Unlicensed Use of the TV White Space:
Wasteful and Harmful

by

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I. SUMMARY AND INTRODUCTION

In a report submitted in 2007 in the FCC's TV white-space proceeding, two of us, Jackson and Robyn, analyzed competing options for managing the TV white space following the digital TV transition. Specifically, Jackson and Robyn compared the unlicensed approach proposed by the Commission with the option of licensing and auctioning the rights to the white space—an approach that previously had received little consideration.[1] Jackson and Robyn concluded that licensing of the TV white space was in fact feasible and that it would be far more beneficial for consumers than an unlicensed approach. Three findings were key to their conclusion.

First, Jackson and Robyn found that licensing would free up substantially more TV white space for productive use. Based on a detailed quantitative analysis of five scenarios, they estimated that *roughly twice as much TV white space would be available for use under a licensed regime as compared to an unlicensed regime*. This estimate reflected two insights: a) licensing would entail less conservative FCC interference-protection rules, and b) whatever the starting point set by the FCC rules, licensees would have both the ability and a strong incentive to negotiate with broadcasters to expand service beyond that baseline, getting additional TV white space into use.

Second, Jackson and Robyn found that the TV white space is poorly suited to most unlicensed applications. Because the incentives for investment would be weak, unlicensed use of the TV white space would support neither innovative short-range data communications such as WiFi nor much-needed long-range rural broadband. By contrast, a licensing regime would be more likely to produce the large infrastructure investments required for rural broadband and other long-range applications—the applications for which the TV band is ideally suited.

Third, Jackson and Robyn concluded that the long-term effect of open access to the TV white space could be perverse. Whereas licensing would facilitate the long-term transition of the TV band to more valuable uses (a goal that unlicensed advocates support), a policy of unlicensed access would actually impede that process by creating tens of millions of spectrum "squatters."

[1] "Comments of Charles L. Jackson and Dorothy Robyn," ET Docket No. 04-186 (January 31, 2007). See also "Reply Comments of Charles L. Jackson and Dorothy Robyn," ET Docket 04-186 (March 2, 2007).

In June, in a separate FCC proceeding, the three of us responded to the Commission's request for information on the potential auction value of the rights to the TV white space (an issue addressed only cursorily in the 2007 Jackson-Robyn report).[2] We used a sophisticated valuation methodology and drew on the results of the recent FCC auction of the 700 MHz spectrum—specifically, the E Block spectrum, which closely resembles the TV white space. We estimated that an auction of rights to the TV white space would generate from $9.4 billion to $24.4 billion, depending on the interference-protection rules and the number of channels included.

In this document, we update the 2007 Jackson-Robyn analysis in two other areas. First, we examine the current availability of unlicensed spectrum. Implicit in the case for open access to the TV white space is the assumption that there is insufficient unlicensed spectrum to accommodate the rapid growth in the use of unlicensed devices. We test that assumption. Second, we look at the suitability of the TV white space for unlicensed use. Advocates of open access assert that the attractive propagation characteristics of the TV band would allow unlicensed devices to operate more effectively and at lower cost there than they can in the higher frequency bands where most unlicensed activity now occurs. We consider whether, as is claimed, unlicensed use of the TV white space would boost investment in short-range WiFi-type systems as well as much-needed long-range systems such as rural broadband.

Our major conclusions are as follows:

- A large amount of spectrum has already been allocated for unlicensed use. The total allocation is about 11 GHz—more than ten percent of the entire spectrum below 100 GHz. Looking just at the spectrum below 6 GHz, the fraction available for unlicensed use is even higher—about 12 percent (707 MHz). The supply of unlicensed spectrum is large not just in absolute terms but by comparison to that of liberally licensed spectrum. The amount of spectrum below 3 GHz that is available for unlicensed use (132 MHz) is about a quarter of the comparable spectrum available for commercial mobile services.

- There is no evidence of congestion that suggests the need for additional unlicensed allocations. Most significant, new products continue to be rolled out in the popular unlicensed bands, as measured by annual FCC equipment authorizations. The fact that manufacturers are investing in these products indicates that the bands are not congested.

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2 "Comments of Charles L. Jackson, Dorothy Robyn and Coleman Bazelon," ET Docket No. 06-150 (June 20, 2008).

- By that same measure, other unlicensed bands appear to experience very little usage. In other words, there is a considerable amount of what amounts to "white space" in the current unlicensed bands. This represents both a major lost opportunity and a further indication that the plea for additional unlicensed spectrum is unwarranted.

- The TV white space is poorly suited for most unlicensed applications because the incentives for investment and innovation would be weak:

    - For short-range data communications, unlicensed TV spectrum would be substantially inferior to the existing unlicensed bands at 2.4 GHz and 5 GHz. The combination of limited data rates, network externalities, and the costs necessary to avoid interference with TV reception and wireless microphones will impede adoption of this band for the much-touted wireless local area network (LAN) applications. The more likely applications (*e.g.*, better cordless phones and wireless game consoles) would add little to what consumers already have.

    - For long-range communications—the services for which the TV band is ideally suited—an unlicensed wireless internet service provider (WISP) would face two major handicaps. One is the threat of interference from other unlicensed operations in the white space—primarily short-range, low-power devices. Another is the low power level restrictions, which would severely limit the range and capacity of unlicensed base stations. These handicaps, which licensed competitors operating in the nearby 700 MHz band will not face, would likely pose an insurmountable hurdle to investment in unlicensed operations in the TV white space.

- There is no evidence for the claim that the TV white space would spur innovation in unlicensed applications. Although unlicensed spectrum can provide a good home for low-power, short-range systems and thus facilitate innovation in such systems, the TV white space is "overqualified" for such applications. Devoting TV spectrum to low-power, short-range systems is like using land in downtown Tokyo to grow rice.

- Instead, the TV white space is ideally suited for long-range applications. Investment and innovation in such applications, however, requires the interference-control that only licensing provides. Thus, a licensed approach to the white space is far more likely to produce large investments in long-range infrastructure and the resulting innovation.

- The TV white space *is* prime spectrum, as unlicensed advocates maintain. Moreover, because of its valuable properties, the TV white space *does* have the potential to generate considerable investment and innovation. But the key to realizing that potential is *access* to the TV white space, not unlicensed access.

II. AVAILABILITY OF UNLICENSED SPECTRUM

Unlicensed advocates claim that open access to the white space would bring large benefits. Implicit in their claim is the assumption that the current allocation of unlicensed spectrum is insufficient to accommodate the rapid growth in the use of unlicensed devices. A second, more explicit, assumption is that the attractive propagation characteristics of the TV band would allow unlicensed devices to operate more effectively and at lower cost there than they can in the higher frequency bands where most unlicensed activity now occurs.[3]

In this section, we examine the assumption that there is insufficient spectrum set aside for unlicensed use. We look first at the sheer amount of spectrum allocated for unlicensed use. We look next at indicators as to the available capacity in those unlicensed bands. In section III, we examine the assumption that the unique characteristics of the TV band would allow unlicensed devices to operate more effectively and at lower cost.

A. Existing Allocation

A substantial amount of spectrum has already been allocated for unlicensed use—a fact that unlicensed advocates tend to ignore or downplay. The FCC traditionally allowed certain bands to be used by anyone who transmitted with equipment that met certain specifications. As of 1997, the Commission had allocated more than 200 MHz of spectrum for such unlicensed use, including bands at 900 MHz, 2.4 GHz, 5.15 GHz and 5.725 GHz.[4] Since then, the FCC has set

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[3] A third, often implicit, assumption is that there is no opportunity cost to allowing unlicensed use of the TV white space because licensing is not feasible. Although an analysis of this issue is beyond the scope of the present document, Jackson and Robyn's 2007 report concluded that licensing is in fact feasible. Moreover, as our recent valuation demonstrated, the opportunity cost of precluding licensed use of the TV white space is very high. See also Coleman Bazelon, "Licensed or Unlicensed: The Economics of Incremental Spectrum Allocations," Analysis Group (October 13, 2006).

[4] FCC staff proposed such flexible bands as early as the late 1970s. In the mid-1980s, the FCC adopted liberal rules permitting the use of spread spectrum radio systems on an unlicensed basis at 902–928, 2400–2483.5 and 5725–5850 MHz. Over time, the rules governing these and other unlicensed bands have been relaxed to permit the use of any digital modulation, not just spread spectrum, subject to limits on power and power density. The FCC's current, more relaxed rules are similar to what FCC analysts proposed three decades ago. See C. Jackson, "The Allocation of the Radio Spectrum," *Scientific American*, Vol. 242, No. 2 (February 1980).

aside a significant amount of additional spectrum for unlicensed use. The newer allocations include a third 5 GHz band, at 5.47–5.725 GHz (the three bands at 5 GHz are referred to collectively as unlicensed national information infrastructure, or U-NII spectrum) and two 10 MHz bands designated for personal communication (mobile phone) service, or PCS. (As discussed below, a third unlicensed PCS band that failed to generate any demand was returned to licensed use.) Most recently, the FCC allocated a 50 MHz band at 3650 MHz for non-exclusive access.[5]

Table 1 shows the major bands of spectrum that the FCC has allocated for unlicensed use. In this context, "unlicensed use" refers to the right to utilize the spectrum for a broad range of relatively "high-power" applications (*i.e.*, up to one watt).[6] We have excluded those unlicensed bands that are limited to very low-power operations such as garage door openers. We have also excluded those unlicensed bands whose use is limited to specialized applications such as medical telemetry and automobile radar.

According to Table 1, approximately 11 GHz of radio frequency (RF) spectrum is available for unlicensed use. This represents more than ten percent of the entire spectrum below 100 GHz. Looking just at the spectrum below 6 GHz, the fraction available for unlicensed use is even higher: 707 MHz, or about 12 percent of the total spectrum below 6 GHz. Of the spectrum below 3 GHz, 132 MHz, or about 4 percent, is available for unlicensed use.

Note that a significant amount of radio spectrum is reserved for use by the federal government and cannot be licensed or repurposed by the FCC.[7] Thus, unlicensed spectrum represents an even larger fraction of the spectrum controlled by the FCC.

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5 Technically speaking, the 3650–3700 MHz band is not unlicensed. Because licensees do not have exclusive access to the spectrum and must work out interference problems by negotiation, however, it is generally regarded as unlicensed spectrum.

6 Such powers create radio frequency (RF) fields near the RF safety limits of the FCC's rules and are thus near the maximum levels for consumer devices. These powers are about the same as the maximum power of cellular and PCS handsets; however, these powers are orders of magnitude lower than the powers licensed operators are allowed to use at their base stations. Thus, from the point of view of commercial operations, these devices are low-powered.

7 According to the Commerce Department's National Telecommunications and Information Administration (NTIA), 14.1 percent of the spectrum below 3.1 GHz is allocated to the government on an exclusive basis.

The supply of unlicensed spectrum is large not just in absolute terms but by comparison to that of liberally licensed spectrum—that is, the bands such as cellular and PCS that permit substantial technical and economic flexibility. We estimate that about 541 MHz of spectrum, all of it below 3 GHz, is available for commercial mobile services.[8] Thus, the amount of spectrum below 3 GHz that is available for unlicensed uses is about a quarter of the comparable spectrum available for liberally licensed use.

Another 54.2 percent is allocated on a shared basis, and some unknown portion of that is set aside for use by the federal government. "Spectrum Policy for the 21st Century: The President's Spectrum Policy Initiative: Report 1" (June 2004). Available at: http://www.ntia.doc.gov/reports/specpolini/presspecpolini_report1_06242004.htm#_Toc74447273.

8 "Comments of Charles L. Jackson, Dorothy Robyn and Coleman Bazelon," *op. cit.*, Table C-1.

Table 1
Unlicensed Spectrum Allocation

Band Name	Allocation	Location	Bandwidth	Power Limit (Watts)	Comments
900 MHz	Pre 1990	900 - 928MHz [a]	28 MHz		
Unlicensed PCS	1993	1920 - 1930MHz [a] 2390 - 2400MHz [a]	10 MHz 10MHz	Varies with bandwidth.	Unlicensed PCS band. Of little utility.
2.4 GHz	Pre 1990	2400 - 2483.5MHz [a]	83.5MHz	1	The FCC rules allow use of antennas that direct the signal in a specific direction. Portable systems have a 4 watt EIRP limit. Fixed, point-to-point, systems can operate with high gain antennas that permit equivalent powers higher than 4 watts.
3650 MHz	2005	3650 - 3700MHz [b]	50 MHz		
U-NII	1997 2003 Pre 1990	5.15 - 5.35GHz [a] 5.47 - 5.725GHz [c] 5.725 - 5.850GHz [a]	200MHz 225MHz 125MHz	Varies. The maximum is 1 watt.	The band 5.15-5.25 GHz is limited to indoor use.
Millimeter Wave	1995	57 - 64GHz [a]	7 GHz	0.5	At these high frequencies, radio waves typically require a line-of-sight path from transmit antenna to receive antenna. This band is a resonance of the O2 molecule and cannot be used for long-range applications.
--	2001	24.0 - 24.25GHz [d]	250MHz	Limit is on field strength not power.	Power limit in FCC rules is given as a field strength limit (2500 mV/m at 3 meters, see 47 CFR 249). MaximumPower Varies with antenna size; 2500 mV/meter at 3 meters corresponds to power in the main beam of about 20 milliwatts.
--	2003	92 - 95GHz [e]	3GHz	0.5	Limited to indoor use.
		Total	**10.9815 GHz**		
		Total Below 6GHz	**0.7315 GHz**		
		Total Below 3GHz	**0.1315 GHz**		

Sources and Notes:
[a] Kenneth R. Carter, Ahmed Lahjouji, and Neal McNeil. "Unlicensed and Unshackled: A Joint OSP-OET White Paper on Unlicensed Devices and Their Regulatory Issues." *OSP Working Paper Series #39* (May, 2003). 5.725 -5.850 GHz was authorized for unlicensed uses in the 1980s. See footnote 4. The U-NII band only includes the portion of that band up to 5.825 GHz.
[b] Federal Communications Commission. "Report and Order and Memorandum Opinion and Order. In the Matter of Wireless Operations in the 3650-3700 MHz Band." ET Docket No. 04-151 (Rel. March 16, 2005).
[c] Federal Communications Commission. "Report and Order. In the Matter of Revision of Parts 2 and 15 of the Commission's Rules to Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz band." ET Docket No. 03-122 (Rel. November 18, 2003).
[d] Federal Communications Commission. "Report and Order. In the Matter of Amendment of Part 15 of the Commission's Rules to Allow Certification of Equipment in the 24.05 - 24.25 GHz Band at Field Strengths up to 2500 mV/m." ET Docket No. 98 - 156 (Rel. December 14, 2001).
[e] Federal Communications Commission. "FCC Opens 70, 80, and 90 GHz Spectrum Bands For Deployment of Broadband 'Millimeter Wave' Technologies." WT Docket No. 02-146 (October 16, 2003).

B. Available Capacity

The fact that a substantial amount of spectrum has already been allocated to unlicensed uses is important, to be sure, but what really matters is available capacity. If the existing allocations lack the capacity to support additional unlicensed applications, it might make sense to allocate more spectrum for unlicensed use. It would be expensive and difficult to provide a direct measure of how much capacity is available in the unlicensed spectrum—one that was also precise and comprehensive—and no one has done so to our knowledge.[9] There are some indirect measures, however. One is economic usage, or demand: if the rate of growth in the use of an unlicensed band falls off, that could be an indication that the band is running out of capacity. Evidence of interference in an unlicensed band could serve as another sign that capacity is limited. Below, we look at each of these indicators.

Economic Usage

The economic usage of an unlicensed band is itself a difficult thing to measure directly. (By contrast, usage of licensed bands can be more readily measured; for example, with mobile commercial bands, there are statistics on subscribers, revenues and investments.) One measure is the amount of (unlicensed) equipment used in the band, as reflected in equipment sales.[10] This measure is imperfect, however, because it says nothing about how frequently or intensively an individual piece of equipment is used or how much bandwidth it requires.

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9 Some people have suggested that spectrum occupancy—the amount of radio energy present in various bands—provides an estimate of utilization. There are limits to that measurement approach, however. For example, the level of radio energy in a band containing many short-range devices may be very high, indicating significant utilization, even though the band could accommodate many more such devices. Similarly, radio energy may overstate utilization if the band is using an economically inefficient technology. Alternatively, radio energy may understate the level of utilization if, say, the band is used for a satellite system which compensates for the low energy by using high-gain antennas and sensitive receivers. For a comprehensive discussion of the limits of spectrum occupancy measures as estimates of utilization, see John T. MacDonald, "A Survey of Spectrum Utilization in Chicago," Report to the Wireless Interference Laboratory of the Illinois Institute of Technology (March 7, 2007), Section 4. Available at http://www.wincom.ece.iit.edu/publications/spectrum.pdf.

10 Kenneth R. Carter, Ahmed Lahjouji, and Neal McNeil, "Unlicensed and Unshackled: A Joint OSP-OET White Paper on Unlicensed Devices and Their Regulatory Issues," *OSP Working Paper Series #39* (May 2003).

An alternative measure of demand comes from data on equipment authorization. Equipment manufacturers must get FCC authorization for their devices to operate legally in any spectrum band, including the unlicensed bands, and one can count the number of authorizations that are on file for a particular band. This too is an imperfect measure: the fact that the FCC authorized a device says nothing about how many of the devices the manufacturer actually has sold. The number of authorizations provides some indication of the popularity of the band, however.

Table 2 shows the total number of authorizations that the FCC has granted for each of the major unlicensed allocations. The FCC has authorized more than fifteen thousand unlicensed devices for operation at 2.4 GHz and another six thousand for use in the 900 MHz band. For the three bands at 5 GHz, the FCC has authorized thousands more devices. These figures are not definitive. They suggest, however, that equipment manufacturers have invested a considerable amount of money in the development of devices for use in the 2.4 GHz and 900 MHz bands. Investment in the 5 GHz band, albeit less, nevertheless appears to be substantial.

The most striking thing about Table 2 is how few authorizations the FCC has granted for several of the unlicensed bands, including the upper portion of the PCS band (2.39–2.40 GHz), the 3650 MHz band and the higher frequency bands. Use of these bands appears to be extremely limited.

In come cases, the lack of interest on the part of equipment manufacturers may reflect technical issues. For example, the development of transmitters and receivers that will operate in the 60 GHz and 90 GHz bands is more challenging than the comparable exercise in the lower bands. (Several IEEE groups are trying to address that challenge in the 60 GHz band.) In other cases, however, the deterrent to investment by manufacturers may be government-imposed rules. For example, in the case of the 3650 MHz band, as we discuss below, manufacturers of equipment for long-range services are concerned that the threat of interference from short-range unlicensed devices will suppress demand for their products.

In sum, although one cannot read too much into the lack of FCC authorizations for these bands, it does appear that a great deal of unlicensed capacity is going unused. Any analysis of the need for more unlicensed spectrum needs to acknowledge this wasted potential.[11] Moreover, at least some of that lost potential is the result of "self-inflicted wounds."

Table 2
FCC Part 15 Authorized Equipment for Unlicensed Spectrum Bands

	All Equip Classes	UWB Only	All Classes Excl. UWB
900 MHz			
900 MHz - 928 MHz	6,060	13	6,047
Unlicensed PCS			
1.92 GHz - 1.93 GHz	354	7	347
2.39 GHz - 2.40 GHz	8	6	2
2.4 GHz			
2.40 GHz - 2.4835 GHz	15,435	6	15,429
3.65 GHz			
3.65 GHz - 3.70 GHz*	69	52	17
U-NII			
5.15 GHz - 5.35 GHz	1,691	9	1,682
5.47 GHz - 5.725 GHz	283	9	274
5.725 GHz - 5.85 GHz	2,324	11	2,313
24 GHz			
24 GHz - 24.25 GHz	464	4	460
Millimeter Wave			
57 GHz - 64 GHz	13	0	13
90 GHz			
92 GHz - 95 GHz	0	0	0

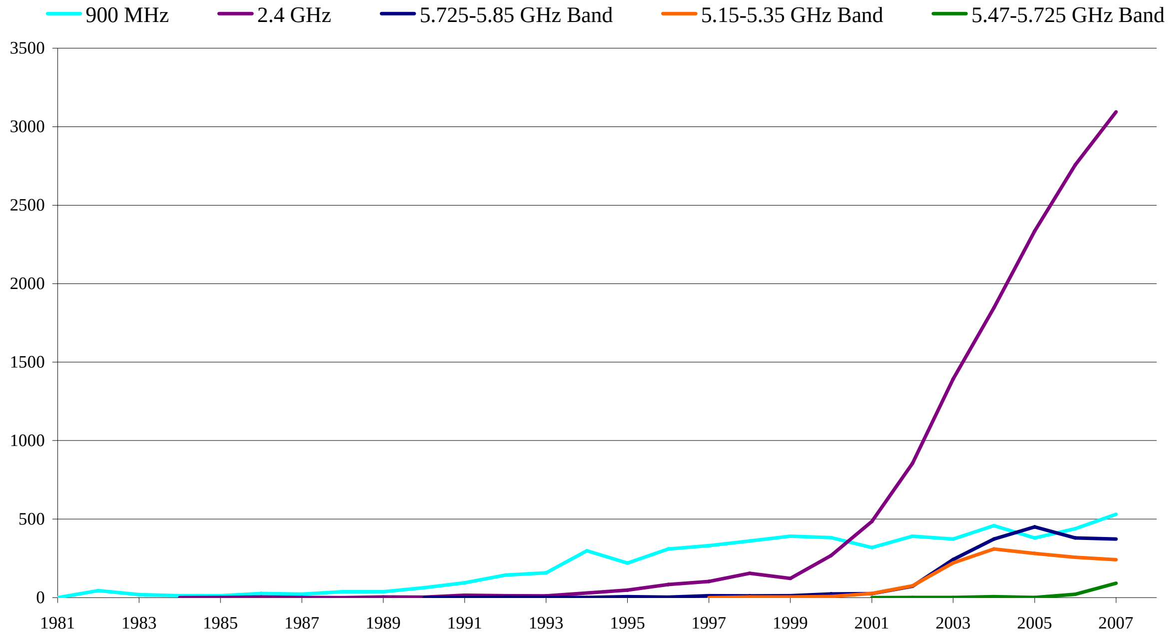
Sources and Notes:
Results from:
https://fjallfoss.fcc.gov/oetcf/eas/reports/GenericSearch.cf
Search parameters:
Application purpose: original grant; Frequency range: 1 MHz inside both the upper and lower bound;
Rule Part: 15.
*Includes Rule Part 15 & Rule Part 90 applications.

[11] Because unlicensed spectrum is free, companies such as Google, Microsoft, Intel and Dell have every incentive to press the FCC to make more of it available, even though some existing unlicensed bands are underutilized. If those companies had to pay for unlicensed spectrum, we suspect that they would be less eager to see the TV white space made available on an unlicensed basis—and that their engineers would find ways to make better use of the "white space" in the existing unlicensed bands.

In addition to the useful “snapshot” that Table 2 provides, one needs to look at the *trend* in FCC equipment authorizations—at least for the high-demand bands. If manufacturers’ interest in a popular band were leveling off or dropping, that could be an indication that the band was becoming congested. Conversely, if manufacturers’ interest in the band were growing, that would suggest that the band was continuing to provide ample capacity.

Figure 1 shows the number of authorizations that the FCC has granted annually for each of the most popular unlicensed bands. (This is the same information contained in Table 2 but presented as a time series.) The 900 MHz band has seen gradual but steady growth in the number of FCC authorizations granted annually. For the 2.4 GHz band, the picture is one of dramatic growth in annual equipment authorizations beginning in the late 1990s, which is when wireless LANs first gained mass appeal. Moreover, that sharp upward trend shows no sign of letting up. At 5 GHz, the two older allocations (5.15–5.35 and 5.725–5.85) saw an impressive growth in the number of FCC authorizations granted during the first half of this decade. Although those numbers have leveled off or dropped slightly, the number of authorizations for the newest 5 GHz band (5.47–5.725) has picked up.

Figure 1
Annual Unlicensed Equipment Authorizations



Sources and notes:
Results from: https://fjallfoss.fcc.gov/oetcf/eas/reports/GenericSearch.cfm
Search Parameters: Application Purpose: Original Grant; Frequency Range: 1 MHz inside both the upper and lower bound

Figure 1 provides no indication that these bands are nearing the limits of their capacity: if capacity was a problem, the prospect of (increased) congestion and interference would lead manufacturers to reduce their level of investment in unlicensed devices, which in turn would result in a fall-off in the number of FCC authorizations. As Figure 1 clearly shows, no such fall-off has occurred. To the contrary, the trends in Figure 1 are consistent with a pattern of continued growth in investment by manufacturers of unlicensed devices. This indicates that the current unlicensed allocations continue to be more than sufficient for the American public.

Congestion and Interference

The existence of congestion and interference would be another, more direct indicator that an unlicensed band was reaching its capacity limits. Evidence of that could take various forms, including publicly aired complaints. If congestion and interference in an unlicensed band were a problem, device manufacturers and users would almost certainly let the press or the FCC know about it.

We did a thorough search of news databases to try to identify any discussion of this issue in the press. In the only relevant article we turned up, there was an unsubstantiated claim that the noise floor in the 900 MHz unlicensed band was increasing.[12] We also reviewed comments in the FCC's TV white-space proceeding (ET Docket No. 04-186). With the exception of statements from WISPS operating in unlicensed spectrum, we found no evidence in the record to suggest that interference in the existing unlicensed bands is a problem.[13] Moreover, the WISPS' quite valid complaint—namely, that their long-range signals experience interference from short-range LAN-type devices—would not be addressed by a decision to allow unlicensed use of the TV white space. That is so because, for the reasons we discuss below, unlicensed short-range devices will always crowd out long-range devices. What *would* address the WISPS' complaint (one of several possible solutions) is to designate additional *licensed* spectrum suitable for the long-range services they offer.

12 Howard Buskirk, "900 MHz Interference Fight Seen as Key for Other Unlicensed Spectrum," *Communications Daily* 27, No. 200 (October 17, 2007). We conducted a thorough search of a wide range of news sources, including 265 telecom-specific publications. We used general search terms such as "unlicensed," "congestion," and "interference," as well as frequency-specific terms such as "2.4 gigahertz" and "pcs."

13 Sixty-six comments were filed in support of unlicensed TV white space (this excludes short text comments). Of those, only fifteen mentioned congestion or interference in existing unlicensed allocations. All fifteen comments were submitted by or on behalf of WISPs.

III. IMPEDIMENTS TO INVESTMENT AND INNOVATION IN UNLICENSED WHITE SPACE

Unlicensed advocates argue that the unique propagation characteristics of the TV band would allow unlicensed devices to operate more cheaply and effectively there than they can in the higher frequency bands where most unlicensed activity now occurs. Thus, even if the existing unlicensed bands have plenty of capacity, they would argue that it makes sense to allocate the TV white space to unlicensed use.

Unlicensed advocates point to two broad sets of applications that would get an economic boost from open access to the TV white space. The first is short-range data communications—essentially, wireless LANS. For example, Dell refers to the white space as "a multi-billion market, just waiting to explode, if [unlicensed] next-generation home and office wireless networking devices are enabled in the white spaces."[14] The New America Foundation touts unlicensed uses such as mesh networks that will provide competition to licensed service providers[15] and "WiFi Plus" that will allow the signals of WISPs to travel further than existing WiFi.[16] Google co-founder Larry Page refers to the TV white space as "Wi-Fi on steroids."[17]

The second set of applications that it is claimed will benefit from open access to the TV white space is long-range voice and data communications. Stressing that the vast majority of TV white space capacity is in rural areas, unlicensed advocates point to the "enormous opportunity for local communities, governments and service providers to transform unused TV channels into

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14 Michael Dell, Ex Parte letter regarding "Unlicensed Operation in the TV Broadcast Bands," ET Docket 04-186 (January 12, 2007).

15 William Lehr, "Dedicated Lower-Frequency Unlicensed Spectrum: The Economic Case for Dedicated Unlicensed Spectrum Below 3GHz," New America Foundation, Spectrum Series Working Paper #9 (July 2004), p. 30.

16 Pierre de Vries, "Populating the Vacant Channels: The Case for Allocating Unused Spectrum in the Digital TV Bands to Unlicensed Use for Broadband and Wireless Innovation," New America Foundation, Spectrum Series Working Paper #14 (August 2006), p. 8.

17 Amy Schatz, "FCC to Decide in Battle for TV Spectrum, *Wall Street Journal* (August 18, 2008), p. B1.

rocket-fuel for wireless broadband."[18] Congressional support for open access to the TV white space rests in good part on claims that it will expand the provision of broadband internet access to rural areas.

However, the claims of unlicensed advocates ignore the fundamental impediments that exist to the use of unlicensed devices in the TV white space—either for short-range data transfer or for long-range voice and data communications, including rural broadband. These impediments, which are largely technical in nature, would more than offset the superior propagation characteristics of this spectrum. As a result, we would see little investment in unlicensed TV spectrum and even less in the way of innovation.

A. Short-Range Data Transfer

For short-range data transfer, unlicensed TV spectrum would be substantially inferior to the existing unlicensed bands at 2.4 GHz and 5 GHz. A key issue for many wireless users is the data rate. There is no assurance that more than 6 MHz of contiguous spectrum in the TV band would be available for unlicensed use at any location, and the proposed FCC rules seem to presuppose that the unlicensed device signal will be contained in 6 MHz. Thus the market would likely provide devices that operated in a single 6 MHz channel as a form of lowest common denominator. A 6 MHz channel would support data rates that are reasonably competitive with those of current wide-area services such as 5 MHz HSDPA and 1.25 MHz EV-DO channels. It would a poor competitor, however, to the 20 and 40 MHz channels at 2.4 GHz and 5 GHz that WiFi (802.11) devices employ.

Specifically, at short ranges—*e.g.*, within a household, where signal attenuation is not usually the limiting factor in wireless LAN performance—the maximum practical data rate of a TV white-space device would be only about one-third or one-quarter that of an 802.11 device operating in

[18] Benjamin Lennett, "Rural Broadband and the TV White Space: How Unlicensed Access to Vacant Television Channels Can Bring Affordable Wireless Broadband to Rural America," New America Foundation, Wireless Future Program, Issue Brief #22 (June 2008), p.1.

the current unlicensed bands.[19] Although there are steps one might take to compensate for this limitation (*e.g.*, dynamic channel bonding), they would require that manufacturers put more transmitters and receivers in the consumer device. That would add complexity and cost, offsetting some of the advantages of the TV band.

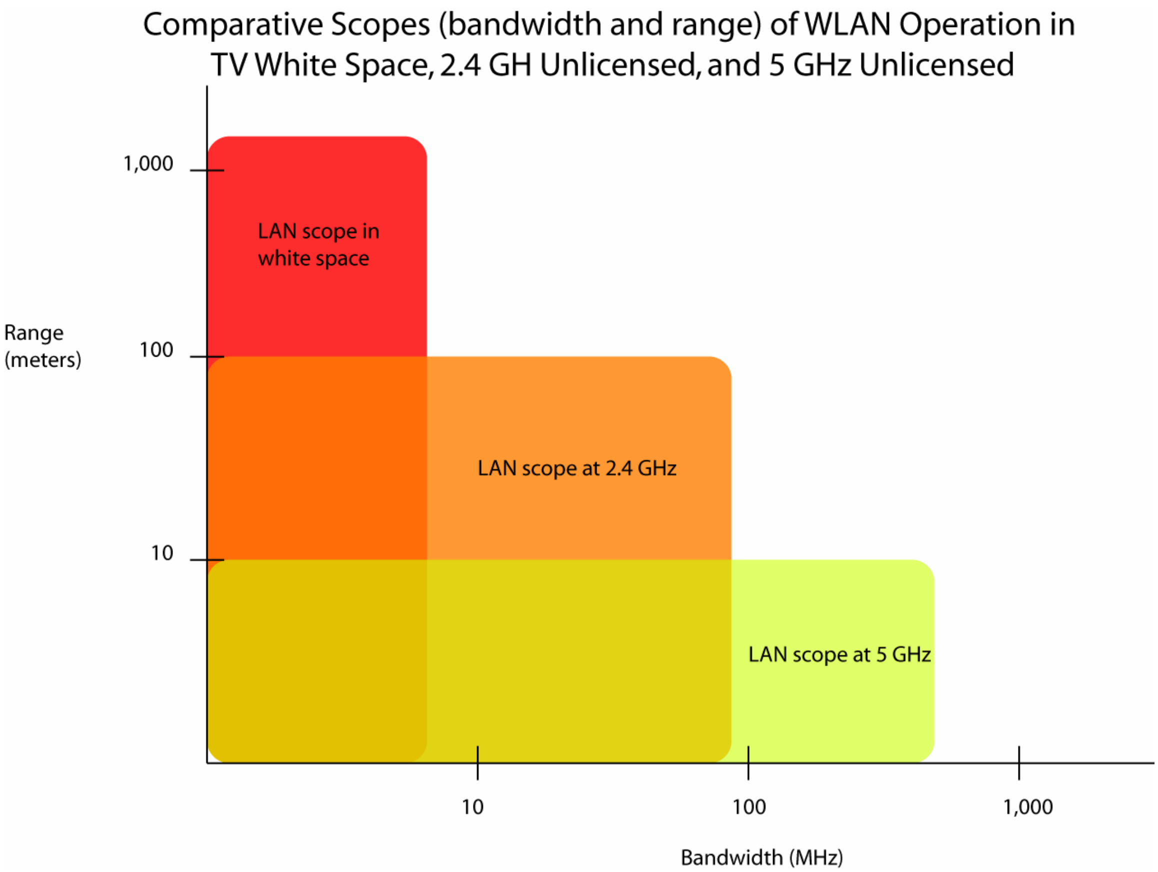
Figure 2 illustrates the relative performance in terms of bandwidth and range of a wireless LAN that exploits the contiguous bandwidth available in three different locations: a TV white-space channel, the 2.4 GHz unlicensed band, and the 5 GHz unlicensed band. Note that both axes are logarithmic. The unlicensed band at 5 GHz is by far the widest but it generally has shorter range. The range at 2.4 GHz is greater than at 5 GHz, but there is only one-sixth as much bandwidth available. The range for a wireless LAN using the TV white space would be longer still, but the per-channel bandwidth would be less than one-tenth of what is available in the 2.4 GHz band.[20]

Generally speaking, the "market niche" for unlicensed TV white space consists of those applications that require significant range but not significant bandwidth. More precisely, the white space would have a comparative advantage over the 2.4 GHz and 5 GHz bands for low-bandwidth applications that require ranges greater than those achievable at 2.4 GHz and that cannot use repeaters to provide that range. That is a narrow niche. In our view, for many applications including wireless LANs, the bandwidth advantages of the 2.4 GHz and 5 GHz bands would outweigh the range advantage of the TV white space. Although some users would no doubt buy LAN gear designed for the TV white space *in addition to* the comparable 802.11 equipment, relatively few users would buy it *in place of* 802.11 equipment.

[19] In both bands the signal-to-noise ratio at the receiver would be high and capacity would be limited by the available bandwidth. A radio using a 40 MHz channel at 2.4 GHz would be able to transfer data about seven times more rapidly than a radio using a 6 MHz channel in the TV white space. As we discuss elsewhere, the greater suitability of 2.4 GHz for multiple-input multiple-output (MIMO) technologies might increase this capacity advantage by another factor of two or three.

[20] Figure 2 is intended to be illustrative, not exact; the values for bandwidth and range used in the figure are reasonably representative of current technology.

Figure 2
Scope of Alternative Wireless LAN Services



In addition to greater raw bandwidth, operations in the 2.4 GHz and 5 GHz unlicensed bands would have other advantages over comparable operations in the TV white space. For one, the higher frequencies permit units with multiple antennas to have greater antenna separation. Modern wireless systems can use multiple antennas to create separate virtual channels in the same radio bandwidth. This technology is called multiple-input multiple-output (MIMO) and has been shown in practice to significantly expand capacity. For example a recent expansion of 802.11 (802.11n) supports MIMO using up to 4 antennas. Generally speaking, antenna separation (measured in units of radio wavelengths) is correlated with capacity, and a rule of thumb says that a separation of one-half wavelength or greater is desirable. One-half wavelength at 2.4 GHz is only 2.5 inches; at TV white-space frequencies (*e.g.*, 600 MHz or Channel 35) the desired separation is 10 inches, which would be impractical for a laptop. Consequently, it is feasible to have multiple, well-separated antennas on a laptop at 2.4 GHz or 5 GHz but not at TV-band frequencies. More generally, MIMO experts, consistent with scientific theory, indicate that MIMO systems will perform better at 2.4 GHz and 5 GHz than in the TV band.[21]

Because the 2.4 GHz and 5 GHz bands offer wider bandwidth and better performance with MIMO, innovators and equipment manufacturers looking at applications that require high-burst data rates or high throughput will almost certainly choose those frequencies. Consider an entrepreneur who wants to provide for wireless distribution of an HDTV or UHDTV signal within the home at data throughput rates in the 20 to 100 megabit-per-second range.[22] Modern wireless systems use techniques such as error detection and retransmission (Automatic Repeat reQuest) or hybrid Automatic Repeat reQuest to compensate for errors and loss of signal. It would require demanding and expensive modulation techniques to make a highly reliable 100 megabit-per-second system work in the 6 MHz channels available in the TV white space. The cost would be much less if the system operated at 2.4 GHz or 5 GHz, given the advantages those bands offer in bandwidth and MIMO performance.

In part because they make possible higher data rates than does the 900 MHz band, the 2.4 GHz and 5 GHz bands have spawned a huge installed base of interoperable equipment known by the name of the relevant IEEE standard (802.11). Manufacturers and users of this equipment benefit from large scale and network economies and a resulting bandwagon effect. IEEE is developing a separate standard (802.22) for the TV white space, but it is aimed at fixed wireless service for rural areas and will not target urban or in-home service.[23] Both because the 802.11 standard will remain dominant and because the 802.22 standard will be limited in scope, manufacturers will face weak incentives to develop equipment for short-range data transfer in the TV white space.

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21 Given the larger number of propagation paths possible at higher frequencies, it may well be the case that indoor radio wave propagation at 2.4 GHz provides a richer multipath environment, further enhancing the performance of MIMO technology in that band relative to the 600 MHz band. However, we are not aware of any published comparative measurements of such propagation differences.

22 For a description of one approach to ultra-high definition TV see: http://www.nhk.or.jp/digital/en/superhivision/index.html.

23 Carl Stevenson, Comments at “MSTV@50: Shaping the Future of Television” (October 3, 2006). Stevenson, President and Chief Technology Officer of WK3C Wireless, is the chair of the IEEE 802.22 working group. See http://www.ieee802.org/22/.

Yet another impediment to the development and adoption of wireless devices for use in the TV white space will be the need for those devices to protect incumbent broadcast and land mobile operations in the TV band. Most of the protective mechanisms that are under discussion (*e.g.*, beacons and geo-location) call for an additional receiver or other electronic device to be installed in the consumer white-space terminal. Such supplementary electronics would add cost and reduce battery life. Even if the added cost were small, it would further reduce the ability of unlicensed wireless LANs operating in the TV white space to compete with the installed base of 802.11 devices.

To be sure, the TV white space would attract some short-range applications. For example, it would support low-cost cordless phones with greater range than today's 2.4 GHz and 5 GHz units, which would be useful in settings (*e.g.*, farms and university and industrial campuses) that require multiple base stations to get good coverage now. Similarly, the TV band would be useful for applications that fit naturally inside of a single TV channel, such as baby monitors, remote surveillance cameras or wireless links between video game controllers and TV displays. Because signals in the TV band propagate somewhat better over non-line-of-sight paths than do signals in higher frequencies, the TV white space might also be attractive for moderate capacity point-to-point links such as those used to connect WiFi hot spots to backbone networks or for the kind of opportunistic point-to-point links that are needed in emergencies. However, these represent incremental improvements; they would add only modest value to what is available in other unlicensed bands today.

In sum, there are substantial barriers to the use of the TV white space for the short-range unlicensed applications touted by Google, Microsoft and others. These barriers include the limited data rates that would be possible in the white space, and the added costs of the capabilities that would be needed to avoid interference with incumbents. The large installed base of equipment that operates in the 2.4 GHz and 5 GHz bands, with which equipment designed for the TV white space would have to compete, represents yet another barrier. Although the TV white space would be put to use in an unlicensed regime, the likely applications, such as longer-range cordless phones and TV remote controls, would add little value to what already exists.

Unlicensed PCS

Similar barriers, together with the FCC's complex coordination rules, fatally impaired the data portion of the unlicensed PCS spectrum. Thus, the unlicensed PCS band provides a case study in what not to do with the TV white space.

The unlicensed PCS spectrum originally encompassed the 1910–1930 MHz and 2390–2400 MHz bands. The unlicensed PCS spectrum at 1910–1920 MHz, devoted to data, had essentially the same propagation characteristics as the nearby 2.4 GHz band, which unlicensed data devices can use under Part 15 rules. However, the 2.4 GHz band is eight times larger, which permits higher data rates. The size of the 2.4 GHz band also gives users the option of changing channels to avoid interference. Those advantages, together with the fact that unlicensed services had a several-year head start at 2.4 GHz, meant that the 2.4 GHz band could support a much larger market than the data portion of the unlicensed PCS band was ever likely to generate.

The data portion of the unlicensed PCS spectrum faced other problems as well. The FCC required unlicensed users to coordinate with the remaining licensed (fixed microwave) users, which added uncertainty and cost. And the FCC's complex radio-channel sharing protocol may have increased the burden on equipment suppliers.

Not surprisingly, the data portion of the unlicensed PCS band saw little if any use.[24] In response, the Commission reallocated it for licensed use, creating parts of what are now called the PCS G and H Blocks.[25] The reallocated spectrum will likely be used for a wireless application similar to the PCS service available in the adjacent bands.

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24 "The record of deployment of UPCS services, to date, has been mixed. Currently, the most widespread application of the 1920–1930 MHz UPCS band is for wireless PBX systems. However, a search of our equipment authorization database has found no UPCS equipment authorized for the 1910–1920 MHz band." Federal Communications Commission, "In the Matter of Amendment of Part 2 of the Commission's Rules to Allocate Spectrum Below 3 GHz for Mobile and Fixed Services to Support the Introduction of New Advanced Wireless Services, including Third Generation Wireless Services," ET Docket No. 00-258 (Rel. September 22, 2004), ¶10.

25 See Federal Communications Commission, "Further Notice of Proposed Rulemaking. In the Matter of Service Rules for Advanced Wireless Services in the 1915–1920 MHz, 1995–2000 MHz, 2020–2025 MHz and 2175–2180 MHz Bands," WT Docket No. 04-356 (Rel. June 20, 2008).

B. Long-Range Communications

Nor is an unlicensed white-space regime likely to promote investment in the infrastructure necessary for long-range communications. But whereas the white space would be inferior to existing unlicensed spectrum for short-range applications, for long-range applications—the applications for which the TV band is ideally suited—it would be inferior to licensed spectrum.

To elaborate, although the TV white space is particularly well-suited to longer-range applications such as wireless Internet access, two substantial limitations would impede investment and innovation. The first is the threat of interference—primarily, from the cordless phones and other (unlicensed) short-range devices discussed above. To the extent that radio wave propagation is better in the TV band than at 2.4 GHz and 5 GHz, the threat of interference from short-range devices will be greater in the TV white space than at 2.4 GHz or 5 GHz. This threat would impose a cost on unlicensed service providers that their licensed competitors, such as the licensees at 700 MHz, will not face.[26]

Because of the threat of interference, the Wireless Internet Service Providers Association (WISPA) opposes the use of short-range unlicensed devices in the white space. In Comments filed in the FCC's white-space proceeding, WISPA said it did not want to see a repeat of the problem it has experienced at 2.4 GHz:

> WISPA is opposed to any use of the Whitespaces for personal portable devices at this time. . . . we do NOT wish to see a spectrum issue similar to the current 2.4 GHz WiFi band. In the 2.4 GHz band channel 6 has become all but useless for large-scale, wide area deployments. . . .We do not wish to see this situation played out in any new bands. . . We believe that personal portable devices, especially in urban and suburban markets, would be best left to the higher frequency bands.[27]

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[26] One of us (Jackson) participated in the due diligence investigation, by a potential investor, of an unlicensed WISP that provided service to subscribers at distances exceeding 10 miles from its antenna sites. The investor, concerned about the WISP's vulnerability to interference problems, ultimately chose not to invest.

[27] WISPA Comments on TV Whitespaces, ET Docket No. 04-186 (February 20, 2007), p. 2. Emphasis in original.

Alvarion, which manufactures WiMAX equipment, made a similar argument in a separate FCC proceeding. After the FCC adopted its final rules on the non-exclusively licensed 3650 MHz band, Alvarion submitted the results of a study showing that short-range WiFi devices could be expected to crowd out longer-range WiMAX devices even if both systems implemented a listen-before-talk protocol.[28]

A second substantial limitation on use of the TV white space for long-range communications is power levels. The current and proposed rules for the TV white space limit transmitted power to 4 watts, including the effects of any antenna gain. This is a relatively low power level for long-range applications. This low limit is reasonable because unlicensed devices are purchased and installed by untrained consumers, and higher limits would run the risk of exposing consumers to signals levels above those allowed by the FCC's RF safety rules.

Because unlicensed TV white-space devices would be restricted to low power levels, a WISP operating in the white space would have far more limited range and capacity from its base stations than would a licensed competitor operating in the nearby 700 MHz spectrum. Under reasonable assumptions, a licensed 700-MHz base station could serve ten times the area that an unlicensed base station operating in the TV white space could serve.[29] The smaller the coverage from a base station, the higher the WISP's costs. To a first approximation, a WISP using the unlicensed TV white space would have capital costs ten times those of a service provider operating in the adjacent 700 MHz spectrum.

In short, the threat of interference and the handicap of low power limits are substantial impediments to the use of the TV white space for long-range, unlicensed communications. Both would impose costs on an unlicensed service provider that its licensed competitors will not have

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[28] Alvarion Ex Parte (August 20, 2007), pp. 8-12. See also Alvarion contribution to the 802.16 (WiMAX) standards process. See: http://www.wirelessman.org/le/contrib/C80216h-07_039r1.pdf.

[29] Assume the following: (1) the white-space base station transmitter is limited to 4 watts EIRP, (2) the licensed 700-MHz base station operates at 400 watts EIRP (well below the power limits that apply in the 700 MHz spectrum), (3) propagation is governed by an inverse-fourth power law, and (4) all other system elements (antenna heights, receiver sensitivity, modulation, etc.) are the same. Given those reasonable assumptions, a 700 MHz-base station would provide equivalent service at about three times the range of a TV white-space base station and would cover ten times the area.

to bear. Either of the impediments, taken alone, would be a major deterrent to investment in an unlicensed WISP. Taken together, they are likely to pose an insurmountable hurdle.

3650 MHz Band

The recent experience with the 3650 MHz band supports our view that the absence of exclusive spectrum rights discourages investment in long-range infrastructure. Under rules adopted in 2005 and 2007, the FCC created a form of commons in the 3650 MHz band: the licenses granted by the FCC do not provide for exclusive use of the spectrum; instead, all systems operating at 3650–3700 MHz are required to adaptively "share" the band using contention-based protocols.[30]

Cisco, which manufactures short-range 802.11 systems, supported the rules as adopted in 2005.[31] However, several firms that manufacture equipment for long-range services, including Motorola, Intel and Alvarion, petitioned the FCC to ask that it reconsider an exclusive-license approach.[32] According to Motorola:

> …the use of a contention-based protocol among multiple unaffiliated users will not allow rapid deployment at 3650 MHz nor offer the most efficient use of the spectrum, particularly in dense urban areas….The combination of exclusive licensed use along with flexible technical standards and secondary market leasing provisions will offer the most efficient and rapid deployment of wireless broadband services across the U.S. using this new band.[33]

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30 Federal Communications Commission, "Report and Order and Memorandum Opinion and Order. In the Matter Wireless Operations in the 3650–3700 MHz Band," ET Docket No. 04-151 (Rel. March 16, 2005), ¶16.

31 "CISCO Opposition to Petition for Reconsideration: Wireless Operations in the 3650–3700 MHz Band," ET Docket 04-151 (Dated: August 11, 2005).

32 Covad, a wireless access provider that serves parts of California and Nevada, took an intermediate position; Covad said the spectrum should be licensed to control interference but that the licenses should be awarded at no cost on a first-come, first-served basis (*i.e.*, no auction).

33 "Petition for Reconsideration of Motorola, Inc. Wireless Operations in the 3650–3700 MHz Band," ET Docket 04-151 (June 10, 2005), p. 6.

The WiMAX Forum, which stressed the importance of quality of service for providers deploying long-range wireless broadband technologies, was even more direct, predicting that "'tragedy of the commons' problems are likely to be severe in large urban areas."[34]

Cisco maintained that the position taken by manufacturers of long-range equipment reflected their financial interest in WiMAX, which was suited to licensed spectrum. But it goes without saying that the manufacturers were self-interested; the same could be said of Cisco. What was significant about the manufacturers' position (and it was consistent with their decision to invest in WiMAX, more broadly) was that it reflected a belief that interference from short-range devices would suppress sales of equipment for long-range systems.

Many service providers also weighed in to say that the current FCC rules would produce interference and that there was no easy or efficient way to control interference in an unlicensed environment. For example, TDS Telecom, which serves more than 900 rural and non-urban communities in 28 states, urged the FCC to adopt a licensed approach in place of contention-based protocols, which it said were "insufficient guards against harmful interference":

> Deployment of wireless broadband requires investment in equipment, software, labor, marketing and other resources. TDS Telecom cannot take the risk that its wireless network will be rendered useless in 5-10 years due to limitless entry into the band.[35]

WISPA, although formally supporting the FCC's 2005 rules, submitted comments that appeared to be quite critical of some aspects of the rules. WISPA referred to the "aggressively inefficient system designs that we've seen all too often under the current rule structure." WISPA also raised questions about how the interference that its comments implied was inevitable would be handled:

> We're also worried about the lack of channel planning. What happens when an inefficient radio system bumps into a highly efficient one and keeps the "better"

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[34] "Ex Parte Comments of WiMax Forum. In the Matter of Wireless Operations in the 3650–3700 MHz Band," ET Docket 04-151 (June 28, 2006), p. 2.

[35] "Ex Parte Notice [of TDS Telecom], ET Docket Nos. 04-151, 02-380 and 98-237, WT Docket No. 05-96," Attachment: *A Call for Licensed MSA/RSA Spectrum in the 3650 MHz Band.* ET Docket No. 04-151 (February 14, 2006).

> one from operating. When a system using 5 MHz of spectrum and a system using 25 MHz want the airspace at the same time, which gets to go?[36]

In its June 2007 response to the petitions for reconsideration, the FCC clarified some details in the rules but kept the basic architecture. Thus the rights assigned to licensees remain non-exclusive and hence ambiguous. The language in the final rules is telling:

> Licensees of stations suffering or causing harmful interference are expected to cooperate and resolve this problem by mutually satisfactory arrangements.[37]

Clearly the FCC expects interference to be a problem.

Other Interference Scenarios

In addition to the kind of unintentional interference that was at issue in the 3650 MHz proceeding, the TV band could well be plagued by "strategic" interference. Consider a licensed wireless access provider, Firm L, which offers its subscribers wireless LAN devices that use the TV white space. One can imagine the circumstances under which Firm L's devices "accidentally" create interference that degrades the service of nearby customers of Firm U, an unlicensed competitor that operates in the TV band.

Other unintended scenarios are not hard to imagine. Under current FCC rules, Firm L could apply for a license for a TV translator or low-power TV station and locate the station transmitter near one of Firm U's base stations. Firm U would be obliged to quit operating on the channel on which Firm L had located its transmitter because it would no longer be considered white space.

Alternatively, Firm L could perform a "public service" by installing a one-watt unlicensed white-space device either to retransmit TV signals or to transmit information such as weather forecasts

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[36] "WISPA Comments in Reply to Petition for Reconsideration in regarding 3650 MHz (04-151)," ET Docket No. 04-151 (August 3, 2005). WISPA suggested rules that would promote efficiency and limit the amount of spectrum any one operator could use. WISPA's point—that unlicensed rules do not provide for priority of one user over another—is a fundamental one. Although WISPA did not acknowledge it, the logical solution is a system of licensed rights, which provide protection against interference.

[37] 47 C.F.R. 90.1319(d).

using the ATSC format. If the unlicensed unit was installed near a base station receiver, Firm L's TV white-space device would jam the desired signals from Firm U's subscribers.

Another conceivable scenario involves a community broadcaster that employs the TV white space to offer an unlicensed TV service. If the service were to use ATSC transmissions and on-channel repeaters, viewers would be able to pick up the signal with their over-the-air TV antenna. If, in addition, a manufacturer were to develop low-cost repeaters for such a service, it would consume a significant amount of the available TV white space. Granted, over-the-air TV would probably not be a very efficient way to provide such a service, but the provider might be someone who entered community broadcasting for pleasure rather than profit.

Licensing Encourages Infrastructure Investment

By controlling interference, licensed access provides better incentives for the provision of long-range services, such as wireless Internet access and wide-area mobile networks—the services for which the white space is ideally suited. Thus, a licensed approach to the white space is far more likely to produce the large investments in long-range infrastructure that rural broadband requires.

A service provider operating in the white space would need to have one or more base stations in order to offer efficient long-range and rural service. Typically, wireless base stations are expensive investments: they require antennas, support structure, electronics, and backhaul equipment. Interference from other service providers or from short-range devices such as cordless phones would substantially reduce the coverage provided by a base station, thereby reducing the value of the investment in the base station. Thus, a service provider interested in investing in long-range systems in the white space would have a strong preference for licensed spectrum over unlicensed spectrum, because it would allow the provider to avoid that threat.[38]

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[38] Short-range systems, such as 802.11 hotspots, face somewhat different incentives with respect to interference. Perhaps most important, the economics of coverage expansion are quite different. If interference knocks out 802.11 coverage in one corner of a Starbucks coffee shop, for a few hundred dollars, Starbucks can put another 802.11 access point in the ceiling and run the necessary Cat 5 wiring back to the network hub. No such low-cost remedy is possible if interference destroys reception at a base station serving hundreds of subscribers.

The FCC's 3650 MHz proceeding, discussed earlier, demonstrated that exclusive rights encourage investment in long-range infrastructure. The FCC's contention-based access rules were opposed by a variety of interests that wanted to provide long-range service or equipment for that spectrum, because they thought the resulting interference would suppress sales.

More generally, licensing would allow wireless service providers operating in the TV white space to have greater control over service quality. A key issue is service reliability. Consumers want to be able to make and receive voice calls anyplace, anytime; they complain bitterly about dropped calls and wireless "dead" zones. Similarly, consumers do not want music or TV programs to go on and off as they walk around listening to and watching their mobile wireless devices. Licensed spectrum, unlike unlicensed spectrum, can support those wireless applications that require reasonably reliable radio links or extensive coverage.

C. Innovation

Beyond their claims regarding the potential for specific services such as wireless LANs and rural broadband, unlicensed advocates claim that open access to the TV white space will be a major catalyst to innovation. According to one group, the white space holds "the key to advances in wireless communications, broadband deployment and accessibility, and mobile Television and video services."[39]

The effect on innovation is a major point of contention in the broader debate over the proper direction for reform of our national spectrum policy. Those who favor property rights (licensing) argue that an unlicensed approach is less conducive to innovation in part because of the fundamental free-rider problem: in an unlicensed regime, some of the benefits from investments in spectrum-conserving innovations will go to all users, not just to those who purchase the innovation. Thus the level of investment in innovation will be less than what is optimal for society. Baumol and Robyn make this point in the context of their critique of the commons approach:

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[39] See http://www.wirelessinnovationalliance.org/index.cfm?objectid=A25E1FC0-F1F6-6035-B363 5EA7D5386BE0

> If manufacturer A's investment in research and development succeeds in reducing interference problems and thereby makes it possible to expand the volume of spectrum activity, only part of the resulting increase in business is likely to go to A. Much of it will also go, in the form of a beneficial externality, to equipment manufacturers B, C and D, some of whom may even be direct rivals of A. Because a substantial portion of the benefits of A's research and development expenditures go to others, it will certainly not pay A to spend as much on research and development as the public interest requires.[40]

Those who favor a broader role for unlicensed spectrum respond that the weakened incentive to invest in spectrum-conserving innovations has little practical effect. They point out that manufacturers can capture the returns from other kinds of efficiency-enhancing innovations (e.g., power-saving techniques that extend the life of the batteries contained in unlicensed devices), and that by their nature many of those innovations also conserve spectrum. They note, moreover, that the process by which industry sets standards for unlicensed devices (*e.g*., 802.11) places a premium on spectrum efficiency because that increases the market for the standard-compliant devices.

Some unlicensed advocates argue that an open access policy is actually superior to licensing as a catalyst for innovation in that it removes some barriers to entry faced by an innovator. Unlicensed spectrum is both free and readily available.[41] In addition, the innovator can deal directly with the end-user without needing to persuade a spectrum licensee to support a new and untested product.

In our view, there is merit in both arguments. Unlicensed spectrum is a good home for low-power, short-range systems and thus facilitates innovation in such systems. By contrast, licensed access encourages innovation in longer-range equipment and infrastructure, because the interference protection that licenses provide is a necessary condition for investment in such capital-intensive systems. In short, an unlicensed access regime facilitates one type of innovation, a licensed regime another.

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40 William J. Baumol and Dorothy Robyn, *Toward an Evolutionary Regime for Spectrum Governance. Licensing or Unrestricted Entry?* (Brookings Press 2006), pp. 32-33.

41 For a response to this point, see Baumol and Robyn, *op. cit.,* pp. 33-34.

For just that reason, licensing will significantly increase the potential for innovation in the TV white space. The TV band is useful for mobile and long-range services because it has better propagation characteristics than higher frequencies—a major plus in rural areas in particular. WiFi and other short-range unlicensed services fail to take advantage of this property of the TV spectrum while potentially disrupting other services that do want to exploit it. Similarly, it is easier to generate significant power in the TV band than at higher frequencies, which is also useful in rural areas. By restricting users to low power limits, an unlicensed approach fails to take advantage of this valuable feature of the TV spectrum.

In short, the TV white space is "overqualified" for the use to which unlicensed advocates want to put it. Even if unlicensed advocates are right about the inexorable growth of low-power WiFi networks, it would be a spectral "sin" of omission to use vacant TV channels to satisfy that demand. Allocation of the TV band for (unlicensed) low-power, short-range wireless networks would be the equivalent of using land in downtown Tokyo to grow rice. Allocation of the TV white space for long-range unlicensed operations would be equally "sinful" because (unlicensed) WISPs would be doubly handicapped—by low power limits and the threat of interference—relative to their licensed competitors operating in 700 MHz spectrum.

In sum, the white space *is* prime spectrum, as unlicensed advocates maintain. Moreover, because of its valuable properties, the white space *does* have the potential to generate considerable innovation. But the key to realizing that potential is *access* to the white space, not unlicensed access.