

### *Should Unlicensed Broadband be Restricted to “Spectrum Siberia”?*

## THE ECONOMIC CASE FOR DEDICATED UNLICENSED SPECTRUM BELOW 3GHz

by William Lehr\*

On May 12, 2004, the FCC issued a notice of proposed rulemaking concerning unlicensed sharing of TV channels 2-51 after the digital television transition.<sup>1</sup> Currently, only a small fraction of those channels are used for broadcasting in each of the nation’s 210 TV markets and the balance could be reallocated, on a dedicated basis, for shared access by unlicensed broadband service providers (WISPs) and others. Separately, both Congress and the FCC are considering the future use of TV channels 52-69, which will be vacated upon completion of the DTV transition and could also be reallocated, in part, to unlicensed services.

Is WiFi and other unlicensed broadband services a wise use for at least part of the freed up spectrum on TV channels 2-69? Many spectrum incumbents and economists have argued that newly-opened, highly-valuable lower frequency spectrum should be reserved for licensed use and that unlicensed access should be relegated to higher frequency spectrum, known in the industry as “spectrum Siberia.” This brief makes the economic case for more dedicated unlicensed spectrum below 3 GHz.

A striking fact is that less than 3% of spectrum below 3 GHz is allocated to unlicensed use on a dedicated basis. Below 1 GHz, where the broadcast band is located and where unlicensed spectrum is needed even more, the figure is an even more dismal 1%. Politically, it is extremely difficult to reclaim any of the balance for unlicensed use because incumbent licensees claim rights to that spectrum, and unlicensed spectrum yields no auction or lease revenues. But just because the political case is difficult doesn’t mean the economic case isn’t quite strong. Indeed, in the years after the Great Telecom Meltdown of 2000, the greatest telecom innovation and growth has centered on this tiny sliver of lower frequency unlicensed spectrum.

### I. THE CHANGING WORLD OF SPECTRUM TECHNOLOGY AND REGULATION

The expansion in wireless services is one of the most important trends that have transformed the Information, Communications and Technology (ICT) sector during the last decade. Mobile telephone services changed from being a premium service for the elite, used mostly from cars, to a

mass market communication service that can be used anywhere. Over the same period, the growth of the Web, email, and the Internet brought data communication services to the mass market for the first time. Now, with the emergence of wireless broadband data services, the two worlds are converging. This convergence will help drive another cycle of investment, innovation, and economic growth.

Figure 1. Common Licensed vs. Unlicensed Devices



Wireless enables mobile computing and ubiquitous connectivity, thereby improving old services and creating opportunities for new ones. Progress in sensor networks, information technology in biotech, multimedia integration, and “GPS” location-based services all depend on wireless technology. Wireless also offers one of the best hopes for

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increased competition for wireline services. Continued growth and innovation in wireless services is critical to the health of the ICT sector, and hence, to the overall economy.

While “wireless services” encompass an incredible diversity of uses, technologies, and markets (see *Figure 1*), one commonality is that they all depend on access to the radio frequency (RF) spectrum. The traditional model for managing spectrum for commercial use has been based on a licensing regime that grants licensees limited and restrictive-use rights to a specific frequency band in a geographic area.<sup>2</sup> In light of advances in wireless technology and the evolution of markets for wireless services, a consensus is emerging that the traditional model for managing spectrum is grossly inefficient.<sup>3</sup> It has impeded innovation and investment in new technologies. The net effect has been to accentuate a perception of acute spectrum scarcity.

The question is not whether spectrum management is in need of reform, but rather *how* it should be reformed. Much of the focus has been on increasing the economic role of market forces in regulating how spectrum is allocated and used. While this represents an important direction for reform, it is generally associated with continued reliance on a regime based on exclusive-use licenses to specific frequency bands. While this licensing model remains important, it is not the only model for managing spectrum.

This issue brief makes the economic case for allocating additional lower-frequency spectrum for dedicated “unlicensed” use (below 3GHz). The market success of services operating in current allocations of dedicated unlicensed spectrum, the potential for unlicensed spectrum to support new and innovative technology and business models, and the need to “future-proof” regulatory policy make it desirable to allocate additional spectrum for unlicensed uses.

The rest of this paper is organized in five sections. Section II explains why there is renewed interest in the unlicensed model, and Section III explains why spectrum below 3GHz is special. Section IV focuses on the arguments in favor of relying on a regime of exclusive licenses instead of unlicensed use, and explains why an additional allocation for unlicensed use would be beneficial. Section V concludes.

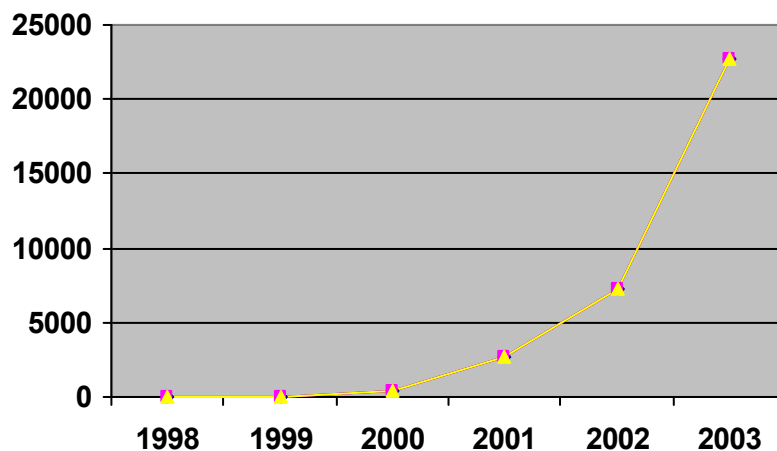
## II. WHY THE INTEREST IN UNLICENSED SPECTRUM?

Traditional spectrum management has been justified, in part, on the basis of hundred-year-old radio receiver technology. To protect radios from interference, exclusive licenses granted radio users the right to deny use of the spectrum to other transmitters operating in that frequency band.<sup>4</sup> This was intended to protect the licensee’s service from interference, but it also allowed licensees to exclude shared use even in situations where such use would not interfere.

Over time, technologies like smart antennas, spread spectrum modulation, and cognitive (software) radios made it feasible for transceivers to dynamically change their frequency, modulation, or power levels to enable more efficient and intelligent spectrum sharing.<sup>5</sup> The traditional logic that exclusive frequency licenses are needed to manage “interference” has been significantly undermined.

The increased interest in the unlicensed model has been prompted, in part, by the dramatic growth associated with wireless Local Area Networks (WLAN). For example, the rapid growth of WiFi – a WLAN technology that operates in the 2.4 GHz unlicensed band – demonstrates the important role that unlicensed can play in the evolution of wireless services. (See *Figure 2*). Considering the sad state of the ICT sector in recent years, it is noteworthy that 22.7 million WiFi units worth \$1.7 billion were sold in 2003, reflecting three-digit growth for each of the preceding two years.<sup>6</sup> Although the reach of a WiFi base station is limited to a few hundred feet, the proliferation of WiFi-based public “hot spots” in government buildings, airports, hotels, coffee shops, and other public areas make it increasingly possible to cyber-forage for a wireless broadband connection.<sup>7</sup> In light of this remarkable growth, it is worth remembering that as recently as five years ago, most analysts expected wireless broadband data access to be delivered by mobile telephone service providers over their 3G networks.

*Figure 2. Worldwide Home Wi-Fi Units Sold (in Thousands)*



Source: In-Stat/MDR, December 2003

Other technologies like ultrawideband (UWB) are challenging the very basis for managing frequency in the form of exclusive licenses. UWB applies spread-spectrum techniques to enable high bandwidth transmissions to efficiently share a broad frequency band without destructive interference. The plethora of wireless technologies is giving rise to new models for deploying last-mile infrastructure. Municipalities,<sup>8</sup> Wireless ISPs (WISPs), and user-cooperatives<sup>9</sup> are taking advantage of WiFi and other of the new types of technologies from companies like Alvarion and Tropos Networks to build out low-cost infrastructure to provide alternative community-owned metro-area networks.

The future wireless world will consist of a heterogeneous mix of overlapping and partially integrated wireless networks and technologies. Legacy technology will mix with a continuous stream of new technology. Short-range networks will mix with longer-range networks. There will be networks limited to an individual’s personal space, networks that reach hundreds of feet, and networks that extend tens of miles.

The need for a mix of regulatory models has been recognized by policy-makers. For example, the FCC’s Spectrum Policy Task Force concludes that “no single regulatory model can or should be applied to all spectrum.” They also argue, however, that in the lower frequencies (below 3GHz), that the FCC “should focus primarily, though not exclusively, on using the exclusive use model.”<sup>10</sup> Before examining the economic basis for the bias in favor of a licensing regime, it is important to understand why spectrum below 3GHz is special, and why additional unlicensed spectrum in the lower bands is necessary to properly respect the Task Force’s worthwhile goal of promoting diversity in the regulatory models employed.

### III. WHY IS LOWER FREQUENCY SPECTRUM SPECIAL?

While technology is making it more feasible for spectrum at different frequencies to support similar services (and hence act as substitutes), there are important differences in the usefulness of spectrum at different frequencies. The chief technical advantage of using lower-frequency spectrum is that lower-frequency signals propagate more easily through the air and are more tolerant if there is not direct line-of-sight (LOS) between the transmitter and receiver. Also, the electronics associated with operating at lower frequencies are less expensive.<sup>11</sup> Finally, there is simply much more spectrum available in higher frequency bands.<sup>12</sup>

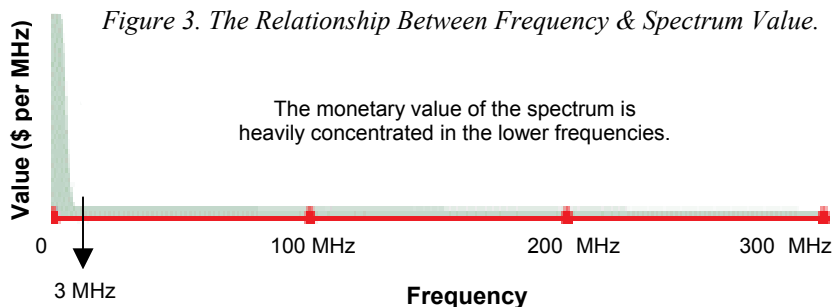


Figure 3. The Relationship Between Frequency & Spectrum Value.

Moreover, because of its attractiveness for offering particular services, its limited abundance, and legacy technology issues,<sup>13</sup> the lower-frequency spectrum is much more crowded with incumbents than is higher-frequency spectrum. Over time, the frontier of usable RF spectrum has moved to ever higher frequencies as improvements in digital technology have made it increasingly viable to digitize and process higher frequency signals. These advances support viable communications using lower power signals in noisier environments, with improved non-LOS performance, and

over longer distances than was previously possible. While this has made it feasible to locate services at higher frequencies than before – and thereby relaxed constraints on available spectrum supply – demand for lower-frequency spectrum has also increased. The changes in technology have not changed the physics of RF transmissions.

The debate over unlicensed versus licensed is not as important at higher frequencies precisely because spectrum is relatively more abundant. It can be allocated to both licensed *and* unlicensed commercial uses. Moreover, because higher-frequency signals travel more nearly in straight lines, an exclusive licensing regime could be based on point-to-point licenses.<sup>14</sup> Because the signals travel in a “pencil beam” (e.g., a wireless fiber substitute), it is feasible to award a large number of non-interfering, exclusive licenses in a small geographic area. This paper focuses on the need for spectrum reform to allocate additional dedicated spectrum below 3GHz precisely because this spectrum is highly desirable and its allocation is contentious. While the “scarcity” of spectrum is debatable, it is clear that regulatory policy can make spectrum scarce when it might otherwise not be.

Today a substantial chunk of prime lower-frequency spectrum is currently occupied by incumbent licensees that offer “broadband” services. Traditional over-the-air radio and television broadcasting in the AM/FM and VHF/UHF bands use valuable lower-frequency real estate for which alternative higher-frequency distribution media are already available (e.g., coaxial cable television and direct broadcast satellites deliver many more programming channels without using lower-frequency spectrum). Partially relocating these services to higher frequency channels or conversion to more efficient broadcast transmission technologies would free up additional commercial spectrum for other uses that currently lack viable alternatives, including allocating additional spectrum for dedicated unlicensed use.

### IV. ECONOMIC ARGUMENTS IN FAVOR OF UNLICENSED

In this section, I first characterize the economic arguments in favor of using exclusive licenses for virtually all lower-frequency spectrum, and then identify the flaws in these arguments.

#### A. Economic basis for supporting exclusive licenses

There are three principle economic justifications for relying on exclusive licenses. The first justification views spectrum as a scarce economic good and focuses on the role of markets in allocating that good. The second justification focuses on the need to give users and providers appropriate incentives to invest in network equipment and services. The third justification recognizes that even when spectrum is not “scarce,” it may be necessary to coordinate user behavior in order to allow users to share spectrum without adversely impacting or “interfering” with each other. Each of these

justifications for the licensed model rests on a common set of assumptions that are open to critique, and therefore, support consideration of an alternative management regime based on unlicensed use. These include assuming that: (1) spectrum is scarce; (2) markets offer the best mechanism for allocating scarce spectrum resources; and licenses are necessary for (3) markets to operate efficiently; (4) provide investment incentives; and (5) to manage interference. The following sub-sections explain why each of these assumptions is questionable, and why an unlicensed regime is better than a licensed regime.

***Scarcity may be a regulatory artifact.*** Since 1995, billions of dollars have been paid in auctions for licenses, providing tangible evidence of industry's willingness-to-pay for spectrum and providing an empirical basis for estimating the opportunity cost for using spectrum. It is unclear how much of this payment reflects artificial scarcity due either to regulatory mismanagement or to exclusive licenses. Incumbents have argued that granting them flexibility would allow spectrum to be redeployed, thereby increasing supply and lowering spectrum costs. They also argue that auctions allow ex ante competition among would-be monopolists extracts any monopoly rents. If this occurs, however, it means that the expected business plan of the winner incorporates those anticipated monopoly profits. The licensee has an incentive to maximize the value of its exclusive license, which includes potentially restricting future access to the spectrum, even when access could be shared at zero cost.

Evidence of current spectrum use suggests that licensed spectrum is under-utilized. If one drives around with a meter measuring the level of RF transmissions in the prime spectrum below 3GHz, one finds under-used spectrum most of the time, in most locales, in most of the frequency bands.<sup>15</sup> While some frequencies are being used intensively in some places (e.g., cell phone calls that are dropped during rush hour), there is usually lots of unused spectrum in adjacent bands. This suggests that most of the observed "scarcity" is a regulatory artifact. Furthermore, as already noted, many of the advances in wireless technology make it possible to use spectrum much more intensively without causing harmful interference. If spectrum is *not* scarce, then one of the significant justifications for supporting exclusive licenses disappears. If there is no scarcity, then it is unnecessary to incur the bureaucratic overhead and transaction costs associated with licenses in order to allocate the resource more efficiently.

***Coordination costs may be lower with unlicensed.*** Although spectrum reform and adoption of new wireless technologies can significantly increase spectrum supply, demand may grow even faster. Even if there is ample

spectrum for most uses in most locales, localized congestion is likely to persist at least under some circumstances. Furthermore, the adoption of efficient spectrum sharing technologies will take time and will not be uniform. For these reasons, it is important to consider how best to allocate the spectrum if it remains scarce.

The standard economist answer is to rely on markets to allocate scarce resources. While this may be the correct solution for most scarce resources, and even for spectrum in many cases, it is worthwhile considering the circumstances within which "market allocation" is *not* likely to offer the best mechanism for allocating scarce spectrum.

For a market to be efficient, a number of assumptions have to apply: the allocated good must be definable, and market. If the goal is to address spectrum scarcity, markets need to be local, making the challenges of supporting an efficient market greater. Under such circumstances it may be simpler to opt for over-provisioning rather than market regulation.

*"If one drives around measuring transmissions in the prime spectrum, one finds under-used spectrum most of the time, in most locales, in most of the frequency bands."*

Furthermore, even if a market price can be determined in a timely fashion, there is no guarantee that it will be efficient. If there is either monopoly or monopsony power, prices may deviate from optimal levels. Incumbents have an

incentive to protect and exploit their market power. By restricting the availability of spectrum, they may be able to inflate prices to capture artificial scarcity rents. Even more perversely, they may selectively restrict spectrum access to new technologies that are expected to pose a competitive threat to their market power, thereby influencing not only end-user prices but also the direction of technical change, and slowing the progress of competition. This can reduce incentives to invest in innovative technologies.

Prices may also deviate from efficient levels if there are externalities that are not reflected in the prices. These could be negative or positive externalities that are not appropriable by the transacting parties and hence not included in the prices. While it may be possible to reform property rights so that these externalities are internalized, it may be better to simply address these externalities via a non-market mechanism.

Even if efficient prices can be set by the market, these do not always offer the best mechanism for coordinating the allocation of resources. If transaction costs are sufficiently high, it may be better to allocate resources using a non-market mechanism. Transaction costs are higher when there are search and information costs, bargaining costs, or policing and enforcement costs. If scarcity is intermittent or localized, these costs may be high relative to the value of the spectrum rights that are being exchanged. Matching spectrum buyers and sellers if the market is decentralized

may be expensive. Alternatively, supporting a centralized market when the transactions need to be decentralized (because scarcity is very localized) may entail substantial transaction costs.

For any level of transaction costs, the lower the marginal value of the spectrum, the more likely that those transaction costs will preclude efficient allocation. With reduced spectrum scarcity, the marginal value of spectrum will be lower. The value of the spectrum being sold may be small if users' willingness-to-pay to avoid "congestion" is low. For example, if the communications are inherently low value or easily shifted in time, modulation, or frequency (so as to avoid interfering), then the "prices" may be so low that coordination might be better achieved using a non-price coordination device that relies solely on signaling instead of market transactions. There are lots of "rules of the road"-type mechanisms that may achieve coordination much more effectively without requiring the overhead of a payment mechanism of enforcement. If spectrum is not scarce and transaction costs are relatively high then an unlicensed model may offer a superior allocation mechanism.

Finally, if history is any guide, then the experience to date of "Quality of Service" pricing in the Internet suggests that it may continue to be cheaper to over-provision capacity than to implement a pricing mechanism to induce more efficient utilization at the margin.<sup>16</sup> During the 1990s, significant academic and industry research and development went towards developing incentive-compatible pricing mechanisms to allow more efficient utilization of Internet capacity.<sup>17</sup> The problem was that the traditional Internet was based on a "best efforts" packet service protocol that results in increasing packet delays during periods of congestion. For delay-sensitive services like voice telephony, this presents a problem. Although numerous technologies have been implemented to support prioritized pricing, most network operators simply opted for over-provisioning rather than incur the added overhead associated with traffic metering and transaction processing. When quality-of-service pricing has been introduced, it has been employed more as a means of supporting pricing discrimination than in order to allocate scarce resources.

***Exclusive licenses are not essential to support market allocation of spectrum.*** While the preceding discussion raised questions about the feasibility and efficiency of using markets for allocating spectrum, these arguments are not conclusive. There may be situations where market-based spectrum allocation *may* be efficient. However, the market-based allocation does not have to be via real-time pricing, and even if it is, it does not require exclusive licenses. On the one hand, market forces could be employed in the selection of a sharing protocol or etiquette to manage the unlicensed spectrum. This could be accomplished by delegating the selection of the protocol to an independent standards development organization. On the other hand, exclusive licenses are not necessary to implement real-time pricing. A licensing regime based on exclusive rights to use a narrow band of frequencies in a specific geographic-area

may prove too rigid. There is no *a priori* reason to believe that the government could not administer a real-time market as efficiently as a private band manager; or, alternatively, why such management could not be outsourced without requiring a grant of private exclusive license rights.

Finally, because the allocation of additional spectrum to dedicated unlicensed is anticipated to occur in conjunction with – not in full replacement of – increased flexibility for licensed spectrum, market trading of exclusive licensing and dedicated unlicensed could co-exist in different frequency bands below 3GHz. Indeed, the availability of low cost unlicensed spectrum would provide a check on the ability of exclusive licensees to extract artificial scarcity rents and would provide a haven for those users and technologies for which market allocation of spectrum may not be efficient, as noted above. As long as both regulatory models exist, relative pricing between the two models will provide a market test and check on potential inefficiencies in both.

***Exclusive licenses are not necessary to promote investment incentives.*** Exclusive licenses are also justified to promote investment incentives. On the one hand, exclusive licenses can provide incentives to use spectrum more efficiently. On the other hand, exclusive licenses are said to be necessary to promote investment in carrier infrastructure. While these benefits may be true, they are neither the only nor best way to promote efficient spectrum use and investment. Although related, these two rationales involve distinct notions and are addressed in the following sub-sections.

(1) Incentives to use spectrum efficiently. A common criticism of the unlicensed model is that it lacks incentives to use spectrum efficiently, resulting in a "Tragedy of the Commons." This arises when each user fails to take into account the negative impact of their usage on the experience of others, resulting in "congestion" or harmful interference.

By assigning a private property right to the spectrum, the owner becomes the residual claimant to the spectrum, and thereby is presumed to have an incentive to manage the spectrum efficiently. Of course, this assumes that the benefits of using the spectrum are fully appropriable and the market allocation is efficient, which may fail to be the case for several reasons. First, spectrum licenses are not granted in perpetuity and are constrained in other ways that limit the owner's ability to fully exploit the benefits of ownership. Second, even if licenses are flexible, there may be benefits from more efficient spectrum utilization which are not appropriable by private licensees. For example, if potential users are sparse and costs must be incurred by the licensee in anticipation of potential buyers who may not materialize, the licensee may simply prefer to avoid leasing. The existence of adequate dedicated unlicensed spectrum provides a test bed where demand can make itself known.

Furthermore, even when markets can adequately internalize the congestion externalities, they do not offer the only mechanism capable of providing incentives to use a scarce resource efficiently. The "tragedy of the commons"

arguments ignore the fact that society has developed a number of management schemes that work quite well for managing collectively-owned resources.

Additionally, incentives to invest in spectrum-efficient technology may be improved in an unlicensed world. If users know that they may have to contend with congestion, this can enhance their incentives to invest in technologies that are robust to interference. While it is possible that these technologies could either ameliorate interference (e.g., switch to an unused channel when interference is detected) or make matters worse (e.g., boost power to drown out the competing signal), additional “rules of the road” could be designed to constrain the types of interference responses adopted to those that are collectively efficient.<sup>18</sup>

(2) Incentives to invest in wireless infrastructure. Some proponents of exclusive licenses argue that these are needed to provide carriers and customers incentives to invest in radio equipment and services because such long-lived assets are co-specialized with their frequencies. Because constructing a traditional carrier network requires large investments that may be substantially sunk, a carrier’s incentive to invest is reduced by the threat of interference. By granting some protection against future interference over the investment horizon, an exclusive license lowers the *ex ante* costs of investing in infrastructure, and thereby may promote investment.

While this reason has provided a valid rationale for why service providers have claimed they need exclusive licenses, and also why these licenses ought to be for long terms and subject to easy renewal, the service provider model is not the only business model for offering wide-area communication services. For example, consider the case of the device that only wants to communicate occasionally, and which may also be quite inexpensive. In such a case, there is no large network investment that needs to be protected. While such services *may* be provided over a service provider’s network, this does not have to be the case.

Moreover, advances in wireless technology are rendering this traditional rationale less relevant. First, wireless technology is increasing the frequency-agility of radio systems. Second, much of the investment in a carrier’s network that is long-lived (towers, cell sites) remains useful even if all of the electronics need to be replaced; and the electronics have much shorter useful lives. Third, with the development of secondary spectrum markets and flexible licensing, exit costs are reduced which further reduces the need for protection from exclusive licenses. Taken together, these advances and changes in the market make the spectrum used and the infrastructure that use it *less* co-specialized, thereby reducing the traditional basis

underlying the need for exclusive licenses to protect carrier investment incentives.

While advances in technology are making the need for exclusive licenses to protect service provider investments in network infrastructure less necessary, these same advances pose an increasing risk for new technologies and innovative services. That is, the property right inherent in an exclusive license gives the licensee the right to charge a non-zero price for spectrum even when it is not scarce. This could be used by the licensee to expropriate the value of an innovative technology, subjecting entrepreneurs with innovative technology to the threat of expropriation and hold-up, effectively deterring them from accessing the spectrum. Entrepreneurs may be unable to raise the funds needed to purchase their own exclusive license, and in any case, the need to purchase such a license solely to protect against *ex post* expropriation with respect to artificial spectrum scarcity rents represents a deadweight loss.

A similar problem arises when intellectual property rights are granted too broadly. While intellectual property rights

*“Preserving regulatory diversity only in higher frequencies fails to recognize the important fact that different frequencies are not perfect substitutes.”*

are intended to provide an incentive to invest in and then share new intellectual content, these rights can also deter investments in complementary intellectual property and efficient access to intellectual property that already exists (e.g., block

“fair use”). To the extent incumbents fear competition from new technologies, they may seek to foreclose these technologies by denying them access to spectrum. Secondary markets reduce but do not eliminate this risk. While it is possible to make services and infrastructure more frequency agile, individual technologies may be optimized for operation in particular RF frequencies and the availability of abundant low-cost licensed spectrum in another RF band will not perfectly discipline prices in the RF band used by a particular technology. New technologies without an established user base (and therefore failing to benefit from positive network externalities) and facing substantial market uncertainty may be especially vulnerable.

***Exclusive licenses not necessary to manage interference.***

Real spectrum “scarcity” arises when two uses of the same spectrum interfere with each other. But assigning a property right that allows exclusion may not always be efficient, as I have explained. Exclusive licenses are not necessary and may be inferior to dedicated unlicensed even if a market allocation process is used.

It is also sometimes argued that the owner of an exclusive license would be more likely to adopt the efficient sharing protocol than would a government manager. There are several responses to this argument: first, dedicated unlicensed that relies on a sharing protocol need not rely on an administrative government process. Second, a dedicated unlicensed regime involves more than just an algorithm for

allocating scarce spectrum. Third, as noted above, a market based on exclusive licenses may fail to be efficient. Allocating additional spectrum for dedicated unlicensed *and* for exclusive licenses will provide a valuable test of which model adopts the most efficient mechanisms for sharing.

It is sometimes argued that exclusive licenses are needed to enable more efficient enforcement of whatever interference management regime is adopted. The claim is that by moving to a regime based on property rights, enforcement via the courts will replace enforcement via a technical protocol or via an administrative body like the FCC and that courts are inherently more efficient. However, tort enforcement by the courts is not necessarily better than enforcement by a different branch of government. Both are vulnerable to influence costs and both may result in lengthy delays and inefficient outcomes. Property rights for spectrum are inherently ambiguous. Moreover, enforcement of spectrum rights is likely to require quite specialized and arcane knowledge that might make it most appropriate for enforcement by specialized “spectrum courts” which may offer only limited improved protection from influence costs relative to the administrative agency they would replace.

Furthermore, as already explained, dedicated unlicensed could be enforced via a market mechanism (*e.g.*, an industry standards body). Even voluntary certification of compliance could be effective. While there may still be opportunistic defections, no enforcement mechanism is perfect and the benefits of better enforcement must be weighed against its costs. If spectrum is relatively plentiful (and hence low cost), voluntary compliance may be sustainable as an individually rational equilibrium. Also, advances in technology such as cognitive radios will make it easier to decentralize interference management.

### **B. Dedicated unlicensed below 3GHz preserves regulatory diversity**

Allocating additional spectrum for dedicated unlicensed in the lower frequency bands would help retain regulatory flexibility and diversity. Preserving such diversity only in higher frequencies fails to recognize the important fact that different frequencies are not perfect substitutes. Regulatory diversity is valuable because no enforcement mechanism is perfect and the uncertainty regarding the optimal regulatory approach is greatest in times of rapid technical progress and industry transformation. Providing for the co-existence of multiple regulatory models supports multiple experiments and thus provides an element of “future proofing,” that is, obviating the need to change regulations and allocation for each new technology. Finally, achieving spectrum reform will be difficult, but dedicated unlicensed services could hasten the necessary reform.

### **C. Dedicated unlicensed supports innovation and investment**

In addition to encouraging investment in smart radio technology, dedicated unlicensed is also more compatible

with decentralized, distributed models for industry evolution. The critical feature of dedicated unlicensed is that no private interest has a right to deny access to potential users. Because users do not have to negotiate a service agreement before accessing unlicensed spectrum, and because there is no one that has an exclusive right to exclude them from using the spectrum, unlicensed spectrum lowers the costs for decentralized, small-scale entry and viral industry growth. This can foster distributed experimentation, and as the WiFi example demonstrates, technologies originally developed for one type of market may evolve to serve other needs.

Although the distributed networks may remain independent, they may also be interconnected. This could be via the public telecommunications network comprised of interconnected service provider networks. When part of the larger communications infrastructure, these distributed, decentralized wireless networks can support edge-based innovation. Innovations can be adopted incrementally, without requiring changes to core network components or without directly confronting the network effects that can make legacy applications so difficult to replace. There are likely to be technologies that we have not yet imagined that may find unlicensed offers a better operating environment.

Finally, unlicensed spectrum may be more likely to support the emergence of networks that are based on an equipment-provider model. That is, networks that may be created when end-users deploy equipment that can operate both as end-nodes and as relay or transmission nodes. By linking series of such devices together in a “grid” or “mesh,” it is possible to create a network capable of supporting communications over a wide area without the intercession of a service provider. If successful, these could offer additional sources of competition for incumbents, further contributing to consumer choice. Unlicensed, shared spectrum could be integrated with exclusive licensed spectrum to improve spectral efficiency and lower spectrum costs without reducing quality-of-service.

## **V. CONCLUSIONS AND POLICY RECOMMENDATIONS**

There is general agreement among industry analysts that the traditional models of spectrum management are in need of reform. Most economists agree that the reform should seek to increase the ability of market forces to shape how spectrum is allocated and used. Traditional licenses that were encumbered with restrictions on the choice of technology, the services offered, their coverage, and the transferability of access rights have imposed a high opportunity cost for spectrum for many advanced communication services, while precluding the deployment of under-utilized spectrum to higher-value uses. This has increased industry costs, reduced incentives to innovate, and slowed the deployment and adoption of new services.

One solution that has been proposed is to transition to a regime of tradable property rights for spectrum based on exclusive use frequency licenses. An alternative approach

for managing spectrum would be to allocate a band or bands of frequencies for unlicensed uses. There seems to be an emerging consensus among those who support increased reliance on market forces that exclusive use licenses offer a superior mechanism for spectrum management, especially for the valuable lower frequency spectrum below 3GHz. The spectrum in these bands available for commercial use (and much of it is not and remains under government control) is heavily populated by licensed incumbents. Support for using exclusive licenses for lower frequency spectrum is justified, in part, via recourse to Coase's (1959) argument that markets do a better job of allocating scarce resources than do central governments. Moreover, it is argued that underlay and overlay easements can accommodate some secondary usage of licensed spectrum.

While the transition to a flexible licensing regime and making provision for unlicensed easements are important reform policies, there is also a need to allocate additional spectrum for dedicated unlicensed use in frequencies below 3GHz. The market success of services operating in current allocations of unlicensed spectrum, as well as the potential for unlicensed spectrum to support new and innovative technology and business models make it desirable to allocate additional spectrum for unlicensed uses.

An allocation on the order of another 100 to 300 MHz would leave plenty of spectrum for the exclusive licensing. Making such a provision is desirable because unlicensed use supports a fundamentally different model for how wireless services may be developed and deployed. This offers a valuable contribution to the wireless ecosystem, as the success of WiFi in recent years attests.

Opposition to dedicated unlicensed is often conflated with the view that unlicensed is inconsistent with auctions, implies spectrum use should be "free," or that supporting unlicensed means opposing liberalization of licensed spectrum. These are misconceptions. An allocation of additional unlicensed spectrum could be included as part of a spectrum auction. Unlicensed access is not "free" but it does preclude a private party using its license to extract rents for access to the spectrum. And, unlicensed spectrum does not imply more regulation and is consistent with increased reliance on market forces.

Additional spectrum for dedicated unlicensed use is important because secondary use easements are neither a foregone conclusion nor an adequate substitute. Spectrum at different frequencies is useful for different things. Indeed, the difference between a licensing and unlicensed regime is less pronounced at higher frequencies. Promoting regulatory diversity is consistent with increased reliance on market forces, since no regime will be completely free of regulation or distortions. Facilitating multiple models at lower frequencies will enhance the forces of market-fueled innovation and competition.

Ultimately, the future of unlicensed access to lower frequency spectrum may depend more on political than

economic considerations. The large band occupied by the politically powerful TV broadcasters, is a timely illustration. One point on which economists agree, whether or not they support lower frequency unlicensed spectrum, is that broadcast spectrum is grossly underutilized. Yet the broadcasters have historically fought against any sharing of the band. With broadcasting allocated more than thirty times the amount of bandwidth allocated to unlicensed services, the FCC's current NPRM to open unassigned channels for unlicensed sharing can correct this imbalance.

## Endnotes

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<sup>1</sup> See "Notice of Proposed Rule-Making" in the matter of Unlicensed Operation in the Broadcast Bands, FCC Docket No. 04-186. Available at: [http://hraunfoss.fcc.gov/edocs\\_public/attachmatch/FCC-04-113A1.pdf](http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-04-113A1.pdf).

<sup>2</sup> A significant share of spectrum is reserved for government use and is managed by the National Telecommunications Information Agency (NTIA). The spectrum that is allocated for commercial and public use is managed by the Federal Communications Commission.

<sup>3</sup> See for example the FCC's Spectrum Policy Task Force Report (2002). Similar discussions have been occurring around the globe. (See <http://www.itu.int/osg/spu/ni/spectrum/index.html> for briefing presentations from around the world from a workshop at the ITU in February 2004).

<sup>4</sup> Exclusive-use licensees share the spectrum among multiple users. The "exclusivity" arises because of the licensees right to determine who is allowed to share the spectrum.

<sup>5</sup> See Spectrum Policy Task Force (2002a), Werbach (2003), and Lehr, Sirbu, and Gillett (2004) for user-friendly discussions of some of the relevant developments.

<sup>6</sup> These estimates are from an In-Stat/MDR Report (see, Shim, Richard, "Report: Wi-Fi Gear Moving on the Double," CNET News.com, January 14, 2004. Available at: <http://news.com.com/2100-7351-5141002.html>).

<sup>7</sup> There are continuously evolving classes of related standards that support "WiFi"-like communications over longer distances, at higher bandwidths, in different frequency bands, and with support for additional applications. See <http://grouper.ieee.org/groups/802/11/main.html> for information on these standards or Lehr & McKnight (2003), for additional references.

<sup>8</sup> See Lehr, Sirbu, and Gillett (2004) and Barranca (2004) for a discussion of how municipalities are using wireless.

<sup>9</sup> See Sandvig (2003) for a discussion of WiFi cooperative deployments.

<sup>10</sup> It is worth noting that while the Task Force recommends primarily relying in the licensing model, it does not argue that this should be the only model in the lower frequencies. The Task Force advocacy of co-existence between licensed and unlicensed is consistent with my argument.

<sup>11</sup> As the market for and experience with operating at higher frequencies grows, the cost disparity in the associated electronics will decrease.

<sup>12</sup> That is, the RF spectrum extends from 3Khz to 300GHz. There is only 3GHz of lower-frequency spectrum as defined here, as opposed to almost a 100GHz above (of currently usable spectrum). Moreover, the 3GHz upper threshold is somewhat arbitrary but is intended to include the unlicensed spectrum currently used by WiFi (2.4GHz) and the MMDS (2.6GHz) spectrum that is under review for reform.

<sup>13</sup> That is, when it was difficult/expensive to digitize higher-frequency signals, services were deployed using lower-frequency channels.

<sup>14</sup> This is the approach that has been adopted by the FCC for spectrum in the millimeter bands above 70GHz (see *FCC WT 02-146 Millimeter Band Proceeding*).

<sup>15</sup> See Johnston and Snider (2003).

<sup>16</sup> In the context of spectrum pricing, "over-provisioning" amounts to adopting technologies to expand the usability of available spectrum, which includes technologies that allow operation in increasingly noisy environments.

<sup>17</sup> See McKnight and Bailey (1998) for a summary of some of this research. See Odlyzko (1998) for argument that over-provisioning is less expensive than charging for quality-of-service.

<sup>18</sup> See Konston (2002).