of smartphones, tablets and other mobile broadband devices. In the near future, wireless connectivity will be embedded in tens of billions of other devices, systems and objects, boosting both business and personal productivity. Policymakers should therefore accelerate and prioritize an increase in the supply of unlicensed spectrum access in frequency bands with a variety of propagation characteristics. Expanding unlicensed access to both the low-frequency TV bands below 1 GHz and the higher, mostly line-of-sight frequencies above 5 GHz is the foundation for a balanced and practical path to avoiding spectrum scarcity and facilitating market competition, consumer choice and innovation.

As described in the section above, the FCC currently has pending a trilogy of rulemakings with the potential to fuel a next generation of ubiquitous and high-capacity wireless connectivity. In each proceeding the Commission's challenge is to find a forward-looking balance between the interests of longtime incumbents (e.g., broadcasters, wireless microphones, licensed carriers, the military) and the proven potential of more expansive unlicensed access. Specifically, in each proceeding the FCC should expedite a final order that achieves the following objectives:

Recommendation One: Move Forward with TV Band Incentive Auctions

Although the planned auction of additional TV band spectrum will inevitably result in fewer "white space" channels for unlicensed use, the FCC should reorganize the band to ensure the availability of at least 30 to 40 MHz of unlicensed spectrum in *every* media market. This will require several band plan and rule changes: First, the guard bands needed to protect licensed services should be wide (e.g., a duplex gap of at least 20 megahertz), contiguous and designated for low-power unlicensed use. Second, Channel 37 should be opened for shared, unlicensed use by relying on the existing geolocation database to enforce exclusion zones to protect incumbent services. Third, the two TV channels now exclusively reserved for wireless microphones should be opened for shared access by unlicensed broadband devices at the times and places they are not needed by microphones. There is no need to reserve any TV channel *exclusively* for microphone use, since mic operators have effective access to a large number of vacant TV channels that are not available for unlicensed use and that can meet their needs under ordinary circumstances. The FCC should require microphones to rely first on these out-of-market TV co-channels before falling back on a database reservation that makes a channel unavailable for unlicensed use.

Recommendation Two: Implement 3.5–3.7 GHz Band Sharing

The FCC's proposal to open this grossly underutilized federal band for a low-power Citizens Broadband Service strikes the right balance between protecting incumbent operations (mostly offshore naval radar) and facilitating private-sector usage on a spectrally efficient, small cell basis. As

described in the section above, the proposal implements the PCAST's three-tier spectrum sharing model and would lay the foundation for a long-term effort to reorient the nation's spectrum policy toward *use* rather than exclusively reserved *non-use* of capacity on the public's infinitely renewable spectrum resource. As the Commission decides rules for shared use of the band, it is critical that a substantial portion of the band should always be available for unlicensed use ("General Authorized Access") in every market nationwide. In addition, GAA users should be able to opportunistically access unused spectrum capacity in the band across the entire 150 MHz, subject to protecting Federal incumbents and secondary "Priority Access" licensees.

Recommendation Three: Expand Unlicensed Use of the 5 GHz Band

The FCC should move as quickly as possible to adopt its proposal to expand unlicensed access to the 5 GHz band, subject to necessary interference protections for Federal and non-Federal band incumbents. Opening the 5.35–5.47 and 5.85–5.925 GHz bands for unlicensed sharing will create the contiguous and very wide channels needed to take advantage of the high-capacity 802.11ac Wi-Fi standard. Adding this 195 megahertz will have a multiplier effect on the value of the band for unlicensed use, since it creates the potential for a contiguous band of 775 megahertz of unlicensed spectrum, enabling very high-capacity Wi-Fi applications. The Commission should also remove current indoor restrictions and authorize outdoor use to the greatest possible extent across all of the current and future 5 GHz unlicensed band segments.

Conclusion

Advancing a national goal of seamless and affordable mobile device connectivity anywhere, anytime, and at high throughputs will require an enormous increase in available spectrum capacity, both licensed *and* unlicensed. Unleashing an abundance of spectrum and driving down its cost as an input for all things mobile is therefore the single best means by which the Federal government can promote innovation and consumer welfare in wireless.

Endnotes

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10. Middle Class Tax Relief and Job Creation Act of 2012, Pub. L. 112-96, § 6407, 126 Stat. 156, 231 (enacted February 22, 2012 and codified in scattered sections of 47 U.S.C.), *available at* http://www.gpo.gov/fdsys/pkg/PLAW-112publ96/pdf/PLAW-112publ96.pdf.
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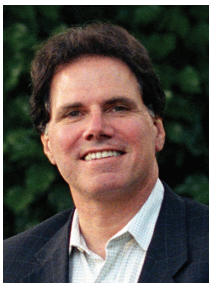
About the Author



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About the Time Warner Cable Research Program on Digital Communications

The Time Warner Cable Research Program on Digital Communications will be dedicated to increasing public understanding of the benefits and challenges facing the future of digital technologies in the home, office, classroom, and community.

The Research Program will focus on the following areas:

- Increasing knowledge about the marketplace and the consumer
- Increasing knowledge about digital technologies
- Increasing knowledge about communications policy
- Increasing knowledge about innovation in digital communications

About the Research Stipends

Individuals receiving a stipend should produce a 25- to 35-page report. The report should be submitted no later than six months after the start of the project.

Proposals from any discipline with research interest in digital communications will be considered. Multidisciplinary research teams, consisting of two or more authors from different fields, are encouraged.

Size of Stipend: $20,000

Application Deadlines for 2013/2014 Awards: November 1, 2013 and April 1, 2014

Submitting Applications: Applications should be submitted online at www.twcresearchprogram.com. Applicants should submit:

- A three-page description of the proposed project
- A resumé (no more than three pages per author)

Applicants will be notified when their application is received and when the proposal review process is completed.

About Time Warner Cable

Time Warner Cable Inc. (NYSE: TWC) is among the largest providers of video, high-speed data and voice services in the United States, connecting more than 15 million customers to entertainment, information and each other. Time Warner Cable Business Class offers data, video and voice services to businesses of all sizes, cell tower backhaul services to wireless carriers and, through its NaviSite subsidiary, managed and outsourced information technology solutions and cloud services. Time Warner Cable Media, the advertising arm of Time Warner Cable, offers national, regional and local companies innovative advertising solutions. More information about the services of Time Warner Cable is available at www.timewarnercable.com, www.twcbc.com and www.twcmediasales.com.

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