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Spectrum Policy for the Emerging Ultrabroadband World: Should Spectrum and Tangible Property Rights Be Bundled?

by

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Spectrum Policy for the Wireless Ultrabroadband World: Should Spectrum and Tangible Property Rights Be Bundled?[1]

Imagine a world with finite spectrum but infinite demand for wireless bandwidth. In such a world, which we shall call the "wireless ultrabroadband world," what would the wireless telecommunications architecture look like? And what type of property rights regime would accompany it?

No telecommunications architecture following known laws of nature could provide infinite wireless bandwidth. But this paper argues that the architecture that would get closest would be one with very short wireless end user links attached to a wired backbone. It further argues that in such a world the most efficient property rights regime for spectrum management would be one that *bundles* rights to use spectrum with rights of possession to tangible property.

Contrast this world to the wireless narrowband world in which we currently live in, where demand for wireless bandwidth is relatively modest, wireless links correspondingly large, and the most efficient property rights regime for spectrum management is predominantly one that *unbundles* spectrum and tangible property rights.

The unbundled property rights regime corresponds to the FCC's current system of licensing spectrumin in which licenses to use spectrum are granted without consideration of tangible property rights. The bundled property rights regime parallels much of the practice--but not the theory--of the FCC's current system of unlicensed spectrum.

This paper is divided into three parts:

1) Bundled versus Unbundled Property Rights
2) Wireless Links in an Ultrabroadband Network
3) Public Policy Recommendations

1) BUNDLED VS. UNBUNDLED PROPERTY RIGHTS

The spectrum policy literature has in recent years distinguished between three models of spectrum resource management: Command & Control, Property Rights, and Commons. A widespread consensus exists that the federal government should move away from the command and control model, with the policy debate centering on whether spectrum rights should be allocated in accord with the property rights or commons models.

[1] Earlier versions of many of the ideas in this paper can be found in: J.H. Snider, "FCC Lets the Telecom Giants Steal from You: Via Eminent Domain, Fat Cat Donors Get Airwaves -- Worth Billions -- In Our Homes," *Sacramento Bee*, April 7, 2002; J.H. Snider with Nigel Holmes, "The Cartoon Guide to Federal Spectrum Policy: What if the government regulated spoken words the way it regulates the airwaves?" (Washington, DC: New America Foundation, April 2004), J.H. Snider, "The Economic Case for Re-Allocating the Unlicensed Spectrum (White Space) Between TV Channels 2 and 51 to Unlicensed Service," Issue Brief #18 (Washington, DC: New America Foundation, February 2006); and "Spectrum Policy Wonderland," a paper delivered at the Telecommunications Policy Research Conference, September 2006.

The debate over the merits of the property rights and commons models of resource management has an illustrious history in the academic literature.[2] Unfortunately, when scholars applied property rights and commons models to the FCC's existing licensed vs. unlicensed spectrum management models, much was lost in the translation.[3]

There were indeed linkages between the property rights and licensed models on the one hand, and the commons and unlicensed models on the other hand. But they weren't as tight as the property rights and commons theorists assumed. As long as the goal of spectrum management was to foster coverage of large areas ("cells") with a single transmitter, these linkages would continue to be apt. But to the extent efficienct use of spectrum came to dictate small cell sizes within property lines, these linkages would break: the unlicensed model would not only take on the characteristics of the property rights model; it would become the dominant model for efficient spectrum use. The dominant enforcement mechanism might be conventional trespass laws rather than FCC standards of harmful interference, but all that is necessary for the property rights model to apply to the management of a specific resource is that a user of that resource has the legal right and practical ability to exclude others from its use.

In recent years, when the anomaly of small unlicensed cells within property lines was explicitly pointed out to them, some property rights and commons theorists acknowledged that their theories broke down in small cell situations. But this anomaly didn't much bother them because they thought it was an insignificant aberration. Their primary goal was to create a new last mile competitor for wired networks so they could free the telecommunications industry from being a monopoly and pursue a deregulatory agenda. Viewing wireless as a complementary good rather than a substitute good to the telecommunications network did not help them pursue that agenda. Small area devices were consigned to the status of little more than toys. Lots of consumers might use them—just like lots of kids like to play with toys--but they weren't worth serious scholarly attention.

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[2] John Locke and Karl Marx were, respectively, famous progenitors of property rights and commons theories. Sophisticated recent theorists include, on the property rights side: Armen A. Alchian and Harold Demsetz, "The Property Rights Paradigm," *The Journal of Economic History*, Volume 33, Issue 1, March 1973, 16-27; and Yoram Barzel, *Economic Analysis of Property Rights*, New York: Cambridge University Press, 1997. And on the Commons side: Elinor Ostrom, *Governing the Commons: The Evolution of Institutions for Collective Action*, New York: Cambridge University Press, 1990; and David Bollier, *Silent Theft: The Private Plunder of Our Common Wealth*, New York: Routledge, 2002.

[3] For spectrum property rights theorists, see R.H. Coase, "The Federal Elections Commission" 2 *The Journal of Law and Economics* (October 1959); Thomas W. Hazlett and Matthew L. Spitzer, "Advanced Wireless Technologies and Public Policy" 59 *Southern California Law Review* 3 (2006); Gerald R. Faulhaber and David J. Farber, "Spectrum Management: Property Rights, Markets, and the Commons" AEI-Brookings Joint Center for Regulatory Studies Working Paper 02-12 (December 2002); and William J. Baumol and Dorothy Robyn, "Toward an Evolutionary Regime for Spectrum Governance: Licensing or Unrestricted Policy?" AEI-Brookings Joint Center for Regulatory Studies (2006). For spectrum commons theorists, see Lawrence Lessig, "The Future of Ideas: The Fate of the Commons in a Connected World" (Random House, 2001); Yochai Benkler, "Some Economics of Wireless Communications" 16 *Harvard Journal of Law & Technology* 5 (2002); Kevin Werbach, "Supercommons: Toward a Unified Theory of Wireless Communication" 82 *Texas Law Review* (March 2004).

However, what if the future belonged to low power small area rather than high power large area wireless devices? Then the distinction between the two types of property rights models could become increasingly important. This paper argues that the key debate in a wireless ultrabroadband world should be between bundled and unbundled models of spectrum property rights.

The Unbundled Versus Bundled Property Rights Models

In the old conceptual scheme, we can distinguish four basic spectrum management models.

1) In the **property rights model**, the government grants *exclusive* rights to spectrum to particular entities.
2) In the **commons model**, the government grants *non-exclusive* rights to spectrum; that is, rights of access are shared by multiple entities.
3) In the **licensed model**, the government grants *exclusive* rights to spectrum to particular entities on an unbundled basis; that is, with no consideration of those entities' pre-existing possession of tangible property rights.
4) In the **unlicensed model**, the government grants the general public the right to use authorized spectrum using devices that transmit energy up to a certain power level.

In the new conceptual scheme, the property rights model is divided into two models depending on whether spectrum is viewed as complementary to or independent of tangible property.[4] When two goods are complementary, the most efficient economic arrangement is to bundle them as a package. For example, real property is generally sold as a bundle of assets wholly separate from personal property. This is explained by the fact that the countless assets that constitute real property are, by definition, tightly fixed to a specific location, so they are complementary. In contrast, personal property, by definition, is easily moveable so is independent of real property.

An example of a complementary good is the windows in a house. There could ostensibly develop separate markets for house frames and house windows. But it is generally recognized that the most efficient market structure is to bundle together the frame and the windows of a house. In contrast, the furniture in a house is generally recognized to be an independent good, so houses with furniture are rarely sold as a bundle.

An underlying reason for the existence of complementary assets is the recognition that transaction costs can be reduced by bundling certain assets. For example, separating home window from home wall ownership would result in large and inefficient transaction costs as wall owners and window owners would spend many wasted hours negotiating

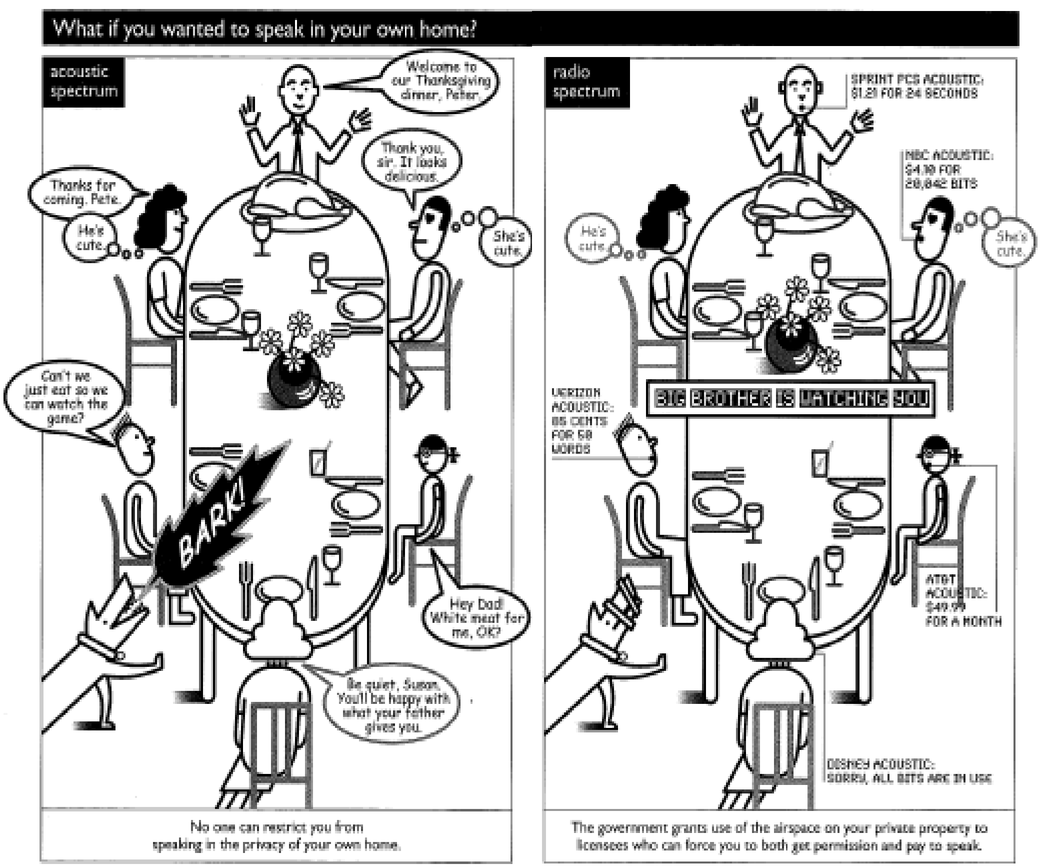
[4] Economists define a complementary good as a good where the cross elasticity of demand is negative; that is, if goods A and B are complements, more of good A being bought would result in more of good B being bought. An independent good is a good where the cross elasticity of demand of zero; that is, more of good A being bought doesn't result in more of good B being bought. Classic complementary goods are pencils and erasers, computers and operating systems, and hot dogs and buns.

with each other. The result is that the demand for houses is greatest when home windows and walls are bundled together.

To the extent that spectrum and tangible property are complementary assets, the most efficient allocation of spectrum rights is to bundle them with *tangible property*. The types of tangible property that are typically *possessed* include homes, offices, vehicles, public-rights-of-way, and space in the immediate vicinity of one's own person. To the extent that spectrum and tangible property are independent assets, the most efficient allocation of spectrum rights is to *third parties*, which the FCC calls licensee. Types of third parties include broadcast, mobile telephone, and satellite operators.

Tangible property--including both real (fixed) and personal (moveable) property--is property that one can touch. Certain types of intangible property, such as the right to communicate via sound waves or walk through open spaces within a house, have generally been treated as complementary to tangible property. The cartoon in Figure 1 suggests that the rights to speak and communicate via spectrum within one's own house are both complementary to possession of real property.

Figure 1. Who Should Have Property Rights to the Air Within Your House?[5]



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[5] From J.H. Snider, "The Cartoon Guide to Federal Spectrum Policy: What if the government regulated spoken words the way it regulates the airwaves?" (Washington, DC: New America Foundation, April 2004), pp. 10-11.

Possession is a property right based on having some degree of control over something else. The legal truism "possession is 90% of the law" captures the legal importance of possession. According to West's Encyclopedia of American Law:

> Possession is a property interest under which an individual to the exclusion of all others is able to exercise power over something. It is a basic property right that entitles the possessor to continue peaceful possession against everyone else except someone with a superior right….To have possession an individual must have a degree of actual control over the object, coupled with an intent to possess the object and exclude others from possessing it.[6]

Rights of possession to tangible property are enforced via trespass laws. Trespass is an intrusion that interferes substantially with the use and enjoyment of one's possessions. Those that trespass face legal sanction.
Note that the right of possession is a property right different from the right of ownership. Both ownership and possession entail the right to exclude others but it is possible to have a right of exclusion without ownership. For example, an individual using a rented car on property he doesn't own still has basic property rights by dint of possession. Similarly, it is illegal for a stranger to forcibly evict me from a park bench on which I sit and thus temporarily possess. But if the stranger first sat on the bench and possessed it, the rights would be reversed.

Unlike ownership rights to real property, rights of possession are hierarchically organized in geographic space. For example, a mall owner may own the land on which I park my car, but he doesn't have the right to take as his property the contents of my car or the clothes on my person.

An important difference between complementary and independent spectrum assets is that with complementary spectrum assets the communications occurs within tangible property lines rather than across them. Consequently, when spectrum is treated as a complementary asset, spectrum rights are more geographically dispersed than when they are treated as an independent asset.

The various spatial distinctions made here loosely correspond to the widely used terms in the telecommunications literature of Wide Area Networks (WANs), Local Area Networks (LANs), and Personal Area Networks (PANs). WANs span property lines; LANs are within real property lines; and PANs are in the immediate vicinity of persons. Spectrum rights for both LANs and PANs are complementary to tangible assets. With a WAN, they are independent of such assets.

Let us now label the two spectrum property rights models--underpinned by different notions of natural linkages between spectrum rights and tangible property--the bundled model and the unbundled model.

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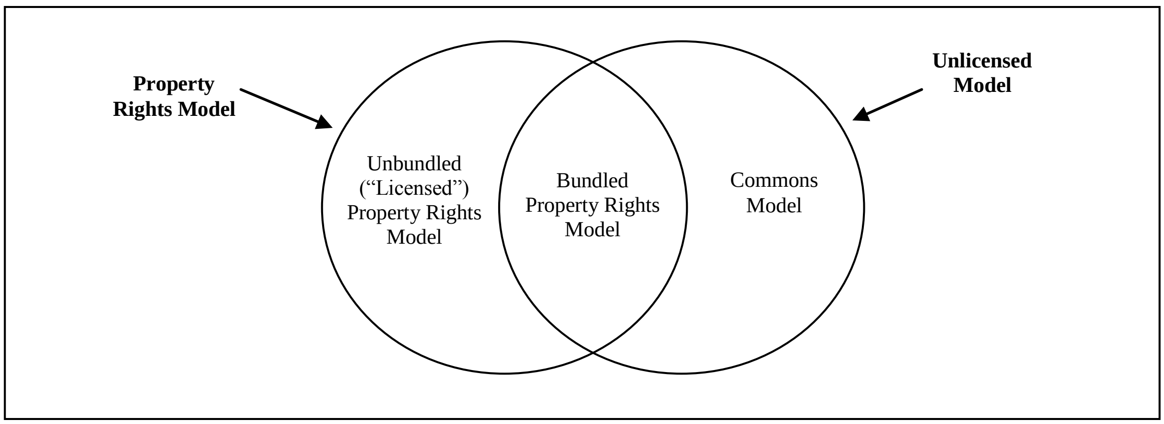
[6] "personal property." *West's Encyclopedia of American Law*. The Gale Group, Inc, 1998. *Answers.com* 17 Sep. 2006. http://www.answers.com/topic/personal-property.

In the **bundled spectrum property rights model ("bundled model")**, the government bundles the possession of tangible property with the exclusive right to use spectrum. Examples include the right to communicate within homes, offices, and vehicles; over local public rights-of-way; and in the immediate vicinity of one's own person.

In the **unbundled spectrum property rights model ("unbundled model")**, the government grants the exclusive right to use spectrum to third parties spanning many tangible property boundaries. Examples include the right to provide broadcast TV, mobile telephone, or satellite radio service across millions of homes and other tangible property subdivisions.

Now that we have defined the various spectrum management models, let's see how they overlap in a Venn diagram.

Figure 2. The Relationship of the Various Spectrum Management Models



The major debate going forward should center on the social welfare gains from each type of model. Now let us define the size of the diagram circles as representing the social welfare gains from each model. Three very distinct possibilities for the distribution of social welfare gains are suggested by the figures below.

Figure 3. The Two Model World of Conventional Commons Advocates

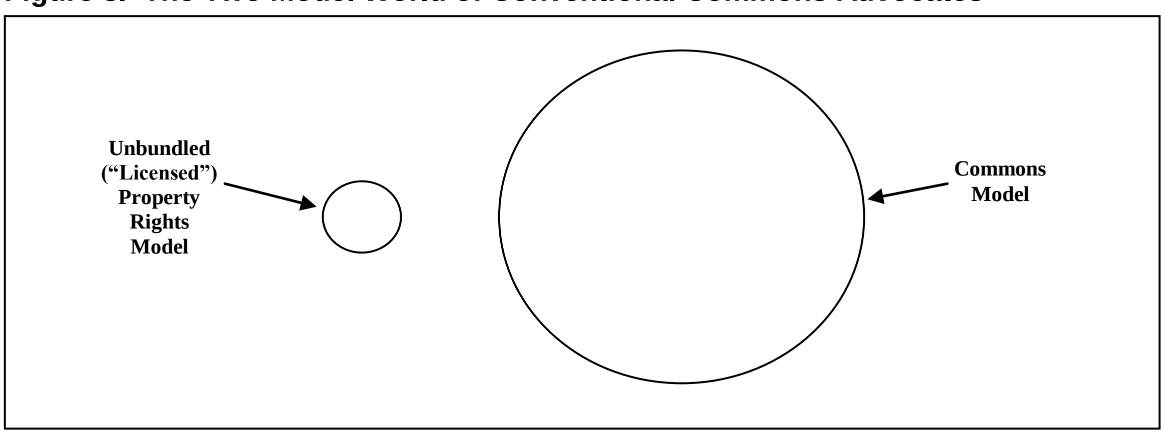


Figure 4. The Two-Model World of Conventional Property Rights Advocates

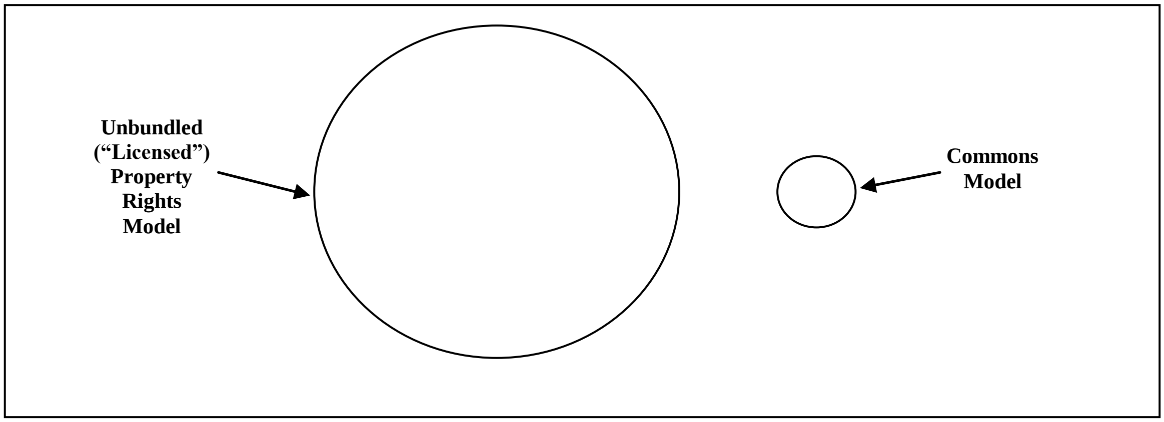
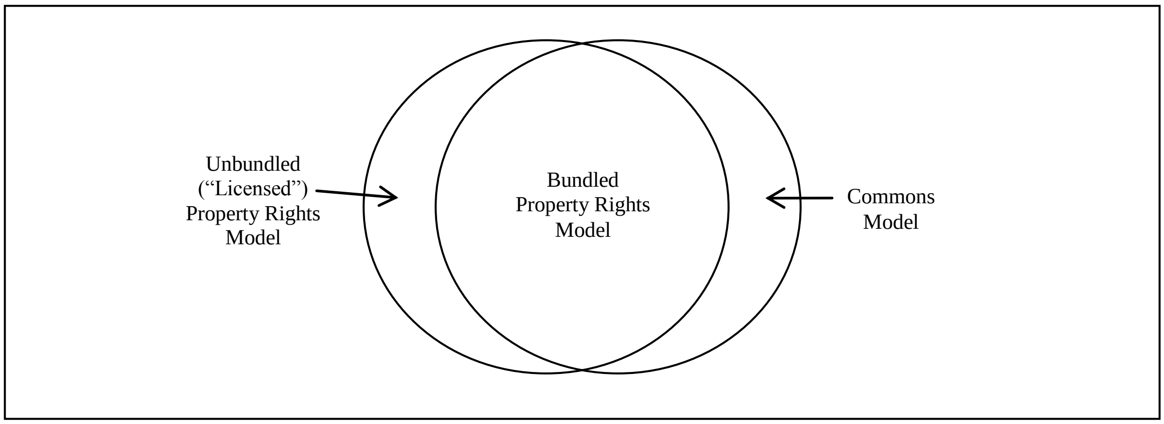


Figure 5. A Three-Model World for the Wireless Ultrabroadband Era



This paper argues that in a wireless ultrabroadband world, Figure 5 may best capture the relative social welfare benefits of the different spectrum management regimes.

Does the relative size of the various social welfare circles make any difference to a public policy agenda driven only by the desire to maximize economic efficiency? The answer is yes only if the initial allocation of rights to spectrum affects the long-term efficiency of using the spectrum. Both property rights and commons theorists agree that the initial distribution of rights between their two models has long-term efficiency implications. But some in the property rights camp, applying a famous economic theory developed by R.H. Coase, have asserted that the initial distribution of rights in a property rights model has no long-term effect on their efficient allocation.[7] There may be an acknowledgment that this conclusion depends on minimal transaction costs and no specialized assets. But it is not a point that tends to be dwelled on for long, especially by the large contingent of property rights theorists who advocate giving incumbent licensees additional spectrum

[7] E.g., see “Report from the Working Group on New Spectrum Policy” (Washington, DC: Progress and Freedom Foundation, March 2006).

"flexibility" because they will quickly put the spectrum to its most efficient use or sell it to someone else who will.[8]

Let us now frame the question more precisely. Does it have long-term efficiency implications if 1) complementary assets are initially allocated as independent assets, or 2) independent assets are initially allocated as complementary assets? Would it make any difference, for example, if a hypothetical Federal Acoustic Commission, patterned after the Federal Communications Commission, granted all rights to acoustic communication to third parties, maybe the same companies that currently have broadcast and mobile telephone licenses, who could then charge real property owners for the right to speak within their own homes? How about a Federal Plumbing Commission that licensed all rights to indoor plumbing to third parties such as various electricians' guilds?

Most people would immediately grasp that this initial distribution of property rights would not only be very inefficient but also very costly to fix. The acoustic and plumbing licensees could extract monopoly rents, and negotiating a transfer of rights from the licensees to the homeowners would probably be very costly in both time and money. Conversely, imagine a world where homeowners owned air rights up to the heavens. It would be very costly for airlines to negotiate for airspace rights with each of these homeowners. Some airspace holders, such as a county or state with a long public road in the flight path of the airplane, could also exert holdup power and thus extract monopoly rents.

The same type of reasoning applies to spectrum management. To illustrate the argument, let us imagine a world where the long-term efficient distribution of spectrum rights favors present spectrum licensees and their uses; that is, the unbundled property rights model. In such a world, if tens of millions of real property owners were granted all initial spectrum rights, it would surely be very costly for the handful of today's broadcasters and mobile telephone operators to reacquire those rights. The negotiation costs alone would be astronomical; billions of hours could be wasted unnecessarily negotiating for rights. Meanwhile, the spectrum would lie fallow, possibly for decades, if the negotiations proved sufficiently costly. Moreover, just a single real property owner in a broadcast or mobile telephone service area could veto the service, thus extracting a monopoly rent for their spectrum property.

Similarly, if the most efficient long-term distribution of spectrum rights favors low power uses where spectrum rights are complements to tangible property, the economics would be reversed. Now those tens of millions of homeowners would have to acquire the right to use spectrum within their own homes from the broadcasters and mobile telephone operators. But the negotiation costs could still be huge and amount to a comparable social welfare loss. Just imagine each of 120 million American households trying to put together a large block of frequencies on their own property by negotiating with each of the hundreds of licensees with rights to tiny slivers of that block. Moreover, to the extent

[8] E.g., Comments of 37 Concerned Economists in the Matter of *Promoting Efficient Use of Spectrum Through Elimination of Barriers to the Development of Secondary Markets*, WT Docket No. 00-230, February 7, 2001.

that there were 1) few licensees with the most desirable frequencies in a particular area, and 2) many homeowners in the same area, the licensees would have great bargaining power and be able to extract monopoly rents.

Thus, if the initial distribution of property rights between the bundled and unbundled property rights models has a significant long-term impact on economic efficiency, it is important to assess what is the most efficient long-term distribution of spectrum property rights. The FCC has actually done a better job at making such allocation decisions than its recent rhetoric in favor of "property rights" (by which it only means unbundled property rights) would suggest.

FCC Precedents for a Bundled Spectrum Property Rights Model

Distinguishing between bundled and unbundled spectrum property rights may seem like a fundamental break with the past in the context of the FCC's recent tendency to equate property rights with licensed spectrum and commons with unlicensed spectrum.[9] However, the distinction between bundled and unbundled rights is consistent with the FCC's traditional conceptualization of its Part 15 rules, which govern unlicensed devices. That traditional conceptualization was driven by engineers responding to immediate practical concerns rather than economists trying to apply theoretical models to the management of a natural resource they barely understood.[10]

The FCC first developed rules for unlicensed devices in 1938 in response to the evident failure of the Communications Act of 1934 to deal with the practical realities of low power electromagnetic emissions. The unlicensed initiative was not based on any grand economic theory but a practical response to manufacturers' and users' concerns. At the public hearing that served as the public record for creating the new unlicensed service rules, the word "practical" appears dozens of times; the phrase "economic theory" or its synonyms does not appear once. Implicitly and sometimes explicitly, the word "practical" is juxtaposed against "licensed."[11]

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[9] *See generally* Spectrum Policy Task Force Report at 5, __ FCC Rcd __ (November 2002).

[10] The first person to have publicly presented some systematic codification of the hidden property rights assumptions behind the Part 15 rules appears to have been Michael Chartier, an Intel engineer. In the fall of 2001 he noted the discrepancy between the claims of the newly influential commons theorists and the actual application of the FCC's Part 15 rules. Chartier, however, was unable to garner much interest in this critique. One reason may be that he appeared to concede that unlicensed low power devices could not cover wide areas and thus could not provide a substitute for licensed high power devices. Only later did meshes of low power devices covering wide areas emerge. Thus, Chartier remained in the FCC tradition of conceptualizing unlicensed devices as bit players, little more than toys, in the grand scheme of spectrum policy. See Mike Chartier, "Enclosing the Commons: A Real Estate Approach to Spectrum Rights," unpublished manuscript presented at the AEI-Brookings Joint Center Conference "Practical Steps to Spectrum Markets," November 9, 2001. Chartier later developed aspects of this idea more fully in "Local Spectrum Sovereignty: An Inflection Point in Allocation," in the *Proceedings of the International Symposium on Advanced Radio Systems, March 2-4, 2004,* Boulder, Colorado: ISART, 2004, pp. 29-36.

[11] Informal Hearing Before the Chief Engineer In the Matter of Proposed Rules and Regulations Governing the Operation of Low Power Radio Frequency Devices, FCC Docket No. 5335, September 19, 1938. In December 2001, J.H. Snider drafted a paper making the property rights argument contained in this paper, but its policy recommendations were inconsistent with his employer's spectrum policy agenda, so was abandoned. The gist of that argument can be found in J.H. Snider, "FCC Lets the Telecom Giants Steal

In the Communications Act of 1934, Congress decided that communication via spectrum was interstate in nature and should come under the jurisdiction of the federal government, with the FCC licensing the rights to spectrum to independent entities such as radio broadcasters and the military, each of which transmitted over an area often spanning thousands of square miles.[12] But it turned out that a lot of devices, such as millions of electric light switches, emitted electromagnetic energy at very low power levels. Although the most publicized and socially important spectrum using services operated at high power, manufacturers had also started building many communication devices, notably certain medical devices and remote controls, which emitted energy at very low power and over correspondingly short distances. As a result, the FCC decided it had to develop rules to manage such devices; thus, the unlicensed rules were born. The FCC's Chief Engineer, Ewell Jett, concisely explained his reasoning in the aforementioned hearing leading up to passage of the first unlicensed rules in 1938:

> What we are concerned with immediately is the problem of interference. If certain low power devices can be used without interfering with radio communications, there would appear to be no engineering reason for suppressing their use.[13]

In formulating the unlicensed rules, the FCC was aware that unlicensed devices were most likely to be used within property lines and that protection of licensed transmissions was most important outside of property lines rather than within them. In the same 1938 hearing, this issue was addressed in an interchange between Chief Engineer Jett and John Potter representing the Radiograph Corporation.

> Mr. Potter: Under this proposed formula the same condition is assumed whether it be urban or rural; that is, you set up the same value—that is, the same field strength for this device whether it be used in the city or on farms. Now, that doesn't seem to follow through because naturally in rural areas there is less interference.
>
> Mr. Jett: Go ahead.
>
> Mr. Potter: That is my point. I wonder if you were going to put any factor in that would take care of density of population.
>
> Mr. Jett: Now, I'm a little amused here about your bringing that question up, because Mr. Ring and I gave a lot of thought to it. We thought of the case where it may be desirable to operate low power devices on the farm where the owner of

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from You: Via Eminent Domain, Fat Cat Donors Get Airwaves -- Worth Billions -- In Our Homes," *Sacramento Bee,* April 7, 2002.

[12] See Kenneth R. Carter, et al., "Unlicensed and Unshackled: A Joint OSP-OET White Paper on Unlicensed Devices and Their Regulatory Issues" (OSP Working Paper No. 39, 2003).

[13] Informal Hearing Before the Chief Engineer In the Matter of Proposed Rules and Regulations Governing the Operation of Low Power Radio Frequency Devices, FCC Docket No. 5335, September 19, 1938, p. 5.

> the farm had control over the area, the entire area, and if we could set up a proper standard with respect to the boundary, we thought that that might be worthy of consideration. And then we thought more of that particular problem—some of the large ranches out in the West, one out on the Pacific Coast 60 miles long, I believe, and a lot of large manufacturing plants where such a rule would apply, and obviously we could not set up a standard which from a possible legal interpretation would hold that such communication was not radio, and still permit communication out to the boundary of one's premises. Then there is always the possibility of an airplane flying over, and so we finally decided on lambda over 2 pi [the power level for unlicensed devices] in accordance with the proposed rules without regard to ownership of premises.[14]

Note that Mr. Jett, in considering that a farmer might seek to use spectrum over his 60 mile ranch, never appears to have considered the possibility that this coverage could have been achieved with a mesh of low power wireless devices rather than a single high power device. The former wireless architecture could have covered the ranch without reaching up to the sky and interfering with airplane communications. Similarly, Mr. Jett appears not to have contemplated a world of smart radios that could adjust to the conditions of their immediate environment—for example, distinguishing between a small apartment and giant ranch, and then setting appropriate power levels for that environment.

Perhaps Mr. Gett, who was clearly a very bright and imaginative man, momentarily considered regulating unlicensed devices by the level of emissions at property lines (the way international spectrum rights and many FCC licenses are specified). If so, he would have immediately recognized that with the technology available in 1938 this type of property rights regime was impractical. The solution he came up with, regulating unlicensed devices based on their transmitted power, was simple, elegant, and clearly the most practical solution given the technology available in 1938.

In a major 1979 rulemaking on unlicensed rules, the FCC articulated the bundled property rights theory more clearly.

> We are most interested in protecting an individual who is receiving interference from his neighbor's computer. To a lesser extent, we are concerned about devices in the same household. In a household, the homeowner or apartment dweller can choose which device he wants to operate. For example, if a second TV set in the same house is receiving interference from a computing device in an adjacent room, there are a number of steps he can take to remedy or minimize the problem, or as a last option, he can always choose which is most important to operate--the TV set or the computing device. One of the first and easiest corrective steps he can take is to move the two pieces of equipment further apart. Another step is to reorient the receiving antenna….
>
> [W]e are adopting minimal regulations which we consider necessary to control potential interference from computing equipment. The regulations are not

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[14] Ibid, pp. 101-2.

> intended to control interference of computing devices with other equipment owned by the same person. In this situation the competing uses of the spectrum are under the control of the same person, and private resolution of the conflict is possible.[15]

One way the FCC implemented these bundled property rights principles was by granting higher power to unlicensed devices used exclusively in industrial applications rather than residential applications. A major consideration was that industrial users occupied plants that were much larger than a typical residence and so could be entrusted with higher power levels.

> [C]omputers are separated into two categories--Class A computing devices governing commercial computing equipment and Class B computing devices governing the computing equipment widely distributed to the general public…. [E]quipment used in manufacturing plants is not likely to cause interference because it is located within the plant and is commonly isolated by the size of the plant facility. Also factory buildings provide some shielding. Thus the Commission can expect few complaints of interference from restricted radiation devices therein.[16]

In implementing these rules, the Commission recognized that its ability to grant flexibility to unlicensed devices within property lines was limited by the primitive technology and institutional arrangements of the day, implicitly suggesting that one day such restrictions might not be needed.

> We have defined Class A and Class B equipment in a way which recognizes broad differences in the circumstances in which computers are used. This allows us to provide protection from interference while limiting both the costs of producing computing equipment which does not interfere and the costs of administering and enforcing the regulations.[17]

In developing rules for unlicensed use of the 900 MHz band in the mid-1990s, the FCC favored unlicensed devices for indoor applications--such as cordless phones and baby monitors--while favoring licensed devices for outdoor uses, notably monitoring cars, trucks, and other vehicles.

Despite the grand rhetoric of property rights versus commons coming out of the FCC beginning in the early 2000s, most notably in the FCC's November 2002 *Spectrum Policy Task Force Report*, it is noteworthy that through the 2000s the FCC's actual rulemakings concerning unlicensed kept fairly close to its traditional unlicensed property rights model

[15] First Report and Order In the Matter of Amendment of Part 15 to redefine and clarify the rules governing restricted radiation devices and low power communication devices, FCC Docket No. 20780. (Adopted: September 18, 1979; Released: October 11, 1979), paras 54, 67.
[16] Ibid., paras 28,29
[17] Ibid., para 69.
[18] The author interviewed long-time FCC Part 15 engineers Art Wall on August 22, 2006 and John Reed on August 24, 2006 to confirm this hypothesis.

set of parameters; namely, it kept power levels very low. For example, it authorized a new ultrawideband (UWB) unlicensed service that could spread its signal across a huge swath of more than 7 GHz of mostly licensed spectrum but at very low power levels so the signal wouldn't create harmful interference to licensed devices more than 30 feet away. The signals were also restricted to indoor use. A popular expected use of UWB, which could offer speeds as fast as 500 mbps, was to replace the spaghetti like configuration of wires used in a typical home to connect computer and consumer electronics equipment. The risk of a UWB device creating harmful interference to a licensed service outside of the UWB device owner's tangible property was minimal.

Economists' Failure to Recognize the Bundled Property Rights Model

In 1959 Ronald Coase proposed the then radical idea that electromagnetic spectrum should be treated like any other scarce natural resource and allocated via markets, with the role of government limited to defining and enforcing private property rights to spectrum.[19]

In that now famous article, Coase never considered the possibility that the primary use of spectrum in coming generations might be for very low power devices where communication was primarily within tangible property lines. Nor did Coase consider the possibility that spectrum property rights attached to tangible property rights might have much lower transaction costs and thus be more efficient than such property rights sold to independent entities, where the possession of spectrum property rights was wholly separated from the possession of tangible property. When Coase illustrated his theory with examples, he invariably granted all the spectrum property rights to independent entities. In equating property rights with licensed property rights, Coase set the terms of the property rights debate that has continued until today among so-called property rights and commons theorists.

A notable recent example of this conceptual failure is the "Report from the Working Group on New Spectrum Policy," issued in March 2006 by the Progress and Freedom Foundation, a major Washington, DC telecommunications policy think tank. The working group members who signed their names to the document consisted of many of the most prominent spectrum property rights theorists, including, alphabetically, Stuart Benjamin, Gerald Faulhaber, Dale N, Hatfield, Thomas W. Hazlett, Michael L. Katz, Thomas M. Lenard, Gregory L. Rosston, Howard A. Shelanski, and Lawrence J. White. Four of the signers were former chief economists at the FCC. Many hold distinguished economics chairs at prestigious universities.

Nowhere in this Report is there a distinction drawn between the commons and unlicensed models. Both are treated as identical. Nor is there an acknowledgment that the unlicensed model encompasses both the property rights and commons models, depending on whether the unlicensed user can use the trespass laws to control sharing. From the standpoint of property rights theory, it does not matter whether the right to exclude is enforced directly via restrictions on the use of radios or indirectly via the trespass laws.

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[19] R.H. Coase, "The Federal Elections Commission," *The Journal of Law and Economics*, Volume 2, October 1959, p. 32.

All that is necessary for the property rights model to work is that the possessor of an asset has a mechanism that can exclude others from sharing it. This conceptual confusion is ironic because the report is sprinkled with references to real estate and trespass as analogies to explain how a spectrum property rights regime would work.

Most important, there is no discussion whatsoever of 1) the extent to which the unlicensed (bundled) property rights versus the licensed (unbundled) property rights model is the most efficient model for spectrum management, or 2) the extent to which it makes a difference whether the initial allocation of property rights is granted to one or the other of these two models. The Report acknowledges the Coasian insight that the existence of transaction costs would make the initial allocation of property rights important. But, like Coase, it does not seriously investigate the implications of this idea in the context of different property rights models.

As is typical of this property rights literature, there is an acknowledgment that the commons model appears to work fairly well in low power situations.

> Spectrum usage charges should reflect marginal congestion costs. In some cases, once a block of spectrum has been allocated to a set of uses, the marginal cost may be zero. This situation is most likely to arise with very low power uses. For example, the incremental congestion costs of a given garage door opener is very likely zero given that a low-power band has been created. One benefit of the commons model is that it can support such efficient pricing.[20]

But then the Report asserts: "we believe that the number of instances in which this is appropriate is likely to be quite small relative to overall spectrum uses."[21] From there it concludes that thanks to these low power applications, "the commons model has a limited, but not necessarily non-existent, role in spectrum policy reform."[22]

A basic fallacy of the Report authors--and unbundled property rights theorists more generally--is the assumption that unlicensed devices cannot provide wide area coverage without a tragedy of the commons. But this is untrue. Low power devices, which individually cover only a small-area, can nevertheless be networked together to cover a wider area. Only when a single unlicensed device transmits signals over a wide area and across multiple property lines does the tragedy of the commons argument apply.

Consider municipal WiFi, the fastest growing and most high-profile type of low-powered wide area network.[23] These unlicensed networks can traverse great distances via public roads and other public rights of way. For example, Philadelphia's plan to build a franchised municipal WiFi system will network some 8,000 access points to cover the

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[20] "Report from the Working Group on New Spectrum Policy" (Washington, DC: Progress and Freedom Foundation, March 2006), pp. 6-7.
[21] Ibid. p. 7
[22] Ibid., p. 7.
[23] E.g., *see* Jesse Drucker et al., "Google's Wireless Plan Underscores Threat to Telecom," *Wall Street Journal*, 3 October 2005, p. A1.

entire 135-square-mile footprint of the city.[24] And the Canamex highway WiFi network in Arizona may cover more than 500 miles before it is complete.[25]

Tens of thousands of other large spaces, including college campuses, hospitals, malls, warehouses, stadiums, K-12 schools, amusement parks and office buildings (see Figure 6), have been building networks of small-area wireless devices that collectively cover large areas.

Figure 6. Sampling of Wide-Area Unlicensed Networks

Municipalities (for public broadband access)
Philadelphia, Pennsylvania
Corpus Christi, Texas
Chaska, Minnesota

Municipal (for public safety only)
Lower Valley Public Safety Network, Yakima County, WA
City of Aurora Police & Fire Departments, Aurora, Colorado
City of San Mateo Police Department, San Mateo, California

Manufacturing, Distribution, and Inventory Management
Biggs' Hypermarket, Mason and Harrison, Ohio
Nine Mile Point Nuclear Station
Nike, Memphis, Tennessee

Universities
Dartmouth College, Hanover, NH
Carnegie Mellon University, Pittsburgh, PA
United States Military Academy, West Point, NY

Hotels (all with Free WiFi)
Best Western
Courtyard (Marriott International Inc.)
Doubletree Hotels (Hilton Hotels)

Offices
Microsoft Campus
Intel Campus
Sears Office Tower

Hospitals
Baycrest Centre for Geriatric Care, Toronto, Canada
Children's Memorial Hospital, Chicago, Illinois
John C. Lincoln Hospital, Phoenix, Arizona

Airlines (only international travel)
Lufthansa
Japan Airlines
Korean Air

Airports
Atlanta International Airport, Atlanta, Georgia
Baltimore-Washington International Airport
Boston, Logan International Airport, Boston, Massachusetts

Convention and Sports Centers
American Airlines Center, Dallas, Texas
Connecticut Convention Center, Hartford, Connecticut
William A. Egan Civic and Convention Center, Anchorage, Alaska

K12 Schools
Lincoln Unified School District, Stockton, California
Arlington Independent School District, Arlington, Texas
Fairfax County Public Schools, Fairfax, Virginia (available in more than 200 schools)

Retail
ALLTEL Stadium, Jacksonville, Florida (host of 2005 SuperBowl)
Barnes & Noble Bookstores, hundreds of locations
Starbucks, thousands of locations

Other
Marinas (Beacon WiFi supplies WiFi service to more than 100 boat marinas)
RV Parks, (Boingo supplies WiFi service to hundreds of RV parks)
Flying J truck stops (hundreds of locations)

Coase's conceptual omissions can be more easily explained than those of the property rights and commons theorists who followed in his wake. In the telecommunications world in which Coase lived, spectrum was primarily used for high powered communications, such as radio and TV broadcasting, which covered vast areas. Indeed, as we have seen, the federal government was originally given jurisdiction over spectrum largely on the assumption that the emissions of individual radio devices were inherently interstate in nature. But in the emerging wireless ultrabroadband world, Coase's assumptions about efficient telecommunications architecture are becoming increasingly untenable. The time has come for Coase's acolytes to wrestle head on with the spectrum management implications of this emerging world.

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[24] *See* "Wireless Philadelphia™ Business Plan," Wireless Philadelphia Executive Committee, February 2005, p.12.
[25] Eliot Cole, "Wi-Fi the Highway," Mobile Government, June 2005, pp. 22-25.

2) Wireless Links in the Ultrabroadband Network

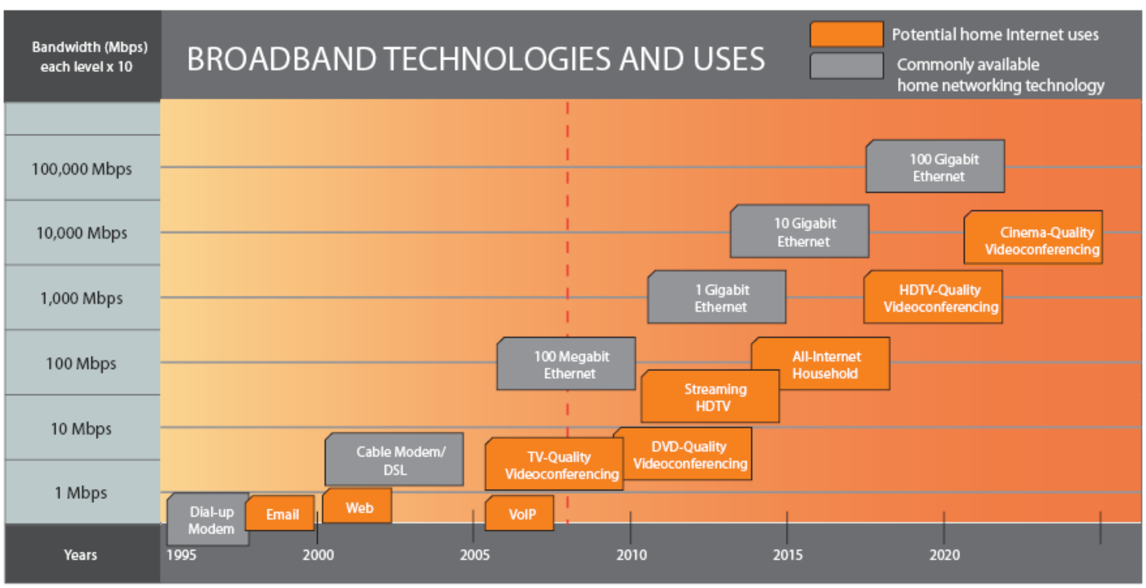
The terrestrial telecommunications network is evolving toward an ultrabroadband architecture consisting of a wired backbone with very short wireless links to the end user. An *ultrabroadband network* is defined as a network with broadband transmission speeds many orders of magnitude faster than today's typical speeds of under 10 mbps. An ultrabroadband network where users communicate over at least one wireless link at ultrabroadband speeds is a *wireless ultrabroadband network.* What follows are five predictions culminating in the observation that in an ultrabroadband world wireless end user links are likely to shrink to a small fraction of their current size.

1. Demand for bandwidth over the network will increase.
2. Demand for pervasive access to the network will increase.
3. Wires will dominate the network's backhaul link.
4. Wireless will dominate the network's end user link.
5. The wireless end user link will shrink.

1. Demand for bandwidth over the network will increase

The assumption that the world is evolving to ultrabroadband transmission speeds appears to be a reasonable extrapolation from historical trends (see Figure 7). The typical speed of consumer data connections over the telecommunications network has gradually increased from 300 bits/second in the late 1970s to over 3,000,000 bits/second (3 Mbps) today. In Japan and South Korea, millions of consumer data connection speeds now run as high as 100 Mbps. Major players in the U.S. cable and telephone industries in the U.S. are expected to provide similar service within the next five years.

Figure 7. Historical and Projected Growth of Bandwidth[26]



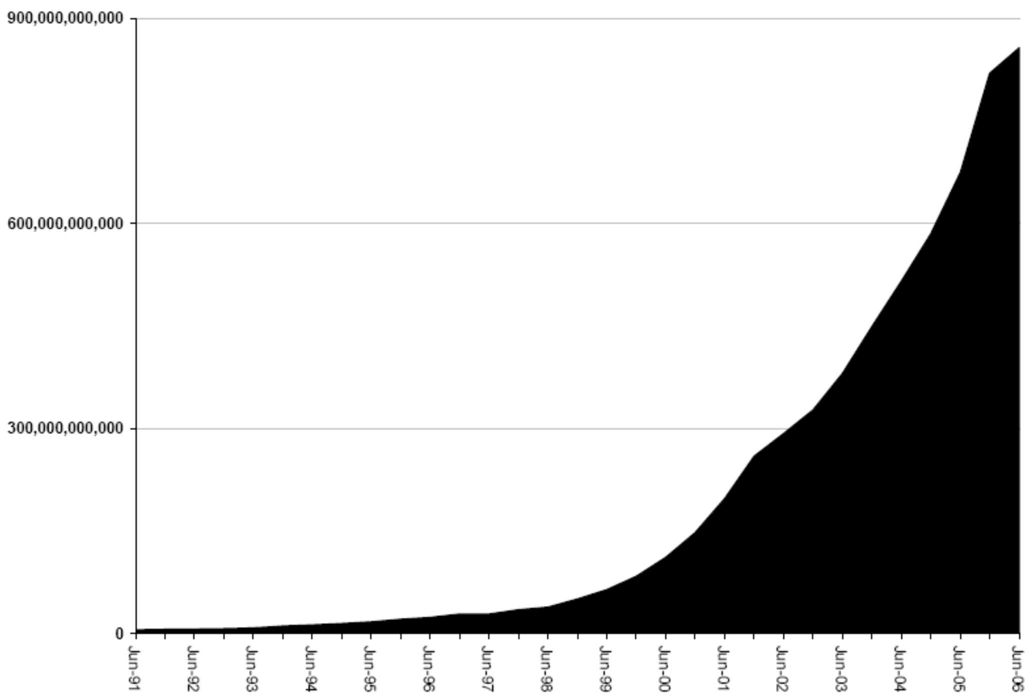
[26] Provided to this author on December 19, 2006 courtesy of Internet2 (www.internet2.edu).

Some people today find it hard to imagine that there will be high demand for massive improvements in broadband speed--for example, to 1 Gbps, 10 Gbps, or even 100 Gbps. But given the recent track record of increasing demand for telecommunications speeds, it is hard to imagine that telecommunications history will soon come to an end. If history has taught us anything, it is that technological improvement in this area is very likely to continue and that new and valuable uses will be found for higher speeds. Thus, it is reasonable to believe that in the coming generations there will be a massive increase in demand for dramatically higher bandwidth.

2. Demand for pervasive access to the network will increase

The assumption that wireless will be a vital link in the ultrabroadband network also appears to be a reasonable extrapolation from historical trends. The demand for mobile communications has skyrocketed over the last two decades and there is every expectation that the demand for mobile communications will continue to increase in the future. For example, the number of minutes annually used by mobile telephone subscribers has increased from little more than zero minutes in 1991 to more than 850 billion in 2006 (see Figure 8).

Figure 8. Growth in Reported Minutes of Mobile Telephone Use[27]



Other terms that convey similar meaning to mobile are "pervasive" and "user centric." The term "pervasive" suggests that access to the ultrabroadband network is available everywhere at all times. The term "user centric" suggests that the network accommodates itself to the location of the user rather than vice versa.

[27] Source: CTIA's Semi-Annual Wireless Industry Survey, June 2006.

It is striking that users are willing to pay a premium for being untethered from the network. For example, mobile telephone service may be more expensive and of lower quality than landline telephone service but users are willing to pay a premium for it. Similarly, cordless phones may be more expensive than corded ones, but consumers now buy more cordless than corded phones.

3. Wires will dominate the network's backhaul link

Given the comparative advantages of wires and wireless, it is likely that in an ultrabroadband network wires will dominate the backhaul and wireless the end user link.

For a point-to-point link, the capacity of a single fiber optic cable is greater than the entire capacity of the radio spectrum. This is a major factor in explaining why fiber optic cable has come to dominate the telecommunications backbone and is moving closer and closer to the customer's premises. The vast majority of intercontinental, continental, and local backhaul communications is now done via wire. In every highly developed country on the earth, plans are under way to bring fiber to the premises or at least to the neighborhood. Millions of Americans already have fiber optics to their premises, and a majority already has fiber optic cable to their neighborhood. These numbers are expected to increase dramatically over the coming generation. In the U.S., Verizon claimed it would pass five million homes by fiber by the end of 2006 and 18 million by the end of 2010.[28]

Wireless does retain some cost advantages for backhaul communications. It can cost upwards of $1 million to lay fiber optic in some urban areas over a ten mile stretch versus $100 to make the same link via a directional WiFi transmitter. But the growing use of fiber optic cable for backhaul communications suggests that any cost advantage wireless might have in the backbone is dwarfed, except in fairly unusual cases, by fiber optic cable's quality advantage.

On a cost per megabyte basis, the difference between long-haul wired and wireless networks is striking. Verizon offers a $33/month fiber broadband package with 5 mbps on an essentially unlimited basis. Verizon also offers a $60/month wireless broadband plan with speeds from 400 kbps to 700 kbps. The wireless broadband plan also limits the total number of bits that can be transferred in any given month to 5 gigabytes and prohibits use of the broadband network to stream media of any kind. A Verizon wired broadband subscriber who downloaded 50 gigabytes per month would thus be paying one-twentieth the cost per megabyte as a Verizon wireless broadband subscriber. Plus, the wired broadband subscriber would receive faster and more varied services, including streaming media.[29]

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[28] "Verizon to Pump $18B Into FiOS by 2010," Light Reading, September 27, 2006.

[29] As of June 19, 2007, Verizon Wireless included the following terms of service for its $60/month broadband plan: "We reserve the right to protect our network from harm, which may impact legitimate data flows. We reserve the right to limit throughput speeds or amount of data transferred, and to deny or terminate service, without notice, to anyone we believe is using one of these Data Plans or Features in any manner prohibited above or whose usage adversely impacts our network or service levels. Anyone using more than 5 GB per line in a given month is presumed to be using the service in a manner prohibited above, and we reserve the right to immediately terminate the service of any such person without notice." See www.verizonwireless.com.

Peter Rysavy, a columnist for *Mobility Loop*, nicely summarizes the advantages of fiber optic cable over wireless.

> With so much emphasis on wireless networking today, you'd think that wireless was about to displace all wire. That simply won't be the case, not because of laws of economics but due to laws of physics. When you look at speeds and capacity, you have to consider the capacity of fiber versus the capacity of radio. Fiber has a theoretical capacity in the range of 10 to 100 Tbps. That "Tbps" is terabits per second, or 1,000 Gbps. Even if you had the entire lower 10 GHz of radio spectrum available to you, and assumed a whopping 10 bps/Hz through the most advanced radio techniques available (likely breaking Shannon's law in any real world deployment with interference), you'd still only end up with 100 Gbps. So, what we have is the entire useful radio spectrum carrying one percent of the theoretical data capacity fiber. Okay, maybe you can only do 10 Gbps over today's fiber system, but remember, that's just one strand. Want more capacity; add more strands. Now, take into account the tiny sliver of spectrum available to any operator, and the ratio of wireless to wireline capacity becomes even smaller.[30]

Of course, one can imagine a world where laying fiber optic cable, or any other wire for that matter, is so expensive that the wireless cost advantage trumps all other concerns when designing the backhaul of the telecommunications network. But that does not appear to be the world in which we live. Wireless appears to retain a very important backhaul niche in rural and poor areas, but those niches appear to be getting smaller every day. As soon as an area achieves a certain wealth and population density, it switches over to fiber.

None of this implies that there isn't a very important long-term role for wireless in the network of the future; its role is just not in the backhaul portion of the network.

4. Wireless will dominate the network's end user link

As the network gets closer to the end user, the comparative advantage of wired over wireless links diminishes. That is partly because wired economies of scale diminish as the network approaches the premises. The biggest cost in laying fiber optic cable is not the cost of the cable but the cost of laying it. Compare these costs on a major city street versus on the lawn of a house. The trench on a major city street may contain fiber optic cable serving 100,000 households; the trench on the lawn only 1 household. In this situation, the cost/household of laying a foot of fiber optic cable could be thousands of times as much under the lawn as under the city street. Thus, wired links have decreasing economies of scale as they get closer to the end user.

However, in the long-term, the dominant force preserving the role of wireless service in the end user link is that wired service is not a close substitute. Telecom network users greatly value the flexibility that comes from a wireless connection to the network. For

[30] Peter Rysavvy, "Wireless vs. Wireline – It's No Contest," *Mobility Loop*, March 22, 2006.

example, a telephone conversation in a car cannot reasonably be made if the phone must be connected via a wire to the telecommunications network. At the same time, the value of being untethered does not change with the length of the wireless link. The value to the end user is the same whether the wireless link is fed from a light post 100 feet away or a cell tower two miles away.

5. The Wireless End User Link Will Shrink in Length.

Given that wires have a comparative advantage for backhaul and wireless a comparative advantage for end user links, how long are the wireless end user links likely to be? In recent decades, end user links have tended to become shorter and shorter. For example, Marconi's most famous telecommunications trial was a wireless message sent across the Atlantic from England to the United States. Today that message would most likely be sent via a fiber optic cable strung under the Atlantic. Fifty years ago, mobile communications such as taxi dispatch communications tended to be citywide and cover hundreds of square miles. Today, most mobile communications is conducted over cell towers covering less than ten square miles each.

What explains the long-term trend to decreasing cell size and shorter wireless links? Consider the following three factors: capacity, battery life, and security.

Greater Capacity. Carriers can purchase rights to use additional spectrum. But since the supply of spectrum is not infinite, this ultimately means robbing Peter to pay Paul. The long-term strategy, then, must be to expand the information carrying capacity of spectrum. Carriers can do this by employing a variety of technologies—such as more efficient data compression and more advanced modulation—that don't involve geographic reuse of spectrum. But such strategies are highly limited, akin to trying to get a car designed to travel 100 miles/hour to travel 500 miles/hour by adding air to the tires and changing to a more aerodynamic hood.

In the U.S., the capacity of wireless networks using licensed spectrum has not kept up with the capacity of wired networks. Next generation wired networks offered by both cable and telephone companies may soon reach 1 Gbps to the household. Virtually all PCs in the United States are shipped with a minimum of 100 Mbps Ethernet connections and many are now shipped with gigabit connections. Common network interfaces such as USB and Firewire already offer speeds in the 500 Mbps to 1 Gbps range.

The International Telecommunications Union has already set a target of 1Gbps for next generation, so-called "4G" wireless networks. No mechanism for achieving such high data rates has been specified and it may be that 1 Gbps is a blue sky number that cannot be achieved in a next generation network. What cannot be disputed is that this would be a giant leap from today's 3G wireless networks, which typically offer well under 1 Mbps, less than a thousandth as much as the new target capacity.

Mobile telephone companies want to do everything possible to expand their capacity without building more cell towers, which are very expensive. But, as the foregoing analysis suggests, current cell sizes are too large to achieve ultrabroadband data rates. Two research engineers from AT&T's prestigious AT&T Labs have calculated that

AT&T may have to subdivide existing cell sites by more than a factor of 100, with cell sizes averaging only 1,000 feet in radius, to efficiently achieve 4G level bit rates.[31]

If wireless end user links are not to become a network bottleneck, they will have to increase their information carrying capacity. The most efficient long-term strategy to do so is to geographically subdivide it so that it can be reused in different geographic areas. Since each cell can reuse spectrum, the information capacity of a cellular network is directly proportional to the number of cells. A carrier can increase capacity by acquiring additional spectrum—or by investing more capital in spectrum efficiency. ArrayComm CEO Martin Cooper has estimated that more than 97.5% of the increase in spectrum capacity since 1960 has come from reducing the geographic coverage area of cells.[32] Vividly demonstrating the diminishing size of cells, New York City leased out its 18,000 light posts, each a potential cell site for up to a half-dozen wireless vendors. See Figure 9 for the growth of cell towers. This growth has largely been driven by the need to subdivide cells to increase information capacity. Another way to subdivide geographic coverage is with directional antennas that point signals in a specific direction and thus can reuse spectrum in different directions. However, reuse via directional antennas cannot bring the order of magnitude capacity increasing effects of reuse via smaller cells. Directional reuse is especially limited in the lower frequencies because the propagation characteristics of large electromagnetic waves don't lend themselves to the formation of narrow beams.

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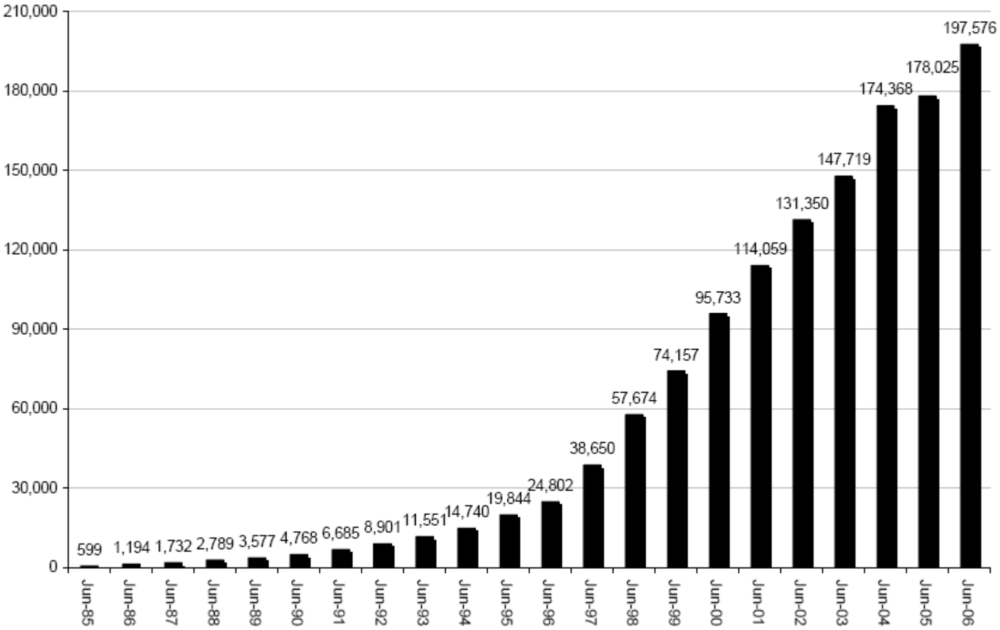
[31] See slide 18 of R. R. Miller and H. R. Worstell, "4G Neighborhood Area Networks," document 802.11-05/0173r0, submitted to the IEEE, March 11, 2005.

[32] *See* "Cooper's Law" at www.arraycomm.com. See also J.M. Vanderau et al., "A Technological Rationale to Use Higher Wireless Frequencies," (Washington, DC: U.S. Department of Commerce, February 1998), p. 10, and Toru Otsu et al., "Network Architecture for Mobile Communications Systems Beyond IMT-2000," *IEEE Personal Communications*, October 2001, p. 33.

Figure 9 - Growth in Cell Sites[33]



To illustrate the efficiencies of small cell size, the 2.4 GHz unlicensed band occupies less than half the spectrum currently occupied by the licesed mobile telephone providers. But in a home and business setting, it can offer data speeds up to 200 mbps (whereas mobile telephone operators struggle to reach 700 kpbs) with fewer service limitations (because it is connected to the wired broadband network and only has that network's limitations) while charging nothing for service (because it piggbacks on the wired broadband network and incurs no extra usage charges).

Obviously, large cell sites still retain cost advantages. Otherwise, more mobile telephone operators would have shrunk their cell sites faster than they have. But the point is, the overall cost-benefit calculation continues to lead mobile telephone operators to decrease their cell size.

Moore's Law of rapidly decreasing computer costs per unit of performance applies to wireless routers just as it does to other computer equipment. A single broadcast TV transmitter installed on a giant 2,000 foot high tower costs millions of dollars. Even the transmitter alone can cost several hundred thousands of dollars. TV transmitters are built in relatively low volume (there are fewer than 2,000 TV transmitters in the United States), each lasts for decades, and each is specially ordered because most operate on different frequencies and at different maximum power levels.

In contrast, the cost of a standalone WiFi router is in the vicinity of $40 dollars. The cost of factory-ordered WiFi chips has already dropped to $5/each in high-volume purchases and that number could drop to pennies within a few years. Other wireless devices, such as

[33] Source: CTIA's Semi-Annual Wireless Industry Survey, June 2006.

Bluetooth, have undergone similar price declines. Such declining prices helps explain why hundreds of inexpensive consumer electronics devices, such as portable game players, MP3 players, and cell phones, now incorporate wireless chips. Unlike high power broadcast and mobile telephone towers, WiFi routers are almost always placed on or within pre-existing infrastructure such as light poles, telephone poles, and buildings. In Amsterdam in the Netherlands, a city ordinance mandates that light poles be wireless ready. But even with light poles in the U.S. that weren't designed with wireless routers in mind, it can take as little as five minutes to install a WiFi router, including connecting the router to the light post's electrical wire.

Now consider this thought experiment that highlights the underlying economic logic. Assume that the cost of small area cells drops to zero while demand for bandwidth increases to infinity. The economic equilibrium derived from such assumptions would be an infinite number of infinitesimal cell sites.

Less Energy and Battery Usage. As portable devices grow in popularity, efficient battery use grows in importance. Physics dictates that the greater the distance a wireless device must send its signal, the greater the power it must use as well as the corresponding size, weight and cost of batteries.[34] Low power also opens up the possibility of solar-powered WiFi, which is useful for a host of military, scientific and municipal applications, as well as in disaster relief, developing countries, and remote rural areas, where there is unreliable or no electricity.[35]

Similarly, physics dictates that the amount of energy required to send information is a function of the number of bits sent. Every additional bit requires more energy. When telephone-quality audio bits are the predominant type of bits sent, power usage is relatively low. But in an ultrabroadband world, hundreds of times more power may be needed. When the bits are coming from a battery-operated portable device, this becomes a major problem. One way to address it is with lower-power links between the transmitter and receiver.

Another advantage of substituting wired for wireless telecommunications wherever feasible is that the energy per foot of sending information over a wire tends to be substantially less than the energy per foot of sending information wirelessly. This has traditionally not been a major factor in choosing wires over wireless for backhaul communictions. But it could become a greater factor in the more energy intensive ultrabroadband world.

Greater Security. Wired communications are more secure than wireless communications because of the confined space in which they operate; it's necessary to dig up a wire to intercept a shielded, buried wired communications link. But the last wireless leg of a

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[34] First Report and Order In the Matter of Amendment of Part 15 to redefine and clarify the rules governing restricted radiation devices and low power communication devices, FCC Docket No. **20780**. (Adopted: September 18, 1979; Released: October 11, 1979).

[35] E.g., *see* Lumin Innovative Products at http://www.luminip.com.

communications link is relatively easy to intercept with any device in its coverage area. Thus, the smaller the coverage area—for example, an office or a block versus an entire city—the more secure the connection.

* * *

Now let us put our observations about the economics of bundled vs. unbundled property rights together with our observations about the likely evolution of wireless links in an ultrabroadband world.

When wireless links become sufficiently short, spectrum rights become complementary to the possession of tangible property. For example, the transaction costs of negotiating with third parties for the right to install base stations in tens of millions of homes and businesses become prohibitive. Similarly, owners of homes, businesses, and local public rights-of-way don't want to pay third parties for the right to the use of spectrum within their own premises. Given a choice, for example, between paying Verizon Wireless $60/month for an on-premise slow speed and highly restricted wireless connection to the network versus paying no usage fees for using a much faster and more versatile WiFi wireless connection to the network, homeowners, businesses, and municipalities are increasingly choosing the latter option.

One potential problem with the bundled property model is that it may give those who possess tangible property monopoly power in ways we haven't seen before. But it turns out this may be more of an apparent than real threat. Consider the acoustic analogy. Municipalities, mall owners, hotels, and other could potentially ban speech on their premises. But they don't because it is not in their self interest to do so. It turns out that even strictly profit oriented private property owners provide "free" (at zero marginal cost) access to all sorts of assets on their property. For example, restaurants provide patrons with salt, utencils, and drinking water for "free." Mall owners and hotels provide access to parking, benches, and rest rooms for "free." And governments often provide even more "free" amenities, including libraries, schools, and police services. Local spectrum use will probably be no different. For example, it's hard to imagine a mall charging for keyless car door entry.

Even when fees are charged, they are likely to be reasonable. For example, hotels might charge for wireless access—as many now do. But if the marginal cost of such access is zero and there is competition in the hotel market, charging unreasonable fees for such access would be economically inefficient for the hotel.

By granting spectrum usage rights based on possession rather than real property ownership, a lot of potential problems are avoided. For example, tenants in a building would have legal rights to use spectrum within their own offices without landlord approval. A cell phone user within a car would be able to make a wireless connection to and from the car's sound system. And a jogger on a public path would be able to wirelessly connect the MP3 player on her hip to the headphones on her ears.

Another potential problem is coordinating roaming arrangements with the more than 20,000 local municipalities, fifty states, and the federal government that control public rights-of-way on everything from interstate highways down to the local neighborhood cul-de-sac. But this may not be materially different in difficulty than coordinating free access to the thousands of networks that currently constitute the Internet.

3) Policy Recommendations

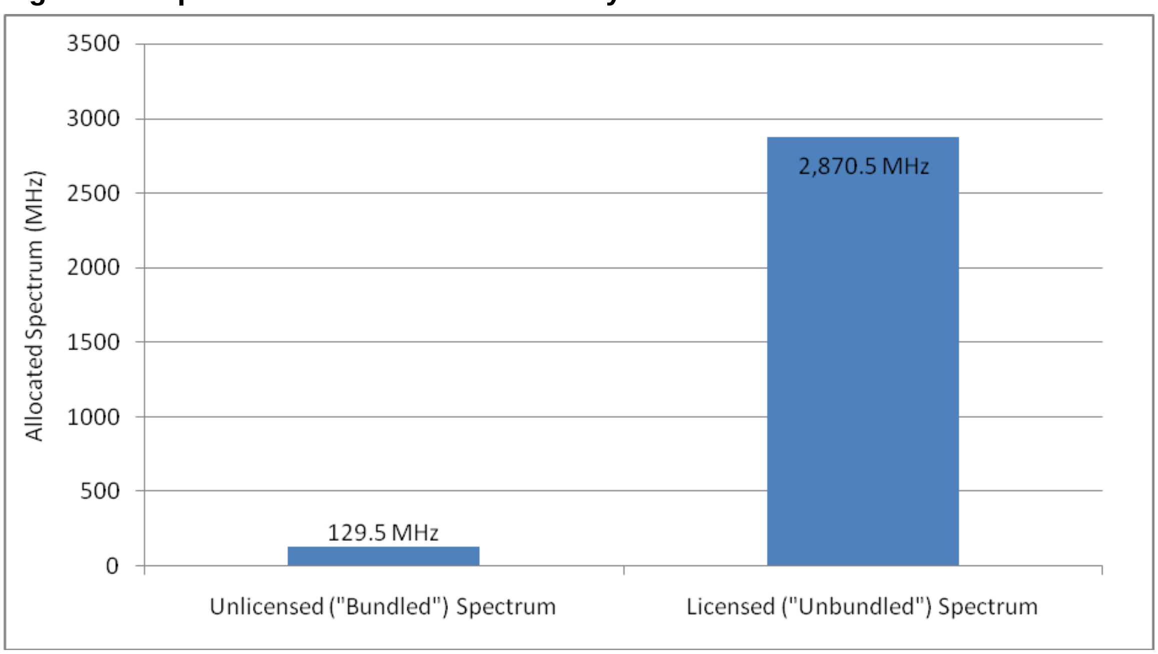
In a wireless ultrabroadband world, the current system of managing spectrum becomes exceedingly inefficient. The following recommendations seek to rectify that inefficiency.

Spectrum rights should be bundled with possession of tangible property

Currently, overwhelming control over spectrum rights is granted to the federal government and giant corporations. For the economic reasons described in this paper, a large measure of this control should be shifted to millions of private property owners, including owners of homes, offices, and local public-rights-of-way.

Current efforts to allocate more unlicensed spectrum are largely consistent with this agenda. Figure 10 depicts the current amount of spectrum primarily allocated to unlicensed versus licensed use below 3 GHz. Since other bands allowed shared licensed and unlicensed use (most notably for very low power underlays under the Part 15 rules), the amount of spectrum primarily allocated to unlicensed use is an imperfect measure of the amount of bundled spectrum. But it is a reasonable proxy that serves to illustrate the government's currently strong bias in favor of unbundled spectrum property rights. Note that licensed spectrum includes largely fallow guard band spectrum necessary to protect licensed services from interference.

Figure 10. Spectrum Allocated For Primarily Unlicensed Versus Licensed Use



Advocates of bundled spectrum property rights should compell the FCC and other spectrum policymakers to clearly distinguish between the unlicensed, licensed, commons, bundled, and unbundled property rights models of spectrum management

Failure to carefully distinguish between the different models of spectrum management can lead to poorly defined problems and muddled solutions. For example, in its interference temperature proceeding, the FCC proposed creating an unlicensed underlay but failed to distinguish between unlicensed commons and bundled spectrum property rights. An unlicensed underlay proposal framed in terms of the possession of tangible property would have led to a very different set of technical and economic issues, with a correspondingly different political dynamic.

Underlay and overlay rights should be separated

What is the efficient mix between unbundled and bundled property rights? One relatively simple solution would be to divide overlay and underlay rights to spectrum. With this division of rights, each set of rights could be equal, just as homeowners have the right to control space within their own homes but airplanes have the right to use space 1,000 feet above their homes. Similarly, sometimes the government separates ownership of resource rights below ground, such as energy and mineral extraction rights, from real property rights above ground. In both cases, the only question is where the dividing line is between two different but adjacent sets of property rights.

Figure 11 depicts one possible relationship between the various spectrum management models, including the distinction between overlay and underlay rights. Here the unlicensed property rights model is restricted to underlays and the licensed property rights and commons models are restricted to overlays. The relative social value created by underlay versus overlay spectrum is obviously a matter of potential dispute as is the relative social value of the two different overlay models: commons and unbundled property rights. Here the relative social value of overlay and underlay rights is depicted as equal as is the relative value of the two types of overlays: commons and unbundled property rights.

Figure 11. Underlays and Overlays in Relation to the Spectrum Management Models

To understand the difference between overlay and underlay rights, an acoustic analogy is helpful. Diners in a restaurant can talk at each table while music plays in the background. The loud music is the overlay right and the soft conversations are the underlay rights. The reason this works out is because waves—whether they are sound waves or electromagnetic waves--pass through each other. To visualize this, recall how waves pass through the wake of a boat. As they pass through the boat's wake, their shape is altered, but as they leave the boat's wake, they return to their normal shape.

Unlicensed underlay rights can be divided into incidental, jamming, and communications. Incidental underlay rights involve the discharge of electromagnetic energy at such low power as to have no discernable impact on communications. Electronic devices emit electromagnetic energy as a necessary byproduct of their operations. But as long as this energy travels only an insignificant distance, such as a few inches, nobody is harmed and nobody cares. For example, every digital wristwatch emits such energy and it is perfectly legal. Even cell phones otherwise using licensed spectrum emit such energy.

Perhaps the most common worldwide use of unlicensed underlays to affect communications is jamming, which is used to disrupt rather than send wireless communication. Jamming is technically illegal, except for federal government officials. For example, The U.S. President rarely goes anywhere without jamming his immediate vicinity. The purpose of the jamming is to prevent eavesdropping and the remote activation of bombs. Military troops in combat, such as in Iraq, routinely use jammers when they patrol. Although jamming is illegal in the United States, jammers are widely sold by spy shops, and embassies and board rooms use them to prevent eavesdropping on sensitive communications.

At least several countries outside the U.S. now allow jamming for such public events as church services, concerts, plays, and movies. The theory is that when people attend such events they are entitled not to be disturbed from beeping cell phones and other mobile devices. In many other countries, such jammers also appear to be used, albeit illegally.

Jamming need not occur through the use of electrical signals. It can also occur by creating a “cage” to keep out electromagnetic radiation. Walls painted with metallic paint can keep out such radiation. Thick walls and underground rooms can also keep out unwanted electromagnetic radiation. Such jamming is perfectly legal and widely used in the United States in sensitive venues such as broadcast studios and corporate board rooms where the practice is to follow the letter but not the spirit of the law banning jamming.

In the U.S., underlays from incidental emissions of electromagnetic radiation from computers and other digital devices are pervasive and probably include billions of devices. But underlays for communications are relatively rare.

One underlay device for communications is the FM modulator, which is used to wirelessly connect MP3 players and satellite radios to a car’s radio using channels in the FM radio band. Usually, FM modulators are tuned to unused radio channels but they need not be. The allowed power levels of FM modulators are such that in ideal circumstances the signals can legally travel about 3 meters (a little more than nine feet). Ideal circumstances include transmitting in a direct line of sight from the FM modulator to the radio and on an empty channel. In practice, FM modulators can often only transmit a clear signal a few feet.

Perhaps the best publicized underlay right for communications is ultra-wideband (UWB). As noted earlier, the FCC authorized UWB service in the early 2000s. UWB spreads energy over a very large bandwidth—3 GHz to 11 GHz—and works at distances of about thirty feet under ideal circumstances. Although some outdoor uses are allowed—such as for ground penetrating radar by pointing an outdoor radio in the direction of the ground—its flexible use is restricted to indoor use. The primary consumer application for UWB is expected to be replacing with wireless links the maze of consumer electronics and computer wires found in most houses. The speed of UWB is comparable to a USB 2.0 wired connector, which is found in almost all new computers. For this reason, UWB is sometimes called “wireless USB.”

Unfortunately, when the FCC issued rules for UWB, it was primarily interested in protecting incumbent licensees from worst case interference scenarios rather than maximizing the social welfare from UWB. For example, its UWB *First Report and Order* acknowledges: “We are concerned… that the standards we are adopting may be overprotective and could unnecessarily constrain the development of UWB technology…. It is our belief that the standards contained in this Order are extremely conservative.”[41] One way this pro-incumbent bias played out was to ban the use of UWB as part of an outdoor municipal WiFi network. As a result, vast amounts of useful spectrum that could facilitate broadband deployment is left unused.

As a general rule, unlicensed devices authorized by the FCC are expected to be secondary to licensed devices. In practice, as a result of trespass laws, they need not be. But trespass laws are not within the FCC's jurisdiction. The one little known exception where unlicensed devices are not secondary to licensed devices is in the 900 MHz band, widely used for cordless phones, baby monitors, and other simple indoor unlicensed devices. The 900 MHz exception occurred because of a historical anomaly. Unlicensed devices were authorized first in this band and licensed services only later. Following its normal practice of protecting incumbents against newcomers, the FCC granted the unlicensed incumbents safe harbor protections against the licensed newcomers. The FCC also granted licenses only for a narrow outdoor use--vehicle monitoring--whereas the unlicensed devices were only protected for indoor use.

In the mid-2000s, the FCC sought to extend the use of unlicensed underlays through what it called the "interference temperature" concept.[36] This was a klutzy, property independent conceptualization of unlicensed service that was in keeping with the regnant commons approach but which was also deeply muddled and was finally defeated in early 2007 partly because no one could figure out a compelling way to make it work. A better approach, as previously noted, might have been to develop an interference temperature metric as part of a bundled spectrum management model.

Regardless of technical details, the central point is that activities that occur within property boundaries that don't unduly harm others should be allowed. Deciding on a standard of harm requires a balancing of interests. That balancing is a staple of American jurisprudence because human activities in the real world rarely are purely self-contained within property lines. For example, the leaves from trees in Joe's yard may fall on neighbor John's yard, the water from John's yard may traverse neighbor Joe's yard, the noise from Joe's kids playing in the yard may cross into John's yard, and the ugly statue installed in John's yard may be seen from Joe's yard. The task is to use common sense reasoning to balance one neighbor's property rights with another's, and the same can be done with spectrum underlays.[37]

The Communications Act of 1934 grants the federal government the authority to transition from the current unbundled property rights regime to a bundled property rights regime because under the Communications Act no licensee can have either ownership rights to spectrum or the right to a perpetually renewed license. All licenses, even those acquired at auction, must be for a limited duration of years.[38] If the government wants to

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[36] Notice of Inquiry and Notice of Proposed Rulemaking in the Matter of Establishment of an Interference Temperature Metric to Quantify and Manage Interference and to Expand Available Unlicensed Operation in Certain Fixed, Mobile and Satellite Frequency Bands, ET Docket 03-237, November 28, 2003.

[37] Ellen P. Goodman, "Spectrum Rights in the Telecosm to Come," San Diego Law Review, Volume 41, 2004: 269-404.

[38] See 47 U.S.C. §301. See also J.H. Snider, "The Art of Spectrum Lobbying" (Washington, DC: The New America Foundation, forthcoming).

reallocate spectrum and divide overlay from underlay rights or switch entirely from an unbundled to a bundled property rights regime, it can legally do so.

Even within the existing license terms of most licensees, the government has the right to separate underlay from overlay rights. In some cases, the disposition of underlay rights is unclear. But in many cases, they have clearly not been allocated as part of a license. For example, terrestrial TV broadcasters currently have the right to transmit a single signal from a particular place at a particular power level in particular directions. This leaves open the possibility that every property owner could reuse that spectrum as an underlay within his or her property. Broadcasters, of course, want those underlay rights for themselves and will fight fiercely against anyone else getting them. Indeed, broadcast licensees have instigated a proceeding at the FCC that, by giving them geographic service area rather that site based rights, will put them well on the road to winning such underlay rights.[39] But the FCC is currently under no legal obligation to give broadcasters such rights.

Enforcement of spectrum rights should be shifted from federal to local authorities

Local disputes over spectrum property rights should be dealt with locally just as other property rights are. The federal government is no better suited to address local spectrum rights disputes than it is to address local acoustic speech disputes, such as one homeowner playing rock music so loud that a neighbor is disturbed.

In particular, the FCC is unsuited to enforcing bundled spectrum property rights. Local governments, which currently enforce other local nuisance and trespass laws, are far better suited to this task.

Advocates of wireless network neutrality should seek to include bundled spectrum property rights as a component of network neutrality legislation and rulemakings

The pursuit of network neutrality has historically been more controversial on wireless than wired networks because of the more limited bandwidth available over wireless networks. When bandwidth is scarce, charging for preferred carriage makes more economic sense. As argued earlier, however, the best way to ensure that wireless end user links don't become inferior to wired ones is to greatly reduce cell size and bundle spectrum rights with the possession of tangible property.

Advocates of bundled spectrum property rights should sue the Federal government under the First Amendment and the Takings Clause in the U.S. Constitution

Disputes over eminent domain have frequently played out in the courts and have occasionally reached the Supreme Court.[40] No tangible property owner has ever brought

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[39] Clarification Order and Notice of Proposed Rulemaking in the Matter of Digital Television Distributed Transmission System Technology, MB Docket No. 05-312, November 4, 2005.

[40] E.g., see Kelo v. City of New London, 545 U.S. 469 (2005).

a suit arguing that the Takings Clause in the U.S. Constitution prevents the Federal government from taking away rights to use spectrum within his or her tangible property lines. But now that low power underlay rights have skyrocketed in value, the time may be right to bring such a suit.

A First Amendment argument can also be made. If the First Amendment grants the public free acoustic rights within the property they possess, why not also electromagnetic speech? Why should Verizon, AT&T, Disney, GE, or any other company be given exclusive rights to use spectrum within America's homes and businesses when if a company sought from the government similar exclusive acoustic rights it would immediately be recognized as a First Amendment outrage?

When incumbent licensees seek "minor modifications" to grant themselves underlay rights, many other statutes may also provide opportunities for suing the government based on some type of unjust enrichment or inefficiency at the public's expense. These statutes include Communications Act, the Anti-Deficiency Act, and Miscellaneous Receipts Act.[41]

Conclusion

Current spectrum management models are fundamentally incomplete. A new spectrum management model is needed that clearly distinguishes between unbundled and bundled spectrum property rights.

In a wireless ultrabroadband world, the most efficient spectrum management model is a bundled one that combines spectrum usage rights with possession of tangible property. To the extent that a bundled property rights regime is desirable and implemented, enforcement of such spectrum rights should be transfered from the federal government to state and local governments.

One simple way to achieve a balance between bundled and unbundled property rights is to allocate overlay rights on an unbundled basis and underlay rights on a bundled basic. Much research needs to be done on how to efficiently allocate underlay rights and establish an appropriate balance with overlay rights. The FCC's interference temperature proceeding was a failed attempt to do this that needs to be revisited with a new conceptual model. The FCC's ultrawideband proceeding was more successful but this underlay approach also needs to be significantly revised and expanded.

Bundling spectrum rights with property rights will foster network neutrality because it will help overcome the capacity constraints associated with today's wide area wireless networks. Advocates of network neutrality should therefore favor this spectrum management regime.

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[41] For a discussion of the FCC's granting of "minor" license modifications worth tens of billions of dollars without public compensation, see J.H. Snider, "The Art of Spectrum Lobbying" (Washington, DC: The New America Fourndation, forthcoming).

Unbundled property rights to spectrum in the form of FCC licenses are hugely valuable. To paraphrase a former FCC Media Bureau Chief, most spectrum licensees would rather kill their mothers than give back their spectrum. They will thus fight bundled property rights tooth and nail. The fact that the public barely understands the nature of spectrum and shows almost every sign that it could care less is equally problematical. The combination of special interest zeal and public apathy is an explosive political combination that, as long as it lasts, will inevitably result in special interest spectrum politics that unduly favors the unbundled over the bundled property rights model.

However, just because power favors the special interests doesn't mean the law necessarily favors them. To the extent that the law, such as the First Amendment and Takings Clause in the Constitution, does not favor today's unbundled spectrum property rights regime, the government should be sued so the law can be upheld.