Supercommons: Toward a Unified Theory of Wireless Communication

Kevin Werbach[*]

The federal government has long controlled the allocation and assignment of electromagnetic spectrum, considered the lifeblood of wireless communication. Critics of government spectrum licensing advance two alternatives: exclusive property rights and unlicensed sharing through "spectrum commons." Yet both sides fail to come to grips with an essential point: there is no such thing as spectrum. It is an intellectual construct whose utility is rapidly decreasing as technology develops. Because spectrum is not a concrete thing, oft-used analogies to land or to natural resources break down.

There is a vast new communications space emerging, whose full extent is unknown. Regulatory proposals based on spectrum as a physical asset denominated by frequencies artificially constrain mechanisms that exploit this "supercommons," producing inefficient outcomes. A better approach is to draw analogies to legal domains that do not presuppose ownership, such as tort. A universal communication privilege, allowing anyone to transmit anywhere, at any time, and in any way, should be the baseline rule for wireless communication. Liability backstops and safe harbor mechanisms can effectively prevent ruinous interference, while efficiently resolving boundary disputes.

The supercommons approach properly refocuses wireless regulation away from spectrum and toward the devices used for communication. It can operate alongside the property and commons regimes, which are just different configurations of usage rights associated with wireless equipment. Bandwidth need not be infinite to justify a fundamental reconceptualization of the spectrum debate. Even with real-world scarcity and transaction-cost constraints, a default rule allowing unfettered wireless communication would most effectively balance interests to maximize capacity.

[*] Founder, Supernova Group LLC. Former Counsel for New Technology Policy, FCC and former Editor, RELEASE 1.0. Thanks to Yochai Benkler, Ellen Goodman, Greg Rosston, Stuart Buck, Scott Rafer, and Phil Weiser for their helpful comments. An earlier version of this Article was presented at the 31st TPRC Research Conference on Communication, Information and Internet Policy. Feedback welcome to kevin@werbach.com.

I. Introduction

A specter is haunting spectrum policy—the specter of commons.[1]

Spectrum policy is fundamental to traditional mass communications and to the emerging digital information infrastructure. All wireless communications devices, from analog television transmitters to Internet-enabled smart mobile handsets, transmit radio waves through the air. The federal government tightly constrains how those devices function based on its control of electromagnetic spectrum. Yet the assumptions underlying that control are under siege.

1. Apologies to Karl Marx and Friedrich Engels. Actually, unlike communism, the commons position is neither anti-property nor anti-markets. *See infra* subpart V(A).

Seventy years after the birth of governmental spectrum management,[2] and forty years after Ronald Coase and his colleagues began a campaign to kill it,[3] the end of history for spectrum regulation seemed close at hand. By the mid-1990s, advocating extensive propertization of electromagnetic spectrum had become, in Eli Noam's words, the "new orthodoxy."[4] Even the Federal Communications Commission (FCC), which would lose much of its power if spectrum were privately owned, seemed to agree. The FCC enthusiastically adopted auctions as its preferred method for assigning spectrum licenses, proposed secondary markets for licensees to lease spectrum they controlled, and issued statements endorsing further expansion of "market-based" spectrum reform.

In recent years, however, a new perspective on spectrum policy has emerged. The "commons" position holds that private property rights in spectrum are as unnecessary as government-issued licenses. Commons advocates claim that, thanks to advances in technology, collections of wireless devices can share spectrum effectively without exclusive rights. They therefore support expansion of "unlicensed" frequency bands and oppose calls to turn spectrum rapidly and exhaustively into private property. Commons advocates offer two lines of support for their claims: the theoretical benefits of unlicensed operation, and the empirical success of unlicensed spread-spectrum devices.

Despite its novelty, the commons position has quickly become a significant force. The FCC's latest comprehensive spectrum reform report endorsed greater use of commons mechanisms, along with expansion of property rights. Commons and property advocates debate each other energetically in both academic and policy circles. Recently, some scholars have claimed that the two camps are not so far apart and have proposed approaches that encompass both mechanisms.[5] Commons advocates have so

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2. *See* 1 ERIK BARNOUW, A TOWER IN BABEL: A HISTORY OF BROADCASTING IN THE UNITED STATES 195–201 (1966) (reviewing the historical development of the Radio Act of 1927, which gave the government authority to control the licensing of radio channels).

3. *See* Ronald H. Coase, *The Federal Communications Commission*, 2 J.L. & ECON. 1, 17–24 (1959) (critiquing government regulation and proposing a new system of pricing and frequency allocation based on private property rights).

4. Eli Noam, *Spectrum Auctions: Yesterday's Heresy, Today's Orthodoxy, Tomorrow's Anachronism. Taking the Next Step to Open Spectrum Access*, 41 J.L. & ECON. 765, 768 (1998).

5. *See, e.g.*, Gerald R. Faulhaber & David Farber, *Spectrum Management: Property Rights, Markets, and the Commons*, *in* RETHINKING RIGHTS AND REGULATIONS: INSTITUTIONAL RESPONSES TO NEW COMMUNICATION TECHNOLOGIES 193, 194 (2003) (arguing that the two positions present "a false dichotomy" and proposing "a legal regime rooted in property rights that can simultaneously support both private markets and a commons"); *see also* Eli Noam, *The Fourth Way for Spectrum*, FT.COM, May 29, 2003, *at* http://news.ft.com/comment/columnists/neweconomy; Ellen P. Goodman, *Spectrum Rights in the Telecosm to Come*, 41 SAN DIEGO L. REV. (forthcoming Feb. 2004) (manuscript at 92–94, on file with the Texas Law Review, *available at* http://ssrn.com/abstract=484922).

far rejected these as essentially the property regime in disguise.[6] However, they have not yet mapped out proposals with the specificity of the more extensive property literature. The debate, while fertile, is at something of an impasse.

Fortunately, there is a way out. The property and commons positions do come together, though not in the ways previously articulated. Both sides use analogies to fixed physical resources such as land that obscure more than they clarify. Consequently, both have wrongly focused most of their energy on the *contents* of frequency-based allocations, rather than questioning whether such allocations are even necessary.[7] In other words, rights are tied to a band of wireless frequencies, whether those frequencies are subject to ownership or shared use. Frequencies are scarce, it is said, so they must be allocated.

Yet as legendary physicist Richard Feynman once said in a different context, "there's plenty of room at the bottom."[8] There are many ways to communicate without disturbing other users of the same frequency band, in what I call the supercommons. The supercommons is hardly exploited today; neither property nor commons advocates devote much attention to it. Yet it may represent the majority of potential wireless communications capacity, and any spectrum policy framework that does not expressly permit supercommons transmissions will unreasonably preclude them.

The supercommons illuminates the flaws in prior spectrum reform proposals, especially those built on exhaustive property ownership. They make assumptions about interference that may once have been justified but are irrational today. In mistakenly associating property rights with wireless frequencies, they make novel forms of communication impractical. Wireless regulation should focus not on ownership of spectrum, which is a construct, but on rights to use wireless equipment in certain ways.

The basic legal framework for wireless communication should build on bodies of law that resolve usage disputes where ownership is not a salient issue, such as tort. As an initial matter, users of wireless equipment should be permitted to transmit anywhere, at any time, and in any manner. This

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6. *See, e.g.*, Yochai Benkler, *Some Economics of Wireless Communications*, 16 HARV. J.L. & TECH. 25, 63 (2002) (conceding that the approaches proposed by Faulhaber and Farber are "better than the pure property system," but arguing that they are "still substantially constraining to open wireless network design").

7. *See* Thomas W. Hazlett, *The Rationality of U.S. Regulation of the Broadcast Spectrum*, 33 J.L. & ECON. 133 (1990); Stuart Buck, *Replacing Spectrum Auctions with a Spectrum Commons*, 2002 STAN. TECH. L. REV. 2, ¶ 47, *at* http://stlr.stanford.edu/STLR/Articles/02_STLR_2/index.htm. Recent property and commons scholarship acknowledges the possibility of non-frequency-based modalities, but fails to grapple with their implications. *See infra* notes 293, 297, 302 and accompanying text.

8. Richard P. Feynman, *There's Plenty of Room at the Bottom*, ENGINEERING & SCI., Feb. 1960, at 22, 24, *available at* http://www.zyvex.com/nanotech/feynman.html. Feynman was referring to the potential for what is now called nanotechnology: machines that operate at the molecular level.

universal entry privilege should carry a duty of care backstop and a set of implied legal safe harbors to balance the interests of transmitters and those affected by their actions. Such a tort-like regime provides a dynamic, distributed mechanism for avoiding and resolving conflicts among wireless users. It combines the deregulatory attributes of the property proposal with the openness of the commons, allowing the full range of communications possibilities to be exploited.

This Article seeks to reconceptualize spectrum policy around wireless equipment rights and the supercommons model. Part II outlines the historical stages of the spectrum debate, the current situation, and where we could go from here. Part III attacks the two fallacies, reification of spectrum and assumptions about usage, that prevent a clear understanding of the problem and its solutions. Part IV recommends rebuilding wireless regulation on the new foundation of equipment usage rights. It outlines how a universal transmission privilege, limited in practice through tort and other means, provides the best and most flexible framework. Part V returns to the property vs. commons debate, concluding that, in the near term, the commons position remains potent despite responses from property advocates. Part VI offers specific recommendations.

The now-dominant government licensing approach may have been defensible in 1920, but its failings were evident by 1960. The property approach made sense in 1960, but is now questionable. The commons approach is viable today. The supercommons may become real sooner than we think.

II. The Spectrum Debate

The proper legal regime for radio frequency spectrum has been the subject of controversy since the early days of the last century.[9] It is remarkable the debate remains recognizable. The usable spectrum today is five thousand times larger in terms of bandwidth than in 1927, when the federal Radio Act was adopted.[10] Where there were once a handful of commercial services, including broadcast radio and maritime communication, now there is a plethora of industries, including television, mobile telephony, satellite communications, radio dispatch services, and

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9. *See, e.g.*, 1 BARNOUW, *supra* note 2, at 31 ("[T]he armed forces . . . began to demand regulation. The amateurs rose in righteous anger, but to no avail. In 1912 the first radio licensing law was passed by Congress and signed by President Taft.").

10. *See* Michael Chartier, Enclosing the Commons: A Real Estate Approach to Spectrum Rights 5 (Nov. 9, 2001) (unpublished manuscript, on file with author) (noting that at the time of the International Radio Telegraph Convention of 1927, all services resided below 1715 kHz, and the extreme range of "experiment" possibility ended at 60,000 kHz, whereas today the FCC's table of allocations ends at 300,000,000 kHz); *An Appraisal*, FORTUNE, Sept. 1932, at 37, 43 (illustrating the allocated radio spectrum as extending from 10 to 30,000 kHz, with an experimental band between 30,000 and 60,000 kHz).

wireless local area networks. Few aspects of twenty-first century communications would be comprehensible to a visitor from the 1920s. Yet when it comes to spectrum, we are still arguing over the same questions: does government need to manage centrally how spectrum is allocated and assigned, and can users of wireless communications devices effectively coordinate their actions to avoid ruinous interference?[11]

Perhaps the debate has endured because spectrum is so very important. Hardly any American is untouched by radio frequency communication. The relevant industries generate billions of dollars in annual revenue.[12] And wireless communication may be the dominant form of speech in our electronic age.[13] The radio spectrum is the town square of our digital polity. It is a major, if not the major, channel through which we obtain our news, entertainment, social interactions, and business communications. Most participants in the spectrum debate claim spectrum is woefully underutilized.[14] If this is true, reforms that foster more efficient use of spectrum would have dramatically beneficial effects on daily life.

There are three major approaches to managing spectrum. I will refer to them as "government licensing," "property," and "commons."

A. The Rise of Government Control

Guglielmo Marconi first patented the mechanism for radio communications in 1897.[15] Radio waves are manifestations of

11. This is not the only enduring aspect of wireless communication. An 80-year-old AM radio can still be a useful device today. No other consumer electronics device has had anywhere near that degree of longevity.

12. *See, e.g.*, Press Release, Veronis Suhler Stevenson, Veronis Suhler Stevenson Forecasts Broad-Based Recovery to Be on Track in the Communications Industry (Aug. 11, 2003), *available at* http://www.vss.com/articles/article_081103.html (stating that advertising revenues for broadcast television exceeded $40 billion in 2002, and radio advertising revenues were nearly $20 billion); CELLULAR TELECOMMUNICATIONS AND INTERNET ASSOCIATION, THE CELLULAR TELECOMMUNICATIONS AND INTERNET ASSOCIATION'S ANNUALIZED WIRELESS INDUSTRY SURVEY RESULTS, JUNE 1985–JUNE 2003 (finding that annual U.S. cellular telephone industry revenues reached $81 billion in 2003), *available at* http://www.wow-com.com/images/survey/2003_midyear/752x571/Annual_Table_Jun03.gif; Robert W. Hahn & Patrick M. Dudley, *The Disconnect Between Law and Policy Analysis: A Case Study of Drivers and Cell Phones*, 55 ADMIN. L. REV. 127, 129 (2003) (stating that revenues in the cellular telephone industry "climbed from less than $1 million in 1985 to almost $60 billion in 2001").

13. *Cf.* ITHIEL DE SOLA POOL, TECHNOLOGIES OF FREEDOM 226 (1983) ("Networks of satellites, optical fibers, and radio waves will serve the functions of the present-day postal system.").

14. *E.g.*, *id.* at 151 (contending that spectrum "is an abundant resource, but a squandered and misused one"); NEW AM. FOUND. & SHARED SPECTRUM CO., DUPONT CIRCLE SPECTRUM UTILIZATION DURING PEAK HOURS 3 (2003), *available at* http://www.newamerica.net/Download_Docs/pdfs/Doc_File_183_1.pdf (last visited Feb. 21, 2004).

15. 1 BARNOUW, *supra* note 2, at 12. There is some dispute about whether Marconi or Nikola Tesla deserves credit for radio. For example, in 1943 the Supreme Court overturned one of Marconi's patents based on prior art including a patent filed by Tesla in 1897. Marconi Wireless Tel. Co. of Am. v. United States, 320 U.S. 1, 13–16, 31–34, 37–38 (1943).

electromagnetic radiation that oscillate at characteristic rates, called frequencies. The radio frequency (RF) spectrum is nothing more than the series of frequencies usable for communications below the range of visible light,[16] approximately 3 kilohertz (KHz) to 300 gigahertz (GHz).[17]

Marconi's original "spark gap" transmitters sent signals across a wide range of frequencies simultaneously. Only a single radio could operate in a particular area at a particular time for its signal to be intelligible.[18] Perhaps the single greatest enhancement to Marconi's original invention was frequency division.[19] A tuning fork vibrating at a characteristic frequency will cause another tuning fork at a distance to vibrate at that same frequency. By impressing a radio signal on a carrier wave of a specific frequency, Marconi was able to transmit that signal to a receiver tuned to the same frequency.[20] Subsequent inventors refined the technique.

Attaching a signal to a frequency allowed other signals associated with different frequencies to be sent at the same time, without preventing mutual reception. In other words, frequency division is a mechanism for subdividing spectrum to enhance communication. It was a design choice, like the packet-switched architecture of the Internet,[21] rather than something present in nature. This seemingly obscure technical fact will become important in the

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16. Free-space optics communications systems can now be built using laser beams that operate at visible-light frequencies above the radio spectrum. Doug Allen, *The Second Coming of Free Space Optics: New Technology Called Free Space Optics May Be the Answer to Bandwidth Bottlenecks*, NETWORK MAG., Mar. 2001, at 55. Vendors such as Terabeam and AirFiber sell free-space optics equipment for high-speed data links comparable to systems using radio frequencies. *Id.* However, since the FCC's authority extends only to "communication by wire or radio," the free-space optics systems are outside of FCC jurisdiction. 47 U.S.C. § 152(a) (2000).

17. *See* NAT'L TELECOMMS. & INFO. ADMIN., U.S. DEP'T OF COMMERCE, UNITED STATES FREQUENCY ALLOCATIONS: THE RADIO SPECTRUM (2003), *available at* http://www.ntia.doc.gov/osmhome/allochrt.pdf. Officially, FCC rules define the radio waves or "Hertzian waves" as "[e]lectromagnetic waves of frequencies arbitrarily lower than 3,000 GHz, propagated in space without artificial guide." 47 C.F.R. § 2.1(c) (2002). A hertz is one cycle per second. A kilohertz (KHz) is a thousand hertz; a megahertz (MHz) is a million; and a gigahertz (GHz) is a billion, or a thousand megahertz.

18. Ironically, this archaic method of "carrierless" wideband wireless transmission has now reappeared in the form of ultra-wideband (UWB), with precisely the opposite result. Where spark gap transmitters prevent any other radios from operating, UWB systems operate at such low power that they can "underlay" virtually any other transmission without noticeable interference. *See infra* note 160 and accompanying text.

19. Marconi received British Patent No. 7,777, filed in 1900, for the use of "resonant tuning" to divide radio communications by frequency. *See* PETER R. JENSEN, IN MARCONI'S FOOTSTEPS, 1894 TO 1920: EARLY RADIO 96 (1994).

20. *See id.*

21. Packet-switching means that information is split into small data "packets," which are routed independently through the networks and reassembled on the receiving end. This contrasts with the "circuit-switched" model of the telephone network, which holds open a dedicated channel for each call. *See* KEVIN WERBACH, DIGITAL TORNADO: THE INTERNET AND TELECOMMUNICATIONS POLICY 2 (FCC, Office of Plans & Policy, Working Paper No. 29, 1997) (discussing the Internet's use of packets in an "adaptive" routing system), *available at* http://www.fcc.gov/Bureaus/OPP/working_papers/oppwp29pdf.html.

discussion below. The point is that dividing radio spectrum into frequencies is just a consequence of a technical approach to interference management adopted in the late nineteenth century.

At first, anyone could operate a radio transmitter.[22] When the first federal radio legislation passed in 1912,[23] radio was primarily used to communicate with ships, and thus of particular interest to the Navy.[24] Under the 1912 Act, radio stations were required to obtain licenses issued by the Secretary of Commerce.[25] By the 1920s, commercial broadcast stations had developed, and disputes about interference began to arise.[26] Secretary of Commerce Herbert Hoover sought to use the government's licensing authority to regulate the nascent broadcast industry.[27] He was rebuffed by the courts, which held in 1923 and 1926 that the Department of Commerce had authority only to issue licenses, not to deny or restrict them.[28] The result was several months in which radio stations jostled with each other to control the airwaves.[29] This period of "chaos" came to a close with the passage of the Radio Act of 1927, which established federal control over the radio spectrum and put in place the licensing regime that persists today.[30]

The primary rationale for government control of spectrum is that spectrum is inherently scarce. The Supreme Court has upheld the FCC's right to determine who can use spectrum on the ground that, thanks to scarcity, open entry would prevent anyone from enjoying the benefits of radio communication.[31] Because of scarcity and spectrum's fundamental importance to the public interest, decisions about who is able to use spectrum are not left to the vicissitudes of the market. At least, this is the argument.

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22. *See* 1 BARNOUW, *supra* note 2, at 4 (stating that the initial face of radio was one of "individuals and small enterprises").

23. Radio Act of 1912, Pub. L. No. 62-264, 37 Stat. 302 (repealed 1927).

24. *See* Coase, *supra* note 3, at 1–2 (describing the Navy's lobbying efforts in favor of government regulation of radio communication).

25. *Id.* at 2.

26. *Id.* at 4.

27. *Id.*

28. *See* Hoover v. Intercity Radio Co., 286 F. 1003, 1007 (D.C. Cir. 1923) (holding that the Secretary's duty to issue licenses to persons or corporations that come within the classification designated in the act is mandatory); United States v. Zenith Radio Corp., 12 F.2d 614, 617 (N.D. Ill. 1926) (holding that the "Secretary of Commerce is required to issue the license subject to the regulations in the act" and that Congress withheld the power to prescribe additional regulations).

29. Coase, *supra* note 3, at 5.

30. Radio Act of 1927, Pub. L. No. 69-632, 44 Stat. 1162 (repealed 1934). The 1927 Act was replaced by the more expansive 1934 Communications Act, which folded the Federal Radio Commission into the Federal Communications Commission that endures to this day. Communications Act of 1934, Pub. L. No. 73-416, 48 Stat. 1064 (codified as amended at 47 U.S.C. §§ 151–615b (2000)).

31. *See* Nat'l Broad. Co. v. United States, 319 U.S. 190, 216 (1943) (declaring "the facilities of radio are not large enough to accommodate all who wish to use them" and stating that Congress delegated to the FCC the task of devising methods to choose among those who apply for spectrum).

The current dominant licensing regime involves a detailed series of top-down government decisions that determine who can build what kinds of systems, in what frequency bands, and for what purposes.[32] The FCC first "allocates" a band of frequencies to put into the marketplace.[33] It designs a set of technical requirements, including subdividing the band into blocks, mandating power limits for systems, and in some cases, determining the specific service to be delivered, such as mobile telephony.[34] The FCC then "assigns" those frequencies to licensees,[35] such as Verizon Wireless or ABC. A licensee is entitled to operate devices that transmit in the specified frequency, usually in a specific geographic area and occasionally during specified times.[36] It is also entitled to protection against other licensees or nonlicensed transmitters that cause it "harmful interference."[37] It is not entitled to sell or subdivide its license without FCC approval, and the license is officially temporary.[38]

B. The Property Critique

The government licensing model for spectrum policy fit the *zeitgeist* of the first half of the twentieth century. This was the high-water point for "scientific management" of economic activity.[39] While the Soviet Union extolled the virtues of central planning, the bureaucrats of Franklin Roosevelt's New Deal preached that expert managers could efficiently steer economic activity.[40] And indeed, radio, television, and other forms of wireless communication became huge and hugely influential industries under the

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32. For an overview of the current spectrum management process, see Charles L. Jackson, *Use and Management of the Spectrum Resource*, *in* 1 NEW DIRECTIONS IN TELECOMMUNICATIONS POLICY 247–71 (Paula L. Newberg ed., 1989).

33. 47 U.S.C. § 303(y) (2000). The FCC has responsibility for privately used spectrum. The National Telecommunications and Information Administration (NTIA) of the Department of Commerce oversees government spectrum usage, in conjunction with the agencies (including the Department of Defense, Federal Aviation Administration, and NASA) that have spectrum allocations. *See* 47 U.S.C. § 305(a) (2000) (stating that government owned and operated radio stations are not subject to FCC regulations except when operating for nongovernment purposes). The government either shares or controls two-thirds of the most easily used spectrum (in the range between 30 KHz and 3 GHz) and outright controls a quarter of it.

34. 47 U.S.C. § 303(b), (c).

35. 47 U.S.C. § 303(c).

36. *Id.*

37. *Id.*; 47 C.F.R. § 2.1(c) (2002).

38. 47 C.F.R. § 73.3540(a) (2004); *see also* 47 C.F.R. § 73.1020(a) (2004) (requiring renewal of broadcast licenses every eight years).

39. *See generally* FREDERICK WINSLOW TAYLOR, THE PRINCIPLES OF SCIENTIFIC MANAGEMENT 26 (Norton 1967) (1911) (describing scientific management as promoting work "done in accordance with scientific laws" and as requiring increased preparatory acts and guidance from management to allow workers to perform effectively).

40. *See* James E. Anderson, *The New Deal, Capitalism, and the Regulatory State*, *in* THE ROOSEVELT NEW DEAL: A PROGRAM ASSESSMENT FIFTY YEARS AFTER 105, 109 (Wilbur J. Cohen ed., 1986) (describing New Deal economic regulation as motivated by a desire to protect the public interest when competition was deemed inadequate to the task).

FCC's stewardship. The FCC's status as the benevolent ruler of the airwaves persisted unchallenged for a quarter century. In the 1950s, however, economists began to critique the rationale for government-issued spectrum licenses.

The economists argued that instead of being managed by government, spectrum rights should be bought and sold like any other commodity. The first to articulate this view was a law student, Leo Herzel, in 1951.[41] The argument was taken up brilliantly by Ronald Coase in 1959 in an article that eventually contributed to his 1991 Nobel Prize in Economics.[42] Coase's basic point was that markets are the most efficient mechanisms for allocating scarce resources.[43] Spectrum is no different from any other scarce resource, so markets should be used to allocate and assign spectrum.[44] Instead of granting licenses, he asserted, government should issue property rights that companies could then trade, subdivide, combine, or modify through mutual negotiation.[45] Later authors, notably Arthur De Vany, Harvey Levin, Jora Minasian, and Milton Mueller,[46] took up the challenge of defining just what those initial property rights should look like.

Along with their proposals for what form spectrum rights should take, economists following Coase suggested a mechanism to use in assigning those rights: auctions.[47] A variety of other mechanisms for spectrum assignment have been used or considered, such as first-come, first-served; comparative hearings; and lotteries.[48] All of these could and did fall victim to inefficiencies, capture by interest groups, or out-and-out corruption.[49]

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41. Leo Herzel, Comment, *"Public Interest" and the Market in Color Television Regulation*, 18 U. CHI. L. REV. 802 (1951).

42. Coase, *supra* note 3.

43. *Id.* at 18.

44. *Id.* at 14.

45. *See id.* at 30 (arguing that subsequent market transactions determine how a right is used).

46. *See* Arthur S. De Vany et al., *A Property System for Market Allocation of the Electromagnetic Spectrum: A Legal-Economic-Engineering Study*, 21 STAN. L. REV. 1499, 1512 (1969) (proposing that the property right be defined using "the time of the transmission, the geographical area covered, and the portion of the spectrum over which radio waves are emitted"); HARVEY J. LEVIN, THE INVISIBLE RESOURCE: USE AND REGULATION OF THE RADIO SPECTRUM 26–39 (1971) (discussing the economic characteristics of spectrum); Jora R. Minasian, *Property Rights in Radiation: An Alternative Approach to Radio Frequency Allocation*, 18 J.L. & ECON. 221, 232 (1975) (suggesting that property rights in electromagnetic radiation should consist of emission rights, admission rights, use, and transferability); MILTON MUELLER, PROPERTY RIGHTS IN RADIO COMMUNICATION: THE KEY TO THE REFORM OF TELECOMMUNICATIONS REGULATION 29–39 (Cato Institute, Cato Policy Analysis No. 11, 1982) (defining the "property" as the transmitter and receiver hardware and inputs, and the property boundaries in terms of avoiding harmful interference to the receivers of other transmitters), *available at* http://www.cato.org/pubs/pas/pa011_es.html.

47. *See, e.g.*, LEVIN, *supra* note 46, at 142–57 (describing and critiquing the use of auctions to determine price).

48. *See* Mueller, *supra* note 46, at 18–20, 28 (reviewing these approaches as ways of controlling markets).

49. *See id.* at 24–29 (explaining the problems inherent in controlled markets).

Spectrum auctions are designed to put licenses in the hands of those who value them most highly and who will therefore make the highest bid. Auctions have become the FCC's preferred assignment vehicle because of their perceived efficiency and revenue-generation benefits for the U.S. government.[50]

The economists' critique of spectrum policy was part of a larger project to demolish the foundations of scientific management.[51] The Austrian School, led by Friedrich Hayek, and its American adherents in the Chicago School, have largely succeeded in promoting laissez-faire principles and price-based mechanisms in almost all areas of economic activity.[52] In fact, wireless communication may be the major sector of economic activity where they have been *least* successful. What the FCC auctions today is still a license, not an alienable property right. In recent years, economists such as Thomas Hazlett and Lawrence White have vigorously pushed the FCC to take the final step and turn spectrum into private property.[53] The FCC, which at first dismissed Coase's proposal, has moved closer and closer to the economists' position. Its 2000 Spectrum Policy Statement extolled the virtues of market forces in spectrum policy, a code word for property rights.[54]

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50. *See* Noam, *supra* note 4, at 772 (claiming that the "underlying objective" for auctions is raising revenues for the government, while "allocating spectrum resources efficiently [is] a secondary goal"); Leonard M. Baynes & C. Anthony Bush, *The Other Digital Divide: Disparity in the Auction of Wireless Telecommunications*, 52 CATH. U. L. REV. 351, 352–53 (2003) (explaining that a competitive bidding process for spectrum licenses is expected to generate billions of dollars for the federal treasury and is favored for its perceived efficiency).

51. It is also part of a more recent deregulatory movement in regulated industries. *See* Joseph D. Kearney & Thomas W. Merrill, *The Great Transformation of Regulated Industries Law*, 98 COLUM. L. REV. 1323, 1329–64 (1998) (chronicling the transformation in the regulation of the transportation, telecommunications, and energy industries).

52. *See generally* Virginia Postrel, *Friedrich the Great*, BOSTON GLOBE, Jan. 11, 2004, at L.1 (stating that Hayek "helped catalyze the free-market political movement in the United States"); Virginia Postrel, *We Are Not All Hayekians Now*, FORBES, Mar. 20, 2000, at 142 (arguing that Hayek's most lasting contribution to economics was "[t]he notion that free markets and free prices are a means of conveying and exploiting information").

53. *See* Thomas W. Hazlett, *The Wireless Craze, the Unlimited Bandwidth Myth, the Spectrum Auction Faux Pas, and the Punchline to Ronald Coase's "Big Joke": An Essay on Airwave Allocation Policy*, 14 HARV. J.L. & TECH. 335, 405 (2001) (stating that private property in spectrum is the "enabling policy" that permits competitive allocation); Lawrence J. White, *"Propertyzing" the Electromagnetic Spectrum: Why It's Important, and How to Begin*, MEDIA L. & POL'Y, Fall 2000, at 19, 20 (advocating that the current system of licenses to use the spectrum be converted into a property rights system of ownership); Pablo T. Spiller & Carlo Cardilli, *Towards a Property Rights Approach to Communications Spectrum*, 16 YALE J. ON REG. 53, 82 (1999) (asserting that the government should designate spectrum as property that can be owned, registered, and titled).

54. *See* Principles for Promoting the Efficient Use of Spectrum by Encouraging the Development of Secondary Markets, 15 F.C.C.R. 24178, 24181 (2000) (policy statement) (stating that the "best way to realize the maximum benefits from the spectrum is to permit and promote the operation of market forces in determining how spectrum is used").

C. The Commons Critique

Just as advocates of property rights in spectrum seem headed for their final victory, they face a new challenge. A novel critique has emerged that does not defend the government licensing regime. In fact, it largely grants that property rights were superior techniques for regulating use of spectrum when Coase proposed them. Its claim is that developments in technology make possible a still-better approach: treatment of spectrum as a commons.[55]

The commons argument recognizes that spectrum can now be shared effectively, without requiring exclusive frequency licensing. Recall that Marconi's use of frequency division to allow signals to coexist was a particular technical choice; it was not a basic property of radio communication.[56] A variety of techniques, some dating back to the 1940s, allow two or more transmitters to coexist on the same frequency. The best-known of these is spread-spectrum. As demonstrated by Bell Labs researcher Claude Shannon in his seminal 1948 papers on information theory, a signal can either be sent across a narrow channel at high power, or spread across a wide channel at lower power.[57] When the signal is spread, the lower power reduces the degree of interference on another signal.

The practical consequence is that no government regulator or property owner need decide which signal is entitled to use the frequency; both of them can use it simultaneously. More generally, spectrum, or portions of it, can be treated as a commons, in which anyone is free to enter. In such an

55. *See generally* Yochai Benkler, *Overcoming Agoraphobia: Building the Commons of the Digitally Networked Environment*, 11 HARV. J.L. & TECH. 287 (1998); LAWRENCE LESSIG, THE FUTURE OF IDEAS: THE FATE OF THE COMMONS IN A CONNECTED WORLD (2001); NOBUO IKEDA & LIXIN YE, SPECTRUM BUYOUTS: A MECHANISM TO OPEN SPECTRUM (RIETI Discussion Paper Series 02-E-002, 2003) (advocating a similar position, but using the term "protocol" instead of "commons"), *available at* http://www.rieti.go.jp/jp/publications/dp/02e002.pdf; Kevin Werbach, *Open Spectrum: The Paradise of the Commons*, RELEASE 1.0, Nov. 2001, at 1. The commons position is also sometimes referred to as "open spectrum" or "open wireless." *Id.* at 18 (using the "open spectrum" terminology); Benkler, *supra* note 6, at 28–29 (using the "open wireless" terminology); *cf.* Scott Woolley, *Dead Air*, FORBES, Nov. 25, 2002, at 138, 138 ("It is the bitter irony of America's skies: Open airwaves are everywhere, yet the people desperate to use them cannot."). I use the term commons here because it is widely used to describe the argument, and because it emphasizes the relationship of this viewpoint to a broader critique of current legal orthodoxies related to the digital world. *See infra* note 71 (discussing the vision of those who support a wireless commons).

56. *See supra* text accompanying note 21. Frequency is a physical property; frequency division is a technical design choice.

57. C.E. Shannon, *A Mathematical Theory of Communication*, 27 BELL SYS. TECHNICAL J. 623, 639–42 (1948) (continuation of paper having the same title published in earlier issue, 27 BELL SYS. TECHNICAL J. 379 (1948)) (deriving expressions representing channel capacity as the product of bandwidth and the logarithm of the transmitter power, such that a given channel capacity can be achieved with either a low power and high bandwidth or vice versa), *version combining both papers available at* http://cm.bell-labs.com/cm/ms/what/shannonday/shannon1948.pdf. *See also* George Gilder, *The New Rule of Wireless*, FORBES ASAP, Mar. 29, 1993, at 96, 98 (describing Shannon's work as illuminating a choice between "narrowband high-powered solutions and broadband low-powered solutions").

environment, property rights are at best unnecessary and at worst deleterious.[58] The main real-world manifestations of spectrum commons are the unlicensed bands, where any device certified to meet specified technical criteria may operate.[59] Unlicensed bands are products of the same FCC allocation process as other frequency bands, but instead of being assigned to an exclusive user or users, they are left open to any devices certified to meet specified technical criteria.[60]

The commons critique was first voiced in the early 1990s by technology pundit George Gilder and renowned network engineer Paul Baran.[61] It was

58. Lessig and Benkler draw a parallel between the possibility of an open-entry commons at the "physical layer" of networks and the commons that the public domain represents vis-à-vis copyright at the "content layer." *See* LESSIG, *supra* note 55, at 23–25 (noting that each layer of communications could be owned or organized in a commons and giving examples); Yochai Benkler, *From Consumers to Users: Shifting the Deeper Structures of Regulation Toward Sustainable Commons and User Access*, 52 FED. COMM. L.J. 561, 562–63 (2000) (suggesting that a communications system should be divided into three distinct layers: "physical," "logical," and "content"). For a further explication of the layered model of communications, see Kevin Werbach, *A Layered Model for Internet Policy*, 1 J. TELECOMM. & HIGH TECH. L. 37, 58–64 (2002).

59. *See* Revision of Part 15 of the Rules Regarding the Operation of Radio Frequency Devices Without an Individual License, 4 F.C.C.R. 3493, ¶ 130 (1989) (first report and order) [hereinafter Revision of Part 15] (establishing the spread-spectrum bands at 900 MHz, 2.4 GHz, and 5 GHz); Amendment of the Commission's Rules to Provide for Operation of Unlicensed NII Devices in the 5GHz Range, 12 F.C.C.R. 1576, 1618–30 (1997) (report and order) [hereinafter U-NII Order] (establishing the Unlicensed National Information Infrastructure Bands).

60. The bands originally designated as unlicensed by the FCC were so full of other uses, including microwave ovens, medical equipment, and garage door openers, as to be unsuitable for licensed operation. Unlicensed bands are sometimes described as "licensed by rule" because they are in fact subject to FCC licenses like any other band. Comments of Microsoft Corporation at 1 n.1 (Jan. 27, 2003), Commission Seeks Public Comment on Spectrum Policy Task Force Report, 17 F.C.C.R. 24316 (2002) (ET Docket No. 02-135), *available at* http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6513404972. The difference is that the license is extended by rule to any device meeting the FCC's technical criteria, rather than those approved by an individual licensee.

61. *See* Gilder, *supra* note 57, at 98–99 (discussing the dilemmas facing corporations and entrepreneurs in the wireless industry in moving from "long and strong" to "wide and weak" frequencies); Paul Baran, Visions of the 21st Century Communications: Is the Shortage of Radio Spectrum for Broadband Networks of the Future a Self Made Problem?, Keynote Address at the 8th Annual Conference on Next Generation Networks (Nov. 9, 1994) (transcript available through the Electronic Frontier Foundation) (hypothesizing that there is no real "shortage of spectrum space" and thus that heavy regulation over such space is not necessary), *available at* http://www.eff.org/GII_NII/Wireless_cellular_radio/false_scarcity_baran_cngn94.transcript. Baran is best known for developing the technique of packet-switching, on which the Internet is built. Gilder's support for a wireless commons is notable given his anti-government bent in other areas. Gilder, in fact, is on most topics a leading advocate of removing the pro-competitive regulatory safeguards that members of the commons camp such as Lessig support. *See* GEORGE GILDER, TELECOSM: HOW INFINITE BANDWIDTH WILL REVOLUTIONIZE OUR WORLD 156–58 (2000) [hereinafter GILDER, TELECOSM] (arguing for deregulation of telecommunications). Gilder's advocacy on technical grounds of unlicensed wireless systems, rather than exclusive rights, hints at the deep connections between the supposedly opposed property and commons positions in the spectrum debate. *See infra* note 233 and accompanying text.

expanded and formalized by two academics, Eli Noam and Yochai Benkler.[62] Noam used the possibility of spectrum sharing to demonstrate the failings of auctions and to show that the economists' critique did not necessarily lead to exclusive property rights to transmit on specified frequencies.[63] Benkler argued that spread-spectrum techniques allowed for institutional arrangements that did away with the need for price signaling in transmission rights entirely.[64] He further claimed that such commons regimes were normatively superior to property regimes, because they allowed more speech and served the preference functions of a wider range of users.[65] Others who have built on the commons critique include myself,[66] cyberlaw scholar Lawrence Lessig,[67] technologist David Reed,[68] and attorney Stuart Buck.[69]

Two elements of the commons critique bear noting. First, it rests on two independent rationales: greater efficiency in optimizing the social welfare gains from wireless communication[70] and better fidelity to social values

62. *See generally* Benkler, *Building the Commons*, *supra* note 55; Benkler, *supra* note 6; Noam, *supra* note 4.

63. *See* Noam, *supra* note 4, at 771–78. Noam's 1998 paper expanded on his earlier work endorsing what he calls "open access" for wireless. *See* Eli M. Noam, *Taking the Next Step Beyond Spectrum Auctions: Open Spectrum Access*, 33 IEEE COMM. MAG. 66 (1995). Noam argues not for free access, but for open entry subject to a variable fee. *Id.* at 66. He acknowledges that his proposal may not be practical today, but argues that when it is, it will achieve the best of both the commons and property worlds. *Id.* at 71–73.

64. Benkler, *Building the Commons*, *supra* note 55, at 324–25, 396.

65. *Id*. at 389–91.

66. *See generally* Werbach, *supra* note 55 (urging government agencies to designate spectrum blocks for open, unlicensed use and to allow ultra-wideband services to overlay licensed bands); KEVIN WERBACH, NEW AM. FOUND., RADIO REVOLUTION: THE COMING AGE OF UNLICENSED WIRELESS (2003) (explaining how the paradigm shift in wireless communication makes the commons approach viable); KEVIN WERBACH, OPEN SPECTRUM: THE NEW WIRELESS PARADIGM (New Am. Found., Spectrum Series Issue Brief No. 6, 2002) [hereinafter WERBACH, NEW WIRELESS PARADIGM] (advocating the promotion of "open spectrum" by the U.S. government); Comments of Kevin Werbach (July 8, 2002), Spectrum Policy Task Force Seeks Public Comment on Issues Related to Commission's Spectrum Policies, 17 F.C.C.R. 10560 (2002) (ET Docket No. 02-135) (advising the FCC to facilitate the continued growth of unlicensed wireless technologies), *available at* http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6513200941.

67. *See, e.g.*, LESSIG, *supra* note 55, at 218–33 (arguing for a system in which parts of the spectrum are designated as commons while other parts are distributed by auction).

68. *See* Comments of David P. Reed (July 15, 2002), Spectrum Policy Task Force Seeks Public Comment on Issues Relating to Commission's Spectrum Policies, 17 F.C.C.R. 10560 (2002) (ET Docket No.02-135) [hereinafter Comments of Reed] (arguing that the "new frontier" being opened up by recent advances in communications technology cannot be properly addressed by a model of exclusive spectrum property rights), *available at* http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6513201195; David Weinberger, *The Myth of Interference*, SALON, Mar. 12, 2003 (explaining Reed's ideas), *at* http://www.salon.com/tech/feature/2003/03/12/spectrum/print.html.

69. Buck, *supra* note 7 (advocating a system of spectrum regulation as a "Common Property Regime").

70. Though economists developed the property position and proponents of the commons emphasize technology, it is too simplistic to cast this as a debate between the virtues of economics and engineering. Commons advocates are perfectly capable of framing their arguments in economic

such as autonomy, diversity, and innovation.[71] Second, commons advocates accept the economists' diagnosis of the problem, just not their solution. The commons critique acknowledges that scarcity does not justify government control of spectrum, but is, in fact, exacerbated by it. It concurs that spectrum should be managed through market forces rather than government dictates.[72] But, it shifts the debate. It highlights the common assumption of exclusivity between government licensing and property rights, and opposes it with lightly controlled forms of shared access.[73]

Despite its relative novelty and the widespread acceptance of the spectrum-as-property position, the commons critique has rapidly gained traction. Advocates of expanded property rights in spectrum have felt the need to critique it, though initially these attacks were dismissive.[74]

D. The FCC Spectrum Task Force Report

The FCC, the object of all this intellectual give-and-take, hasn't been a passive bystander. Though the Commission initially dismissed the economists' critique,[75] it gradually came around to the view that a market-based spectrum policy, and particularly spectrum auctions, were preferable to the tools it had previously used.[76] The FCC won authority from Congress in

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terms. *See, e.g.*, Benkler, *supra* note 6, at 49–56; Noam, *supra* note 4, at 778–80 (both describing the "open-access model" using economic principles). The normative prong of the commons attack offers an independent justification even if the economic debate is stalemated.

71. *See* Benkler, *Building the Commons*, *supra* note 55, at 386–88 (discussing the social implications of unlicensed wireless operations); Yochai Benkler, *Siren Songs and Amish Children: Autonomy, Information, and Law*, 76 N.Y.U. L. REV. 23 (2001) [hereinafter Benkler, *Siren Songs*] (discussing the effect of different policy choices on autonomy); LESSIG, *supra* note 55, at 266 (describing the correspondence between free resources and innovation). Like the economists who developed the property rights proposal for spectrum, the leading academic supporters of a wireless commons have a larger program in mind. They envision communications, media, and technology industries that respect the value of commons to promote innovation and allow greater freedom and control for individuals. *See* Benkler, *supra* note 58, at 568 (asserting that "open and equal participation" will help to secure "both robust democratic discourse and individual expressive freedom").

72. In this case, though, the market is for end-user equipment rather than tradable spectrum rights.

73. *See* Noam, *supra* note 4, at 768–69 (noting that the new paradigm of "open access" diverges from previous paradigms, which were based on "licensed exclusivity").

74. *See* Thomas W. Hazlett, *Spectrum Flash Dance: Eli Noam's Proposal for "Open Access" to Radio Waves*, 41 J.L. & ECON. 805, 816–19 (1998) [hereinafter Hazlett, *Spectrum Flash Dance*] (stating that the "open spectrum access model" fails because of "twin fallacies"); Hazlett, *supra* note 53, at 481–510 (discussing the "spectrum abundance fallacy" upon which the commons critique purportedly rests).

75. When Coase testified before the FCC in 1959, one FCC Commissioner began by asking whether his proposal was just a big joke. Hazlett, *supra* note 53, at 343.

76. *See, e.g.*, FCC Chairman Reed E. Hundt, Spectrum Policy and Auctions: What's Right, What's Left, Remarks to Citizens for a Sound Economy (June 18, 1997) (discussing the advantages of the "New Spectrum Policy" that relies on markets and competition), *at* http://www.fcc.gov/Speeches/Hundt/spreh734.html.

1993 to issue licenses through auctions.[77] It held its first major auctions, for Personal Communications Service, in 1995.[78] By 1997, auctions had become the FCC's preferred mechanism for spectrum assignment,[79] and the Commission was well on its way toward adopting the rest of the economists' proposals: flexibility,[80] secondary markets, and (ultimately) full property rights. The word "unlicensed" does not appear in the November 1999 FCC press release announcing its comprehensive Spectrum Policy Statement.[81] As recently as November 2000, the FCC's major spectrum reform initiative was a proceeding to authorize secondary markets.[82]

Given this history, the FCC's November 2002 Spectrum Policy Task Force Report[83] is surprising. The Task Force worked for several months to develop a detailed comprehensive blueprint for future FCC spectrum decisions. The report endorsed expansion of property rights in spectrum, or as it preferred, "exclusive use." It also, however, devoted a significant portion of its analysis to the commons model, treating it as a promising approach on par with exclusive use.[84] The report suggested that exclusive use should generally be the primary mechanism for desirable lower-frequency spectrum, while commons should be the primary mechanism above 50 GHz.[85] Following the Spectrum Task Force Report, the Commission launched several proceedings to make available more unlicensed spectrum, including the allocation of an additional 255 MHz in

77. *See* Omnibus Budget Reconciliation Act of 1993, Pub. L. 103-66, 107 Stat. 312 (1993) (codified at 47 U.S.C. § 309 (2000)). *See generally* Omnibus Budget Reconciliation Act of 1993, Pub. L. 103-66, 107 Stat. 312 (1993) (codified at 47 U.S.C. § 309). This Act explicitly gives the FCC the authority to grant licenses "through a system of competitive bidding." 47 U.S.C. § 309(j)(1).

78. Press Release, FCC, FCC Opens First Ever Airwave Auctions (July 25, 1995), *available at* http://www.fcc.gov/Bureaus/Wireless/News_Releases/nrwl4006.txt.

79. *See* Hundt, *supra* note 76 ("Auctions are superior in every way to all other forms of licensing."); Buck, *supra* note 7, at ¶¶ 13–19 (discussing the history of spectrum auctions); *see also* EVAN KWEREL & JOHN WILLIAMS, A PROPOSAL FOR A RAPID TRANSITION TO MARKET ALLOCATION OF SPECTRUM (FCC, Office of Plans and Policy Working Paper No. 38, 2002) (proposing a restructuring of the current auction system).

80. *See* Gregory L. Rosston & Jeffrey S. Steinberg, *Using Market-Based Spectrum Policy to Promote the Public Interest*, 50 FED. COMM. L.J. 87, 99–100 (1997) (noting that the FCC was taking steps at the time to increase flexibility in ownership rights for new and existing spectrum).

81. *See* Press Release, FCC, FCC Issues Guiding Principles for Spectrum Management (Nov. 18, 1999), *available at* http://www.fcc.gov/Bureaus/Engineering_Technology/News_Releases/1999/nret9007.html.

82. *See* Press Release, FCC, FCC Takes Steps to Make More Spectrum Available Through the Development of Secondary Markets (Nov. 9, 2000) (announcing that the FCC intends to promote development of secondary markets in radio spectrum), *available at* http://www.fcc.gov/Bureaus/Engineering_Technology/News_Releases/2000/nret0012.html.

83. *See* Spectrum Policy Task Force Report, ET Docket No. 02-135 (FCC Nov. 15, 2002) [hereinafter Spectrum Task Force Report], *available at* http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-228542A1.pdf.

84. *See id.* at 35–37.

85. *See id.* at 38–41.

the 5 GHz range[86] and a proposal to allow unlicensed "underlays" in the broadcast television bands.[87]

There are several reasons for the rapid legitimation of the commons argument, beyond the rhetorical persuasiveness of its proponents: lingering fears about the consequences and irreversibility of spectrum propertization, excitement about unlicensed wireless data networks due to the business success of WiFi,[88] and desire for fresh approaches given the collapse of the telecom sector and the problems with some spectrum auctions in the United States and Europe.[89] Regardless, the commons position is now entrenched as a factor in spectrum policy. The debate is now between two rival proposals, instead of about whether or not to change from the status quo.

E. Seeing Clearly

Unfortunately, the argument is being framed in the wrong way. The common picture of the spectrum debate as a winner-take-all battle over whether to treat frequency bands as private property or unlicensed commons is problematic. Property and commons are not polar opposites. They are different, and the differences matter, but both will almost certainly be part of spectrum policy for the foreseeable future. More important is what the simplistic property vs. commons description leaves out. It ignores an array of new techniques that could transform use of the radio spectrum. Both proposals structure rights too coarsely, creating insurmountable transaction costs for novel communications mechanisms. An expanded formulation of the commons critique reveals not just an alternate way to manage frequency bands, but an entirely different way to look at wireless communication. Understood properly, spectrum is more than frequencies and less than a scarce physical resource.

By challenging the assumption that interference risk necessitates legally enforced exclusivity, the commons argument opens the door to a fundamental reframing of wireless regulation. We've been engaged in the

86. *See* Unlicensed Devices in the 5 GHz Band, 68 Fed. Reg. 44,011 (proposed July 25, 2003) (to be codified at 47 C.F.R. pts. 2 and 15). The FCC also released a staff working paper reviewing the benefits of unlicensed spectrum. *See* KENNETH R. CARTER ET AL., UNLICENSED AND UNSHACKLED: A JOINT OSP-OET WHITE PAPER ON UNLICENSED DEVICES AND THEIR REGULATORY ISSUES (FCC, Office of Strategic Policy Working Paper Series No. 39, 2003), *available at* http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-234741A1.pdf.

87. Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band, 17 F.C.C.R. 25, 632, 25, 635–40 (2002) (notice of inquiry) [hereinafter TV Band NOI].

88. *See infra* note 404 and accompanying text. WiFi (wireless fidelity) is a family of protocols for wireless local area networks issued by the Institute of Electrical and Electronic Engineers (IEEE). *See* Amey Stone, *Wi-Fi: It's Fast, It's Here—and It Works*, BUSINESSWEEK ONLINE, Apr. 1, 2002 (discussing the business potential of wireless Internet technology), *at* http://www.businessweek.com/technology/content/apr2002/tc2002041_1823.htm.

89. *See* Peter W. Huber, *Telecom Undone—A Cautionary Tale*, COMMENTARY, Jan. 2003, at 34, 34–38.

wrong debate about the wrong things. The wrong debate, because both property and commons are configurations of the same matrix: a web of rights, privileges, and duties assigned to certain types of equipment. The wrong things, because as Part III will demonstrate, concepts such as "spectrum," "interference," and "frequency bands" are deeply misleading. Removing those veils makes possible a new theory of wireless regulation that best promotes efficiency, equity, and freedom.

Both the property and commons approaches propose that users of wireless transmitters and receivers be subject to special legal conditions not applicable to other forms of private property.[90] For example, transmitters may only operate on certain frequencies. The government licensing model has the same effect. It differs in the restrictiveness of the conditions (for example, specifying services and protocols) and, most importantly, in forbidding any changes to the property rights without government authorization. The major innovation of the commons mechanism is in what the property rights *do not* grant. They do not impose duties upon other equipment as a corollary to the transmission rights.[91]

A broadcast license allows the licensee to build a transmission tower and to summon federal marshals to tear down pirate antennas in the same region.[92] This power extends even to pirate broadcasters operating in adjacent locales or bands, if those cause harmful interference to the licensee.[93] A fee simple ownership right granted to that broadcaster would have the same benefits. The fact that the right is now "private," and can be traded or altered through the market, does not alter its basic structure. Government is not just giving something to the broadcaster; it is taking something away from all potential pirate radio operators, even though they are not party to the agreement. Using a commons approach, however, the

90. The FCC's rules governing "unintentional" and "incidental" radiators technically constrain property rights in other kinds of devices, such as microwave ovens and the microprocessors powering personal computers. *See* 47 C.F.R. §§ 15.13, 15.102, 15.103 (2002). Since these devices are not intended for communication, they do not fall within this analysis.

91. The exception is a commons with a "Part 16" duty imposed on devices that are not part of the commons. Apple proposed such a mechanism for the U-NII band, but the FCC rejected it as unnecessary. U-NII Order, *supra* note 59, ¶ 91. Benkler advocates such a rule. *See* Benkler, *Building the Commons*, *supra* note 55, at 392; Benkler, *supra* note 6, at 77–78 (both arguing that the FCC should reopen its U-NII proceedings to adopt the Part 16 model). Part 16 is a further refinement of the commons model in which the absence of corollary duties extends only to devices of the same class as the transmitting device.

92. *See* 47 U.S.C. § 510(a) (2000) (equipment used in unlicensed transmissions may be seized and forfeited to the United States); United States v. Any & All Radio Station Transmission Equip., 204 F.3d 658, 661–62 (6th Cir. 2000) (recounting the government's filing of an action to seize pirate radio equipment subsequent to a complaint by a licensed radio station); Press Release, FCC, FCC Closes Down 15 Unlicensed Radio Stations in Miami Area (Aug. 18, 1998), *available at* http://ftp.fcc.gov/Bureaus/Compliance/News_Releases/1998/nrci8017.html.

93. 47 U.S.C. § 301 (2000) (prohibiting various unlicensed transmissions, including those causing interference).

property right would still include an entitlement to transmit but not the corollary ability to exclude other transmitters in the same band. Every WiFi user is both an authorized transmitter and a "pirate" to other authorized transmitters.

Why should rights granted to one user imply obligations on other users not subject to that grant?[94] The reason is that rights are relational. They have no value if others take actions that render those rights worthless. Whether and how that should be factored into the legal allocation, however, is a contingent decision. Law offers many configurations for different situations. Ownership of land conveys a right to exclude others from that land (trespass) and rights to regulate actions taken elsewhere (nuisance). Trademarks convey rights to prevent others from engaging in similar uses but not to prevent different uses or descriptive utterances. The Fifth Amendment protection against self-incrimination conveys a privilege to remain silent and a duty on the government not to interrogate you, but no right to prevent others from incriminating you.

So, where on the spectrum (pardon the pun) does spectrum fit? My claim is that spectrum is at worst like trademark and at best like self-incrimination, yet it is being treated like land. The common metaphor of trespass to spectrum oversimplifies the diverse mechanisms for structuring legal obligations around wireless devices.

Computational technology has enjoyed such huge improvements that today's wireless devices are qualitatively different from those of Marconi's day. Even the technology and usage patterns of the 1950s and 1960s, when Coase issued his critique and others elaborated upon how it could be implemented, are barely relevant today. Wireless rights look the way they do because of assumptions about interference.[95] Modern wireless systems, and those just over the horizon, are not just orders of magnitude more efficient at minimizing interference. They turn interference into a different kind of problem. In so doing, they turn the spectrum debate upside down.[96] Instead of strengthening exclusive control of frequencies through perpetual property rights, we should be making it broadly possible to share spectrum in ways we cannot even imagine today.

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94. Saying that the right to exclude is fundamental to the grant of rights begs the question. *See* Loretto v. Teleprompter Manhattan CATV Corp., 458 U.S. 419, 435 (1982) ("The power to exclude has traditionally been considered one of the most treasured strands in an owner's bundle of property rights."). Why should a right to transmit or a possessory right in real property include a right to exclude as part of the bundle? The answer is that the overall right becomes meaningless if others interfere with the signal or trample the land. This is just another way of saying that rights are inherently social and dependent on assumptions about how third parties can and will behave.

95. *Cf.* White, *supra* note 53, at 22 ("From the early 1900s to the present day the basic problem of using the spectrum has been seen as that of interference.").

96. *See Watch This Airspace*, ECONOMIST, June 22, 2002, at 14 (describing four disruptive technologies that "could shake up the wireless world").

III. The Spectrum Fallacy

To rebuild the legal framework for wireless communication, we must first remove the façades that obscure clear thinking. Spectrum policy falls victim to several fallacies. Each is demonstrably false, yet remarkably durable. The most damaging is the notion that there is such a thing as spectrum and that it behaves as a fixed physical resource like land. Establishing a legal regime under such a misconception is like sailing west from Europe to find a shorter trade route to India. You might find something interesting along the way, but you will never achieve your objective.

The fallacy is not confined to any side in the spectrum debate. However, overcoming the confusion provides ammunition for the commons position.

A. There Is No Cat

1. Spectrum.—Albert Einstein, when asked to explain radio, is reported to have replied:

> You see, wire telegraph is a kind of a very, very long cat. You pull his tail in New York and his head is meowing in Los Angeles. Do you understand this? And radio operates exactly the same way: you send signals here, they receive them there. The only difference is that there is no cat.[97]

Einstein's analogy is accurate because it says only what spectrum *is not*. There is no proper way to explain what spectrum is because there is no such thing as spectrum. It is an illusion we grasp hold of to avoid concepts that trouble our intuitions about how the world works. Radio transmissions are tied to frequencies only because that is the mechanism Marconi developed for multiplexing simultaneous signals in the same physical space.[98] Spectrum as a progression of frequencies tied to services exists nowhere in nature. It is analogous to the periodic table of elements, helpful for understanding, but purely an intellectual construct. The reification of that construct into a concrete physical manifestation causes nothing but confusion.[99]

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97. Allen H. Kupetz, *A Nightclub in Your Pocket; Playing Around with 4G Wireless*, WIRELESS BUS. & TECH., Apr. 1, 2003, at 18. The quotation is probably apocryphal.

98. *See supra* notes 19–21 and accompanying text.

99. The desire to treat spectrum as a physical resource parallels the tendency to see cyberspace as a place. Dan Hunter has explored the significance of the "cyberspace as place" metaphor in detail. *See generally* Dan Hunter, *Cyberspace as Place and the Tragedy of the Digital Anticommons*, 91 CAL. L. REV. 439 (2003). Drawing on the work of cognitive scientists, especially George Lakoff, Hunter argues that the physical metaphor for cyberspace is so embedded as to be nearly impossible to replace, despite scholarly rejection of the association between the online world and a distinct physical space. *Id.* at 514–16. The best we can hope for is to contest the implications of the metaphor. *Id.* at 516–18. Spectrum poses a similar challenge. Like cyberspace, it is an unfamiliar, difficult concept. A physical space of frequency bands is much more comfortable to

In any wireless communications system,[100] there are only three elements: transmitters, receivers, and electromagnetic radiation passing between them. The waves do not ride on any medium; they are the medium. In information theory and engineering practice what lies between transmitter and receiver is called a channel. A channel is just another convenient way to describe the interaction of transmitters, receivers, and electromagnetic waves. It does not exist outside those interactions.

The popular notion that radio waves travel through spectrum does not reflect the deep physical structure of reality. It recalls the luminiferous aether, the universal fluid that Isaac Newton postulated to explain how bodies moved through space.[101] The world's leading scientists accepted Newton's construct for centuries, until it became clear that it did not accord with experimental results.[102] It took Einstein's theory of relativity to demonstrate that the aether was a fiction and to offer a new mechanism to do what that fiction had done.[103]

It is no more rational to talk about rights in spectrum than rights in the musical scale.[104] What government is assigning are rights to use certain types of equipment. That is true whether the legal regime is licensing, property, commons, or anything else that can be imagined.[105] Government

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imagine. By attacking the "spectrum as land" metaphor, I do not imagine it can be eradicated. If policymakers could understand not to treat spectrum as property simply because land is property, that would be sufficient. For the same reason, I will continue to use the term "spectrum" in the remainder of this Article.

100. The word "wireless" is not without its own difficulties. It is, like the horseless carriage, defined by what it is not. In the 1880s, when essentially all long-distance communication passed through wires, it was useful to speak of Marconi's invention as removing those wires. The lack of wires, however, no more describes the essential elements of wireless communication than the lack of a horse describes an automobile. An electromagnetic wave propagating through the air is no different than a wave propagating through a wire. The wire confines the signal to a defined physical space, which from a practical standpoint mitigates problems of interference and reception. It also reduces the legal and economic difficulties of determining the ownership or location of a wireless transmission. These are distinctions, but whether they make a difference is an empirical matter.

101. ALEXANDRE KOYRÉ, NEWTONIAN STUDIES 46–48 (1965).

102. The aether has occasionally made explicit appearances. Coase quotes the congressional testimony of Josephus Daniels, the Secretary of the Navy, in 1918: "There is a certain amount of ether, and you cannot divide it up among the people as they choose to use it; one hand must control it." Coase, *supra* note 3, at 3 (citing *A Bill to Further Regulate Radio Communication: Hearings on H.R. 13159 Before the House Comm. on the Merchant Marine and Fisheries*, 65th Cong. (1918)).

103. NICK HERBERT, QUANTUM REALITY: BEYOND THE NEW PHYSICS 7–8 (1985).

104. Coase used this analogy. Coase, *supra* note 3, at 32–33. The musical scale may have some instructional or emotive value, but the fact that the notes may be arranged this way provides no basis for rationing them through a price mechanism.

105. Ironically, Herzel's original article was properly focused on equipment rather than spectrum. Herzel suggested a market mechanism to address competing transmission standards for color television, which had been the subject of controversy at the FCC. He did not recommend treating the spectrum as freely alienable private property. What he actually proposed were long-term leases with complete technical flexibility. Herzel, *supra* note 41, at 811. It was Coase who, while stating that spectrum was not a thing, redirected the property approach toward interference optimization in a hypothetical spectrum resource. *See* Coase, *supra* note 3, at 27–28, 33 (arguing

cannot issue rights in radio frequencies themselves because those frequencies are just properties of electromagnetic waves emitted and received by particular devices. Yet the literature is replete with articles that declare "spectrum" imaginary and proceed to treat it as a concrete physical asset.[106]

The problem is not that spectrum rights are an administrative creation associated with an intangible asset. So are pollution emission credits.[107] The trouble with assigning rights to the administratively created spectrum resource is that it serves no useful purpose. The equivalent would be to assign rights in masses rather than in physical objects such as cars and books that possess those masses. Standing behind the spectrum construct is frequency, which is just a property of electromagnetic waves, which are just energy radiated by equipment with particular properties.[108] Nothing is gained through this indirection. We can consider the equipment properties directly, and in an age of cheap computation and flexible devices, equipment is the better locus for regulation.

Even worse is the pervasive analogy to real estate. Courts considering the exotic realm of cyberspace frequently grasp at familiar common law doctrines designed for land.[109] Spectrum policy experts make the same connection.[110] Yet land is not only a thing, but a thing with very particular

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that property rights in frequencies should be clearly delineated with a goal of maximizing output rather than minimizing interference, while noting that "the properties [of spectrum] correspond exactly to those of something which does not exist").

106. *See infra* notes 110–18 and accompanying text.

107. *See* Carol M. Rose, *The Several Futures of Property: Of Cyberspace and Folk Tales, Emission Trades and Ecosystems*, 83 MINN. L. REV. 129, 164 (1998) (pointing out the prevalence of "hybrid" property rights and describing the "scheme for tradable emission rights for air pollution" incorporated under the 1990 Amendments to the Clean Air Act).

108. Existing spectrum licenses and proposed spectrum property rights involve other restrictions, principally power, geographic location, and time. De Vany and his collaborators combine power and location into a single variable representing the output area of the signal. De Vany et al., *supra* note 46, at 1513–15. However, frequency is always one of the parameters. It is usually the distinguishing one. No one talks about owning a right to emit 10,000 watts or a right to transmit all day; the discussion always centers on control of a frequency band such as 800-806 MHz. *See, e.g.*, *id.* at 1512 (limiting analysis of a property for spectrum-use rights to the frequencies between "50 and 1000 MHz").

109. *See, e.g.*, eBay, Inc. v. Bidder's Edge, Inc., 100 F. Supp. 2d 1058 (N.D. Cal. 2000) (finding trespass to chattels for automatically extracting data from an auction Website); Intel Corp. v. Hamidi, 114 Cal. Rptr. 2d 244 (Ct. App. 2001) (finding trespass to chattels for sending unwanted email to company employees); Compuserve, Inc. v. Cyber Promotions, Inc., 962 F. Supp. 1015 (S.D. Ohio 1997) (finding trespass to chattels for sending unsolicited bulk email).

110. *See* Goodman, *supra* note 5, (manuscript at 16–19) (describing "spectrum as land" as one model used in telecommunications regulation); White, *supra* note 53, at 21 ("Throughout this essay I will employ the analogy of real estate and the property rights that attach to real estate . . . ."); Hazlett, *supra* note 7 (applying legal doctrines derived from land to spectrum); PETER HUBER, LAW AND DISORDER IN CYBERSPACE: ABOLISH THE FCC AND LET COMMON LAW RULE THE TELECOSM 29 (1997) ("[T]his simple idea would have created property rights in the ether, much as common law had created property rights in the land beneath it . . . ."); Hazlett, *Spectrum Flash Dance*, *supra* note 74, at 814 (asserting that the "analogy to land" is "an excellent analogy"). Even Coase, who later in his article stated quite clearly that spectrum was not a physical resource, fell into the trap of drawing parallels between spectrum and land in connection with interference. *See infra* note 123.

qualities. Comparing wireless communication to grazing sheep in a meadow suggests that a whole series of legal and economic constructs applied to meadows can usefully be applied to spectrum. They cannot. A meadow has a specific amount of grass, and one sheep eats so much of that grass each day. Wireless communication works differently.[111]

Even if one were to grant that interference among wireless communications devices is similar to nuisances that adjacent land owners impose on one another, that would not make spectrum analogous to land. The proper analogy would be between wireless communications rights and certain *uses* of land. Ownership of private property always includes limitations on how that property can be used. A murderer, for example, cannot claim he was merely exercising his right to use his legitimately owned gun.[112] A hog farm or tannery may be subject to restrictions for the benefit of adjacent homeowners, not because its activities somehow invade the homeowners' land, but because its use of its own land is inconsistent with the homeowners' enjoyment of theirs. The land is still property, with the same physical boundaries, but the bundle of rights associated with that land has changed.

Crucially, the contours of the landowner's usage rights are defined in a social context, with reference to other owners who may be affected.[113] So too with spectrum. Interference is a function of collective uses and equipment choices, not of the medium involved.

A better, but still misleading, analogy is between spectrum and natural resources. This view appears most prominently in the work of Harvey Levin.[114] Yet even Levin acknowledges that, in precise terms, spectrum is "a three-dimensional *capability* for transmitting information with electromagnetic energy."[115] A capability is not the same as a resource. The

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111. The land analogy is problematic in cyberspace as well. *See* Dan L. Burk, *The Trouble with Trespass*, 3 J. SMALL & EMERGING BUS. L. 27, 32–33 (2000) (questioning the application of trespass to cases such as *Hamidi*); Hunter, *supra* note 99, at 483 (suggesting that the courts' decision to apply trespass to chattels in a cyberspace context is an "extraordinarily damaging" development).

112. This analogy comes from Joseph Singer. *See* JOSEPH WILLIAM SINGER, ENTITLEMENT: THE PARADOXES OF PROPERTY 3 (2000). Coase also used the example of a gun, but for a different point. *See infra* note 340 and accompanying text.

113. *See* SINGER, *supra* note 112, 13–15 (describing the intimate relationship between entitlements and social relations).

114. *See* LEVIN, *supra* note 46, at 16 (stating that "[r]adio spectrum is today not only a [natural] resource but a scarce resource"); Harvey Levin, *The Radio Spectrum Resource*, 11 J.L. & ECON. 433, 433 (1968) [hereinafter Levin, *Radio Spectrum Resource*] ("For practical purposes, the radio spectrum is a three-dimensional natural resource . . . ."); *see also* Christian A. Herter, Jr., *The Electromagnetic Spectrum: A Critical Natural Resource*, 25 NAT. RESOURCES J. 651, 651 (1985) ("Relatively little . . . has been written about a very different natural resource, the electromagnetic spectrum.").

115. Levin, *Radio Spectrum Resource*, *supra* note 114, at 437 (emphasis added).

spectrum resource Levin imagines still has an independent existence from the devices that engage in transmission. Levin admits that, unlike other resources, spectrum is perfectly and costlessly renewable, but suggests this is only a difference of degree.[116] He argues that spectrum is a common property resource that, like oil or fisheries, must be subject to administrative regulation or exclusive property rights to avoid over-use and depletion.[117] In other words, spectrum is a resource because it is subject to interference. Lawrence White makes the same linkage.[118] This assumption is false, for reasons I explain in the next section.

Not all scholars of spectrum policy treat spectrum as corporeal. Benkler repeatedly emphasizes that spectrum is not a thing. He goes so far as to label his preferred solution as "open wireless networks" to avoid references to a "spectrum commons."[119] Benkler wants to avoid the spectrum fallacy because he argues for an industry model, based around end-user purchases of equipment, that operates without licensing. If spectrum is a thing, granting property rights in that thing seems only natural. Better to compare exclusive transmission rights and opportunities for manufacturers to build and sell frequency-sharing equipment.[120]

Coase also clearly understood that spectrum was not a thing. As he explained in his seminal article on the FCC:

> Every regular wave motion may be described as a frequency. The various musical notes correspond to frequencies in sound waves; the various colors correspond to frequencies in light waves. But it has not been thought necessary to allocate to different persons or to create property rights in the notes of the musical scale or the colors of the rainbow.
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> . . . .

116. *Id.* at 454. Levin argues that spectrum has elements of both a fixed "stock" resource (like minerals) and a fluid "flow" resource (like water). *Id.* at 452. Noam argues that spectrum is all flow, *see* Noam, *supra* note 4, at 770, leading Hazlett to counter that there is no difference between the two categories. *See* Hazlett, *Spectrum Flash Dance*, *supra* note 74, at 813–16. The reason for this disagreement is that the basic analogy to natural resources is flawed.

117. Subsequent scholarship has challenged Levin's assumption that common property resources always experience the tragedy of the commons. *See* ELINOR OSTROM, GOVERNING THE COMMONS: THE EVOLUTION OF INSTITUTIONS FOR COLLECTIVE ACTION 15–18 (1990) (advocating establishment of cooperative agreements between "common pool resource" users to solve commons dilemmas such as the tragedy of the commons). *See supra* note 5 and accompanying text; *infra* notes 324–38 and accompanying text.

118. *See* White, *supra* note 53, at 21 ("For spectrum uses, however, transmission interference has been considered fundamental and has provided the tried-and-true justification for the rejection of explicit property rights . . . .").

119. Benkler, *supra* note 6, at 36.

120. And in fact, Benkler develops an economic analysis of why the equipment-oriented market structure is likely to maximize communications capacity. *See id*. at 47–71.

> What does not seem to have been understood is that what is being allocated by the Federal Communications Commission, or, if there was a market, what would be sold, is the right to use a piece of equipment to transmit signals in particular way.[121]

Coase needed this point to counter a different argument than that faced by Benkler. The FCC licensing system bases government control not only on interference avoidance, but on the idea that spectrum is a "public trust."[122] If there is a thing called spectrum that belongs to the American people, government should regulate access to it in the same way it regulates access to the Grand Canyon. Privatizing the Grand Canyon is abhorrent to most Americans. How could government turn over a public treasure in perpetuity to the rapacious interests of private companies? Hence, Coase first had to replace the public airwaves with a set of private transmission rights. He could then convincingly argue that markets should allocate those transmission rights.

2. Interference.—Coase in the 1950s understood that spectrum was an incoherent concept. A related point, the incoherence of interference, would have to wait until technology evolved beyond the analog broadcast systems prevalent at that time.[123] Coase's property rights solution made sense when he developed it, though his work on transaction cost economics revealed just how contingent the determination was.[124] With what we know today, the same analysis leads to a very different conclusion.

It turns out that interference, like spectrum, is a convenient fiction. As a physical matter, radio waves do not bounce off one another. They continue merrily on their way, propagating through free space forever, though attenuating in strength until they become undetectable. In a sense, therefore, interference is always present. No transmitter on Earth is perfectly immune from other signals.[125] What matters in communications systems, however, is

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121. Coase, *supra* note 3, at 32–33.

122. LEVIN, *supra* note 46, at 54.

123. With regard to interference, Coase fell into the very trap of equating spectrum with a physical resource such as land that he warned against later in his paper: "It is clear that, if signals are transmitted simultaneously on a given frequency by several people, the signals would interfere with each other and would make reception of the messages transmitted by one person difficult, if not impossible. The use of a piece of land simultaneously for growing wheat and as a parking lot would produce similar results." Coase, *supra* note 3, at 25.

124. *See* Ronald H. Coase, *The Problem of Social Cost*, 3 J.L. & ECON. 1, 15–19 (1960) (acknowledging that market transactions alone will not maximize output if the cost of optimizing transactions exceeds the value of the resulting increased output); *see also infra* note 426.

125. *See* Hazlett, *supra* note 53, at 374 (recognizing that the proper goal is not to minimize but to optimize the level of interference). The ubiquity of interference is a consequence not only of the fact that signals radiate indefinitely, but also of subharmonic and intermodulation effects. Geographically adjacent systems can experience interference when their transmissions are on exact fractions of each other's frequency, or when the sum of two frequencies equals a third. *See*

not the waves themselves, but the ability to extract information from them. If two waves are nearby in frequency and location, it may be difficult for a receiver to determine which is which.[126] This is no different than the difficulty the receiver has in distinguishing a single wave from the ever-present background noise produced by everything from electric motors to cosmic radiation.[127]

Interference manifests itself in the receiver, not in the radio transmissions themselves. Moreover, it is a function of the receiver's computational intelligence. A digital mobile phone handset sold today would pick up crystal-clear conversations, where devices built in 1960 hear only static. The issue is not merely sensitivity. Claude Shannon's capacity theorem, developed in his classic papers that established the foundations of information theory, holds that the capacity of a communications channel is proportional to the width of the channel and the transmission power used.[128] In other words, more bandwidth, all things being equal, means more capacity. Bandwidth is therefore commonly used as a synonym for capacity.

However, the concepts are not equivalent, because the other variables can change. A system may offer more capacity with *less* bandwidth, so long as it increases power. Or it can keep capacity constant at lower power by increasing bandwidth. This last scenario is important because high transmission power overwhelms receivers and causes what we call interference. Faced with a high-power and a low-power signal, the receiver will detect the high-power signal or some combination of the two. If the first signal is spread across a wider bandwidth and sent with very low power, however, the receiver may be able to pick up the second signal cleanly.[129] The most common technique for trading off bandwidth and power in this way is known as spread-spectrum.[130]

Spread-spectrum is not the only method for mitigating interference. The simplest version of Shannon's theorem provides the capacity of a communications channel between a single transmitter and a single

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Minasian, *supra* note 46, at 226–27 (describing subharmonic radiation); De Vany et al., *supra* note 46, at 1520–21 (describing intermodulation).

126. As a matter of fundamental physics, the two waves are in a state of quantum superposition. *See* David P. Reed, How Wireless Networks Scale: The Illusion of Spectrum Scarcity, Presentation to the FCC Technological Advisory Council (Apr. 26, 2002), *available at* http://www.reed.com/OpenSpectrum/Spectrum%20capacity%20myth%20FCC%20TAC.ppt.

127. The common engineering measure of interference is signal-to-noise-ratio, where noise represents any detectable emissions other than the desired transmission for that particular receiver. Of course, if the receiver always knew what was signal and what was noise, it would have no trouble distinguishing between the two. Smarter systems can tolerate lower signal-to-noise-ratios.

128. *See* Shannon, *supra* note 57, at 639–42 (deriving expressions representing channel capacity as the product of the bandwidth and the logarithm of the transmission power).

129. *See supra* note 57 and accompanying text.

130. *See* GILDER, TELECOSM, *supra* note 61, at 86–88.

receiver.[131] In the real world, though, we are concerned with radio communications *systems*, which can involve many transmitters, many receivers, and many intervening factors such as walls that reflect or distort the signals. This might seem to make the interference problem worse. And indeed it does, if we limit ourselves to the primitive radio technology of the 1920s. Fortunately, technology has come a long way. We are nearly three times as far in time from the 1927 Radio Act and the birth of regulated broadcasting as it was from Marconi's experiments.

Research in multi-user information theory has identified numerous mechanisms to enhance capacity and avoid interference.[132] For example, receivers can be designed to function simultaneously as relay transmitters, allowing messages to hop from node to node like packets across the Internet, an architecture known as meshed networking.[133] This and other techniques exploit what David Reed calls *cooperation gain* and what multi-user information theory labels *diversity gain*.[134] They share the property that additional nodes in the network add capacity as well as consuming it.

131. Even in that simplest case, there are more possibilities than there seems to be. Most computer dial-up modems sold today deliver 56 kilobits per second, which exceeds the Shannon's Law limit expected for systems including analog telephone lines. *See, e.g.*, GILBERT HELD, UNDERSTANDING DATA COMMUNICATIONS 106 (3d ed. 2000) (stating that Shannon's Law limits transmission over a conventional analog telephone channel to about 30 kilobits per second); Steve Graves, *Hayes' 56-Kilobit/sec Modem Comes Close to Its Touted Speed*, GOV'T COMPUTER NEWS, Sept. 15, 1997, at 42 (relating that modem speeds were previously thought to be limited according to Shannon's Law to about 34 kilobits per second because of noise associated with analog telephone lines), *available at* http://www.gcn.com/archives/gcn/1997/September15/rev2.htm. The secret is that the modems are asymmetric: they send data down to the user faster than the user can send data back to the network. *See* Stephen J. Bigelow, *Better Dial-Up Access*, PC MAGAZINE, Feb. 4, 2003, at 68 (explaining that the common v.90 modem protocol enables average downstream data rates of 52 kilobits per second but upstream data rates that rarely exceed 33 kilobits per second). This asymmetry can be implemented because, although the channel at the modem user's end is an analog telephone line, the channel is digital at the Internet service provider's end. Graves, *supra*. Analog-to-digital conversion along the channel is required in the upstream (away from the modem user) direction, but not in the downstream direction, causing upstream transmission to have more noise and be more severely limited by Shannon's Law. *See* HELD, *supra*, at 106. Since most online applications today, such as email, browsing the Web, and downloading files, involve more downstream than upstream transmission, this is a tradeoff worth making.

132. *See infra* section III(A)(3).

133. *See* Glenn Fleishman, *Take the Mesh-Networking Route: Mesh Networks Offer an Agile, Cost-Effective Alternative*, INFOWORLD, Mar. 10, 2003, at 27; Steven M. Cherry, *Broadband a Go-Go*, IEEE SPECTRUM, June 2003, at 20 (giving a nutshell account of meshed networks and reporting on one company's vision of creating broadband mesh networks that allow wireless Internet access across large distances). Tim Shepard's 1995 dissertation outlined how a meshed network could overcome traditional capacity constraints. *See* Timothy Shepard, Decentralized Channel Management in Scalable Multihop Spread-Spectrum Packet Radio Networks (1995) (unpublished Ph.D. dissertation, Massachusetts Institute of Technology), *available at* http://www.lcs.mit.edu/publications/pubs/pdf/MIT-LCS-TR-670.pdf. Meshed networks may be particularly valuable for providing "last mile" broadband connection. *See* Tim Fowler, *Mesh Networks for Broadband Access*, IEE REVIEW, Jan. 2001, at 17.

134. *See* Comments of Reed, *supra* note 68; Benkler, *supra* note 6, at 44. The two concepts are similar. Cooperation gain refers to mechanisms in which devices act together to enhance capacity;

How far back can the interference frontier be pushed? We don't know. It is an open research question whether the capacity of a physically-bounded network with an arbitrary number of transmitters and receivers can scale linearly with the number of nodes.[135] If it can, each new user would add as much to the network as it took away. Even if it cannot, interference might become such a minor problem that legal regimes to cope with it are overkill. How close usage comes to some theoretical optimum matters less than whether, in practice, the benefits from more users exceed the costs. The more likely it is that interference will be a practical problem, the more transaction costs we should tolerate to avoid it.

Even the baseline for interference is not where it seems to be. Virtually every frequency through the 5 GHz range has been assigned either to a licensee, unlicensed operation, scientific activity such as radio astronomy, or government. The fact that there are few if any unassigned spaces on the frequency dial, even as wireless services become more popular and varied, reinforces the popular notion of a "spectrum drought."[136]

Examining actual usage reveals a very different picture. Most frequencies are idle in most places most of the time. They may be off-limits to protect against interference with adjacent channels, the licensee may not actually be transmitting (as with many UHF television licensees), or the authorized service may not saturate the channel. A cellular phone tower, for example, is active only when communicating with a handset in its range. A recent survey by Shared Spectrum Inc., sponsored by the New America Foundation, found that two-thirds of the most desirable beachfront spectrum was "immediately available for shared, license-exempt use."[137] And that was during peak hours in a dense urban area.[138]

One final point about interference. Because it is solely a phenomenon of receivers, the receivers are legitimate subjects for allocation of legal

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diversity gain involves exploiting more than one signal path for the same purpose. Though these cooperative approaches are important technical foundations for the commons critique, the argument does not rest on a specific architectural proposal such as a densely meshed network. Stuart Benjamin, for example, takes Benkler's "ideal network" as a blueprint rather than a theoretical construct, thereby reducing the many variations of wireless commons to a single form, which he calls "abundant networks." *See* Stuart Minor Benjamin, *Spectrum Abundance and the Choice Between Private and Public Control*, 78 N.Y.U. L. REV. 2007, 2014–16 (2003). Benjamin then proceeds to attack the commons position based on problems with his straw-man conception. *See id.* at 2076–90. Dense meshed networks have exciting potential, but they are not the only mechanism for a commons.

135. *See* Reed, *supra* note 126, at 7 (suggesting that the capacity of multi-terminal systems is unknown but subject to study).

136. *See, e.g.*, Press Release, FCC, FCC Chairman Kennard Urges Three-Pronged Strategy to Promote Wireless Web (May 31, 2000) ("All of the new technologies—mobile phones, faxes, wireless computers—are consuming spectrum faster than we can make it available, and we are in danger of a spectrum drought."), *available at* http://www.fcc.gov/Bureaus/Miscellaneous/News_Releases/2000/nrmc0032.html.

137. NEW AM. FOUND. & SHARED SPECTRUM CO., *supra* note 14, at 3.

138. *Id.* at 1.

rights. Our intuitive notion is that interference results from unauthorized transmissions that "block" other transmissions. However, the same "interfering" transmission may be totally unnoticeable to a more robust receiver.

Say A has a mobile phone license, and B establishes a wireless Internet link nearby over adjacent frequencies. It suddenly becomes difficult for A's customers to receive calls when they are near B's transmitter. One interpretation is that B is "causing" the interference and should be shut down. Another interpretation, however, is that A should bear the responsibility. A decided to use receivers that could not distinguish B's signal. Society could make a choice to protect A rather than B. However, that choice would be based not on causation but on some calculation of the welfare effects of assigning the right to one side or the other.[139]

Coase engaged in exactly this analysis in both his FCC article[140] and his seminal paper, *The Problem of Social Cost*.[141] For illustration, Coase used a nineteenth-century case involving a confectioner and a doctor who builds an examining room at the edge of an adjacent property.[142] The doctor finds his work impaired amid the vibrations from the confectioner's machinery.[143] As Coase pointed out, we could say the confectioner caused injury to the doctor, or that the doctor is excessively sensitive to vibrations.[144] We can choose, but to do so is a value decision between two legitimate activities.[145] Any claim about interference can be expressed either in terms of transmitter intrusiveness or receiver sensitivity. We can choose to impose a duty on the transmitter, or we can impose a duty on the receiver, but either way we make a choice.[146]

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139. An equivalent concept appears in tort law in the form of the "eggshell plaintiff" problem. People and companies are not always required to act in a manner that protects even the most abnormally sensitive person. The "reasonable person" standard is an attempt to codify this distinction. I consider tort law below in section IV(D)(2).

140. Coase, *supra* note 3.

141. Coase, *supra* note 124.

142. Coase, *supra* note 3, at 26 (citing Sturges v. Bridgman, 11 Ch. D. 852 (Eng. Ch. App. 1879)); *see also* Coase, *supra* note 124, at 2 (referring to the discussion in the earlier Coase article and very briefly summarizing the facts of the case). Ironically, the court granted the doctor an injunction even though he built his examining room substantially after the confectioner began operating his machinery. Coase, *supra* note 3, at 26. In other words, the court applied exactly the opposite of the "first in time, first in right" doctrine Hazlett suggests would govern a spectrum common law regime. *See infra* note 258 and accompanying text (discussing Hazlett and the "first in time, first in right" doctrine).

143. Coase, *supra* note 3, at 26; Coase, *supra* note 124, at 2.

144. *See* Coase, *supra* note 3, at 26; Coase, *supra* note 124, at 2 (both noting that avoiding harm to one party inflicts harm on the other).

145. Benkler uses Coase's example to attack Faulhaber and Farber's contention that a non-interfering easement within a property system eliminates the need for commons. *See* Benkler, *supra* note 6, at 62–67. I address the easements proposal in more detail below in subpart V(E).

146. This is not a theoretical question. In the FCC's ultra-wideband (UWB) proceeding, manufacturers of Global Positioning System (GPS) equipment argued that UWB should not be

Surprisingly, the FCC's rules implicitly acknowledge the contingency of interference. They define interference as "[t]he effect of unwanted energy."[147] Interference is not an action, or even a state; it is an "effect." Moreover, it occurs only when energy is "unwanted." Unwanted by whom? The erstwhile receiver of some other "wanted" energy. The transmissions themselves have no idea whether they are welcome or not.

The collective nature of wireless communications rights is clearly apparent in the FCC's definition. I can emit the same radio waves a hundred times, but if you decide the next emission is "unwanted" for your simultaneous communications, it suddenly becomes interference. Interference is a social construct arising from collective uses of wireless devices. It depends on the technical capabilities of those devices as well as the applications and services for which they are employed.

The ultimate policy goal is not to eliminate interference. That is hopeless. Some energy will always propagate where it is not desired. More fundamentally, though, interference is not an evil that must be eradicated at all costs. Interference is a by-product of the very phenomenon policymakers hope to achieve: more value from wireless communication. If there were only two radio stations using the entire spectrum there would be little opportunity for interference. The widespread possibility for interference is a sign of success, not failure. Focusing too hard on eliminating it would be like killing off an annoying animal species, only to cause a worse pest, which the first species had kept in check, to multiply.[148]

The proper goal is to optimize interference.[149] A transmission should take place if the marginal value it adds exceeds its marginal cost, with interference counting as a cost. This analysis becomes complicated because

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permitted because it would prevent reception of GPS signals. *See* Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems, 17 F.C.C.R. 7435, ¶ 71 (2002) (first report and order) [hereinafter UWB Order]. Engineering studies revealed that most GPS equipment was robust enough to ignore the UWB signals, but some poor-quality receivers might experience interference. *Id.* at 7478. The FCC had to choose between protecting UWB transmitters and protecting GPS receivers. *Id.* at 7476.

147. 47 C.F.R. § 2.1(c) (2002).

148. *See* Coase, *supra* note 3, at 26–27 ("It is sometimes implied that the aim of regulation in the radio industry should be to minimize interference. But this would be wrong. The aim should be to maximize output.")

149. Hazlett recognizes that this is the correct formulation. *See* Hazlett, *supra* note 53, at 374. The idea that interference must be eradicated is a legacy of the old government licensing regime, which he hopes to replace with a more fluid property system. *Id.* at 360, 369–74, 403–05. However, when it comes to the commons proposal, Hazlett suddenly frets about "over-exploitation and airwave chaos." *Id.* at 485. He takes the large sums spent on FCC license auctions as evidence that investors value freedom from interference. *Id.* at 489. Indeed they do, but the auctions provide no mechanism to determine whether those investors are making the optimal tradeoff between interference they tolerate and additional interference-generating communications. The licenses are exclusive, and moving to any arrangement that allows some interference if its value exceeds its costs requires transactions that are unlikely to occur. *See infra* subpart V(D).

interference is neither a localized nor an all-or-nothing phenomenon. The interfering "noise" for any transmission is a combination of intentional and unintentional emissions from many other sources, which affect reception both individually and collectively.[150] A degradation of reception may mean a slight hiss in the background of a phone call or a lost message between an air traffic controller and a jumbo jet pilot. The proper analysis is not whether a regime prevents or tolerates interference, but how it resolves boundary cases and allows for tradeoffs along many dimensions.

3. Frequency Blocks.—A third aspect of the spectrum fallacy is the emphasis on frequency blocks as the unit of allocation.[151] Frequency is indeed a physical property of radio waves.[152] The relevant legal structures, however, are designed not for science experiments but for communications systems. Frequency, like bandwidth, is but one aspect of those systems. Though every wireless license or property right includes other constraints as well, frequency has been the central delimiter among systems since Marconi's day.[153]

The commons critique coalesced with the development of spread-spectrum systems in the unlicensed 900 MHz, 2.4 GHz, and 5 GHz bands.[154] Benkler's touchstone was the FCC's 1997 decision to allocate spectrum at 5 GHz for unlicensed National Information Infrastructure (U-NII) devices.[155] Subsequently, the rapid growth of the market for WiFi devices, primarily in the 2.4 GHz Industrial, Scientific, and Medical (ISM) band, has proved both the feasibility and dynamism of a commons-like arrangement.[156] In both cases, the commons exists within a "park" designated exclusively for unlicensed operation. Emphasis on these developments has created the misconception that the commons critique relies on dedicated unlicensed frequency bands.

Hence, property advocates claim that governments will fall victim to the same failings in allocating bands for unlicensed use as they do in allocating

150. Transmitters even generate internal noise so that they interfere with themselves.

151. *See, e.g.*, Hazlett, *supra* note 7, at 138 ("The interference problem is widely recognized as one of defining separate frequency 'properties' . . . .").

152. Frequency means what it sounds like: how often the wave oscillates. The higher the frequency, the shorter the wave. (Think of an undulating piece of string bunched up or pulled taut.)

153. *See* Krystilyn Corbett, *The Rise of Private Property Rights in the Broadcast Spectrum*, 46 DUKE L.J. 611, 615–16 (1996) (noting that the common law dealt with property issues in the early days of wireless communication by applying the "first in time" principle to frequencies). Even Part 15 (low-power, unlicensed, and ultra-wideband) devices are limited in which frequencies they can exploit.

154. These unlicensed bands were established in 1989. *See* Revision of Part 15, *supra* note 59, ¶ 130.

155. *See* U-NII Order, *supra* note 59, at 1621–24; Benkler, *Building the Commons*, *supra* note 55, at 331 (calling the U-NII Order "inspiring").

156. *See* WERBACH, NEW WIRELESS PARADIGM, *supra* note 66, at 10.

bands for licensed systems.[157] They assert that if unlicensed parks such as the U-NII band are valuable, they will appear in a property-rights world either through government creation of "public parks" or manufacturers buying rights to create "private parks."[158] I address these arguments in Part IV. Even if they are correct, though, they fail to rebut the commons critique. The wireless commons involves more than unlicensed bands.

There are several technical mechanisms to communicate without assigning dedicated frequency bands to each channel. All of them provide pathways to expand wireless communications capacity other than exploiting higher frequencies or using existing frequencies more intensively, which are the primary techniques property advocates have considered.[159]

a. Wideband Underlay.—Take spread-spectrum to its logical conclusion, and the result is ultra-wideband (UWB). UWB transmissions use such large bandwidth that they can transmit at power levels below the "noise floor" for other devices. In other words, a licensed system operating in a band covered by the UWB system will not even know it was there. The FCC authorized such "underlay" techniques in its February 2002 UWB order.[160] Most UWB systems are carrierless: in contrast to virtually all other radios since Marconi's day, they do not operate by impressing messages upon carrier waves of a specified frequency. Instead, they use extremely short electrical pulses.[161]

The FCC's UWB order effectively created a commons without setting aside a dedicated unlicensed band. It had to. As a matter of physics, the shorter the duration of a wireless signal, the wider it spreads. To achieve its

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157. *See, e.g.*, Benjamin, *supra* note 134, at 2048–50 (predicting that government control of abundant networks will lead to the same inefficiencies, such as lobbying and rent-seeking by the politically powerful, that accompanied the governmental allocation of licensed bands).

158. *See, e.g.*, Faulhaber & Farber, *supra* note 5, at 213–14.

159. Levin makes the most serious attempt to incorporate enhancements in equipment capability into a model of exclusive spectrum rights. *See* LEVIN, *supra* note 46, at 19–24. He describes possible improvements in the intensive margin (denser multiplexing of frequencies) and extensive margin (transmission at higher frequencies than was previously possible). Because his analysis assumes the primacy of frequency, improvements in the intensive and extensive margins as he describes them are simply further subdivisions of the preexisting frequency pie represented by the traditional spectrum assignment chart. Improvements and sharing along planes orthogonal to the boundaries of established rights do not enter into his consideration. Hazlett similarly dismisses novel wireless techniques as "not new, not unique" because he reduces them incorrectly to frequency re-use. Hazlett, *supra* note 53, at 486–88.

160. *See* UWB Order, *supra* note 146, at 7436 (permitting use of UWB technology and noting that "UWB devices can operate using spectrum occupied by existing radio services without causing interference"). The FCC has for some time allowed very low-power Part 15 devices to operate on an unlicensed basis throughout most of the spectrum, except for certain restricted bands. *See infra* note 224 and accompanying text. These devices, however, tend to be frequency limited. The power limits for Part 15 devices are so strict that they generally cannot be used for high-speed or long-range applications.

161. David G. Leeper, *Wireless Data Blaster*, SCI. AM., May 2002, at 65, 67.

full potential, UWB cannot be confined to traditional frequency blocks of a few megahertz. The FCC's order, for example, authorizes UWB across a range of seven gigahertz, though not every system will use the entire range.[162] There is no way a prospective UWB system manufacturer could possibly negotiate with all the constituent frequency bands for authorization.[163] The problem is not that a particular allocation mechanism involves too-narrow blocks; it is that any limitation on frequency range will constrain some UWB systems which it may be optimal to permit.

b. Opportunistic Sharing or Interweaving.—Many frequencies, even those ostensibly licensed for established services, are actually empty much of the time.[164] Some allocated frequencies are even required to be unused. For example, television channels 3 and 6 are occupied in Philadelphia, while 2 and 4 are vacant. The reverse is true in New York City. At the time broadcast television was introduced, receivers in Philadelphia could not distinguish between signals on channel 2 and channel 3, or between the local channel 2 and channel 2 in New York. So some channels simply lie fallow. In other cases, such as UHF television and ITFS fixed wireless, licensees may have the right to transmit but are not doing so for economic reasons. Or a system, such as a cellular telephone network, may operate throughout the licensed band, but not transmit in all places at all times.

Current technologies can exploit some of these holes, a process known as opportunistic sharing or interweaving.[165] In particular, software-defined

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162. The FCC allowed UWB to operate between 3.1 GHz and 10.6 GHz. *See* UWB Order, *supra* note 146, ¶ 5, at 7438. However, it defined UWB as any system with bandwidth exceeding 500 MHz. *Id.* at 7449. Some vendors are building "multiband" UWB equipment that splits the available spectrum into slices, and can simultaneously transmit on any of them.

163. Coase presciently anticipated this problem in 1958. Though UWB had not been developed, he pointed out that "some types of medical equipment can apparently be operated in such a way as to cause interference on many frequencies and over long distances." Coase, *supra* note 3, at 30. Coase believed that such a situation called for regulation, even within the general context of property rights he advocated. *Id.*

164. *See* NEW AM. FOUND. & SHARED SPECTRUM CO., *supra* note 14, at 4 (reporting that in a study of spectrum in an urban area of Washington, D.C., "wide swaths of spectrum lay empty for significant amounts of time").

165. *See* Comments of Intel Corporation at 4 (Apr. 7, 2003), Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band, 17 F.C.C.R. 25632 (2002) (ET Docket No. 02-380) [hereinafter Comments of Intel] ("Preliminary technical analysis conducted by Intel and testing performed by the Communications Research Centre Canada, on Intel's behalf, demonstrate that technically viable broadband services can be operated on a non-interfering basis with both analog and digital TV broadcast services in a major metropolitan area in which many overlapping TV service contours exist."), *available at* http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6513982734; FCC SPECTRUM POLICY TASK FORCE, REPORT OF THE INTERFERENCE PROTECTION WORKING GROUP 5 (2002) [hereinafter FCC INTERFERENCE WORKING GROUP REPORT] ("Due to advances in digital signal processing and antenna technology, communications systems and devices are becoming more tolerant of

radio, which uses reconfigurable software to tune radios to different frequencies and encoding schemes, holds great promise for facilitating more powerful opportunistic sharing strategies, should the law change to permit them.[166] The Defense Advanced Research Projects Agency (DARPA), which funded much of the basic networking research that led to the Internet, is actively exploring one opportunistic sharing mechanism through its XG research program.[167] In the future, "cognitive radios" may be able to scan the local spectral environment, find an open frequency, transmit there using an efficient encoding mechanism, and move to another frequency so quickly that a coexisting system will not even know it is there.[168] Allocation according to frequency blocks would hamstring such devices.

Though the "holes" opportunistically exploited are usually frequency-based, this is not always the case. For example, some meteorological radar systems are in operation only a few minutes per hour. Another system could split use of the frequency purely on a time basis.[169]

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interference through their ability to sense and adapt to the RF environment."), *available at* http://www.fcc.gov/sptf/files/IPWGFinalReport.pdf.

166. *See* William Lehr et al., Software Radio: Implications for Wireless Services, Industry Structure, and Public Policy 11 (Aug. 30, 2002) (unpublished manuscript, on file with the author) ("It is not unreasonable to consider software radio as a disruptive technology, with the potential for radically altering the structure of the industry within which radios are designed, manufactured, deployed and operated."), *available at* http://intel.si.umich.edu/tprc/papers/2002/62/Software_Radio_Lehr_Gillett_Fuencis_Aug2002.pdf *or* http://itc.mit.edu/itel/docs/2002/Software_Radio_Lehr_Fuencis.pdf; Authorization and Use of Software Defined Radios, 16 F.C.C.R. 17373, 17374 (2001) (first report and order) ("Software defined radios could allow more efficient use of spectrum by facilitating spectrum sharing and by allowing equipment to be reprogrammed to more efficient modulation types."); Comments of Vanu, Inc. at 1–2 (Feb. 28, 2003), Commission Seeks Public Comment on Spectrum Policy Task Force Report, 17 F.C.C.R. 24316 (2002) (ET Docket No. 02-135) ("Software-Defined Radio (SDR) technology brings unprecedented flexibility to wireless systems, and will be able to take advantage of new, more flexible regulatory policy."), *available at* http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6513583375.

167. *See* XG Working Group, The XG Vision: Request for Comments 4–6 (explaining the goals and motivations for developing a "new generation of spectrum access technology"), *at* http://www.darpa.mil/ato/programs/XG/rfc_vision.pdf (last visited Feb. 21, 2004). The military is a major contributor of funding and research for advanced wireless systems. Soldiers, especially when operating in a foreign country, may not have dedicated spectrum assigned for their communications needs. The hope of XG, as well as the military's Joint Tactical Radio System, a software radio program now in procurement, is to use spectrum opportunistically, without needing prior allocations. *See id.* at 5; Joint Tactical Radio System Technical Overview, *at* http://jtrs.army.mil/sections/technicalinformation/fset_technical.html (last visited Jan. 24, 2004).

168. *See* Bruce Fette, *'Cognitive' Radios the Next Step for SDR*, EE TIMES, Nov. 13, 2003, *available at* http://www.commsdesign.com/showArticle.jhtml?articleID=16502397; *Tomorrow's 5G Cell Phone*, INFOWORLD, Feb. 28, 2003 (describing how cognitive radio could "redefine cell phone technology"), *at* http://www.infoworld.com/article/03/02/28/09ctlong_1.html.

169. IKEDA & YE, *supra* note 55, at 7–8 (describing how splitting time can lead to "more efficient use of idle spectrum" for wireless local area networks). In theory, time division could be applied to many wireless communications systems. With the exception of broadcast services that transmit continuously, most forms of wireless communication are intermittent. Even when the transmission appears continuous to the receiver, it may in fact be a series of packets interspersed with white space so quickly that the ear cannot detect the discontinuity. For example, such time-

c. Intelligent Coding and Smart Antennas.—Smart digital devices can employ many techniques other than frequency diversity to improve the performance of wireless systems.[170] These mechanisms use factors such as the physical location of transmitters, motion, or the scattering effects of intervening obstacles, which portions of the signal bounce off of, to better lock onto signals and distinguish them from noise.[171] For example, the BLAST system developed at Bell Laboratories uses multiple antennas on both the transmitter and receiver. By tracking the multiple signal paths between the antenna arrays, BLAST obtains a better understanding of the signal characteristics.[172] This type of approach is known as space-time coding or multiple in, multiple out (MIMO).

These are not just theoretical ideas. Airgo Networks, a Silicon Valley startup, announced MIMO chipsets in Summer 2003 that extend the range and capacity of WiFi systems.[173] Companies such as Northpoint Technology have demonstrated "angle of arrival" systems that allow for terrestrial wireless communications on the same frequencies used for satellite uplink and downlink, with neither service subject to interference.[174] The "new"

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division multiplexing is used in GSM, the dominant standard for today's digital mobile phone networks. LAWRENCE HARTE ET AL., GSM SUPERPHONES 1–2 (1999).

170. *See* Robert J. Matheson, *The Electrospace Model as a Tool for Spectrum Management*, *in* U.S. DEP'T OF COMMERCE, PROCEEDINGS OF THE INTERNATIONAL SYMPOSIUM ON ADVANCED RADIO TECHNOLOGIES MARCH 4–7, 2003, at 126, 128–30 (Nat'l Telecomm. & Info. Admin. Spec. Publ'n SP-03-401, 2003) (proposing "electrospace dimensions" through which radio signals can be distinguished, including time, spatial location, angle of arrival, polarization, and modulation).

171. *See* P. Gupta & P.R. Kumar, *Towards an Information Theory of Large Networks: An Achievable Rate Region*, 49 IEEE TRANSACTIONS ON INFO. THEORY 1877, 1883–86 (2003) (suggesting a method of obtaining improved capacity through a particular placement of transmission nodes); Matthias Grossglauser & David N.C. Tse, *Mobility Increases the Capacity of Ad Hoc Wireless Networks*, 10 IEEE/ACM TRANSACTIONS ON NETWORKING 477, 477–80 (2002) (finding that in certain networks which can tolerate long delays and in which the network topology varies over time because of user mobility, the network capacity is not diminished by adding more users), *available at* http://www.stanford.edu/~changhua/reference2.pdf.

172. Press Release, Lucent Technologies, Bell Labs Scientists Shatter Limit on Fixed Wireless Transmission (Sept. 9, 1998), *available at* http://www.bell-labs.com/news/1998/september/9/1.html; Andrew Backover, *Wireless Links Could Blast Off*, USA TODAY, Nov. 18, 2002, at 5E. *See also* G.J. Forschini & M.J. Gans, *On Limits of Wireless Communications in a Fading Environment when Using Multiple Antennas*, 6 WIRELESS PERS. COMM. 311, 314–16 (1998) (exploring the utility of multiple antennas for wireless transmission).

173. John Markoff, *Start-Up Plans to Introduce Alternate Wi-Fi Technology*, N.Y. TIMES, Aug. 18, 2003, at C2.

174. *See* Amendment of Parts 2 and 25 of the Commission's Rules to Permit Operation of NGSO FSS Systems Co-Frequency with GSO and Terrestrial Systems in the Ku-Band Frequency Range, 17 F.C.C.R. 9614 (2002) (memorandum opinion and order & second report and order) (giving approval to Northpoint's proposed system). Northpoint first brought its technology to the FCC in 1994 and filed formal applications for spectrum allocation in 1999. The FCC eventually concluded that Northpoint's approach was workable but elected to auction an exclusive license rather than grant one directly to Northpoint. *See* Amendment of Parts 2 and 25 of the Commission's Rules to Permit Operation of NGSO FSS Systems Co-Frequency with GSO and Terrestrial Systems in the Ku-Band Frequency Range; Amendment of the Commission's Rules to Authorize Subsidiary Terrestrial Use of the 12.2-12.7 GHz Band by Direct Broadcast Satellite Licensees and Their

spectrum, which could in theory be a commons, perfectly overlaps the frequencies of the satellite system and uses similar power levels.

Intelligence can be built not just into the software that processes signals at the transmitter or receiver, but into the antennas they use. The classic TV aerial on the roof of a house is exceedingly simple. It uses horizontal bars of lengths that match the periodic frequencies of a broadcast channel. Modern electronic antennas can be highly directional and adaptive. They can even be tuned dynamically to lock on and shape a narrow directional beam to a signal, preventing it from spreading widely where it might impinge on other signals.[175]

d. Physical Space.—Wireless systems can also be divided by physical location.[176] A low-power wireless transmitter in a house may not create noticeable interference to any system outside that house.[177] That is true regardless of what frequency band the transmitter uses. Under long-standing doctrines of property law and the Fourth Amendment, people are permitted to engage in many forms of conduct in their own homes that would be impermissible in public.[178]

Michael Chartier of Intel has proposed a rule that wireless transmission rights should be "fixtures" to private property in certain bands.[179] This principle could be adopted more broadly. If a transmission within a house does not radiate outside to the point at which it affects other signals, why should there be any constraints on that transmission? Property owners are entitled to knock down walls of their houses or decorate their bedrooms in a manner others would find garish. If I choose to operate a wireless system in my house whose only negative externality is that I knock out my own broadcast TV reception, perhaps that should be my choice.

Affiliates; and Applications of Broadwave USA, PDC Broadband Corporation, and Satellite Receivers, Ltd. To Provide a Fixed Service in the 12.2-12.7 GHz Band, FCC 02-97, ET Docket No. 98-206 (Apr. 22, 2003) (fourth memorandum opinion and order) (affirming the FCC's earlier decisions in view of requests for reconsideration).

175. Martin Cooper, *Antennas Get Smart*, SCI. AM., July 2003, at 49.

176. Space-time coding distinguishes based on the relative location of transmitters and receivers. Multiplexing by physical location, which could be called space division, means distinguishing by the absolute location in space of the overall wireless system.

177. The signal is not confined to the house. As noted, it can penetrate walls or other obstacles. However, many low-power indoor signals attenuate so greatly in that process as to be largely undetectable outside.

178. *See* U.S. CONST. amend. IV (stating that the "right of the people to be secure in their . . . houses . . . shall not be violated"); Washington *ex. rel.* Seattle Title Trust Co. v. Roberge, 278 U.S. 116, 121 (1928) (holding that restrictions on the use of private property cannot be imposed unless they bear a substantial relation to the public health, safety, morals, or general welfare).

179. *See* Chartier, *supra* note 10, at 17.

e. Endless Possibilities?— There is no reason to think all possible mechanisms for sharing spectrum on a basis other than frequency division have been invented. Computers continue to become more powerful, opening up new possibilities that were not feasible before. Multi-user information theory is a particularly fertile research area in which several major problems remain unresolved. Many of the intelligent coding mechanisms have the interesting property that they take phenomena that once "caused" interference and use it to improve reception. For example, when portions of a signal bounce off walls or other obstacles, they arrive at a receiver slightly after signals that passed straight through the air. Such "multipath fading" is the bane of wireless systems because receivers do not realize that the second signal is a copy of the first. If, however, the system is smart enough, it can correlate the two signals and combine them, improving reception. This suggests we may just be seeing the beginning of the post-frequency wireless era.[180]

4. Architecture.—The spectrum fallacy is pernicious not only in placing too much focus on frequency but also in directing attention away from other characteristics that matter a great deal, such as architecture. Architecture is an essential element of any communications system.[181] In this context, archi-

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180. *See* Comments of Reed, *supra* note 68, at 3 (observing that the technological changes affecting communications systems are "far from reaching any fundamental limits"). To be clear, I am not saying that wireless capacity is infinite. At any given time there will be an optimal amount of communication that can be supported, based on demand and the state of technology. How congested spectrum seems reflects the ratio between actual communication and what is theoretically possible, modified by the cost of routing around other signals and the degree of degradation those signals generate. At some point spectrum can feel uncongested for important applications even if there are real limits on how much can be transmitted.

Hazlett invokes Say's Law, popularly formulated as "supply creates its own demand," to attack the "physical abundance" arguments of commons advocates. *See* Hazlett, *supra* note 53, at 489. Say's Law states that total demand will never fall below or exceed total supply in an economy as a whole. THOMAS SOWELL, SAY'S LAW: AN HISTORICAL ANALYSIS 3 (1972). It does not suggest that supply and demand for any one input are always in equilibrium. *See id.* at 16–17 (quoting Adam Smith's statement that although a particular merchant "may sometimes be ruined by not being able to sell [his goods] in time, a nation or country is not liable to the same incident") (citation omitted). Even in the absence of legal or regulatory constraints, there are costs for any potential spectrum user to make use of the available communications capacity. For example, better or different equipment may be required. There are also substitutes for wireless communication, including wireline transmission and storage, that factor into the decision whether to exploit any "empty space" for wireless transmission. Say's Law is not violated in a world where total communications capacity is in equilibrium but some users can engage in wireless transmission as though capacity were not scarce.

181. *See* Kevin Werbach, *The Architecture of Internet 2.0*, RELEASE 1.0, Feb. 19, 1999, at 10–11 (arguing that the closed architecture of some broadband networks would constrain growth and innovation); LAWRENCE LESSIG, CODE AND OTHER LAWS OF CYBERSPACE 30 (1999) ("[T]he nature of the Net is set in part by its architectures, and . . . the possible architectures of cyberspace are many."). The first prominent thinker to use "architecture" in this context was Mitch Kapor, founder of Lotus Development Corp. and cofounder of the Electronic Frontier Foundation. *See* John Perry Barlow, Stopping the Information Railroad, Keynote Address at the 1994 Winter USENIX Conference (Jan. 17, 1994) (transcript available through the Electronic Frontier

tecture refers to the organizing principles and structure of relationships among the network's components.[182] Focusing on spectrum rather than the devices obscures the different ways those devices can be designed and connected. This in turn produces a blind spot about how architecture can enhance wireless capacity and value.[183]

Wireless communications systems are more than isolated transmitter-receiver pairs. Two systems in the same frequency and location may deliver very different services if their architectures are different. For example, a broadcast service such as television sends the same signal from a central transmitter to many passive receivers. A cellular service such as mobile telephony uses many smaller transmitters that connect locally to two-way handsets. Each user may get less capacity in the cellular model, but the total capacity of the system is much greater because so many different transmissions can occur simultaneously. The broadcast and cellular networks may be alternative uses for the same location, time, and frequency, but they are not interchangeable.[184] Each produces a different utilization pattern. And each produces a different boundary along which other communications systems could theoretically coexist.

The development of cellular systems was a key innovation in wireless technology because it allowed many small networks to operate as one big network.[185] Meshed networking takes that concept even further, turning receivers into repeaters that add capacity as they consume it. Another new architecture is ad hoc networking, in which new nodes anywhere

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Foundation) (discussing how Barlow and Kapor developed the notion that structural or architectural changes, instead of legal changes, could be implemented to protect people's First Amendment rights), *available at* http://www.eff.org/Publications/John_Perry_Barlow/HTML/info_railroad_usenix.html.

182. The Internet and the public switched telephone network both route messages among distant nodes, but they have very different architectures. The Internet's distributed packet-switching and end-to-end principle make it a more open platform for innovation than the centralized, circuit-switched phone network.

183. *See* Comments of Reed, *supra* note 68, at 2 ("[T]he useful economic value in a communications system architecture does not inhere in some abstract 'ether' that can be allocated by dividing it into disjoint frequency bands and coverage areas. Instead it is created largely by the system design choices . . . .").

184. These three variables make up the TAS (for "time," "area," and "spectrum") system that De Vany and his collaborators propose. De Vany et al., *supra* note 46, at 1501.

185. Each tower is responsible only for communication within a small radius. Towers therefore can use relatively low power, enabling users connected to one tower and users connected to another tower on the same frequency to talk at the same time. This phenomenon is known as spectrum or frequency re-use. Cellular technologies are often compared on the basis of their frequency re-use efficiency. Re-use is an example of how technology can create "more" spectrum out of nothing. It is not, however, a complete description of current capacity-enhancing techniques, as Hazlett suggests. *See* Hazlett, *supra* note 53, at 486 ("Frequency re-use purportedly unleashes unlimited bandwidth."). Frequency re-use is a form of subdivision that leaves the basic pattern of wireless transmission intact. In effect, it is a simple trade of power for range. Systems that exploit cooperation and diversity gain, as well as software-defined or cognitive radios, do not rely on this mechanism alone.

automatically become part of the network, compared to the planned expansion of traditional systems. How spectrum is made available influences network architectures, which in turn affect how spectrum can be used. A commons, which substitutes open entry for exclusive control, tends to foster decentralized networks of many transmitters, with capital expenditures centered on user purchases of commodity equipment. Exclusive licensing or property rights favor centralized infrastructure investment by an operator.[186]

5. *Implications for the Property vs. Commons Debate.*—The spectrum fallacy puts the debate on the wrong terms. Analyzing property and commons models for rights in a spectrum resource is an interesting intellectual exercise, but it is not a discussion about the real world. The only things that matter are the effects of the two regimes when seen for what they really are: different configurations of the rights in wireless transmitters and receivers. And in that context, many arguments for property rights are valid only under particular factual assumptions which are increasingly questionable.

The property critique falls headlong into the spectrum fallacy.[187] Granted, property advocates understand the basic physics of wireless communication. Their arguments, however, ineluctably lead to a model of spectrum as land.[188] It is difficult to advocate ownership without a tangible resource to be owned. The land metaphor allows property advocates to fit extensions such as easements and subdivisions into a consistent cognitive map.[189] However, as I discuss below in Part IV, there are reasons to be skeptical that the property system can accommodate the wealth of additional possibilities that are now becoming real for wireless communication. The only way to treat frequency blocks like land is to ignore the mechanisms under which spectrum can be used differently.

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186. *See* Benkler, *Building the Commons*, *supra* note 55, at 361 ("[J]ust as property rules can bring into play the incentives of spectrum owners to maximize the value of their spectrum, spectrum-sharing rules can bring into play the incentives of equipment manufacturers to optimize the use of spectrum by their devices."). The De Vany group acknowledges that its system of spectrum property rights systematically benefits transmitter owners rather than receiver owners. *See* De Vany et al., *supra* note 46, at 1518 (stating that the system was "designed for use by" transmitter owners). This choice may have been justified in a broadcast context, where receivers are merely passive devices. As receivers become more intelligent and contribute to optimization of spectrum use, however, the bias in the legal regime away from them becomes a negative instead of a positive. I consider further the different incentives of property and commons regimes in Part V.

187. *See supra* note 110 and accompanying text (providing examples of spectrum scholars who have fallen into the trap of drawing parallels between spectrum and land); White, *supra* note 53, at 31 ("In sum, this ideal system would look much like the current system of property rights that apply to real estate."). Mueller does focus on equipment rights, but these are rights to deploy particular kinds of transmitters and antennas, rather than rights to emit particular kinds of radiation. *See* MUELLER, *supra* note 46, at 31–32 (evaluating proposals for a system of freely transferable rights).

188. *See* Goodman, *supra* note 5 (manuscript at 16–19).

189. *Cf.* Hunter, *supra* note 99, at 458 ("Cognitive psychological theories of how we construct our understanding of the world provide this account [of why we think of cyberspace as a place].").

The debate between property and commons is not a fight over spectrum; it is a fight about different configurations of rights. The policy question, therefore, is which constellation of rights is most efficient and socially desirable. As Coase demonstrated, there is no "correct" place to assign rights.[190] Once the right is assigned, the parties may bargain to reassign it. The assignment does, however, affect the likelihood and transaction costs in getting to that equilibrium point. The property and commons regimes for wireless communication involve different kinds of transaction costs in modifying transmission rights. By placing all of the burden on the potential entrant to aggregate information and negotiate the purchase of the necessary rights, the exclusive property rights model imposes a bias toward established uses and techniques. By making boundary definition between systems necessarily a market-based transaction, it adds rigidity and cost to the evolving process of determining the most efficient configuration of devices.[191]

Exclusive property rights are superior to unconstrained entry for most physical resources. Wireless is different.[192] It is different because spectrum is not a physical resource, and because users can add capacity or avoid conflicts dynamically. If spectrum were a thing, the transaction cost analysis for a property regime would be relatively simple. The FCC-defined constraints on licenses could be converted into private property rights to transmit in certain frequency bands. If, as seems likely, the existing boundaries were not completely efficient, rights holders could buy or sell them. The spectrum market would reshuffle the ownership of frequency blocks, much as the real estate market reshuffles title to land.

Eliminate the spectrum fallacy, and the picture becomes more complicated. Frequencies are not the only dimension for transactions, because they are far from the only variable that determines interference. Underlay mechanisms, to take one example, depend on nonexclusivity of frequency blocks. So does opportunistic sharing through cognitive radios, but in a completely different manner. The more different ways there are to configure wireless communications systems in order to increase capacity, the more complex the transactional regime to implement those mechanisms

190. *See* Coase, *supra* note 3, at 34 (discussing how such rights must arise out of practical experience).

191. *See infra* subpart V(D).

192. Hazlett and Huber argue that policing radio transmissions through a generalized legal framework not specific to communications is itself beneficial, because it reduces the possibility of regulatory capture or inefficiency. *See* Hazlett, *Spectrum Flash Dance*, *supra* note 74, at 807; HUBER, *supra* note 110, at 205–06. There are three responses to this argument. First, one size doesn't always fit all. If wireless is sufficiently distinct, shoehorning it into generalized models does more harm than good. Second, I am proposing to use generalized common law frameworks to resolve spectrum disputes, just not on the basis of exclusive property rights. Third, the supercommons model can be seen as part of a different generalized framework. The framework involves networks, which have powerful characteristics that have not fully been analyzed for their legal significance. However, this Article is not the place for a full explication of network law.

becomes, assuming each time there must be a financial transaction. A property regime may still be a good answer, but the choice is not so clear ex ante.

B. Deep Uncertainties

1. What We Don't Know Could Hurt Us.—Closely related to the false vision of a spectrum resource is an epistemological fallacy. We think we know how wireless communications systems will be used. Though rules are described in general terms, we typically have a particular service, or group of services, in mind when we talk about them.

Historically, wireless policy was about broadcast. Broadcast radio was the primary commercial application that drove the government to assert control over the airwaves in the 1920s. Broadcast television, which supplanted radio as the most lucrative method of wireless communication, was the initial animating service for the economists' critique.[193] In the 1980s and 1990s, cellular telephony became the focus, and it was the testing ground for the FCC's auction movement.[194] The commons critique takes wireless local area networks and other data connections as its examples.

The emphasis on specific services is partly a legacy of the FCC's practice of designating frequencies for particular applications. However, that does not completely explain the extent to which analysis has been tied to uses. Wireless communication is mysterious and ethereal. Just as it is easier to talk of frequency blocks than incorporeal phenomena, it is easier to think about concrete services than pure radiation. Easier, but misleading. In the current digital world, there is no fundamental difference among the content delivered through any communications service. Bits are bits. Therefore, many service-specific policy decisions no longer have the same force. At the same time, services differ greatly in the architecture, business dynamics, and social significance. A broadcast-oriented regime may be inappropriate for ad hoc sensor networks, both technically and in the substantive tradeoffs it makes.

Future usage patterns are heavily uncertain. Consumer demand for information technology is notoriously difficult to predict. Recent history is littered with examples of smart, successful companies wasting huge sums pursuing chimeras like video-on-demand while ignoring fax machines and the Internet.[195] Customers in Europe or Japan have different preferences than

193. Herzel's groundbreaking article was, according to its title, focused on color television standards. *See* Herzel, *supra* note 41.

194. *See supra* notes 76–79.

195. *See*, *e.g.*, Pat Baldwin, *A Small Player in a Big Race*, DALLAS MORNING NEWS, June 5, 1993, at 1F ("Giants like AT&T, IBM, Tandem Computer, Northern Telecom, and Blockbuster Entertainment are all vying for pieces of the . . . video-on-demand market."); Mary Lu Carnevale,

those in the United States, causing different usage patterns for technologies such as mobile messaging and broadband Internet connections.[196] Usage is influenced by regulation, which can itself be unpredictable. Mobile phones were launched earlier in the United States than Europe, but grew more quickly in Europe once the GSM standard and "calling party pays" roaming agreements were in place.[197]

Usage also depends on substitutes. Eighty-five percent of American homes get their television from something other than a terrestrial broadcast signal, even though those broadcast licenses are considered the crown jewels of spectrum.[198] If those transmitters were turned off, a substantial majority of Americans would not even notice.[199] Finally, spectrum usage depends on technology, which is always changing. We can make educated guesses about how much room cognitive radios linked into meshed networks will have to maneuver forty years from now, but no one can really be sure. Infinite capacity and total gridlock are both speculative outcomes.

The usage fallacy matters when we attempt to define what the ultimate objective of wireless policy should be. Different kinds of networks are measured based on different variables. For example, Benkler declares that the proper objective of wireless policy is to maximize network capacity[200] and describes an "ideal" wireless network as a ubiquitous mesh of interconnected nodes. He builds an economic model to show the superiority of the commons on a capacity-maximization basis. Yet Benkler never elaborates on his choice of capacity as the proper economic objective.[201]

Ring in the New: Telephone Service Seems on the Brink of Huge Innovation, WALL ST. J., Feb. 10, 1993, at A1 (describing competition between the Baby Bells and cable companies for an anticipated multi-billion-dollar video-on-demand market).

196. *See View from Tokyo*, PC WORLD, Mar. 1, 2004, at 28 (comparing cell phone usage preferences among Japanese, British, and American youth).

197. AMIT NAGPAL & IAIN MORRIS, ANALYSYS CONSULTING, US WIRELESS: LEADER OF THE PACK OR ANOTHER DROPPED CALL? (2001), *available at* http://www.analysys.com.

198. Annual Assessment of the Status of Competition in the Market for the Delivery of Video Programming, 17 F.C.C.R. 26901, 26975 (2002). The number is higher for UHF stations. Nationwide, only 7% of assigned UHF channels are even in use. J.H. SNIDER & MAX VILIMPOC, RECLAIMING THE 'VAST WASTELAND': UNLICENSED SHARING OF BROADCAST SPECTRUM 20 (New Am. Found., Spectrum Series Issue Brief No. 12, 2003), *available at* http://www.newamerica.net/Download_Docs/pdfs/Pub_File_1286_1.pdf.

199. The bulk of television broadcast revenue now comes from legally mandated "must-carry" retransmission on cable and satellite platforms. *See* 47 C.F.R. § 76.56 (2003) (laying out the must-carry requirement); Turner Broad. Sys., Inc. v. FCC, 512 U.S. 622, 647 (1994) (noting that "must-carry rules ensure that broadcast television stations will retain a large enough potential audience to earn necessary advertising revenue"); Edward Felsenthal et al., *Justices Uphold 'Must Carry' Broadcast Rules*, WALL ST. J., Apr. 1, 1997, at B1 (suggesting that broadcast stations would be "driven out of business" without the must-carry rules). The biggest stick in the broadcaster's bundle of "spectrum rights" is the entitlement to transmission over a wire.

200. Benkler, *supra* note 6, at 29.

201. Benkler does identify other benefits of the commons approach outside the realm of comparative economic efficiency. Following Lessig's discussion in *The Future of Ideas*, he argues that a commons policy is better for innovation. *Id.* at 72. He also notes that, because a commons-

More capacity is certainly a good thing, but it is not the only thing. Why not optimize for the network that reaches the most users, or that transmits the farthest distance, or that saves batteries by using the least power?

Furthermore, capacity has more than one meaning. Does it refer to the number of connections or the number of bits transferred? The network that transfers the most bits in a given period of time, or the network that delivers the most valuable bits? And how should value be measured—in dollar terms or based on some normative concept?[202]

These are the issues network designers consider case-by-case. Design decisions in any network will optimize for some values and therefore make certain services more difficult or even impossible. The Internet's "best efforts" transmission policy has a myriad of benefits, but this policy makes it difficult to use the public Internet for latency-sensitive applications such as telephony and videoconferencing. As a general rule, meshed wireless networks do not optimize for latency, because a message may pass through a large number of intermediate nodes to reach its destination.[203] And even if an unlicensed ad hoc meshed network could deliver broadcast television, it would likely be more complex (and thus more costly) than the existing high-power, dumb receiver broadcast infrastructure. A property advocate would argue that markets should decide which uses should be advantaged because any external decision to privilege one type of network will be biased.

Yet property advocates are not immune from the usage fallacy. Coase and Herzel's original proposals focused on broadcasting, because that was the dominant form of commercial wireless communication at the time. The property regime implies certain uses in the very nature of the rights it grants, especially when those rights are based initially on existing FCC licenses.[204] Those licenses were, in most cases, designed with specific services in mind.[205] Finally, as Benkler explains, an exclusive rights regime for

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based market is based on end-user equipment purchases rather than carrier infrastructure build-outs, the commons network will respond more quickly to user preferences. *Id.* at 73.

202. Benkler's position is that policymakers optimize for information-theoretic capacity in terms of bits, because the cost of determining whether subjective value has been maximized is likely to be too high in lost capacity. *See id.* at 82. He may be right. However, my argument is that a real-time mechanism of common law backstops and safe harbors can optimize for value better than any a priori allocation such as a price mechanism.

203. *See* Dale N. Hatfield, *The Current Status of Spectrum Management*, *in* ROBERT M. ENTMAN, ASPEN INST., BALANCING POLICY OPTIONS IN A TURBULENT TELECOMMUNICATIONS MARKET: A REPORT OF THE SEVENTEENTH ANNUAL ASPEN INSTITUTE CONFERENCE ON TELECOMMUNICATIONS POLICY app. at 29, 35 (2003) *available at* http://www.aspeninst.org; Werbach, *supra* note 55, at 8–9 (quoting Hatfield).

204. *See* Faulhaber & Farber, *supra* note 5, at 203 (noting that the use of spectrum by licensees has properties, such as high power and dedicated frequencies, that are facilitated by a fee simple property rights regime); Minasian, *supra* note 46, at 227–29 (noting ways in which the present licensing system regulates the "use to which an assigned frequency may be put").

205. *See* Goodman, *supra* note 5 (manuscript at 11–12) ("After zoning frequency bands for particular uses, the FCC designs service and technical rules for each spectrum block. . . .After

spectrum leads to a top-down market structure of few service providers controlling what their customers can do. This in turn produces services oriented toward the most widely inoffensive second-best options, rather than reflecting the broad range of individual preferences.[206]

The best response to uncertainty is diversity. Many experiments are more likely to hit on the right approach than a few all-or-nothing guesses. Conversely, locally unpredictable risks can even out when aggregated with other risks. This is why insurance is such a large industry and why financial advisors recommend diversification of stock portfolios.

2. Architectural Choices.—Uncertainty is also high regarding how wireless networks will be organized. This is one area in which frequency does matter. The frequency of radio waves affects their propagation characteristics, making different frequencies more or less amenable for certain uses. Lower-frequency waves better penetrate walls, trees, water, and other obstructions, and travel farther through the air. Wireless communications systems first exploited the lowest frequencies and have gradually migrated up to higher frequencies as technology has improved. Radio operates in the kilohertz or lower, television broadcasts operate in frequencies between about 300 and 800 MHz, and most cellular phone systems operate between 900 MHz and 3 GHz. Still, 90 % of all use of the radio spectrum occurs in the 1% of frequencies below 3.1 GHz.[207] Higher-frequency systems tend to operate over shorter distances, or on a more directional basis, to compensate for propagation loss.

Frequency is not, however, the absolute determinant of which applications can be supported. There are many ways to skin a cat (or in Einstein's terms, to skin no cat). For example, low-power systems, such as UWB or in-home devices, can be connected with a small number of high-power "backhaul" links or chained together into meshed networks to provide wider coverage. A higher frequency that requires a more expensive network of devices to exploit may be cheaper overall if there is no fee to access that spectrum. These tradeoffs can best be made in real time on a distributed

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setting these rules, the FCC . . . sells . . . licenses to individual users to operate in accordance with the service rules.").

206. *See* Benkler, *Building the Commons*, *supra* note 55, at 387 (arguing that privately-owned infrastructure operating in a broadcast model has tended to homogenize and standardize information content for mass appeal). *See generally* Benkler, *supra* note 71 (arguing that property rights regimes for spectrum limit customer autonomy).

207. *Spectrum Management: Improving the Management of Government and Commercial Spectrum Domestically and Internationally: Hearing Before the Senate Comm. on Commerce, Science, and Transportation*, 107th Cong. (2002) (statement of Peter F. Guerrero, Director, Physical Infrastructure Issues, General Accounting Office), *reprinted in* GENERAL ACCOUNTING OFFICE, TELECOMMUNICATIONS: HISTORY AND CURRENT ISSUES RELATING TO RADIO SPECTRUM MANAGEMENT, GAO-02-814T, at 4 (2002), *available at* http://commerce.senate.gov/hearings/061102guerrero.pdf.

basis.[208] The appeal of a property rights regime for spectrum is that it seems to allow market mechanisms to execute such real-time transactions. In reality, though, as Noam argues, exclusive ownership of frequencies would be more of a barrier to real-time transactions than a facilitator.[209] In Part V below, I analyze the competing spectrum proposals' influence on real-time transactions more closely.

Wireless systems may also trade off among the three fundamental variables in any data network: transmission capacity, switching, and storage. Consider an analogy from the wired Internet. The Internet is packet-switched: all communications are broken up into small pieces called packets. Because it is a best-efforts network, delivery of an individual packet can never be guaranteed. Yet some applications, such as streaming video, cannot tolerate jitter, which is the degradation of picture quality due to excessive packets lost in transit. One solution is buffering. A small portion of the video file is downloaded to the user's computer before the video stream starts running. While the user watches that section, the next chunk is being downloaded in the background, and so forth. The added buffer between transmission and viewing effectively makes the system more forgiving to packet loss in the network.

Buffering works by trading storage (the user's hard drive) for transmission.[210] It is a special case of a fundamental equivalence in networking among transmission, switching, and storage. Another case is packet-switching's "wasting" of computation by distributing switching to routers operating throughout the network.[211] In so doing, it economizes on

208. *See infra* subpart V(D).

209. *See* Noam, *supra* note 4, at 766–69 (outlining the problems of exclusivity regimes and explaining that paradigms of licensed exclusivity in spectrum allocations are being displaced, thanks to new digital technology).

210. In this case, the tradeoff imposes a penalty in the form of latency, or delay prior to the start of the video transmission. Caching, or storing frequently-accessed content close to the user and intelligently delivering it from those nearby stores rather than across the network, has the opposite effect. *See, e.g.*, DAVID G. MESSERSCHMITT, NETWORKED APPLICATIONS: A GUIDE TO THE NEW COMPUTING INFRASTRUCTURE 356 (1999).

211. Hazlett mistakenly sees this feature as a bug. *See* Hazlett, *supra* note 53, at 491–93. Noting that spectrum commons advocates often draw analogies to the Internet, he argues that the Internet is inherently wasteful and will fail to deliver promised service without imposition of usage-based pricing mechanisms. *Id.* It is true that some services such as real-time streaming video are difficult to deliver on a best-efforts network. One response has been content delivery networks such as Akamai that use local caches to improve performance. *See, e.g.*, SOCIAL AND ECONOMIC TRANSFORMATION IN THE DIGITAL ERA 183 (Georgios Doukidis et al. eds., 2004). Caching is another example of "wasting" storage and processing to economize on transmission. *See supra* note 210. Another solution has been the deployment of private Internet connections, in some cases employing usage-based pricing. Contrary to many predictions, though, the existence of such "premium" services has neither displaced the best-efforts Internet nor relegated it to awful performance. The Net has been exceptionally resilient to its own growth and to attacks and failures which might have shut it down. Hazlett points to fiber backbone operators that raised large amounts of capital and had huge market capitalization based on the premise they would overcome the Internet's messy capacity limitations. Hazlett, *supra* note 53, at 489–91. Most of these companies

transmission in contrast to circuit-switched networks that hold open an end-to-end circuit for the duration of every call. The costs of computing are falling faster than those of end-to-end transmission, which is one reason the Internet is so successful.[212] Spread-spectrum is another example of wasting computation in order to economize on transmission—in this case the wireless channel.

Traditional broadcast networks are "better" than the Internet in their ability to guarantee delivery of the same content to every user, and to do so with simple (and therefore cheap) equipment. Yet the Internet is "better" than broadcast in its ability to support two-way interactivity, a multitude of services and content offerings, as well as rapid innovation. If there must be a choice between using spectrum for broadcast or Internet applications, there is no neutral way to decide.

C. Perils of Paradigms

1. The Right Kind of Mistakes.—The fact that spectrum is not a thing, or that assumptions about wireless systems cannot be sustained, does not necessarily mean those viewpoints are not useful. We merrily act as though the physical world were solid and deterministic even though quantum mechanics tells us with great confidence that it isn't. Neoclassical economics rests on the idea that even though people may not always behave rationally, we can act as though they do. The simplifying assumption of individual rationality allows economists to make accurate predictions about collective behavior, which smoothes out the variations. The spectrum fallacy is different. It produces ideas that are not just wrong—they are dangerous.

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subsequently saw their stock prices collapse and several are in bankruptcy. *See* Yochi J. Dreazen, *Wildly Optimistic Data Drove Telecoms to Build Fiber Glut*, WALL ST. J. ONLINE, Sep. 26, 2000 (including WorldCom, Global Crossing, 360networks, Velocita Corp. and others among the "casualties"), *available at* http://www.cmg.org/downloads/Fiber_Glut_WSJ_020926.pdf. Few of the promised bypass routes have been built. *See id.* (reporting that only 2.7% of recently-installed fiber is being used). Yet the "wasteful" Internet continues to grow.

212. Under the famous Moore's Law, computational power doubles approximately every 18 months, all other things held equal. GILDER, *supra* note 61, at 2. Background information on Moore's law, which was originally an observation regarding integrated circuit densities, can be found on Intel's web site at http://www.intel.com/research/silicon/mooreslaw.htm. Transmission capacity on a per-link basis is doubling roughly every 12 months, though end-to-end capacity improves more slowly because it is no better than the weakest link in the chain. *See* RICHARD BROOKES & ROGER PALMER, THE NEW GLOBAL MARKETING REALITY 169 (2004) (asserting that increases in bandwidth cause the cost of data transmission to halve every 12 months); Andrew M. Odlyzko, *Internet Traffic Growth: Sources and Implications*, *in* OPTICAL TRANSMISSION SYSTEMS AND EQUIPMENT FOR WDM NETWORKING II, at 1 (B.B. Dingel et al. eds., 2003) ("Internet traffic continues to grow vigorously, approximately doubling each year, as it has done every year since 1997."). Storage is improving the fastest of all, doubling in capacity every nine months. Dan Orzech, *Rapidly Falling Storage Costs Mean Bigger Databases, New Applications*, CIO UPDATE, June 4, 2003, *at* http://www.cioupdate.com.

The idea of spectrum as a concrete thing divided by frequencies is a paradigm, in the sense made famous in Thomas Kuhn's *The Structure of Scientific Revolutions*.[213] A paradigm provides an organizing worldview that is useful most of the time, when incremental advances take the form Kuhn called "normal science."[214] At some point, though, the paradigm can become a liability. It obscures truly radical ideas that may be major improvements on the current paradigm. On rare occasions, the paradigm itself must shift for science to move forward. The classical spectrum paradigm has served us well, but it is nearing the end of its usefulness.

Treating spectrum as a thing begs the very question spectrum policy must answer: how scarce spectrum really is. Two people cannot farm the same plot of land at the same time. Saying that spectrum is like land implies that the same exclusivity applies. But as I have explained, it does not. Such constraints on simultaneous usage as do exist are a complicated function of system design, equipment capacity, and application robustness. Treating spectrum as a resource defined by frequencies makes it difficult or even impossible to allocate it along different dimensions, even if that would increase the capacity and value of that spectrum.

A more subtle danger of the spectrum fallacy is that it implies false certainties. This in turn makes the inevitable errors of spectrum policy more difficult to correct. An analogy to the scientific method may prove helpful. A scientific theory can never be right. It can only be wrong.[215] That is because no theory is ever a perfect description of reality, or at least we can never prove that it is. The object of a theory is explanation, which leads to prediction and action. The beauty of the scientific method is that, purely through constant iteration of prediction and experimentation, it shows which theories are wrong and therefore produces better theories.

Newton's mechanics told astronomers that the orbit of the planet Uranus was being deformed by some other massive body, and told them where to look for it. Lo and behold, they discovered Neptune in precisely that place.[216] Yet as we now know, Newton's mechanics are wrong. They suffice to describe the macro-scale world of our subjective experience, but not the cosmological world of astronomical scale nor micro-world of funda-

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213. THOMAS S. KUHN, THE STRUCTURE OF SCIENTIFIC REVOLUTIONS, at viii (2d ed., enlarged) (defining paradigms as "universally recognized scientific achievements that for a time provide model problems and solutions to a community of practitioners").

214. *See id.* at 24 (describing normal science as research directed at supporting and extending the currently accepted paradigm).

215. For this reason, the philosopher Karl Popper has described the scientific method in terms of falsifiability. *See* KARL POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY 41 (1934) (stating that "it must be possible for an empirical scientific system to be refuted by experience"). A non-scientific contention, such as "God exists," may in fact be true. The trouble is that if it is not, there is no means to prove it false.

216. JOAO MAGUEIJO, FASTER THAN THE SPEED OF LIGHT: THE STORY OF A SCIENTIFIC SPECULATION 58 (2003).

mental forces and particles.[217] Einstein's theories of special and general relativity, combined with quantum mechanics, form a more accurate understanding of reality.

An incorrect theory may, however, still be useful. It is Newton's physics, not Einstein's, that is taught to every high school student today. For most phenomena we are concerned with, Newton's physics still gives the correct answer. And Newton's physics is simpler in application and more tractable in concept than Einstein's. By contrast, no physics or astronomy course teaches Ptolemy's theory of planetary epicycles. Not only is it more complicated than the alternative—elliptical orbits around the Sun—its assumption that the planets revolve around the Earth offends our modern perspective.

So our goal is a theory of wireless communications that, at worst, encourages Newtonian errors. It should remain useful even if some of its assumptions later turn out to be false. Ideally, it should adapt gracefully to such shifts. The only constancy, after all, is change. The best policy approach to wireless communications is one that mimics the current regime only if capacity and other limitations are in fact as Congress believed them to be in 1927. If not, it should adapt to handle new efficient usage patterns under the technical backdrop now widely accepted, one of digital convergence and significantly less scarcity.

Crucially, it shouldn't stop there. If the rules governing radio transmissions simply allow more high-power broadcasters or cellular telephony systems to exist, we will have won the last war. Yet if technology and society continue to evolve, making new systems viable that roll back scarcity beyond the perceptual horizon, rules that build in today's assumption will produce the same welfare losses over the next seventy years as the licensing regime has over the last seventy.

For all its flaws, the government licensing model of spectrum is resilient to certain errors. Herbert Hoover, opening the first National Radio Telephony Conference in 1922, expressed the technical conviction of the day that "the use of the radio telephone for communication between single individuals as in the case of the ordinary telephone is a perfectly hopeless notion."[218] Yet Hoover's licensing regime was able, many years later, to accommodate cellular telephony. Because the government retains ultimate control over spectrum, it can reallocate or reassign frequencies to allow for

217. Astronomers used the same method that had predicted Neptune to postulate a planet inside Mercury's orbit. However, this time they found nothing where the planet should have been. The discrepancy turned out to be evidence that at these great scales, Newtonian mechanics broke down. *See id.* at 58–59.

218. Herbert Hoover, Keynote Address at the First National Radio Telephony Conference (Feb. 27, 1922), *reprinted in* 2 HERBERT HOOVER, THE MEMOIRS OF HERBERT HOOVER: THE CABINET AND THE PRESIDENCY 140 (1952).

new possibilities. Unfortunately, that control comes at a cost in efficiency. The FCC did not license cellular until the 1980s, though such systems were technically feasible decades earlier. This delay resulted in a huge economic loss.[219]

The property rights and commons models both remove the paralyzing requirement that any change in the configuration of spectrum rights requires government approval. However, both risk pushing spectrum in suboptimal directions that are difficult to reverse. Three main dangers for the property model are monopolization, holdouts, and transaction costs. Spectrum owners may refuse to engage in transactions that would, in a global sense, be efficient, or transactions won't take place because of the overhead of market pricing and negotiation. The perceived danger of the commons model is chaos. Either users will step on each other to the point where spectrum is useless, or the administrative costs of dispute resolution will be too great.

In both cases, the failures could be difficult to fix. Private property can only be taken back by the government with compensation, which can be a costly, political, and time-consuming process. Unlicensed devices, once sold, are under the control of individual users, making it difficult to switch from a commons to another form of spectrum rights.[220]

2. Coexistence.—Given the risks inherent in the property and the commons approaches, the best spectrum policy framework should tolerate both.[221] As I explain in greater detail in Part V, the choice between property and commons is essentially a bet about scarcity and transaction costs. Where wireless devices can easily coexist, and transactions for proprietary transmission rights are costly, commons is the right approach. I believe this will ultimately be the case more often than not, but such an outcome is not guaranteed. If equipment coexistence is expensive (i.e., "spectrum is scarce") and transactions are cheap, exclusive property rights are a superior mechanism.

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219. One study estimates that the delay reduced U.S. economic welfare by at least $86 billion in 1990 dollars. JEFFREY H. ROHLFS ET AL., NAT'L ECON. RESEARCH ASSOCS., ESTIMATE OF THE LOSS TO THE UNITED STATES CAUSED BY THE FCC'S DELAY IN LICENSING CELLULAR COMMUNICATIONS 2 (1991).

220. The commons may not be as difficult to reverse as it appears. *See infra* notes 455–57 and accompanying text.

221. Coase, though rightly cited as the father of the property rights approach, made clear that only with experience could it be determined how widely such rights should be employed. *See* Coase, *supra* note 3, at 34 ("How far this delimitation of rights should come about as a result of strict regulation and how far as a result of transactions on the market is a question that can be answered only on the basis of practical experience.").

Fortunately, the property and commons models are not mutually exclusive.[222] The FCC today controls some spectrum through traditional government licensing (for example, the broadcast bands), allows flexible use of some spectrum (the PCS bands), and provides for unlicensed commons (in the 2.4 GHz ISM band and the 5 GHz U-NII bands, as well as for Part 15 and UWB devices).[223] Far from being a completely new idea, unlicensed operation has been recognized in FCC rules since 1938, in the form of Part 15 devices.[224] Part 15 devices can transmit in a large section of spectrum, so long as they operate with very low power (less than one watt).[225]

Property and commons coexisting makes sense for other reasons. The easiest way to make a wireless commons work is to limit power output of devices. This significantly reduces the number of situations where two transmissions will be in conflict because less power means less range.[226] Unlicensed systems have therefore tended to be either short-range or highly directional. WiFi, for example, delivers signals less than 300 feet. Broadcast applications, which seek to blanket an area the size of a city with the same content, generally use high-power narrowband transmission. A single WiFi hotspot is not a substitute for an over-the-air television broadcast tower.[227] On the other hand, a broadcast system cannot support millions of independent transmitters in a city the way WiFi can. It is more difficult to guarantee quality of service or equipment compatibility in an unlicensed environment than under an exclusive use model, but it is still more difficult to allow for experimentation by equipment vendors under exclusive use.

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222. Proponents of both models now advocate a hybrid approach to move forward. *See supra* note 5. The convergence of the property and commons models for spectrum policy tracks efforts in other areas to bring together these two approaches. *See, e.g.*, Rose, *supra* note 107, at 155 (describing "limited common property" situations that are exclusive on the outside and commons on the inside).

223. *See generally* 47 C.F.R. pt. 73 (2002) (regulating broadcast television and radio); 47 C.F.R. pt. 23 (2003) (regulating personal communication services (PCS)); 47 C.F.R. pt. 18 (describing regulation of devices for industrial, scientific, or medical (ISM) use); 47 C.F.R. pt. 15 (2003) (regulating unlicensed National Information Infrastructure devices and other unlicensed devices).

224. *See* Revision of Part 15, *supra* note 59, at 3494 (recounting the history of Part 15).

225. 47 C.F.R. § 15.247 (2002).

226. Technically speaking, power is a more complicated concept because it can be measured in different ways for wireless systems. A spread-spectrum system may have relatively high total power when output, but low power measured at any individual frequency—this is known as power spectral density. *See* MISCHA SCHWARTZ & LEONARD SHAW, SIGNAL PROCESSING: DISCRETE SPECTRAL ANALYSIS, DETECTION, AND ESTIMATION 115–16 (1975) (defining and discussing power spectral density). Or the power may be focused in a narrow beam which goes a long distance but does not spread significantly in other directions.

227. It may, however, be possible to deliver a wide-area broadcast service at low power using some cooperation gain techniques such as mesh networking, directional antennas, and intelligent coding. *See, e.g.*, Fowler, *supra* note 133, at 19 (discussing techniques for providing wide-area broadcast service to a larger number of customers than xDSL or existing wireless networks). These techniques do impose a tax in the form of latency or higher equipment costs, though these are technological variables that will decrease over time. It is fair to say that existing commercial unlicensed systems are no substitute for broadcast, but that may eventually change.

Despite the intensity of the debate between property and commons advocates, the FCC, at least, sees no reason to choose. It adopted its secondary markets order and its decision to allocate 255 MHz of new spectrum for unlicensed operation on the same day in May 2003.[228] And as noted above, the Spectrum Policy Task Force recommended expanded use of both the exclusive rights and commons paradigms.[229] Both overcome the artificial scarcity and inefficiencies of the FCC licensing mechanism that has dominated up to now. What the FCC recognized is that spectrum scarcity is not a global constant. It may exist in certain places and times, but not in others. Whether spectrum is scarce depends on propagation characteristics, other users, the nature of the desired service, and the state of technology.

The FCC was mistaken, however, in assuming that scarcity and transaction costs can be mapped mechanically to frequencies. Specifically, the FCC proposed that exclusive property rights be the primary mechanism at lower frequencies, and commons the primary mechanism above 50 GHz, because there is less scarcity and higher transaction costs at those higher frequencies.[230] Such a blanket statement is simply not accurate. The FCC's own Television Band Notice of Inquiry proposes allowing unlicensed devices to operate in the low-frequency broadcast bands, recognizing the significant amount of "white space" in those frequencies.[231] The Northpoint technology that allows terrestrial and satellite systems to coexist reduces scarcity in ways that are independent of the frequency in which the technology operates.[232] The FCC's thinking is still constrained by the frequency-denominated spectrum fallacy, in which lower bands have many assigned licensees and most frequencies in the tens or hundreds of gigahertz are "empty."

The way for property and commons to coexist is not to give the beachfront to one model and a few acres of empty desert to the other. That assumes too much about scarcity and transaction costs. If the assumptions prove wrong, the basic split among the two models would need to be changed, but at that point it would be too late. The "property" section of spectrum would be locked in place by the constitutional ban on uncompensated takings, and the "commons" section would be filled with transmitters.

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228. Press Release, FCC, FCC Adopts Spectrum Leasing Rules and Streamlined Processing for License Transfer and Assignment Applications, and Proposes Further Steps to Increase Access to Spectrum Through Secondary Markets (May 15, 2003), *available at* http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-234562A1.pdf; Press Release, FCC, FCC Proposes Additional Spectrum for Unlicensed Use (May 15, 2003), *available at* http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-234566A1.pdf.

229. *See supra* notes 83–87 and accompanying text.

230. Spectrum Task Force Report, *supra* note 83, at 38–39.

231. TV Band NOI, *supra* note 87, at 25632 (calling for public comment on the feasibility of, and technical requirements for, allowing unlicensed devices to use the TV broadcast spectrum when idle).

232. *See supra* note 174 and accompanying text.

An appropriate division between commons and property in spectrum would have to take into account the multitude of possible technologies and architectures for wireless communication, as well as the architectural biases of each regime. Each regime can hypothetically support any outcome, but each creates incentives that make certain business models more or less viable.

IV. Supercommons

The previous Part detailed the problems with the conventional understanding of spectrum, concluding that the optimal regime would be one that accommodated both property rights and commons mechanisms in a sensible way. In this Part, I develop such a proposal. The building blocks of this new framework are bundles of use rights associated with wireless communications equipment. As explained above, nothing else is real. After reconstructing the spectrum debate in terms of equipment rights, I outline a proposal for expanding on previous property and commons ideas.

All of the spectrum policy regimes involve property rights. These are not rights in spectrum or frequencies, but in equipment. The seemingly wide gap between the property and commons models is actually two small differences in the configuration of those rights.[233] The exclusive rights model vests rights in the first instance in intermediary service providers, while the commons model generally vests them in end-users. And the exclusive use model associates the transmission rights with correlative duties upon other transmitters that the commons model does not impose. Proponents of both models have typically linked them to frequencies, though there is no fundamental reason to do so.

A wireless communications model without the limiting assumptions of the spectrum fallacy could exploit the many dimensions of freedom for adding capacity identified in the previous Part. It would be similar to the

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233. Howard Shelanski and Peter Huber reach a similar conclusion from a different direction. *See* Howard A. Shelanski & Peter W. Huber, *Administrative Creation of Property Rights to Radio Spectrum*, 41 J.L. & ECON. 581, 583 (1998). Their objective is to demonstrate that the FCC has actually created significant property rights in spectrum through administrative decisions regarding licenses. *Id.* To consider these attributes "property rights," they must replace the idea of a holistic "ownership" with a legal realist bundle of rights. *See id.* at 584. And to do that, they must acknowledge that spectrum is not a thing to be owned:

> The mere label of "ownership" is unhelpful. With spectrum especially, that label often obscures more than it illuminates. There is no such thing as "spectrum" out there, any more so than there was "ether," to be bottled by the Commission or anyone else. "Spectrum" is composed entirely of the engineering characteristics of transmitters and receivers.

Id. Shelanski and Huber go on to build an impressive case that the FCC has, in fact, strengthened the bundle of transmission and reception rights it allocates to spectrum licensees. *Id.* at 605. Doing so does not, however, imply that the FCC *should* be moving toward greater property rights, merely that it can. Overcoming the spectrum fallacy as a descriptive matter destroys much of the basis for the program of spectrum propertization.

commons model, but would find virtual commons everywhere. Such a model, which I call supercommons, combines incremental experimentation from current baseline licenses with a universal access privilege wherever a transmission would not be harmful to other systems. The white space that is now off-limits may turn out to be bigger than the entire "usable" spectrum today. It is as though we have been mining quartz and tossing aside the shiny nuggets of gold that are pulled up as well.

A. Defining Rights

1. Uncertain Borders.—The debate about whether to turn spectrum into private property, or to open up unlicensed commons, has often ignored the critical issue of how to define the rights involved. Saying there should be wireless property rights makes no sense without a clear understanding of what those rights entail.[234] A vaguely defined right invites litigation, which increases the administrative costs of the property system. As the nations of the former Soviet Union and Eastern Europe have found, capitalist mechanisms that thrive elsewhere fail if implemented poorly.[235] For land, there are centuries of legal precedent and webs of formal regulatory, as well as informal customary boundaries, that make abstract property rights useful. This backdrop does not exist for spectrum, which, to reiterate, is not a physical resource like land.[236]

Nor does the possibility of private contracting after the rights have been assigned solve the problem.[237] Parties engaged in such Coasian bargaining

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234. "If the right to use a frequency is to be sold, the nature of that right would have to be precisely defined." Coase, *supra* note 3, at 25. Yet Coase himself failed to offer such a definition in his original paper. *See id.* at 34 (suggesting instead that such a definition must come from practical experience). He merely stated that rights should be alienable and subject to subdivision, aggregation, or modification upon agreement of the parties involved. *Id.* The De Vany group, writing a decade later, acknowledged that no one had yet provided a concrete proposal for spectrum property rights: "It is our belief that the parties to this debate have never truly joined issue. The market mechanism *as a theory* cannot be offered as an alternative to FCC regulation; to make the debate useful it is first necessary to articulate a detailed system of property rights in spectrum usage." De Vany et al., *supra* note 46, at 1500–01. Coase and two co-authors did develop a more thorough proposal for spectrum property rights in 1963, but it was deemed too controversial to publish at the time. *See* R.H. Coase, *Comment on Thomas W. Hazlett: Assigning Property Rights to Radio Spectrum Users: Why Did FCC License Auctions Take 67 Years?*, 41 J.L. & ECON. 577, 579–80 (1998) (recounting Coase, Meckling, and Minasian's preparation of a draft report and its suppression by the RAND Corporation). The report was published by RAND in 1995 as an "unrestricted draft." RONALD COASE, WILLIAM H. MECKLING, & JORA MINASIAN, RAND CORPORATION, PROBLEMS OF RADIO FREQUENCY ALLOCATION, at iii (RAND unrestricted draft no. DRU-1219-RC, 1995) (noting that "[f]or various reasons, [the manuscript] never reached the publication stage").

235. *See* HERNANDO DE SOTO, THE MYSTERY OF CAPITAL: WHY CAPITALISM TRIUMPHS IN THE WEST AND FAILS EVERYWHERE ELSE 6 (2000) (identifying the lack of formal property systems in many developing countries as an impediment to the successful implementation of capitalism).

236. *See* Goodman, *supra* note 5 (manuscript at 13) (noting ways in which spectrum is not like land).

237. As Singer describes:

must understand what they have as a baseline for negotiation. Otherwise their agreements will be inefficient at best, impossible at worst, and costly to achieve regardless. Initial conditions matter. Inefficient initial definition of rights can be reinforced through path dependence, becoming an insurmountable obstacle to optimization.[238] The terms of the bargains that can be struck depend on the parameters of the rights granted. If spectrum property rights are all frequency-delimited, private negotiation will artificially be constrained in terms of frequencies.

The boundaries of spectrum rights seem clear today because the FCC has restricted the possibility space, and because many techniques have only recently become technically feasible. Under the prevailing government licensing model, wireless transmission systems may not be altered beyond government-mandated specifications, which are tied to frequency bands. How far the licenses extend has been a moot point, because no one else could test their limits without themselves running afoul of regulatory constraints.

The FCC's ultra-wideband (UWB) proceeding gives a glimmer of the difficulties to be expected with ill-defined spectrum rights under a property or commons model. The FCC proposed in 1998 to authorize UWB devices across a wide swath of licensed spectrum, on the grounds that such devices used extremely low power and could coexist without causing harmful interference.[239] It finally did so in February 2002.[240]

The UWB proceeding was intensely controversial, stretching over four years and generating many hundreds of comments and significant congressional interest. A central issue was whether the UWB devices would be detrimental to various licensed users of spectrum, including public safety services, Global Positioning System receivers, and mobile phone systems.[241]

> Before two parties can enter into a contract, we must define what they own. Otherwise, we cannot determine who is buying and who is selling. In situations involving neighboring owners, for example, we cannot just leave it to the market—that is, rely on private contracting alone—to determine which party should prevail.

SINGER, *supra* note 112, at 59.

238. Property advocates argue that any property rights are better than the current licensing regime. And they may be correct. However, a short-term efficiency gain at the cost of long-term structural inefficiency is not a worthwhile trade.

239. Revision of the Rules Regarding Ultra-Wideband Transmission Systems, 65 Fed. Reg. 37332 (2000) (proposed rule). UWB's basic technology is described above. *See supra* notes 160–63 and accompanying text.

240. UWB Order, *supra* note 146, ¶¶ 4–5.

241. Hazlett criticizes the FCC for taking so long to authorize UWB. The alternative he proposes is an administrative allocation of several exclusive underlay property rights: "Several licenses could be allocated per band, up to the ceiling set by the 'noise floor' limits extended licensees transmitting over the underlay rights." Hazlett, *supra* note 53, at 509. This simply wishes away the thorny problem of potential interference that was the cause of the drawn-out FCC proceeding. There are no clear "noise floor limits" in existing FCC licenses, nor does Hazlett propose any for the spectrum property rights he favors. Furthermore, the argument of the licensed service providers is that even if one UWB device is infinitesimally faint, many will in aggregate exceed the noise floor. Hazlett offers no mechanism by which his underlay rights holders would be able to show they were not exceeding noise floor boundaries in aggregate.

Despite intense pressure, the FCC concluded they would not.[242] However, the Commission imposed extremely conservative initial limits on UWB to protect incumbent services.[243] The FCC stated that it planned to review those limits in the future, to determine if they could be relaxed.[244]

The UWB proceeding illustrates how difficult it can be to analyze interference claims when nonfrequency limited communications systems are involved. It also provides a good example of how fuzzy spectrum property rights would be. Sprint, which operates a licensed Personal Communications System (PCS) cellular network, opposed authorization of UWB on the grounds that its FCC licenses gave it exclusivity over the bands where it operated.[245] In other words, Sprint claimed its license implicitly granted it a degree of control similar to an exclusive use property right, even below the noise floor.

The FCC rejected Sprint's claims, stating that "[t]his spectrum is not, and has never been, exclusive to Sprint or to any other licensee or user."[246] However, this is no guarantee that a court would hold similarly if Sprint's license were a property right. The FCC, after all, was the very agency that granted Sprint its license, and that license had explicit limitations and conditions.

It is one thing for the FCC to hold that the license, which already carved out a space for low-power Part 15 devices, was also not exclusive to underlay UWB devices. It would be a different thing for a court to conclude that a licensee such as Sprint with exclusive property rights was subject to the same limitation. If Sprint and the FCC disagree today about the boundaries of Sprint's license, how will the answer be any clearer with no authoritative FCC in the picture? The judicial process of fixing such boundaries, and then

242. UWB Order, *supra* note 146, at ¶ 18.

243. Separate Statement of Commissioner Michael J. Copps re: Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems, 17 F.C.C.R. 7551 (2002) ("Because the effects of widespread use of UWB are not yet fully known, and interference could impact critical spectrum users, I will support, albeit somewhat reluctantly, the ultra-conservative ultra-wideband step we have taken today.").

244. *Id.*

245. *See* Sprint Petition for Reconsideration at 4–8 (June 17, 2002), Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems, 17 F.C.C.R. 7435, 17 F.C.C.R. 10505 (2002) (ET Docket No. 98-153) (arguing that PCS licensees hold exclusive licenses and that the FCC cannot require them to be shared), *available at* http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6513198006; Letter from Charles W. McKee, General Attorney, Sprint PCS, to Bruce A. Franca, Acting Chief, Office of Engineering and Technology, Federal Communications Commission 8 (Feb. 21, 2001) ("Having received valuable consideration for issuing exclusive licenses, the Commission does not now have the legal right to convert these licenses into non-exclusive licenses and to require Sprint PCS to share its spectrum with others, much less share its spectrum for free."), *submitted as* Written Ex Parte Notification (Feb. 21, 2001), Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems, 15 F.C.C.R. 12086 (2000) (ET Docket No. 98-153), *available at* http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6512560405.

246. UWB Order, *supra* note 146, ¶ 271, at 7526.

transacting around them, would create costs and uncertainties for both Sprint and potential UWB entrants.

The FCC's determination does not mean Sprint has no rights against other users in the frequencies covered by its licenses, but merely that its rights are not absolute.[247] The FCC could not authorize an identical PCS system in the area of Sprint's license that would cause massive interference, or, to take an extreme case, a PCS jamming service. Sprint's rights must have some boundaries. They are just not well-defined. And that means that the rights of erstwhile UWB transmitters that wish to underlay Sprint's system are equally ill-defined.

What about the FCC's commitment to review those rules? The FCC's imposition of stringent limits on UWB was based on the expectation that a cautious approach would not cause too great a loss for the UWB market, because those limitations could be relaxed in the future.[248] Why should the UWB vendors lose the possibility of relaxing the restrictions, or be forced to pay each property rights owner for a larger underlay, simply because inalienable licenses have turned into permanent property rights? The UWB underlay commons is property as well, and UWB device owners have a right to use their equipment like the owners of devices operating in licensed spectrum. On the other hand, exclusive use property owners can make a legitimate argument that the underlay rights must end somewhere, or their property rights have no meaning.

The question, therefore, is how to draw boundaries. And those boundaries will change over time, based on evolving technology and usage.

The UWB case is one example of a much larger problem. The rights encoded in existing FCC licenses are broadly under-specified or mis-specified.[249] They seem clear only because participants in the market have been artificially constrained from pushing on them for so long. If we want to move from the brittle and inefficient government licensing model to one that offers significantly greater flexibility, as both the property and commons camps propose, the content and contours of wireless communications rights will be extremely important. They will be the baselines for negotiations, litigation, or technical standards.

Consider a conventional high-power television broadcaster today. What exactly does it possess? The traditional formulation is that it has a government-issued exclusive license to a six-megahertz range of frequencies,

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247. The distinction is a semantic one. Though the FCC did not use these terms, it found that Sprint's "exclusive" license gave it rights to exclude other high-power transmitters, but not to be the sole exclusive transmitter operating in those frequencies. *Id.*

248. UWB Order, *supra* note 146, ¶ 178.

249. *See* Stuart Minor Benjamin, *The Logic of Scarcity: Idle Spectrum as a First Amendment Violation*, 52 DUKE L.J. 1, 85 n.259 (2003) (recognizing that "new uses of allocated spectrum raises the question of the breadth of the existing licenses").

with certain geographic, service, and technical limitations. Though such a description has proven useful over the years, it is misleading. The frequencies do not belong to the government to license to the broadcaster; they are simply a parameter of a physical phenomenon—electromagnetic radiation. The restrictions on the license are expressed in terms such as power output, antenna location, waveforms, or protocols, which are characteristics of equipment.

In the broadcast case, the license also incorporates a mandatory protocol, NTSC, which applies not only to the broadcaster's own equipment, but to FCC-certified television receivers.[250] The ability to broadcast would be of no value if standard televisions could not receive those broadcasts. Those receivers, however, are neither built nor owned by the broadcaster, and they receive many frequencies other than the ones our broadcaster controls.

How far does the broadcaster's exclusive license in the frequencies extend? "Exclusive" would seem to imply that no one else may transmit in those frequencies.[251] However, as the Sprint UWB challenge shows, that statement is too broad. Many intentional or unintentional emitters of radiation will radiate discernable signals within the frequency range and geographic footprint of the license. Two physically adjacent licensees in the same frequencies will experience mutual interference or cross-fading at some intermediate point. A transmitter in an adjacent frequency to that of the license using different waveforms may disturb reception for some of the broadcaster's customers, even though it is not "in" the licensed frequency. The ever-present "noise floor" will vary over time and location, and at some distance from the licensed broadcast transmitter the signal may be difficult to pick up purely due to ambient noise. In spectrum other than the broadcast bands, the FCC has authorized low-power Part 15 and ultra-wideband devices to operate in the same frequencies as licensed services.[252] All of these are implicit constraints on the licensee's exclusive rights.

The FCC expresses the licensee's exclusivity as freedom from "harmful interference," which is defined as unwanted energy that "seriously degrades, obstructs or repeatedly interrupts" a licensed radio communications service.[253] In the static, broadcast-oriented environment that prevailed when

250. NTSC stands for National Television Systems Committee, the group that formed a common broadcasting standard. The standard has been the exclusive form of broadcasting in the United States since 1940. *Id.* at 19 n.57.

251. Even this is not always the case. In some frequencies, there are primary and secondary licensees. The secondary licensee is not protected against interference from the primary licensee, but is protected against harmful interference from others. *Id.* at 8–9.

252. *See* Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems, 15 F.C.C.R. 12086 (May 10, 2000).

253. 47 C.F.R. § 97.3(a)(23) (2002).

the government licensing regime was established, these concepts had some meaning. An observer could compare the television picture with and without an offending transmission and make a judgment about whether the degradation is "serious," for example.[254] Even in this simple case, though, there may be difficulties. The same signal will more seriously degrade the picture on a TV far from the transmitter.

Now assume that the broadcaster's license is converted into a fee simple property right. The time duration, public interest obligations, and restrictions on alienability in the FCC-granted license go away. However, the frequencies are still just a parameter of equipment, not something the broadcaster can own.[255] In fact, surprisingly little has changed. The broadcaster still has a transmission right bounded by frequency and technical restrictions, and ill-defined protection against interference.

Though the broadcaster now has the nominal right to alter its service, for example by changing from UHF television to cellular telephony, in practice it is limited to the dimensions of the erstwhile FCC license. This is because the technical parameters of the license were designed to prevent interference between the licensee and other licensees. Changing the service by altering the power, transmitter or antenna location, or waveforms may cause serious degradation of adjacent property rights holders. Or it may cause them to claim such degradation as a means to preclude competitive entry.

Deciding whether the interference claim is legitimate will not be easy. The property right is based on the preexisting FCC license, whose dimensions were defined with regard to the service originally authorized by the Commission. The dimensions of adjacent licenses were also defined based on assumptions about interference from the authorized service. If other spectrum owners complain that some of the hundreds of towers that make up the new cellular data network are causing interference that the single central UHF broadcast tower did not, some dispute resolution mechanism must come into play.[256] Common law doctrines of nuisance and

254. In reality, the interference rules have been interpreted to bar transmissions that would interfere with a hypothetical receiver within the licensee's footprint, even if no such receiver exists. *See, e.g.*, Spectrum Task Force Report, *supra* note 83, at 25–30 (describing predictive interference modeling and a proposed "interference temperature" metric to quantify the RF power available at a hypothetical receiving antenna). In other words, the mere fact that someone could put a television in a particular spot and experience degraded service is enough to shut down another transmitter.

255. Coase, *supra* note 3, at 32–33 (clarifying that what is actually being allocated is a right to use a piece of equipment in a certain way and not a frequency per se).

256. *See* Goodman, *supra* note 5 (manuscript at 4–6) (advocating the continued use of a regulatory agency in resolution of the spectrum conflicts that "will arise after the hypothesized sunset of command and control regulation"). Property advocates acknowledge the need for dispute resolution mechanisms. *See* Hazlett, *supra* note 53, at 551–53 (proposing a spectrum court to replace the FCC).

trespass may be used to resolve such disputes, but the only recognizable baseline will be the preexisting license constraints.[257]

Property proponents have advanced two concrete mechanisms for defining spectrum rights. The first is organic evolution of common law. Tom Hazlett argues that the Federal Radio Act of 1927 stopped the natural development of a spectrum jurisprudence in state courts based on the doctrine of "first in time, first in right."[258] This claim is based on a single unreported state case and is therefore problematic on its own terms. Even granting that a first in time doctrine would have worked in 1927, however, does not mean it is anywhere near sufficient in the twenty-first century. The case of two well-defined adjacent broadcasters[259] is light years away from the situation of many roving ad hoc transmitters using some combination of spread-spectrum, directional antennas, meshed networking, and software-defined radio. Saying that the first transmitter in a frequency has rights against any future transmissions in the frequency is simply a recapitulation of the problematic FCC licenses.

The second set of proposals involves formal definitions of initial property rights. The effort led by Arthur De Vany is the most detailed.[260] Unfortunately, the oft-cited law review article by De Vany and his collaborators was published in 1969, virtually as close to the creation of the FCC in 1934 as it is to the present day. De Vany's system, like Hazlett's aspirational common law approach, implicitly assumes the static broadcast world of the past rather than the dynamic environment today's technologies make possible.[261] It is a means to resolve interference among users of frequencies, when neither interference nor frequency holds sway in the way it once did.[262]

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257. *See* Faulhaber & Farber, *supra* note 5, at 200–01 (explaining that property rights in spectrum would be constrained in a manner similar to real property rights and that the constraints would be the "technical restrictions in current licenses"). The FCC, in fact, already uses doctrines similar to those in nuisance law. *See* Goodman, *supra* note 5 (manuscript at 50) (stating that "the FCC has used concepts and techniques that are familiar from nuisance law" to resolve spectrum disputes).

258. Hazlett, *supra* note 7, at 148–52 (citing Tribune Co. v. Oak Leaves Broad. Station (Ill. Cir. Ct. 1926), *reprinted in* 68 Cong. Rec. S215, 215–19 (1926)).

259. *See id.* at 149 (recounting the complaint by Chicago's WGN that another Chicago broadcaster had injured it by moving to an adjacent wavelength that interfered with WGN's signal).

260. *See generally* De Vany et al., *supra* note 46 (proposing a system for defining property rights in the electromagnetic spectrum).

261. The De Vany system is based on three parameters: time, area, and spectrum (frequency) of transmission. *Id.* at 1501. Such "TAS packages" are a reasonable description of broadcast systems, but break down amid the dynamic, cooperative, non-frequency-based systems that now exist.

262. *See supra* subpart III(A).

For example, the De Vany system delineates rights in terms of total received field strength.[263] Consequently, it always treats multipath propagation as a harmful phenomenon.[264] A transmitter is liable if multipath reflection causes another receiver to encounter more unwanted energy than the transmitter is permitted to radiate.[265] However, as described above, today's intelligent systems can use multipath effects to *enhance* communication.[266] There is no way to match the capacity-enhancing value of a multipath-aware system against the increased costs the unwanted energy imposes on other systems, because the multipath effect is always treated as harmful. The De Vany proposal would have the perverse effect of restricting techniques that improve spectral efficiency.

Moving from a government licensing system to a property system does not eliminate, or even significantly reduce, the difficult conflicts that arise among overlapping wireless transmissions. The rights a spectrum property holder would possess are in many ways identical to those a licensee possesses today. The major difference is in the way the configuration of rights can be changed.[267] Any changes under government licensing must be reviewed and approved by the FCC. Under a property regime, the rights holder would be free to make any changes that do not alter the frequency band of transmission or interfere with other owners. This includes subdivision or sale of its rights. The owner could make other changes, but it must negotiate with owners that would have their own property rights affected.

Surprisingly, a commons environment is conceptually similar in many ways. A wireless commons is often thought of either as an absence of property rights,[268] or as a system in which transmission parameters are defined by government agencies or standards bodies rather than the holders of the transmission rights themselves.[269] The former view is simply wrong.

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263. *See* De Vany et al., *supra* note 46, at 1513 (suggesting that an actor should have "the exclusive right to originate radiation subject to the constraint that the field strength achieved by this radiation does not exceed a specified limit").

264. *Id.* at 1519–20.

265. *See id.*

266. *See supra* section III(A)(3)(e).

267. The property right also differs in being permanent and irrevocable. However, this is more a legal difference than a practical one. *See* Shelanski & Huber, *supra* note 233, at 585–89 (arguing that the trend by the FCC away from revoking broadcasters' licenses creates an expectation of renewal and an increased ownership interest in spectrum). Conversely, property rights may be taken away by the government through eminent domain, so long as compensation is paid.

268. *See, e.g.*, Benjamin, *supra* note 134, at 2009 (describing a commons as a network in which no one owns spectrum rights); Hazlett, *supra* note 53, at 484 (ascribing to the commons position the belief that "[i]t is inefficient and even unconstitutional to promote property rights").

269. *See, e.g.*, Benjamin, *supra* note 134, at 2031 (asserting that the commons model requires government regulation to avoid excessive interference and free-riding); Hazlett, *supra* note 53, at 484 ("Gilder, Benkler, and Lessig pursue government regulation to police the commons.").

The latter is relatively accurate in some cases, but fails to differentiate commons rights from exclusive property rights in any substantial way.

It is true that, in a commons regime, the rights involved are generally vested directly in device users, rather than in an intermediary such as a carrier. The carrier may impose additional limits on the devices that can operate within the space of the rights, but ultimately its transmission rights are passed through to the end-users who operate those devices. Whether wireless systems are user-defined or operator-defined has significant implications in terms of economic incentives, innovation, and the social values of the resulting communications.[270] These differences may well be determinative in choosing one regime or the other. The policy decision should turn on such considerations, however, not on some simplistic comparison of "property" and "regulation."

In a commons environment, as under the property regime, rights holders are entitled to transmit under defined parameters, and to transfer their rights to others. What is missing is protection against incursions from other transmitters. Commons rights holders may not claim protection against other commons rights holders. Under current FCC rules, they also may not do so against licensed transmissions.[271]

2. A Legal-Realist Perspective on Spectrum.—Whether the regime is government licensing, property, or commons, what is at issue are usage rights for wireless communications equipment. Just as the property right in a gun allows its owner to shoot it at a firing range but not, absent extraordinary threats, on a crowded street, the property right in a wireless transmitter allows its owner to emit certain kinds of radiation but not others.

TABLE 1: COMPARISON OF TRANSMISSION RIGHTS

	Alienable/ Unencumbered?	Correlative Duty	Where Vested	Frequency Delimited
Government Licensing	No	Yes	Service Providers	Yes
Property	Yes	Yes	Service Providers	Yes
Commons	Yes	No	Users	Yes (unlicensed bands) and No (Part 15, UWB)

270. *See, e.g.*, Benkler, *Building the Commons*, *supra* note 55, at 340–58 (arguing that a user-defined wireless system is more efficient at meeting the wants of individuals).

271. U-NII Order, *supra* note 59, ¶ 93. Benkler has proposed that commons rights include "Part 16" protection against other transmitters. *See* Benkler, *Building the Commons*, *supra* note 55, at 392.

A right to transmit can be described or circumscribed in any number of ways, some of which involve frequencies and some of which do not.[272] However, wireless communications rights can be distinguished based on two major parameters: what they allow the holder to do, and the correlative duties (if any) they impose on others.[273] These distinctions are summarized in Table 1.

The rights in FCC-granted licenses are heavily encumbered. They do not include alienability, the ability to sell or subdivide the right. Nor, in most cases, do they permit the licensee to alter the physical parameters or service offering it delivers. The property camp attacks these limitations. Its primary claim is that the spectrum resource will be more efficiently exploited if the rights to exploit it can be bought, sold, traded, torn apart, and recombined.[274]

Yet the lack of alienability is not the only characteristic of traditional government spectrum licenses. The licenses give something—a right to transmit in certain frequencies—but also take something away.[275] They prevent others from transmitting in that same frequency by defining such transmissions as interference. In fact, all property rights necessarily have a reciprocal character. This is because an individual's property rights mean nothing in isolation. Individual ownership implies that there are other owners and, therefore, that there is not just property, but a property rights

272. The electrospace model that Matheson advocates is one framework that goes beyond frequencies to take into account other properties of wireless communication. *See* Matheson, *supra* note 170, at 128–30 (describing the dimensions used to distinguish signals in the electrospace model). However, Matheson's model is still incomplete. Because it focuses on an abstract spectrum "space" rather than actual devices, electrospace fails to account for approaches such as low-power underlays or opportunistic sharing of frequencies through software-defined radios. It is impossible to incorporate such techniques into an exclusively orthogonal model of the spectrum. *See* William D. Horne, Adaptive Spectrum Access: Using the Full Spectrum Space 2–3 (Sept. 20, 2003) (unpublished manuscript, on file with the Telecommunications Policy Research Conference) (describing "orthogonal" dimensions in spectrum space as those that can "uniquely define a point in the space," and noting that "several of the possible parameters . . . do not necessarily define an orthogonal parameter"), *available at* http://intel.si.umich.edu/tprc/papers/2003/225/Adaptive_Spectrum_Horne.pdf. Electrospace, then, is simply a metaphor. Like other physical metaphors for spectrum, it is helpful to a point but ultimately misleading.

273. My description of the property rights in wireless devices builds on the legal realist notion of property as a bundle of rights. *See* SINGER, *supra* note 112, at 82–84 (describing the legal realists' view of property "as a bundle of identifiable entitlements, each of which should be considered separately to determine its meaning and scope").

274. *See, e.g.*, Rosston & Steinberg, *supra* note 80, at 97–98 (arguing that the FCC should introduce measures designed to make networks more like private, property-based markets so that more participants can compete to provide more efficient services); Spiller & Cardilli, *supra* note 53, at 69 ("For spectrum to be transferred to its highest value use, this right must be transferable, as well as fragmentable, which in turn requires that the right be specified not in terms of service, but rather in terms of usage or outputs.").

275. *Cf.* Charles A. Reich, *The New Property*, 73 YALE L.J. 733, 771 (1964) ("Property draws a circle around the activities of each private individual or organization. Within that circle, the owner has a greater degree of freedom than without. Outside, he must justify or explain his actions, and show his authority. Within, he is master, and the state must explain and justify any interference.").

system.[276] By commission or omission, any statement in that system about one owner's right is a statement about other owners as well.

The idea that rights impose duties on others was explored in detail by the legal realist Wesley Hohfeld early in the last century.[277] Hohfeld's formal language of jural logic eliminates the sloppiness that often mars discussions of rights. A right is an entitlement to act, which in the wireless case means the ability to emit radiation with the authorized power, frequency, or other characteristics. Its opposite is "no right." Hohfeld's innovation was to recognize that in addition to opposites, these categories have what he called "correlatives."[278] Where opposites concern the same entity, correlatives describe the effect of the category on others. The correlative of a right is a duty.[279] In other words, a broadcaster's right to transmit on certain frequencies imposes a duty upon the rest of the world not to do so, or face penalties.[280] An affirmative duty on others is more precise than a right to exclude, which incorrectly suggests an all-or-nothing physical boundary.[281]

Duty also has an opposite, called privilege.[282] Tying the relationships neatly together, the correlative of a privilege is no right.[283] In other words, a privilege to transmit, unlike a right, does not impose a duty on others. It does not by itself give others a right to transmit either; they are simply spectators. A spectrum commons is a system for wireless communications built on privileges rather than rights. Each device user has a privilege to transmit, but that does not come with a club to prohibit others in the commons from doing so.[284]

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276. *See* SINGER, *supra* note 112, at 15 (observing that "the idea of private property . . . assumes that there will be many owners" and rules governing property rights are therefore needed "to make the system of property ownership run smoothly").

277. *See* Wesley Newcomb Hohfeld, *Some Fundamental Legal Conceptions as Applied in Judicial Reasoning*, 23 YALE L.J. 16 (1913). *See generally* Joseph William Singer, *The Legal Rights Debate in Analytical Jurisprudence from Bentham to Hohfeld*, 1982 WIS. L. REV. 975 (claiming that Hohfeld's analysis is part of a long debate within analytical jurisprudence about the meaning of legal liberties or legal rights); Arthur L. Corbin, *Jural Relations and Their Classifications*, 30 YALE L.J. 226 (1921) (defending Hohfeld's analysis against the criticism of Albert Kocourek).

278. Hohfeld, *supra* note 277, at 30.

279. *Id.* at 31–32.

280. Technically, the relationship means that there is at least one entity subject to the correlative category.

281. *See supra* note 94 and accompanying text.

282. Hohfeld, *supra* note 277, at 32. The full Hohfeldian system includes a second set of four categories—power, immunity, disability, and liability—in the same configuration. These describe the ability that parties have to alter the system or determine where burdens are imposed. *Id.* at 30–58.

283. *Id.* at 32.

284. If licensed devices have duties not to transmit in unlicensed bands, those duties arise from the licenses themselves. This was part of the FCC's rationale for rejecting "Part 16" protection for U-NII devices, which could be seen as a collective right against systems outside the commons. It

The Hohfeldian framework provides a better way to understand what is being granted to spectrum property holders or commons participants. It does not, however, indicate how to define the rights or privileges that are granted. Even if the category is clear, conflicts will arise at the boundaries of the right or privilege. Such conflicts are pervasive in all forms of property.[285] For wireless communications they are even more pronounced than usual. As described above, overlap is a ubiquitous aspect of wireless communication. Every transmission may impinge on the rights of others. Determining whether or how users of wireless communications devices impose correlative duties on others is thus absolutely critical.

B. The Space of Possibilities

Reconceptualizing the spectrum debate in terms of usage rights illuminates the space of possibilities. The legal regime should take into account the full web of responsibilities and opportunities that can inure to wireless devices, in all their possible gradations. A license or property right based on frequencies privileges frequency-based techniques. Alternative mechanisms such as wideband underlay or opportunistic sharing through cognitive radio are square pegs among the round holes of frequency blocks, presumptively prohibited and difficult to accommodate. Consequently, a variety of techniques that could improve efficiency of spectrum usage are ignored or barred.

The Northpoint case is illustrative. Northpoint developed a system to underlay existing satellite broadcast systems by distinguishing terrestrial and satellite transmissions based on the angle of arrival.[286] Devices smart enough to know that satellites are overhead and ground-based transmitters are not can send and receive signals in the same frequency bands without interference. Northpoint's system is backward-compatible; the existing satellite system need make no changes to its equipment to coexist with the new terrestrial system.[287]

This sounds like a huge win: a way to get something for nothing. Given the alleged spectrum drought and the FCC's promotion of technological

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concluded such a rule was unnecessary because licensed devices were already limited by the terms of their licenses. *See* U-NII Order, *supra* note 59, at 1614–15.

285. *See* SINGER, *supra* note 112, at 19–25, 56–61 (identifying property rights conflicts within cases involving such claims as the right to "withdraw 'vast quantities of underground water'" and the right to restrict condominium owners from leasing their units).

286. Catherine Yang, *The Scuffle Over Sharing Spectrum*, BUSINESS WEEK ONLINE, Apr. 19, 2002 (suggesting that Northpoint might be required to purchase its desired spectrum in an auction), *at* http://www.businessweek.com/technology/content/apr2002/tc20020419_7220.htm; *see also* Stephen Labaton, *An Earthly Idea for Doubling the Airwaves*, N.Y. TIMES, Apr. 8, 2001, § 3, at 1; Paul Davidson, *Northpoint Proposes Satellites to Get License,* USA TODAY, Mar. 25, 2002, at B4 (both describing the history of Northpoint's efforts).

287. *See* Yang, *supra* note 286.

innovation, one might think Northpoint's system would be quickly approved. Yet it wasn't. Like ultra-wideband, another technology that did not fit the frequency-oriented paradigm, Northpoint's proposed service was the subject of bitter, protracted regulatory wrangling. Nearly a decade after Northpoint first brought its technology to the FCC, the FCC approved Northpoint's approach, but refused to grant Northpoint the exclusive license it claimed it needed.[288]

The Northpoint case looks like yet another example of how government allocation of spectrum is political and inefficient. It shows the public choice problems with a system that vests allocation and assignment decisions in regulators. Property rights, however, would not necessarily do better.[289] If the incumbent satellite system had a property right rather than a government-issued license, it could make the decision through private bargaining whether to allow Northpoint's system to operate. Or could it?

First, this assumes the satellite system's property right is exclusive to all transmissions in its frequencies, even those that do not interfere because they operate on another dimension (angle of arrival). That control is part of the FCC's residual authority today, but that does not mean it would be part of the satellite operator's property right tomorrow. Saying that property rights will be "exhaustive" assumes potential transmission mechanisms can be enumerated ahead of time. As I have explained, however, that assumes too much.

Second, it would be difficult to determine the price and terms for such a subdivision of the satellite system's property. With no precedent or comparable transactions, the results are unlikely to be efficient. If, in fact,

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288. *See supra* note 174.

289. Hazlett asserts that property rights in spectrum would have solved Northpoint's problem: "In a more efficient world, innovative wireless companies such as Northpoint would simply buy the spectrum they need, much as any company buys labor, raw materials, and capital inputs." *Rural Wireless Technology: Hearing Before the Subcomm. on Communications of the Senate Comm. on Commerce, Science, and Transportation*, 108th Cong. (2003) (testimony of Thomas W. Hazlett, Senior Fellow, Manhattan Institute for Policy Research), *available at* http://www.manhattan-institute.org/html/testimony_hazlett_5-22-03.htm. However, the fact that Northpoint was not actually able to afford the relevant license when the FCC finally auctioned it belies this assertion.

Certainly, if spectrum were private property, Northpoint would be allowed to buy exclusive use of a frequency block. However, the price for controlling the entire band would presumably be even higher than the price for what Northpoint needs: only the ability to share the band with direct broadcast satellite systems. Northpoint would also be inefficiently hoarding spectrum if it controlled an entire band. Whether Northpoint could buy solely the right to share the DBS spectrum in a property regime is an open question. The DBS operator and Northpoint would have to work out interference boundaries. Also, the DBS operator would have strong incentives to refuse to sell to Northpoint if it feared competition from the new service. FCC economist Douglas Webbink, a long-time property advocate, acknowledges in an article considering spectrum-sharing arrangements such as Northpoint's proposal that, "[i]n reality, defining such rights may be extraordinarily complex." Douglas W. Webbink, *Property Rights, Flexible Spectrum Use, and Satellite v. Terrestrial Uses and Users*, *in* COMMUNICATIONS POLICY AND INFORMATION TECHNOLOGY 277, 281 (Lorrie Faith Cranor & Shane Greenstein eds., 2002).

Northpoint's system causes no interference with the existing satellite transmission, whatever the property owner charges is an inefficient rent that reduces the likelihood Northpoint will find it economically worthwhile to deploy. Perhaps the property system will get to the capacity-maximizing result more quickly than the government did. Then again, perhaps not.

The narrowness of the traditional frequency-based view of spectrum also corrupts the debate among property and commons models. The alternative to property rights in frequency blocks is more than frequency blocks open to any device following technical protocols. That is too limited a formulation. It ignores many possibilities, including underlay uses such as the following: ultra-wideband; opportunistic sharing, such as agile radio in the broadcast television guard bands; short-range communications within the home; and truly unregulated frequency blocks. As I have stressed, the real choice is among configurations of usage rights in wireless communications devices.

Focusing on the devices is also important because many of the new techniques for enhancing spectral efficiency are by nature cooperative. They use other devices as part of a communications system that is more efficient than any simple transmitter-receiver pair could be alone. The result is diversity or cooperation gain, which I outlined in Part III. The "same" spectrum may support more devices, more capacity, or different kinds of devices based on the overall architecture of the communications systems those devices support. What matters, therefore, is how and whether the devices can be configured to participate in such cooperative efforts. Though the end result applies to systems of many devices, that is a question about the properties of each individual device. It is not a question about the spectrum in which they operate.

The best regime for allocating spectrum and resolving disputes would be decentralized. The basic problem with the FCC as the arbiter of spectrum use rights is not that it is a public actor instead of a private market participant. Instead, the FCC cannot possibly be efficient because it is a single actor seeking to allocate resources ahead of time. Fortunately, as complexity science has demonstrated, complex adaptive systems can self-organize without any central control mechanism.[290] In other words, a collection of independent actors, all seeking to maximize their own welfare, may produce a more efficient global result than any central traffic cop.[291] This is

290. ROGER LEWIN, COMPLEXITY: LIFE AT THE EDGE OF CHAOS 43, 183–84, 191–92 (1992).

291. *See* Arthur De Vany, Implementing a Market-Based Spectrum Policy 25, Paper Presented at FCC License Auctions: From Concept to Policy (July 27–29, 1996) (unpublished manuscript, on file with the author) (explaining why the decentralized approach has a strong attractor to "integrated and compatible" networks); *cf.* David G. Post & David R. Johnson, *"Chaos Prevailing On Every Continent": Towards a New Theory of Distributed Decision-Making in Complex Systems*, 73 CHI.-KENT L. REV. 1055, 1083–85 (1998) (using complexity theory to argue for decentralized legal regimes in cyberspace).

in some ways an elaboration and expansion of Adam Smith's insights about self-interested economic activity, with a more rigorous explanation of how and why the "invisible hand" operates.

Consider by analogy the two very different legal regimes called "copyright." Originally, the term was used in connection with royal printing monopolies. Those who wished to print needed a copyright from the Crown. This system operated very much like the government licensing system for spectrum. It centralized control in an actor impervious to market forces, predictably depressing production, stifling speech, and allowing inappropriate factors to influence decisionmaking.

One solution would be to take the right to control printing away from the king and give it to private printers in the form of a charter or property right. The printers could then determine who could publish, and could buy or sell their charters to do so. This approach decentralizes rights, but only somewhat. The goal is to maximize the social welfare from printing, and print has enormous positive externalities. A better solution would be to give individual authors the right to publish, constrained only by their economic ability to pay the relevant costs, and establish exclusive rights in the publications themselves. The last part is of course what we today call copyright.[292]

C. From Commons to Supercommons

1. Beyond Unlicensed Bands.—Commons has from its beginning been associated with the FCC's existing unlicensed bands and with the WiFi and U-NII systems that operate in those bands.[293] There are many good reasons for designating frequency bands for unlicensed operation rather than granting licenses or exclusive rights in those frequencies. That does not mean unlicensed bands are the full realization of the commons model. In fact, they are but a small part of it. The commons comprises all those virtual locations where a wireless system can operate on the basis of privileges rather than rights. As discussed in Part III, there are a large and growing number of mechanisms that can create non-interfering "white space" throughout the radio spectrum. Like the invisible dark matter that cosmologists infer must

292. This analogy resembles Benkler's "trade with India" analogy. *See* Benkler, *supra* note 6, at 25–27 (hypothesizing that a "trade exchange would facilitate a robust, flexible, and efficient secondary market" for trading rights, and would be more efficient compared to a planned trade model). The important difference is that the decentralized solution retains some legal regime to incentivize activity and resolve disputes, rather than simply allowing "free trade." Of course, "free trade" in the real world often involves tariffs, duties, legal requirements, and other limitations.

293. Benkler does advocate "underlay and interweaving" in addition to designated unlicensed spectrum. *Id.* at 79–80.

make up the bulk of the universe, the wireless commons may be all around us.[294]

The primary reason to broaden the commons is that it could allow many additional wireless systems that otherwise would not be permitted to operate, expanding the capacity of spectrum. There are, however, other benefits. Opponents of the commons approach, such as Stuart Benjamin, equate the wireless commons with regulated unlicensed bands, and then critique it for being subject to the inefficiencies of government management that private market arrangements avoid.[295] This line of attack rests on the false assumption that the commons relies on a specific legal or technical approach.

Recent scholarship acknowledges that property and commons models should coexist. Property advocates such as Faulhaber and Farber argue that something like a commons can be established within the property regime (in the form of private or public "parks") or alongside property rights (through easements).[296] Hazlett proposes overlay and underlay rights in broadcast spectrum.[297] Noam suggests that access could be open but still subject to a price mechanism.[298] Benkler, though rejecting the assumption that property rights should be the baseline, nonetheless proposes experiments with both property and commons systems for a period of time, building in reversibility once the experiment is over.[299]

Once some frequency bands are turned into property and others are opened up as commons, what remains are all the opportunities to communicate without dominating a frequency. This superstructure may have more capacity than what all established wireless systems exploit today. It should be open to innovation and free from the forced exclusivity of formalized property rights.

In other words, the commons would be the baseline, with property encompassed within it, rather than the reverse. The initial legal rule for wireless communication should be universal access. Anyone would be permitted to transmit anywhere, at any time, in any manner, so long as they

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294. To take just one possibility, a study commissioned by Intel found the equivalent of nineteen vacant television channels in the San Francisco Bay Area, even while licensed stations were still offering both analog and digital broadcasts. *See* Comments of Intel, *supra* note 165, at 8.

295. Benjamin, *supra* note 134, at 2043–76. Commons advocates bear some blame for this confusion. Early work advocating the spectrum commons model often described the concept in too-narrow technical terms, focusing on particular advances such as spread-spectrum. *See, e.g.*, LESSIG, *supra* note 181, at 184 (referring to architecture that requires no spectrum allocation as "Spread Spectrum").

296. Faulhaber & Farber, *supra* note 5, at 14, 213–14.

297. Hazlett, *supra* note 53, at 548–55. Hazlett proposes an administrative definition of exclusive underlay property rights, along with a blanket underlay for low-power devices "creating material signal degradation only in the user's immediate jurisdiction. . . ." *Id.* at 553. As with other property rights, the initial boundaries may not be workable, and transactions to redistribute them may be too complicated.

298. Noam, *supra* note 5.

299. Benkler, *supra* note 6, at 82–83.

did not impose an excessive burden on others. Conflicts among users of wireless devices should be addressed through a "negative" regime of tort and an "affirmative" regime of safe harbors. To a first approximation, this regime collapses to the system we have today, but it allows for expansion, potentially in radical directions.

I call this regime supercommons.

As the name suggests, the supercommons is a superset of the approach that Benkler and Lessig advocate. Benkler's primary policy recommendation is to expand the frequency bands dedicated to unlicensed use, either by loosening rules or by adding additional bands.[300] Entry would be based on technical standards developed in part by private standards bodies and endorsed by central authorities.

The supercommons picks up where these steps, which I endorse, leave off.[301] The two differences are that the supercommons is not limited to designated frequencies, and it uses tort and other backstops rather than equipment standards as the legal threshold for entry. Benkler hints at something similar in his proposal for underlay and interweaving privileges for ultra-wideband and software-defined radio. However, he devotes a single paragraph to the idea, and still suggests ex ante technical requirements rather than common-law backstops.[302]

2. The Space Around Exclusivity.—Universal access is not as radical as it may seem. Portions of the U-NII band, for example, are limited in terms of power but little else.[303] The FCC's UWB decision, rejecting Sprint's claim that its license rights granted it exclusivity within its bands, suggests there is some white space that is not part of the rights granted to licensees.[304] The FCC in 1981 floated the idea of allowing spread-spectrum devices to underlay licensed transmitters throughout the radio spectrum, though it never followed through.[305] Noam proposes an "open access" regime that would require only that prospective wireless users pay a dynamically calibrated

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300. *Id.* at 76–80.

301. Paul Baran advocated something like this in his original speech contesting the need to ration scarce frequencies. The only restrictions he thought necessary were power limits: "In such an environment anyone would be allowed to use the spectrum, without the high front-end costs that keep out the true innovators. Of course, the allowable power and power densities would have to be realistically restricted." Baran, *supra* note 61.

302. For underlay and interweaving, Benkler postulates strict power limits and automated sensing to identify and avoid licensed transmissions. Benkler, *supra* note 6, at 79–80.

303. Jon M. Peha, *Wireless Communications and Coexistence for Smart Environments*, IEEE PERS. COMM., Oct. 2000, at 66, 67.

304. *See supra* notes 245–47 and accompanying text.

305. *See* Authorization of Spread Spectrum and Other Wideband Emissions Not Presently Provided for in the FCC Rules and Regulations, 87 F.C.C.2d 876, 880–88 (1981) (addressing the advantages and disadvantages of the use of spread-spectrum "in a civilian environment").

price for the privilege.[306] In the real world, Haiti appears to have no limits on the use of devices in its unlicensed bands, though admittedly it is a less-crowded spectral environment than the United States.[307]

The supercommons also parallels the FCC's longstanding policy approach to the Internet.[308] The FCC has never subjected Internet services to most of its requirements for telecommunications services. However, Internet services are clearly within the FCC's broad jurisdiction. What one FCC staff working paper calls "unregulation" was a conscious decision not to impose certain rules, and a further decision to fence off certain kinds of services from incumbents.[309]

The important parallel with spectrum is that the FCC's policy, when formulated in the 1980s, was made amid deep uncertainties about how technology and markets would develop. The FCC did not predict the emergence of the commercial Internet. Its officials were as surprised as the private sector about the growth of the World Wide Web. What the FCC appreciated was that computers attached to communications networks could create fundamentally new types of services and applications. Without both regulatory restraint and protective regulatory intervention, those new services could be stillborn. So the FCC created a protected space for innovation, which it called enhanced services.[310]

The uncertainties about spectrum are of a similar character. We know that powerful computers controlling radios have the potential to revolutionize wireless communications, just as the FCC knew that powerful computers attached to communications networks had great potential. We don't know how and when those revolutionary possibilities will manifest themselves. For example, we can only guess at the degree to which interference will be a significant practical problem. A legal regime that assumes interference will always be a serious problem requiring costly price or property rules is as un-

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306. Noam, *supra* note 4, at 778–79.

307. *See* Jon M. Peha, *Lessons from Haiti's Internet Development*, COMM. OF THE ACM, June 1999, at 71 (noting that while no licenses are required for spectrum access, utilization is low, reducing congestion); Peha, *supra* note 303, at 66–67 (recognizing that while Haiti has unlicensed bands with no constraints on device operations, this system would lead to acute problems in countries with a greater density of devices).

308. *See* JASON OXMAN, THE FCC AND THE UNREGULATION OF THE INTERNET 6 (FCC, Office of Plans & Policy, Working Paper No. 31, 1999) (discussing how the FCC "set forth the necessary unregulated landscape for the growth and development of the Internet"), *available at* http://www.fcc.gov/Bureaus/OPP/working_papers/oppwp31.pdf.

309. *Id.*

310. *See* Regulatory and Policy Problems Presented by the Interdependence of Computer and Communications Services and Facilities, 7 F.C.C.2d 11, 11–12 (1966) (notice of inquiry); Amendment of Section 64.702 of the Commission's Rules and Regulations (Second Computer Inquiry), 77 F.C.C.2d 384, 385–87 (1980) (final decision); Amendment of Section 64.702 of the Commission's Rules and Regulations (Third Computer Inquiry), 104 F.C.C.2d 958, 964 (1986) (report and order).

justified as one that eliminates all legal protections against interference today.

The supercommons also bears some similarities to fair use in copyright law. Fair use helps to reconcile the contradictory public policy imperatives to protect property rights and free expression.[311] It also mitigates market failure when transaction costs of licenses are excessive,[312] when societal benefits of noncommercial sharing are external to the copyright holder,[313] or when new technologies cannot easily be accommodated in the copyright framework.[314]

In short, fair use is outside but not opposed to the exclusive rights created by copyright grants. It is a realm of unconstrained sharing that balances a complex array of competing claims on published work. All of these rationales can be applied to supercommons transmissions around the exclusive transmission rights that administrative licensing or private ownership guarantee. The primary difference is that fair use is limited to functions such as education and parody that do not directly compete with the primary commercial exploitation of the work. The supercommons is a full-fledged communications space that may be utilized for any purpose.

The universal access privilege, in effect, would provide that any transmission that is not otherwise prohibited is allowed, though whether it is subject to a Hohfeldian privilege depends on whether it exceeds a flexible set of boundaries developed through decentralized legal mechanisms. This proposal reverses the current approach, under which actions must be expressly authorized by the government or, in a property regime, by the property owner. It resembles the unambiguous language of the First Amendment ("Congress shall make no law"), which nonetheless is limited and balanced in application.[315] Jurisprudence fits the absolutist text into the inevitable grey areas of real-world cases.

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311. *See generally* Dan L. Burk & Julie E. Cohen, *Fair Use Infrastructure for Rights Management Systems*, 15 HARV. J.L. & TECH. 42, 43 (2001); Harper & Row, Publishers, Inc. v. Nation Enters., 471 U.S. 539, 560 (1985) (both discussing the contours of the fair use doctrine).

312. *See* Wendy J. Gordon, *Fair Use as Market Failure: A Structural and Economic Analysis of the* Betamax *Case and Its Predecessors*, 82 COLUM. L. REV. 1600, 1605 (1982) (suggesting that "fair use should be interpreted as a mode of judicial response to market failure in the copyright context").

313. *See* Julie E. Cohen, Lochner *in Cyberspace: The New Economic Orthodoxy of "Rights Management"*, 97 MICH. L. REV. 462, 551–59 (1998) (discussing the social costs of externalities); Yochai Benkler, *Free as the Air to Common Use: First Amendment Constraints on the Enclosure of the Public Domain*, 74 N.Y.U. L. REV. 354 (1999).

314. *See* Pamela Samuelson, *Fair Use for Computer Programs and Other Copyrightable Works in Digital Form*: *The Implications of* Sony*,* Galoob*, and* Sega, 1 J. INTELL. PROP. L. 49 (1993).

315. The analogy is no accident; wireless communication is speech. In proposing universal entry, I am not here asserting that such an outcome is constitutionally required, though that is one possible interpretation. Stuart Benjamin has examined in detail the First Amendment implications of government decisions barring low-power radio stations that cause only minimal interference, concluding that they are constitutionally suspect. Benjamin, *supra* note 249, at 65; *see also* Mark S.

The supercommons approach can theoretically apply to the entire radio frequency spectrum. However, two sets of frequencies deserve special treatment. Radio astronomy bands such as broadcast channel 37 must be as free as possible of any other signals to maximize reception of distant astronomical phenomena.[316] In the interests of science, intentional transmissions in these bands should continue to be prohibited. There are no means to weigh potential benefits against societal losses when basic research into the nature of the universe is disrupted.

Other noncommercial bands, for uses such as public safety, military, and aerospace communications, do not necessarily raise such concerns. The same boundary enforcement mechanisms and incentives that protect commercial wireless systems could apply to these uses, perhaps with more protective default rules or liability standards. Technical mechanisms could be used to "reclaim" spectrum during times of emergency.[317] However, in an abundance of caution, some or all of the noncommercial frequencies could be declared off-limits from supercommons transmission for an initial period.

3. Universal Entry in a World of Uncertainty.—If wireless communications will be limited in practice, why adopt a default rule of universal access? Because there is such profound uncertainty about where to draw boundaries between permissible and impermissible uses. The danger of any preconceived limitations on wireless communications techniques is that they will be self-fulfilling prophecies. They will make spectrum scarce by ruling out approaches that could mitigate scarcity. Or they will push usage toward suboptimal equilibria.

Going forward, the only certainty is that wireless technology will evolve through more powerful computing devices and more sophisticated mechanisms to share spectrum. Legal rules that make innovative forms of communication too difficult will produce suboptimal results, because there

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Nadel, *A Technology Transparent Theory of the First Amendment and Access to Communications Media*, 43 FED. COMM. L.J. 157, 161–62 (1992) (arguing that, if changing regulation can make broad access to a medium possible, the First Amendment compels the government to implement a property rights structure). Ironically, Benjamin opposes the commons approach, which he equates with government control. *See* Benjamin, *supra* note 134, at 2043–44. Others have questioned whether spread-spectrum, by undermining the scarcity rationale for spectrum regulation, makes the current regime unconstitutional. *See, e.g.*, Yochai Benkler & Lawrence Lessig, *Net Gains: Is CBS Unconstitutional?*, NEW REPUBLIC, Dec. 14, 1998, at 12. A full analysis of the constitutional implications of the supercommons is beyond the scope of this Article. My claim here is simply that the supercommons approach is the best policy framework.

316. *See* COMM'N ON RADIO ASTRONOMY FREQUENCIES, HANDBOOK FOR RADIO ASTRONOMY 86–89 (1997), *available at* http://www.esf.org/generic/70/CRAFhandbook.pdf.

317. *See* Mark M. Bykowsky & Michael J. Marcus, Facilitating Spectrum Management Reform via Callable/Interruptible Spectrum 4–5 (Sept. 13, 2002) (unpublished manuscript, on file with the Telecommunications Policy Research Conference) (explaining how the use of "preemption rights" in the event of an emergency would reduce the risks involved in using a "market mechanism"), *at* http://intel.si.umich.edu/tprc/papers/2002/147/SpectrumMgmtReform.pdf.

will be less communication, smaller markets for services or equipment, and less innovation. As has been stressed repeatedly, wireless systems must tolerate some interference.[318] At some level, though, the cost of upgrading systems to be robust to interference, or the administrative costs of detecting and punishing those responsible, will be greater than the benefits from the additional communications.

The property vs. commons debate has largely hinged on which of these scenarios is more likely. One side worries about innovative technologies being blocked by spectrum owners; the other worries about legitimate systems being rendered useless by interference. Yet there is another way rules can fail. They may be too brittle. They may strike an appropriate balance between entry and protection but be unable to adapt when conditions change. What is impractical or unlikely today may be routine in the future, thanks to changing technology and usage patterns. The optimal level of interference is steadily increasing. A legal regime that cannot adapt quickly is doomed to failure.

For this reason, the solution is not simply to define existing rights more concretely. As noted above, the boundaries of existing wireless licenses are vague. Yet eliminating that vagueness without providing an efficient mechanism for change could make things worse.[319] The defined boundary might be too high or too low to accommodate efficient entry. It might be right for urban areas but not rural ones, or for certain system architectures but not others. It would require the FCC to engage in a top-down definitional exercise, subject to the same inefficiencies as the current licensing process. And it would likely consider only some sharing mechanisms, such as low-power underlay, while excluding other possibilities.

As a threshold matter, if the legal regime is going to be wrong, better for it to be too lenient towards new services. If incumbents know that they must tolerate other systems and that the boundaries of their rights are subject to review, they will have incentives to make their receivers more robust. This is itself a beneficial outcome. Better receivers mean less interference—in effect increasing the available spectrum.

The optimal situation is one in which each user takes steps that increase the marginal capacity of spectrum *as a whole*, while exceeding the marginal cost of each step. Where users enjoy legally enforceable protection against interference, they have no incentive to exercise a higher standard of care, even if such steps were efficient from the point of view of the system as a

318. *See* Coase, *supra* note 3, at 28 (noting that it may be efficient for market participants to accept some level of interference).

319. Thus, for example, the FCC's interference temperature metric, while a promising "safe harbor" mechanism within a supercommons tort regime, cannot be the sole boundary between exclusive and supercommons transmissions. *See infra* section IV(E)(3).

whole. The only exception is if prospective entrants could pay the incumbents to improve their equipment. Such transactions are unlikely for reasons I discuss below.[320] Even if they did occur, the least-cost avoider of the harm is likely to be the incumbent, who can design robustness into its original equipment specifications.

D. Dispute Resolution

In proposing a universal access privilege, I am not arguing for anarchy. Even when rights are expressed in absolute terms, common law doctrines, administrative rules, custom, and economic interests all function to constrain what real-world actors do. Undoubtedly there will be conflicts, especially at first. That would be true under any new spectrum regime. The mere possibility of disputes is not a reason to reject the supercommons if those disputes can be avoided or resolved in an efficient manner.

In this section, I first discuss why a regime built on a principle of universal access will not necessarily lead to chaos. I then outline the basics of a legal regime that could address those disputes that do arise among competing wireless users.

1. Of Commons and Tragedies.—The idea that unconstrained entry causes a tragedy of the commons is so patently obvious to most scholars as to hardly need defending.[321] Hazlett calls this point "undisputed."[322] Consider it disputed. Try walking a few blocks down Fifth Avenue in midtown Manhattan during the Christmas shopping season. The sea of humanity surging along the sidewalks will slow your trek, but it won't stop it. People may jostle one another, but fistfights are quite rare. Why doesn't this street scene, with open entry, potential for "interference," and incentives for free riding degenerate into a melee? The answer is that individual actors in complex adaptive systems can sometimes self-organize and find globally efficient arrangements.[323] They do not need property rights or price mechanisms to do so.

Garrett Hardin may have coined the phrase "tragedy of the commons,"[324] but every commons does not lead to a tragedy. For example, people don't chop down trees and build houses in public parks, because there are rules and enforcement mechanisms to preserve the public character of the

320. *See infra* subpart IV(F).

321. The fear of overuse of the spectrum commons calls to mind the Navy's claims as early as 1910, quoted by Coase, that "there exists in many places a state of chaos" with early unregulated radio transmission. S. REP. NO. 659, at 4 (1910), *cited in* Coase, *supra* note 3, at 2.

322. Hazlett, *supra* note 53, at 485.

323. For an introduction to complexity theory, see generally M. MITCHELL WALDROP, COMPLEXITY: THE EMERGING SCIENCE AT THE EDGE OF ORDER AND CHAOS (1992); LEWIN, *supra* note 290; JAMES GLEICK, CHAOS: MAKING A NEW SCIENCE (1987).

324. Garrett Hardin, *The Tragedy of the Commons*, 162 SCIENCE 1243, 1244 (1968).

space. CB radio is often cited as proof that wireless commons will collapse, but a closer examination reveals the boom and bust cycle of a consumer fad—with interference playing no significant role.[325] Scholars such as Elinor Ostrom have examined conditions under which commons are self-regulating.[326] Stuart Buck has applied this work to wireless communications, arguing that spectrum can be thought of as a common pool resource.[327]

Countering the tendency toward over-exploitation of any commons is the fact that wireless communications systems involve strong network effects. One transmitter is as valuable as one fax machine, which by itself is not worth very much. Systems gain value the more users they can support. This is why WiFi was such a significant boost to usage of the 2.4 GHz band. The band was available for unlicensed devices for years before WiFi was standardized.[328] Then and now, non-WiFi devices operate in the same band, but they have a far smaller market. Vendors build devices to the WiFi standard because they benefit from interoperability with millions of existing users of other vendors' products.[329] In the future, manufacturers who want to sell large numbers of devices will have incentives to build devices that do not cause a paralyzing tragedy of the commons or constant litigation over interference with other services. Both situations would limit or even destroy the market for devices.

Incentives on equipment manufacturers may prevent theoretical conflicts from appearing. Assume A and B are communicating on an unlicensed basis. C arrives on the scene and wants to send a message to D, but doing so on the same channel would result in neither message being received. C could use higher power and "shout" above A and B, assuming there was enough headroom in the relevant power limits. This might work at first, but would ultimately provoke an arms race preventing anyone from communicating effectively. We must take a step back. C is constrained by two conditions—she wants to communicate, and she wants to use a particular piece of equipment. C's equipment can do only what its manufacturer

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325. *See* Carol Ting, Johannes M. Bauer, & Steven S. Wildman, The U.S. Experience with Non-Traditional Approaches to Spectrum Management: Tragedies of the Commons and Other Myths Reconsidered 16–18 (Sept. 20, 2003) (unpublished manuscript, on file with the Telecommunications Policy Research Conference) (discussing the boom and bust of CB radio), *available at* http://intel.si.umich.edu/tprc/papers/2003/216/Ting-Bauer-Wildman2.pdf.

326. *See* OSTROM, *supra* note 117, at 58–102; *see also* Rose, *supra* note 107, at 177–79 (explaining how "community-based property regimes" are actually commons regimes, even though they may not appear to be).

327. *See* Buck, *supra* note 7, ¶¶ 20–31.

328. *See* Amendment of Part 15 of the Commission's Rules Regarding Spread Spectrum Devices, 17 F.C.C.R. 10755, 10773 (2002) (second report and order) (discussing unlicensed uses within the 2.4 GHz band generally).

329. *See* Glenn Fleishman, *What's Next; Wireless? You Bet. Compatible? Well, Maybe*, N.Y. TIMES, Dec. 12, 2002, Late Edition, at G5 (discussing interoperability among WiFi devices).

allows. The manufacturer wants to sell lots of equipment, which means it wants to see lots of communication. It therefore has an incentive not to sell C a device that makes it easy to produce the shouting match described above. There is no law preventing C from buying such a device, but perhaps there need not be.[330]

The evolution of unlicensed wireless local area networking standards shows how this dynamic works. Two other standards were developed around the same time as the WiFi: Bluetooth and HomeRF. Bluetooth is a short-range low-power specification initially developed as a wire replacement, and HomeRF was designed for networking computers within the home.[331] All three used the same 2.4 GHz band.[332] Because they employed different technical forms of spread-spectrum, there were concerns the three technologies would interfere with one another if used in close proximity. The feared conflicts never arose. WiFi obliterated HomeRF in the marketplace, causing vendors to switch to the winning technology.[333] Meanwhile, the relevant standards bodies implemented technical modifications, some of which had to be incorporated by the FCC into the 2.4 GHz rules, to ease the potential collisions between the systems.[334] It is simply in no vendor's interest to sell devices that do not work.

As wireless devices become smarter, participants in the supercommons will have a wider range of choices for avoiding conflicts with other users. Their decision will involve whether to expend some additional cost—either in a more sophisticated device or in using a different method to communicate—or try a brute-force approach in the hope that someone else won't have the same idea. It is wrong to assume the answer is necessarily the same as it would be for shepherds in a common meadow.

2. *The Common Law of Spectrum.*—When the incentives described in the previous section are insufficient to ensure harmonious coexistence of unlicensed supercommons devices, a common law tort-like regime can take up the slack. Those aggrieved by the actions of a supercommons transmitter

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330. C could build one herself, but still would have incentives to create something that could communicate with others. Moreover, "do it yourself" hobbyist creations would be built in significantly smaller numbers (and therefore cause less of an interference problem) than mass-produced equipment.

331. Hazlett, *supra* note 53, at 503–04; Buck, *supra* note 7, ¶ 32.

332. Hazlett, *supra* note 53, at 503–04.

333. *See, e.g.*, Glenn Fleishman, *Future of HomeRF After Intel Decision*, WI-FI NETWORKING NEWS (Apr. 10, 2001) (reporting Intel and Microsoft decisions to incorporate WiFi rather than HomeRF technology into future products), *at* http://wifinetnews.com/archives/000991.html.

334. *See* Amendment of Part 15 of the Commission's Rules Regarding Spread Spectrum Devices, 17 F.C.C.R. 10755, 10757 (2002) (second report and order) (explaining that the rule changes were motivated by the desire "to provide manufacturers with the flexibility to design and market a more diverse set of products which are able to operate efficiently").

could sue for injury or violation of a duty of care and obtain either damages or injunctive relief.

Many property advocates accept that a workable legal regime for spectrum disputes was in the process of developing prior to the Federal Radio Act of 1927.[335] There were no rules prohibiting any kind of transmission in those days, save for the requirement of a license from the Commerce Department (which the courts held could not be denied).[336] The claim is that, had spectrum not been taken over by the federal government, courts would have developed common law doctrine turning broadcasters' de facto rights into de jure private property, and would have fashioned rules on a case-by-case basis to resolve disputes as they arose.[337]

It would be hypocritical for property advocates to argue that courts are a good means of resolving boundary disputes over spectrum in an environment of exclusive property rights, but not a good mechanism when there is a presumptive universal privilege to transmit.[338] The supercommons is still a world of property rights. Those rights are vested in equipment, not spectrum, but as I argue above, this is no different than under the exclusive rights model.[339]

Coase offered an analogy, albeit for a different purpose, that precisely illustrates this point. He argued that spectrum was mistakenly treated as a physical thing because of a faulty analogy to the law of airspace. The problem was not so much that the association could not be made, but that it needlessly complicated the issue. A case involving a man who scared away a flock of ducks on a neighboring property by shooting his gun could, Coase explained, be decided based on the shooter's rights to violate his neighbor's airspace. However, a more straightforward analysis would focus on the shooter's rights to use his gun.[340]

Similarly, if there is a dispute about whether A's transmitter improperly degrades B's reception, we could look at whether A "trespassed" on B's exclusive territory. Or we could consider whether A exceeded the bounds of his legal privilege to transmit. The only difference is the perspective, and the complexity of the analysis. The second formulation is the one I propose to apply to supercommons devices under the universal entry privilege.

The usual expectation is that trespass and nuisance, two doctrines that apply to land, would form the basis for a common law of spectrum. As Ellen

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335. Hazlett, *supra* note 7, at 147; *cf.* HUBER, *supra* note 110, at 73–74 (arguing that common law can solve spectrum disputes).

336. *See supra* note 28 and accompanying text.

337. *See* HUBER, *supra* note 110, at 74.

338. *See* De Vany, *supra* note 291, at 32 n.10 (acknowledging that the system he codeveloped in 1969 could just as easily be applied without property rights).

339. *See supra* text accompanying note 233.

340. Coase, *supra* note 3, at 34.

Goodman explains in a forthcoming article, these concepts are often invoked in the spectrum context, but seldom explained in detail.[341] Goodman articulates how the application of nuisance or trespass law to disputes over spectrum property rights would not be as simple as property advocates assume.[342] Goodman applies to spectrum the famous *Cathedral* framework originated by Guido Calabresi and Douglas Melamed for resolving property disputes.[343]

Nuisance and trespass are doctrines deeply rooted in land. Because spectrum is not a physical resource, there is no precise analogy to the physical entry onto another person's land. Trespass is especially inapt for spectrum.[344] Trespass law is built on bright-line distinctions, with the central notion being intrusion on land owned by another. With spectrum, however, there is no difference between a signal that "intrudes" on spectrum controlled by another entity and one that does not. All wireless signals potentially intrude on all others, because radio waves do not stop at any defined physical boundary. The same signal may be invisible in one case or totally prevent communication in another.

Nuisance law makes more sense in the wireless context. It does away with the requirement of physical intrusion and focuses attention properly on the effects of different uses of property. Modern nuisance law requires a finding that a nuisance is substantial and unreasonable in order to impose damages or injunctive relief.[345] As Goodman explains, these tests require a public interest determination very similar to what the FCC does today.[346]

If we go down the path of using tort concepts to assign liability for impermissible uses of wireless devices, why apply this regime only to property holders? Nuisance and trespass assume the injured party is also a landowner. Torts, however, include all sorts of injuries or accidents that do not involve property ownership. For example, products liability law imposes liability on defective products that cause harm. This body of doctrine has evolved to balance incentives on product manufacturers between protecting consumer safety and investing in new products. The modern rule is generally

341. Goodman, *supra* note 5 (manuscript at 47).

342. *See id*. (manuscript at 47–74) (explaining the difficulty of applying trespass and nuisance law to spectrum); *see also* Webbink, *supra* note 289, at 3 (explaining the regulatory and microeconomic difficulties of a system of spectrum property rights).

343. *See* Goodman, *supra* note 5 (manuscript at 54–72). *See generally* Guido Calabresi & A. Douglas Melamed, *Property Rules, Liability Rules, and Inalienability: One View of the Cathedral*, 85 HARV. L. REV. 1089 (1972).

344. *See* Goodman, *supra* note 5, (manuscript at 49) ("The problem with such a trespass approach . . . is that interference does not really work this way and spectrum property rights are unlikely to be defined this way.").

345. DAN B. DOBBS, THE LAW OF TORTS § 465, at 1325–26 (2000).

346. *See* Goodman, *supra* note 5, (manuscript at 72–74) (stating that "courts balancing the varied interests in a spectral nuisance case will likely do what the FCC itself has done" by "consider[ing] public interest goals").

strict liability, imposing damages on the manufacturer without requiring a showing of negligence. However, liability generally requires proof of a harm and of a defective product.[347] A wireless transmitter that allows its user to emit signals that disrupt other communications systems can be thought of as a defective product that causes harm. The harm requirement bears a striking similarity to the FCC's notion of "harmful interference."[348]

Tort law is far from perfect. It could produce several kinds of errors in the wireless context. Courts could adopt too lenient a standard, forcing incumbents to tolerate more interference than they should. The delay and cost of litigation could produce a similar result. Incumbents might be forced to deal with excessive interference because they are forced to upgrade their equipment to protect their customers while litigation is pending. Or they may decline to pursue an action that would ultimately succeed, because the time, expense, and uncertainty involved are too great. In such cases, the legal standard would be correct, but the system would still be inefficient.

These risks, however, exist in most of tort law. Unauthorized transmission is not a pure harm. It produces a social benefit—more communication—that must be weighed against the social costs it also may impose. Courts have developed a range of mechanisms and doctrines to deal with these problems. I am not suggesting that importing product liability law whole-hog into the wireless context would solve all the complexities of interference disputes. A device that causes harm only when used in certain places at certain times with certain settings is not obviously defective. Products liability law directly polices manufacturers, whereas in wireless the manufacturers are stepping stones to the real actors, who are users. My point is that tort law has wrestled with the kinds of questions that a common law of wireless communications will need to address. The basic building blocks for a workable legal regime to deter, police, and punish inefficient and irresponsible signals are already there.

Interference is a negative externality of wireless communication. It is a cost that the transmitter imposes on others—a cost that may not be figured into the transmitter's economic decision about whether to transmit. The point of liability rules backing exclusive property rights or technical standards for unlicensed devices is to internalize those externalities. The reason for doing so is that the one doing the transmitting is likely to be the Coasian least-cost avoider of the undesirable result. Imposing a legal duty on transmitters, therefore, creates incentives to avoid excessive interference or

347. DOBBS, *supra* note 345, § 354, at 977–78. The De Vany group suggested strict liability for spectrum conflicts, because it proposed a "bright line" set of boundaries around exclusive rights. *See* De Vany et al., *supra* note 46, at 1540–42.

348. *See* 47 C.F.R. § 2.1(c) (2003) (defining harmful interference as "interference which endangers the functioning of . . . safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with these . . . Radio Regulations").

to negotiate with those affected when the transmitter values its interfering transmission highly enough.[349]

Tort law does this by imposing duties of care. We are not always free to do as we please, regardless of whether we are doing so with our own property. In the modern administrative state, tort-based limits on action coexist with regulatory requirements. Bodies such as the Occupational Safety and Health Administration or the Consumer Product Safety Commission impose mandatory baselines upon actors they regulate.[350] Regulation can function as a screen to overcome the inefficiencies of the court system. As I describe in the next section, a government entity could facilitate spectrum dispute resolution as well by fashioning default rules.[351]

There are three classes of interference that could take place. Supercommons devices might unintentionally interfere with each other, they might unintentionally interfere with licensed systems, or they might deliberately degrade other transmissions. There are also two kinds of systems that can be harmed: private communications networks and public systems such as public safety networks, military radars, global positioning system satellite transmissions, and communication with airplanes.

One simple way to apply tort law to spectrum disputes would be to ratchet the duty of care up or down depending on the situation. Interference with public systems, which can cost lives, could be subject to strict liability, as well as to strong remedies—including injunctive relief and even criminal punishments. As noted above, the supercommons might initially have a flat prohibition on transmissions in public bands.[352] At the other extreme, suits for interference among unlicensed devices could require a showing of recklessness or even intentionality. In the middle, claims of interference between unlicensed devices and private networks subject to government licenses or exclusive property rights could use the negligence standard that is the most common threshold for ordinary torts.

349. A regime involving private litigation does have significant inefficiencies, because litigation can be very costly and time-consuming. However, those very costs prevent most actors from entering into litigation unless the matter is very significant and they are confident of their chances of success. Spectrum property rights advocates recognize this point. *See, e.g.*, De Vany et al., *supra* note 46, at 1519 (predicting that "small or infrequent violations will pass without protest" in light of litigation costs, evidentiary requirements, and the need for harmonious relations between neighbors).

350. *See* Occupational Safety and Health Act (OHSA) of 1970, 29 U.S.C. § 651(b)(3) (2000) (authorizing "the Secretary of Labor to set mandatory occupational safety and health standards applicable to businesses affecting interstate commerce" enforceable by the Occupational Safety and Health Administration); 16 C.F.R. § 1000.1(a)(3) (2003) (describing the purpose of the Consumer Product Safety Commission to include "develop[ing] uniform safety standards for consumer products").

351. Goodman also argues for the value of a regulator to smooth the nuisance-based dispute resolution process. Goodman, *supra* note 5 (manuscript at 96–98).

352. *See supra* note 317 and accompanying text.

Enforcement under the regime I have described would not be significantly more difficult than it is today. Under the current government licensing system, unauthorized "pirate radio" transmitters or authorized transmitters that cause harmful interference must be identified and held responsible for their actions.[353] The FCC conducts regular monitoring,[354] but the licensees affected by the interference have the best incentives to report and track down violators. An unlicensed device operator that blasts high-power signals in a way that causes significant degradation of other systems is no more difficult to find and prosecute than a pirate radio broadcaster today. Lower-power, more adaptive, and more mobile devices may be harder to track down, but for the same reasons they are less likely to cause significant, ongoing interference to other systems.

Finding the proper boundaries among growing networks of wireless devices is not an easy matter. As Goodman describes, it will necessarily involve a messy process informed by public interest calculations, and in all likelihood looking to a government regulator for help.[355] If, however, a common-law liability regime can work to resolve spectrum disputes, there is no reason to require pre-assigned exclusive property rights as the price of entry to that mechanism.

The uncertainties of a common-law liability regime suggest that experimentation would be valuable. The supercommons could be tried initially in a portion of spectrum where the risks of failure are lower, excluding public safety and military bands.[356] Legal doctrines could be developed and tried out for a period of time. This could reduce the transaction costs of the liability system when applied to the whole spectrum.

E. Safe Harbors and Backstops

The common-law liability regime for wireless disputes that I describe will function more efficiently if default rules can be established. Litigation is costly. "Rough justice" rules can reduce the number of situations in which market participants will avail themselves of the court and will provide guidelines to equipment vendors and users considering engaging in a novel form

353. *See* 47 C.F.R. § 15.5(c) (2003) ("The operator of a radio frequency device shall be required to cease operating the device upon notification by a Commission representative that the device is causing harmful interference.").

354. *See* Federal Communications Commission, Enforcement Bureau, Field Activity and Actions ("The Enforcement Bureau[] . . . [is] responsible for handling . . . on-scene investigations and inspections in response to complaints and in support of the Commission's operations. . . . [The Bureau] also investigates unauthorized operation in violation of . . . the Communications Act."), *at* http://www.fcc.gov/eb/rfo/ActAct.html (last visited Jan. 22, 2004).

355. *See* Goodman, *supra* note 5, (manuscript at 96).

356. Benkler, *supra* note 6, at 34 (suggesting "no rules" in very high frequencies). Although Benkler would "permit unregulated commercial experimentation and use alongside the amateur uses," his proposal is initially limited to extremely high frequencies. *Id.* at 34, 76–80. This may be a valuable first step, though I believe we can go farther.

of transmission. Below I list some mechanisms that could be employed. Further work would need to be done to determine which would make sense in what situations and the specifics of how these safe harbors and backstops would be defined.

Commons opponents would argue that any safe harbor standards mandated or approved by the government are subject to significant inefficiencies and public choice concerns.[357] The restrictions I am describing, however, are not government-defined protocols. They are procedural mechanisms to facilitate private negotiations. Moreover, an exclusive property rights regime does not eliminate the need for such mechanisms.

1. Technical Standards.—One option for supercommons devices is a mandatory certification regime, similar in some ways to the FCC's current rules for unlicensed bands. Benkler proposes such a system, under which device standards approved by recognized standards bodies would receive fast-track approval by the FCC, and proprietary designs could be certified through a more detailed review.[358] A certification mechanism addresses the concern that a larger spectrum commons would collapse into a tragedy of mutual interference. Participants on technical standards bodies have an incentive to produce standards that allow for widespread usage of the frequencies in question. They are generally representatives of hardware vendors who want to sell more hardware, and they can do so only if there is a market for more devices.

With a common law liability system standing behind the standards, they become default rules or safe harbors, rather than mandates. One way to merge private standards with a liability regime is to shift the burden of proof if a device is certified to comply with technical standards adopted by a properly constituted open industry standards body. Or, industry best practices and standards could be incorporated into the "reasonable person" standard that is used as the liability test in assessing tort liability.

Another way to look at technical standards for supercommons devices is as external boundaries around hybrid limited common property. Buck examines this approach, drawing on the work of Carol Rose.[359] Limited common property arrangements are exclusive to the outside world, but shared among participants. To use in the existing unlicensed bands, for example, equipment manufacturers must receive a certification that their devices comply with FCC-mandated technical requirements.[360] WiFi devices are subject to a further requirement that they comply with industry-defined

357. *See supra* note 157 and accompanying text.

358. Benkler, *supra* note 6, at 78.

359. *See* Buck, *supra* note 7, ¶¶ 32–34; Rose, *supra* note 107, at 164–66 (defining and discussing the origins of hybrid property).

360. Buck, *supra* note 7, ¶ 41.

standards, and be subject to interoperability testing by the WiFi Alliance if they wish to use the WiFi trademark.[361] Once devices pass those hurdles, they are free to operate wherever and whenever their owners desire.

An abundance of caution may justify imposing such restrictions on the supercommons initially.[362] Any fixed technical requirements will prevent some transmissions that it would be efficient to permit. However, reasonable technical standards would allow much more than either that status quo or a system of exclusive property rights.

2. Trademark Concepts.—An alternate safe harbor regime would be a publication mechanism similar to that used in trademark law.[363] Those seeking federal protection for trademarks must submit an application to the Patent and Trademark Office (PTO), which engages in an initial review to determine if the trademark is confusingly similar to existing marks or is nontrademarkable, as with descriptive terms. The PTO then publishes the proposed trademark. This gives those who believe the application would infringe on their existing rights the opportunity to oppose the trademark prior to its issuance.[364]

A similar mechanism could be used for wireless devices. Those who wished to deploy devices that used techniques or protocols not covered under existing authorizations would be required to publish a technical description of their system through an open publication system managed by the FCC or some other agency. The government would perform only a perfunctory review of the proposal to ensure it met basic technical and administrative requirements and did not duplicate already-approved technologies. Those who felt the design would interfere with their own systems would have an opportunity to file an opposition. If none were filed after a reasonable period of time, the design would be approved. There would have to be limitations

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361. *See id*. ¶ 91 n.240.

362. An additional technical requirement that could facilitate such a limited supercommons is transmitter power control (TPC). *See* FCC INTERFERENCE WORKING GROUP REPORT, *supra* note 165, at 15–16 (finding that TPC is now used, though generally not legally required). TPC is an engineering mechanism for politeness. In non-technical terms, it says, "don't shout if you can whisper." Devices can emit no more power than necessary for the transmission they wish to engage in. *Id.* at 15. A transmitter communicating with a nearby receiver will modulate its power down compared to one communicating with a distant receiver. TPC is a common element of modern wireless communications systems such as cellular networks and wireless local area networks. *Id.* at 16. There is reason to believe equipment designers would employ it even absent a requirement. Mandating TPC is not the same a specifying a protocol or particular interference avoidance mechanism. It is simply a technical implementation of what a rational wireless user would do if it recognized that other users are equally free to transmit.

363. *See generally* Tom W. Bell, *The Common Law in Cyberspace*, 97 MICH. L. REV. 1746, 1766–67 (1999) (proposing a trademark-like regime for spectrum). In fact, Bell tantalizingly raises, but does not answer, some of the very questions I consider here. *See id.* at 1767 n.100 ("How well would the trademark analogy protect the right to transmit via a CB radio or low power device?").

364. Schulya M. Goodson & Segeta Ranjeet, *Domestic and International Trademark Protection Programs*, *in* UNDERSTANDING BASIC TRADEMARK LAW 213, 226 (2003).

on frivolous filings to prevent companies from strategically opposing any new technology.

Trademark law provides other concepts that could profitably be incorporated into spectrum policy, as Tom Bell has noted.[365] The key connection is that trademark rights are based on use, not on abstract ownership. A trademark owner gains access to remedies based either on actual use in commerce (through common law or registration) or on filing its bona fide intent to use the mark.[366] Similarly, a wireless rights holder should not be able to preclude transmissions that do not affect its own use of devices, even if they cross the wavelengths where it is entitled to transmit.

Finally, trademark law has wrestled with many of the same difficulties that arise in the wireless context. It has a formal taxonomy of industries—the SIC code system—to distinguish parallel uses that are, in the language of spectrum, per se noninterfering.[367] It has a hybrid system of common-law and statutory rights, facilitated by a nonregulatory government agency. It even has a concept, dilution, similar to the "pollution" that can occur when wireless devices collectively raise the noise floor even though they are individually distinguishable.[368]

The analogy between wireless communications and trademarks is just that. Beyond the publication concept outlined above, further analysis would be needed to determine how specifically trademark concepts could inform a supercommons wireless regime. It may turn out that the specific solutions used in trademark are inapposite here. Regardless, trademark shows how a legal regime can grow up to police conflicting uses in a complex space of economic activity, without assigning exclusive ownership rights in an abstract concept.

3. Interference Temperature.—The FCC's concept of noise or interference temperature is another possible mechanism for per se boundaries. The FCC Spectrum Task Force introduced the idea in its November 2002 report,[369] and the Commission formally began a proceeding

365. Bell, *supra* note 363, at 1766–67. Bell points out that the *Oak Leaves* case that Coase, Hazlett, and Huber cite as defining embryonic property rights in spectrum actually spoke in terms of goodwill, unfair competition, and trade names, which are trademark rather than property concepts. *Id.* at 1767.

366. *Id.* at 1767.

367. *See* Marshall Leaffer, *Domain Names, Globalization and Internet Governance*, 6 IND. J. GLOBAL LEGAL STUD. 139, 157 (1998) (describing the use of Standard Industrial Classification, or SIC, codes).

368. *See* Peter E. Mims, *Trademark Licensing: Fundamentals and Practical Considerations*, *in* UNDERSTANDING THE INTELLECTUAL PROPERTY LICENSE 391, 408 (2003) (explaining the concept of trademark dilution).

369. *See* Spectrum Task Force Report, *supra* note 83, at 12–15 (describing interference temperature).

on interference temperature in November 2003.[370] The starting point for the FCC's proposal is that the boundaries of licensees' rights are, as I have explained, not well-defined.[371] In particular, the strength of a wireless signal decays as distance from the transmitter grows, meaning that the same signal will be more difficult to receive in some places than others. At some point, the signal will be so faint that it will drop below the ambient noise floor. That point is not always well-identified today, leaving licensees unsure whether the inability of the distant receiver to understand the transmission results from background noise (which it must tolerate) or an interfering signal (which it can ask the FCC to shut down).

The noise floor is not constant. It varies over time and location, based on the radiators (intentional or unintentional) and physical geography in any given area. Since the signal decays over distance, there may be areas within the geographic scope of the license where transmissions already cannot be received. As a practical matter, the licensed transmission can only guarantee reception where its signal strength exceeds the highest value of the noise floor.

The FCC's interference temperature proposal seeks to formalize this noise floor boundary. It would define peak noise floor levels, presumably on a band-by-band basis and permit unlicensed devices to operate presumptively below this floor. The FCC's argument is that since the licensed operators cannot reliably transmit below this level anyway, they are giving up nothing by accepting such underlay uses. In fact, the licensees would benefit from knowing exactly how far down their rights extend. Conversely, unlicensed devices would gain greater headroom above the one watt Part 15 limits, which are very low and do not vary across frequency bands.

Interference temperature is a novel concept. It has already provoked opposition from licensed wireless operators.[372] At best, it would provide a safe harbor only for low-power underlay, not for other supercommons mechanisms such as opportunistic sharing. Nonetheless, as a rough cut to minimize unnecessary litigation, interference temperature may be a useful metric. Its virtue is that it makes quantitative what is today undefined or uncertain. As long as it is not the only boundary between the supercommons and other devices, interference temperature may prove to be a useful measure. More work should be done to determine how to implement

370. *See* Meeting Notice, 68 Fed. Reg. 64107-02 (Nov. 6, 2003); Interference Temperature Operation, 69 Fed. Reg. 2863, 2863 (proposed Jan. 21, 2004) (to be codified at 47 C.F.R. pt. 15) (noting that the corresponding FCC Notice of Proposed Rulemaking was adopted November 13, 2003).

371. *See supra* note 234 and accompanying text.

372. *See, e.g.*, Comments of Cingular Wireless LLC at 27–37 (Jan. 27, 2003), Commission Seeks Public Comment on Spectrum Policy Task Force Report, 17 F.C.C.R. 24316 (2002) (ET Docket No. 02-135) (arguing that the Spectrum Policy Task Force's proposed interference temperature model suffers from insurmountable legal, economic, and technical flaws), *available at* http://gullfoss2.fcc.gov/prod/ecfs/.

interference temperature, and to ensure that it provides enough room for additional unlicensed devices to operate.[373]

4. Localization.—Owners of real property could have a per se right to transmit however they wish within their own property. There is no reason to limit this right to certain frequency bands, as Chartier proposes,[374] except possibly to exclude public safety bands. Transmissions that stay within a building are non-interfering with other users, except for those the building owner invites in. This rule would allow some equipment to be operated only within the home or other private property. The same device would no longer be subject to the safe harbor if used on a street corner or a neighbor's lawn.

The local safe harbor works only for short-range devices. However, there may be significant markets and applications for such systems if restrictions on transmission are eased. Various mechanisms could be employed to ensure the devices are not misused, including geo-location technologies and beacons to check that the devices are in range of some fixed point in the home.

5. Cognitive Radio.—Software-defined radio opens up a new set of possibilities for backstops. Cognitive radios can sense the spectrum around them, not transmit if they see a licensed signal, and move out of the way when a licensed signal appears after they have begun transmitting.[375] A requirement that some unlicensed devices include such mechanisms would impose a significant cost tax on the equipment, but that might be worth it, especially if spectrum agility is already necessary for the kinds of activity the device engages in.

Devices could even be required to have remote cutoff or override capability. An authorized entity, such as a court or a public safety authority, could send out a signal that would temporarily or permanently disable the device. Such a capability would have to be designed carefully, and the devices might be subject to pranks or other attacks to disable them unjustifiably. However, this is no more a show-stopper than the fact that any wireless device is subject to eavesdropping or identity theft.

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373. Interference temperature differs from the permeable boundary between licensed systems and supercommons devices in that it is fixed ahead of time. A fixed boundary enhances certainty, but guarantees that the line will not always be drawn in the optimal way.

374. *See* Chartier, *supra* note 10, at 15 (proposing the assignment of certain frequencies to property owners). A property owner should be able to choose whether to interfere with her own broadcast television reception, but choosing to interfere with police or rescue personnel in the event they must enter the property is another matter.

375. *See* Joseph Mitola III, *Cognitive Radio: Making Software Radios More Personal*, IEEE PERS. COMM., Aug. 1999, at 13, 13–14 (discussing the features of cognitive radio); Cognitive Radio Technologies and Software Defined Radios, 69 Fed. Reg. 7397, 7399 (proposed Feb. 17, 2004) (to be codified at 47 C.F.R. pts. 2, 15, 90).

Cognitive radios are not yet on the market.[376] However, the basic technology required is just a function of computational price/performance and miniaturization, which have followed steady improvement curves for decades. Once such devices are commercially feasible, they will have a disruptive effect. A cognitive radio is a computer that happens to talk through radio waves. Computers are radically reconfigurable, since the cost of software upgrades is far less than hardware changes. When new communications techniques, standards, or protective measures involve software downloads rather than new equipment, adaptations that seemed infeasible become inevitable. Greater utility and lifespan ultimately offset higher initial cost.

6. Insurance.—Finally, if all else fails, various risk-sharing mechanisms are commonly used to deal with situations of potential liability. Manufacturers or users of unlicensed devices could purchase insurance against damages for interference. Requiring manufacturers to have insurance could guarantee that those harmed by overreaching unlicensed devices would be made whole. It would also create incentives for the manufacturers to build "polite" devices, and ensure that their customers do not exceed the bounds of politeness. The insurer would become another private, decentralized actor pushing the unlicensed devices toward optimum coexistence with each other and with licensed devices. Bonding and indemnification could also be employed.

F. Expectation Interests

Proponents of exclusive property rights may argue that a supercommons, even if workable, fails to provide adequate certainty to incumbent users of spectrum. If some new system might interfere, they will have less reason to spend money building their own systems. Yet this possibility already exists under the status quo. The supercommons regime still prohibits and imposes liability on systems that cause excessive harm to other transmitters. Where the supercommons might be different is the degree to which it protects exclusivity for its own sake or enshrines poor quality receivers as the standard for interference. These are the cases where absolute protection of incumbents, whether through government licenses or exclusive

376. On the other hand, many wireless devices already on the market can be upgraded through software. The radio and chipsets in an ordinary WiFi access point are physically capable of transmitting on adjacent licensed frequencies. The firmware in these devices is software-upgradeable, so users can install security patches and other enhancements. C. Brian Grimm, *WiFi's Protected Access Wireless: The Background*, NEWSWIRELESS.NET, Nov. 23, 2002, *at* http://www.newswireless.net/articles/021123-protect.html. Experimental supercommons transmissions, albeit unauthorized, may be closer than we suspect.

spectrum rights, makes it harder to achieve the welfare-maximizing configuration of wireless devices.

The property rights system always vests rights in incumbents, which is inefficient on three levels. The incumbent may hold out or refuse to negotiate with an entrant that would enhance spectrum efficiency. The incumbent may be unaware of whether the new technology would work. Or the entrant itself may be unable to determine whether access is worth negotiating for, because even experimentation with possible shared use mechanisms can occur only at the sufferance of the incumbent rights holder. The company best able to take the risks in developing and testing the new technology is the entrant, but it needs the freedom to do so. The supercommons regime gives the entrant the right to transmit in the first instance, which is likely to be the least-cost rights allocation.

The other problem with the investment incentives argument is that it is frequently used to justify inefficient monopolies. Companies invest in capital-intensive projects all the time without a guarantee they will earn a rate of return. It is reasonable for companies to want to understand the risks so they can make appropriate decisions about how to act, but the existence of some risk does not paralyze investment. Legitimate concerns about risk that investments will be undermined by unexpected factors sometimes mask assumptions that the right to deploy a communications system is a right to be free from competition. The FCC and the courts have consistently rejected the argument that an entitlement from the government grants protection against future government entitlement of competitors.[377]

The argument about investment incentives also ignores the fact that there are different types of investments. Wireless systems can be built through capital-intensive deployment of network infrastructure, which is then recouped through service revenues. Or they can be built through sales of equipment directly to end-users, who themselves pay the costs of building out the network. The former model is the traditional model for wireline and wireless operators; the latter is how WiFi has grown. As Benkler explains, both are legitimate capital formation mechanisms.[378] They simply create different kinds of incentives.

377. *See* UWB Order, *supra* note 146, at ¶ 271 (rejecting Sprint's claim that its exclusive licenses prohibited UWB underlay); *cf.* Proprieters of Charles River Bridge v. Proprietors of Warren Bridge, 36 U.S. (11 Pet.) 420, 477 (1837) (holding that a government entitlement to operate a ferry did not protect against the government's later authorization of a competing bridge).

378. *See* Benkler, *supra* note 6, at 70 ("The choice is between a market in infrastructure rights and a market in equipment, not between a market approach and a non-market approach.").

V. Property vs. Commons in a Use-Rights Framework

With the universal entry privilege as a baseline, the question then becomes whether to employ exclusive property rights or expressly defined spectrum commons for everything else. Both should be used, and doubtless both will. Bearing in mind that this is not an absolute question, this Part examines the relative benefits of the two models through the lens of use rights I have developed.

Both commons and property advocates reject the assumption in the government licensing model that changes in the contours of use rights for wireless equipment should be forbidden unless specifically authorized through a government regulatory process. Both allow new users or technologies to gain access to spectrum, thereby improving efficiency and enhancing welfare.

The difference between commons and property regimes is how they manage these boundaries. Exclusive property rights give the rights holder a veto power over any new entry. Non-rights-holders must either acquire the owner's spectrum rights completely or must negotiate a subdivision of rights such as a low-power underlay. Commons approaches allow the new entry by default. The traditional commons position bounds this entry right with technical standards; my supercommons proposal would expand the entry right using a liability system as the backstop.

I am joining this debate in progress. Proponents of exclusive property rights advance five primary arguments against the commons position:

- Markets are the best mechanism for allocating scarce resources;
- Commons equals regulation;
- "Parks" will naturally emerge;
- Scarcity and transaction costs favor property rights; and
- Commons may be accommodated through easements.

The earlier analysis in this Article provides a framework to evaluate these claims. In every case, the attacks fail to destroy the commons position. At best, there are strong reasons for continuing to experiment with both exclusive rights and unlicensed systems, because we cannot be certain the commons approach will be superior. There is no basis, however, for concluding that exclusive rights are necessarily the best answer.

A. Are Markets Always Best?

The property camp's primary argument is that, however we define the situation, market mechanisms are the best way to allocate resources. This viewpoint is perhaps best summarized by Peter Huber, who rebuts George Gilder's claim that spectrum property rights are unnecessary by asserting that, "the one certain thing is that true wisdom in matters this complex does not emerge from centralized commissions, nor even from visionary pundits. Wisdom emerges from markets."[379]

The problem with this argument is that a wireless commons is not an absence of markets. It is a different form of market from those prevalent in exclusively controlled spectrum. Commons are markets for equipment, not access.[380] By making access costless, they actually facilitate more active and efficient markets for devices and ancillary services, much as the government's construction of highways facilitates better markets for cars.[381] There may be reasons to prefer a market for access over a market for equipment in some situations, such as when access is a scarce resource subject to a low-cost transaction regime. Or there may be situations in which a market for access generates an access price of zero. However, these are not arguments for a blanket preference toward exclusive rights.[382] When pressed, the markets-über-alles argument devolves to either one about scarcity and transaction costs or to a claim that private parks will naturally develop. I address both of these arguments below.

Furthermore, markets are not the right answer for every situation. There is no market for the right to breathe the air, for example. Air is so abundant that a market mechanism would be overkill, even if it would ultimately produce a zero price in most cases. And in situations where air was not abundant, few would support letting people suffocate based purely on who could pay the most to breathe. The more spectrum looks like air, both in its abundance and its social value as a fundamental speech entitlement, the less markets for spectrum access make sense.[383]

The problem is that we don't know with certainty how abundant spectrum will be in the future. Huber is right that just because George Gilder

379. HUBER, *supra* note 110, at 75.

380. Benkler explores this point and the comparative economics of the two models, in detail. *See* Benkler, *supra* note 6, at 78–79.

381. *See* WERBACH, NEW WIRELESS PARADIGM, *supra* note 66, at 9 (commenting on society's acceptance of the automobile and trucking industries, which depend upon public roads and highways that are free to use and that are maintained by the government). The same is true for commons at other layers of the network. For example, the public domain in intellectual property is a resource that can contribute to private works, rather than threaten them. Most of Disney's animated movies use fairy tales and characters in the public domain. *See* LESSIG, *supra* note 55, at 106.

382. Coase understood this point well. For example, in his seminal spectrum article, he noted that the coordination costs involved when there were many participants in transactions might overcome the benefits of a market: "When large numbers of people are involved, the argument for the institution of property rights is weakened and that for general regulations becomes stronger." Coase, *supra* note 3, at 29; *see also* De Vany et al., *supra* note 46, at 1509 (stating that exchange and enforcement costs will increase as the number of parties increases).

383. Goodman in fact sees the commons position as essentially a claim that spectrum is like air. *See* Goodman, *supra* note 5 (manuscript at 74) (stating that commons theory is "built on a conception of spectrum as air, not land"). I would not go so far. Air, though intangible, is a concrete physical resource. Spectrum is not. I use the analogy in the text only to show how markets sometimes are not the proper answer to allocation problems.

thinks spectrum has infinite capacity does not mean we should bet the future of spectrum on that prediction. The reason that, as Huber puts it, "wisdom emerges from markets"[384] is that markets can be good distributed signaling mechanisms under conditions of uncertainty. However, under some conditions, markets may not be the best means to perform that signaling function. Spectrum is such a case.

The critical resource for any form of social organization is information. The value of a good is a piece of information that is usually costly to obtain, so costly as to be practically impossible in most social situations.[385] Markets obtain this information by delegating decisionmaking to the distributed mechanism of price signaling rather than using a central decisionmaker. The market clearing price of a transaction is a distributed regulator of individual actions, giving participants better information than any central allocation of resources.[386]

There can, however, be other distributed signaling mechanisms that play the same role as markets in allocating resources. Scientists studying the phenomenon of complexity have found numerous examples of physical and biological systems that self-organize without central control mechanisms or the formality of a price mechanism.[387] Ant colonies, for example, find short paths to food sources through a purely random, uncontrolled process of exploration.[388] They do so with an ingenious signaling mechanism: pheromone trails that are reinforced as more ants follow the efficient path. Scientists see no evidence of ant banking systems or currencies.

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384. *See supra* note 379 and accompanying text.

385. Coase used the difficulty of information gathering as an argument that a central administrative agency could not hope to allocate spectrum efficiently:

> [I]t cannot, by the nature of things, be in possession of all the relevant information possessed by the managers of every business which uses or might use radio frequencies, to say nothing of the preferences of consumers for the various goods and services in the production of which radio frequencies could be used.

Coase, *supra* note 3, at 18. Only the market as a whole possesses such information. A distributed price mechanism can therefore produce more optimal results than the best central regulator under most circumstances. As Coase acknowledged, though, the market is not always superior. Transaction costs and in particular the coordination costs of many actors can overcome the benefits of a price mechanism. *Id.* at 18, 29.

386. *See* F.A. Hayek, *The Use of Knowledge in Society*, 35 AM. ECON. REV. 519, 526 (1945) (explaining that "[t]he mere fact that there is one price for any commodity . . . brings about the solution which . . .might have been arrived at by one single mind possessing all the information").

387. *See* STUART KAUFFMAN, AT HOME IN THE UNIVERSE: THE SEARCH FOR THE LAWS OF SELF-ORGANIZATION AND COMPLEXITY 71–72 (1995); JOHN H. HOLLAND, EMERGENCE: FROM CHAOS TO ORDER (1998); KEVIN KELLY, OUT OF CONTROL: THE RISE OF NEO-BIOLOGICAL CIVILIZATION 12 (1994) (discussing the organization of honeybee hives in which "no one is in control, and yet an invisible hand governs"); *see also* Arthur De Vany, *The Emergence and Evolution of Self-Organized Coalitions*, *in* COMPUTATIONAL ECONOMIC SYSTEMS: MODELS, METHODS AND ECONOMETRICS (Manfred Gilli ed., 1996) (describing a simulated coordination game in which near-optimal levels were reached even though each individual was acting without knowledge of the larger group).

388. ERIC BONABEAU ET AL., SWARM INTELLIGENCE: FROM NATURAL TO ARTIFICIAL SYSTEMS 26 (1999).

Intelligent wireless communications devices can fulfill the same function as the ants' pheromone trails. By communicating with one another and adjusting their behavior dynamically, they can perform the distributed, bottom-up signaling function that markets achieve through the transaction mechanism. In fact, they may do better. Since markets involve time lags for price signals to propagate, they can be distorted through market failures or holdouts; they can be misdirected toward maximizing transaction revenue rather than the value of communications; or they may signal efficiently but for the wrong variable.[389] In these cases, nonmarket signaling mechanisms may prove superior. Software-defined radios and meshed networks in particular may be able to adapt more effectively to optimize spectral efficiency than transaction-based market mechanisms.

The argument comes back to Coase. Only this time, not the Coase of *The Federal Communications Commission* and *The Problem of Social Cost*, but the Coase of *The Nature of the Firm*.[390] Coase's insight there was that firms use nonmarket mechanisms internally for management because the transaction costs of market mechanisms would be too great. Similarly, some wireless communications systems may operate better in a nonmarket configuration.[391]

As evidence that property-based markets are superior to commons, Hazlett points to the large sums that companies were willing to pay at auction for exclusive rights to spectrum.[392] The spectacular bids he references have since been revealed as bubble-era irrational enthusiasm. More fundamentally, focusing on the monetary value paid for spectrum under the current regime is a mistake. Both property and commons approaches would sharply reduce the value, on a per-unit basis, of the hypothetical spectrum resource. In so doing, however, they would increase the collective value of economic activity associated with spectrum use. Spectrum is expensive today because it is artificially scarce. A major goal of both property and commons advocates is to reduce that scarcity, either through transfers of unused or underused spectrum to those who will use it more, or by encouraging innovations that improve spectral efficiency. Increase supply without an equivalent increase in demand, and price will drop.

The cost of spectrum access is not a proper yardstick for comparing spectrum uses. PCS cellular operators (who paid billions for their spectrum rights) compete against successors of the local exchange carriers that

389. *See* Noam, *supra* note 4, at 771–77 (discussing similar kinds of failures in the auction process).

390. Ronald H. Coase, *The Nature of the Firm*, 4 ECONOMICA 386 (1937); *see also* Yochai Benkler, *Coase's Penguin, or, Linux and* The Nature of the Firm, 112 YALE L.J. 369 (2002).

391. The difference with Coase's analysis in *The Nature of the Firm* is that the nonmarket mechanisms in firms are top-down, hierarchical management, whereas the nonmarket mechanisms for wireless devices are decentralized, bottom-up signaling processes that do not rely on prices.

392. *See* Hazlett, *supra* note 53, at 489 (arguing that companies have bid competitively at FCC auctions in order to "escape the commons").

received original cellular licenses for free, and against Nextel, which cobbled together taxi dispatch licenses through regulatory entrepreneurship. What spectrum costs is far less important than how spectrum is used. And, legal structures that require an ex ante transaction to acquire transmission rights from a private owner make certain forms of spectrum use more difficult.

B. Degree of Regulation

Next, property advocates attack spectrum commons as regulation in disguise. Hazlett and Benjamin, for example, point out that bands such as 2.4 and 5 GHz, where WiFi, operates were set aside and protected by the FCC for unlicensed use.[393] They, therefore, equate commons with explicit government management of spectrum and list in great detail the ways that government is a poor decisionmaker for this function compared to private actors.[394]

There are several responses to this argument. Benkler offers two. First, exclusive property rights are hardly free from government involvement.[395] As I note in Part III, the shape of these entitlements are not predetermined by nature. Whether or not they track existing FCC license terms, such rights are artificial constructs of the same government actors that define the boundaries of an unlicensed band.[396] Second, unlicensed bands may require initial government actions to facilitate a commons. But after that, they devolve power to individual users, who can employ equipment however they wish within the bounds of the commons. This contrasts with the centralized approaches in which spectrum owners determine the services available to their users. If freedom from regulation is defined as government nonintervention in individual decisionmaking, then government action to create a commons is the approach involving less regulation.[397]

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393. *Id.* at 498–99; Benjamin, *supra* note 134, at 2014.

394. *See* Hazlett, *supra* note 53, at 496–98 (asserting that the profit motive drives private licensees or band managers toward "value-maximizing traffic strategies," while government regulators could arrive at an optimum strategy only by luck).

395. *See* Benkler, *supra* note 6, at 66 (arguing that having efficient property rights requires that the government provide the institutional design that defines, enforces, and updates the definition of the content of those rights).

396. For example, De Vany and his coauthors acknowledge that their property rights regime would push certain kinds of systems into particular points on the spectrum, which is exactly the inefficient "block allocation" structure today's property advocates decry. Because of the way the De Vany group defines output rights, it produces greater zones of confusion among adjacent rights holders at lower frequencies. *See* De Vany et al., *supra* note 46, at 1523. They propose to overcome this by having "transmitters serving large areas" in lower frequencies, and "transmitters serving small areas" in higher frequencies. *Id.* They do not specify how such an arrangement would arise. Presumably, it would have to be built into the initial rights assignment, or entail significant transaction costs for parties to trade their initial rights to achieve the efficient organization.

397. *See* Benkler, *supra* note 58, at 568 (asserting that an open peer-to-peer network enables democratic discourse and individual freedom better than the current mass-media model); Yochai Benkler, *The Battle Over the Institutional Ecosystem in the Digital Environment*,

Another difficulty with the commons as regulation argument is that it presumes too stark a difference between the two regimes. As I have explained, commons and property are two configurations of use rights in wireless equipment. They are not radically different concepts. Under each arrangement a variety of rules are possible. Some involve more up-front government decisionmaking, and some require less.[398] Even within a "public park" commons, government can impose many levels of requirements. The unlicensed PCS bands have more stringent protocol mandates than the 2.4 GHz band, which in turn has more detailed requirements than some portions of the 5 GHz band.[399]

Similarly, property rights can involve more or less interference protection, based on government decisions in defining those rights. In simple cases, the rights-holder and prospective entrants or adjacent rights-holders may be able to negotiate around the initial rules. If the owner holds out, though, or if the proposed transaction requires reaggregation of rights from too many sources (the "anti-commons" problem), the inefficient government allocation will have decided the boundary between competing uses.

Finally, equating commons with regulation assumes expressly established commons bands. The underlay rights the FCC established through Part 15 and its ultra-wideband decision, for example, do not involve frequencies that the FCC has allocated for unlicensed operation instead of licensed uses. They involve an area below the exclusivity bounds of preexisting licenses.[400] Software-defined radios in the broadcast bands would similarly not represent public uses crowding out private uses because no private uses exist in the guard bands.

The universal entry privilege I propose in Part IV is fundamentally a deregulation of spectrum. It puts decisions about who can transmit in the hands of those who wish to transmit and makes use of the private mechanism of common law courts to sort out disputes. The regime that prevents transmissions because government has issued an exclusive property right is arguably the regulatory one.

COMMUNICATIONS OF THE ACM, Feb. 2001, at 84, 89 (arguing that a commons in the information environment would enhance individual autonomy).

398. It is worth noting that, for all their talk of privatization, property advocates generally acknowledge the continuing need for a regulator. *See, e.g.*, White, *supra* note 53, at 32 ("There would still be a role for a national spectrum agency. . . ."). White specifically suggests that this agency "could serve as a vehicle for encouraging the coordination on technical standards that is often desirable in network industries." *Id.* In other words, precisely the sort of "regulatory" standards coordination that Benkler proposes. *See* Benkler, *supra* note 6, at 77–78.

399. *See* Peha, *supra* note 303, at 67.

400. *See* UWB Order, *supra* note 146, at ¶ 18 (concluding that while UWB devices would operate in the same frequency bands as licensed services, they would operate at low enough power to avoid creating harmful interference with those services).

C. Unlicensed Parks

Property advocates, most notably Faulhaber and Farber, assert that if unlicensed commons are beneficial, they can and will appear within an overarching property framework.[401] Government can buy spectrum in a property regime and set it aside as a commons (the equivalent of public parks). Or private owners can open up their spectrum to any users who employ certain forms of equipment (private parks). The notion is that private parks would likely be created by equipment vendors or by service providers which could charge a royalty on devices to cover the costs of acquiring spectrum. These examples show that commons can exist within a property world. Exclusive property rights cannot, however, exist within a commons because a commons means the absence of exclusivity.[402] Therefore, property should be the baseline rule.

As with the transactions around default property rights in the previous argument, parks sound nice in theory but are unlikely to happen in practice. As Benkler explains, there is a collective action problem for either the government or any private actor to purchase the necessary spectrum to establish a park.[403] Many existing licensed spectrum bands, such as the PCS and Wireless Communications Service (WCS) bands offer significant flexibility to licensees. Yet no company has ever purchased some of that spectrum at auction in order to make it available as a commons through an equipment royalty model, nor even proposed such a plan.

Unlicensed parks will not emerge within a property regime because of an information capture problem. A company bidding for spectrum property rights in a government-run auction or a private negotiation must determine whether the value it would receive from the asset acquired would exceed the cost it will pay. For a centrally controlled licensed service, benefits are straightforward to calculate. Service revenues are a function of the number of users. The discounted cash flow from those revenues can be matched against the net present value of the expenses involved, including the initial spectrum cost, the infrastructure build-out to provide service, and ongoing maintenance.

In an unlicensed environment, however, the discounted cash flow analysis is not so simple. A commons depends on competition among

401. *See* Faulhaber & Farber, *supra* note 5, at 213 ("Commons . . .can exist within an ownership regime."); Hazlett, *supra* note 53, at 538–42 (positing that public systems like police would benefit from privatization of spectrum); HUBER, *supra* note 110, at 75 (suggesting that markets in spectrum will create public spaces when it is the most profitable thing to do).

402. A commons can, however, coexist in the same band with licensed services. The unlicensed devices can be required to operate without interfering with the primary licensed service. Such an approach could be used, for example, as a transition mechanism in the 700 MHz band, which is to be cleared as part of the digital TV transition. *See* WERBACH, NEW WIRELESS PARADIGM, *supra* note 66, at 18.

403. Benkler, *supra* note 6, at 65 n.47; Benkler, *Building the Commons*, *supra* note 55, at 362–63.

manufacturers to develop better equipment and sell it to users. As more users take advantage of spectrum, the value of communications within it grows thanks to network effects. The spectrum owner cannot measure these values ahead of time, because it must calculate the price it will pay for exclusive control of the entire band instead of whether there is enough of a market to recoup the expenses of selling a device. If the spectrum owner mandates that only certain equipment may be used, it is no different than a licensed service provider.

In other words, auctions require an ex ante decision about the value of spectrum, whereas value determinations in a commons are made real-time by many actors. The 2.4 GHz band is a perfect example. Before WiFi, this was known informally as the "junk" band, because it was so heavily congested with uses such as cordless phones, baby monitors, and microwave ovens. These "industrial, scientific, and medical" devices were thought to cause so much interference that the band would have little or no value if given exclusively to a licensee. Opening it up as a commons therefore had little opportunity cost for the FCC and significant potential benefits.

At first, nothing happened. Gradually, pioneering manufacturers such as Apple began selling wireless local area networking gear that took advantage of the 2.4 GHz band. Then the WiFi equipment market took off, reaching $2 billion in 2003, and it is still growing rapidly.[404] Today, the 2.4 GHz band is the foundation of an extremely valuable and dynamic industry. Yet how could a prospective owner of an exclusive property right over the 2.4 GHz band have predicted that economic value ahead of time?

Public parks in spectrum are subject to the same failings. Government is no better able to capture ahead of time the value that could be generated from buying up spectrum and making it into a commons. The 2.4 GHz unlicensed band happened because there was effectively no cost for making it unlicensed, both because there was no charge for government to acquire spectrum and because the preexisting uses ruled out exclusive licensed operation. Public spectrum parks have the added problem that they require government to muster the resources to buy back spectrum rights. Given the vagaries of the budget process and the fact that spectrum in the age of auctions is thought of as a revenue *generator* for government, it is hard to see this happening.

Ultimately, the analogy with parks is flawed, and not just because it is an extension of the land metaphor I attacked in Part III. Parks compete with

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404. *See* Press Release, Gartner, Inc., Gartner Dataquest Says Worldwide Wireless LAN Shipments to Grow 73 Percent in 2002 (Sept. 19, 2002) (projecting a 26% increase in revenue for the wireless LAN industry in 2002 and that its growth would remain healthy for the next four years), *available at* http://www.gartner.com/5_about/press_releases/2002_09/pr20020919a.jsp; Press Release, Allied Business Intelligence, Wi-Fi IC Shipments Set to Top Expectations, According to ABI Study (Dec. 18, 2002) (predicting continued strong growth in the wireless LAN industry), *available at* http://www.abiresearch.com/pdfs/wlic03pr.pdf.

ownership of land, not with use of land. Central Park has different functions from the rest of midtown Manhattan—that's the point of having a park. In the spectrum case, by contrast, the erstwhile parks would compete to provide the same kinds of services as privately controlled spectrum. The choice between whether to apply one model or the other is therefore not a fair one.

D. Scarcity and Transaction Costs

I have already touched on the next argument against wireless commons: scarcity is high and transaction costs are low.[405] The FCC's Spectrum Task Force correctly identified these as important variables to consider in assessing the proper legal regime.[406] It failed, however, in claiming these measures called for exclusive property rights to be the dominant paradigm in all but the highest frequencies.[407]

Contrary to the Spectrum Task Force's blithe assertions, scarcity and transaction costs are not simple to determine. Both are recursive. How spectrum is used, in terms of architectures, services, and technologies, influences both scarcity and transaction costs. And these influence how spectrum is used. The branch of mathematics known as chaos theory demonstrates that seemingly simple equations can become hopelessly complex when they include recursive elements.[408] Even when inputs follow deterministic laws to outputs, reconstructing the inputs may be impossible. Once again, the difficulty is informational. There is no way to keep track of the tangle of interacting variables or even know their starting points precisely.

Imagine, for example, a frequency band licensed to a mobile telephony operator that uses code division multiple access (CDMA), a common technology for second- and third-generation cellular networks.[409] An equipment manufacturer wishes to sell unlicensed ultra-wideband gear to operate across a frequency range that includes this band.[410] Is spectrum in the band scarce? In general, the level of activity in spectrum will depend on how densely the operator has built out its network of transmission towers and how many customers it has. For the UWB system, scarcity is even more complicated. UWB operates below the noise floor of background radiation

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405. *See supra* note 230 and accompanying text.

406. Spectrum Task Force Report, *supra* note 83, at 38.

407. *Id.* at 54–55.

408. *See* DIMITRIS N. CHORAFAS, CHAOS THEORY IN THE FINANCIAL MARKETS 117 (1994).

409. CDMA is actually a spread-spectrum technology, developed by Qualcomm, that is predominantly employed in licensed bands. *See* JHONG SAM LEE & LEONARD E. MILLER, CDMA SYSTEMS ENGINEERING HANDBOOK 7 (1998) (describing Qualcomm's IS-95 spread-spectrum CDMA system).

410. The FCC's current ultra-wideband authorization restricts the technology to frequencies above 3.1 GHz, meaning that it cannot operate in PCS cellular bands. UWB Order, *supra* note 146, ¶ 5, at 7438.

because it employs such low-power signals.[411] Spectrum below the noise floor is therefore not scarce, at least from the perspective of high-power systems above it, because these systems ignore radiation at that level. CDMA, however, dynamically alters power output of its transmitters to maximize utilization.[412] In effect, it manages the noise floor. UWB systems, though they individually use infinitesimal power, can gradually increase the noise floor in aggregate by increasing the overall radiation levels in a band.[413]

The point at which the CDMA and UWB transmissions meet is the scarcity boundary. Where this boundary appears is highly contingent on time, location, the usage of the CDMA system, and the usage of the UWB devices, not to mention other background radiators and natural thermal fluctuations. Given any set of initial conditions, there is an optimal solution for the two systems to share spectrum, and an optimal transaction to reach this solution. There is, however, no simple way to find that optimal point, especially since the initial conditions are constantly changing. The value of a universal entry privilege for spectrum is that it would not absolutely preclude the UWB system from operating in the band absent government authorization or a transaction with the spectrum owner. It would give the UWB manufacturer leeway to experiment, with liability or technical standards as evolving backstops. It is a distributed solution to the intractably distributed problem of scarcity and transaction costs in this type of situation.

In general, the scarcity of spectrum is entirely dependent on the observer's perspective. Today, the "ultra high frequency" (UHF) television bands are near the bottom of the spectrum chart because so much higher-frequency spectrum that was once unusable has been populated. FCC orders through the years are replete with categorical statements about the channel capacity available for broadcasting.[414] None of these supposed limits have

411. Kazimierz Siwiak, *Ultra-Wide Band Radio: Introducing a New Technology*, in 2 IEEE VTS 53RD VEHICULAR TECHNOLOGY CONFERENCE 1088, 1088 (2001).

412. LEE & MILLER, *supra* note 409, at 368. CDMA is not the only technology that controls power in this way. I use the example because the boundary between CDMA PCS systems and UWB devices has already been a topic of discussion in the FCC's UWB proceeding. At some point the FCC is likely to consider expanding the available spectrum for UWB or other underlay devices, which will bring this conflict to the fore.

413. Comments of The Boeing Company at 5–6 (Sept. 12, 2000), Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems, 15 F.C.C.R. 12086 (2000) (ET Docket No. 98-153), *available at* http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6511757922.

414. *See, e.g.*, Amendment of Section 2.106 of the Commission's Rules to Allocate Spectrum at 2 GHz for Use by the Mobile-Satellite Service, 15 F.C.C.R. 12315, 12319 (2000) ("In many markets, all seven BAS channels in the 1990-2110 MHz band are not fully used . . . ."). *See* Margaret Kriz, *Supervising Scarcity*, NAT'L J., July 7, 1990, at 1660 ("On April 13, the FCC handed out the last remaining substantial portion of prime radio waves . . . ."). Similar are the periodic declarations that all the "prime" spectrum has now been assigned, and a choking "spectrum drought" looms. *See, e.g.*, Press Release, FCC, FCC Chairman Kennard Urges Three-Pronged Strategy to Promote Wireless Web (May 31, 2000), *available at* http://www.fcc.gov/Bureaus/Miscellaneous/News_Releases/2000/nrmc0032.html.

withstood the progress of technology. Furthermore, capacity is a function of system architecture. A broadcast network may deliver more bits to each user, but a cellular network carries more total bits and more independent conversations. A system employing inefficient receivers has less capacity than a system that swaps those out for better devices, even if the system architecture remains constant. Hence, each digital television channel can support up to six broadcast-quality streams in the same bandwidth that today carries just one.[415]

The choice between exclusive property rights and commons affects the scarcity value of spectrum as well. At first blush, a commons would seem to increase scarcity. Unconstrained entry can lead to a tragedy of the commons, in which every user rationally consumes more than its efficient share of the resource. Yet as WiFi and the Internet itself demonstrate, not all commons end tragically. Well-designed technical or legal constraints can keep the system from collapsing.

In fact, commons can reduce scarcity by changing the incentives of participants. Operators of licensed systems have incentives to make receivers as cheap as possible within the constraints of their license authority and system design goals. Less robust devices cut down on costs, which means more bottom-line profit for the service. Such devices, however, make spectrum more scarce, because they are less able to tolerate other users outside the licensed system. In other words, the fragility of the receivers is a negative externality of the licensed system.

This externality is internalized in an unlicensed environment. Because there is no guarantee to be free from interference from other devices, equipment vendors have incentives to make their gear more robust. An unlicensed receiver less able to tolerate interference is likely to be less successful in the market, forcing the equipment manufacturer to factor this variable into its decisionmaking.[416] Because a commons is open, equipment manufacturers are free to innovate and experiment with new approaches. They need not gain the permission of a regulator or owner to launch a better device into the marketplace.

Transaction costs similarly are higher than they appear in a property regime, and lower than they appear in a commons. Exclusive rights mean that every change requires a formal transaction. The potential entrant must

415. *Digital Television: Hearing Before the Senate Comm. On Commerce, Science, and Transportation*, 105th Cong. (1997) (statement of Reed E. Hundt, Chairman, Federal Communications Commission) (referring to the ability of then-current technology to digitally broadcast six or eight standard definition streams in the bandwidth used by one analog standard definition broadcast), *available at* http://www.fcc.gov/Speeches/Hundt/spreh749.html.

416. If the more robust receiver is substantially more expensive, users may opt for the cheaper alternative. However, this only reinforces the value of the commons. It is a case of market forces determining how good a receiver to build, taking all factors into account. A functioning commons optimizes the design of devices globally to balance efficiency against cost, rather than optimizing solely to meet the private goals of a licensee or spectrum owner.

find the rights owner, determine how much it is willing to pay, negotiate a transaction, and have that transaction recognized through the ancillary legal regime that accompanies every functioning property system. The rights-holder effectively holds a veto over any transaction, no matter how efficient.[417]

Noam's proposed regime, in which transactions would occur in a real-time market based on dynamic pricing, removes some of these barriers, but still requires payment and adds overhead to enforce those payments.[418] The overhead of a transactional system can exceed the value of the transactions themselves. In the telephony world, a substantial portion of the price of a local call goes to the convoluted web of billing and tracking infrastructure that carriers operate to meter calls.[419] In local area data networking, the winning protocol was Ethernet, which cannot prevent collisions when two packets are sent through the network simultaneously.[420] Competing protocols such as token ring prevented such "interference," but at too great a cost.[421]

The aggregate costs of spectrum transactions increase as the transactional environment becomes more dynamic. If frequency is the only variable, and frequency blocks are well-defined, transactions may be relatively cheap. This is the animating vision of the propertization literature

417. The FCC's struggle with low-power FM radio is an example of how spectrum incumbents seek to block entry. Congress substantially rolled back the FCC's proposal for non-interfering low-power FM stations, on the grounds that more low-power stations would cause major interference with high-power broadcasters. *See* Benjamin, *supra* note 249, at 16 (discussing President Clinton's signing of legislation in December 2000 that reduced the number of operable low-power stations by over 50%). Those fears proved to be overblown. *See* MITRE TECHNICAL REPORT, EXPERIMENTAL MEASUREMENTS OF THE THIRD-ADJACENT-CHANNEL IMPACTS OF LOW-POWER FM STATIONS: FINAL REPORT, at xxvi–xxvii (2003) (finding no significant interference from low-power FM transmitters), *available at* http://babel.serve.com/mitre/mitre4.pdf. In a property regime, the high-power broadcasters might be able to sell low-power rights, but it is hard to imagine they would do so broadly. Incumbents do not have a good track record of voluntarily allowing in competitors, even when they are compensated. The general failure of the "unbundling" requirements of the 1996 Telecommunications Act shows this dynamic well. *See* Telecommunications Act of 1996, 47 U.S.C. § 251(c)(3) (2000) (requiring that incumbent local exchange carriers provide "nondiscriminatory access to network elements on an unbundled basis" to "any requesting telecommunications carrier"); Reza Dibadj, *Competitive Debacle in Local Telephony: Is the 1996 Telecommunications Act to Blame?*, 81 WASH. U. L.Q. 1, 39–41 (2003) (noting how local exchange carriers have delayed repairs, not processed orders, and accepted large fines in order to frustrate the intent of the "unbundling" requirement).

418. Noam, *supra* note 4, at 777–80.

419. *See* LAWRENCE BERNSTEIN & C.M. YUHAS, BASIC CONCEPTS FOR MANAGING TELECOMMUNICATIONS NETWORKS: COPPER TO SAND TO GLASS TO AIR 158–60 (2002) (illustrating the allocation of costs in the telecommunications industry).

420. GILBERT HELD, ETHERNET NETWORKS: DESIGN, IMPLEMENTATION, OPERATION, MANAGEMENT 30–32 (2003). Ethernet does, however, implement the Carrier Sense Multiple Access with Collision Detection protocol, which allows most potential collisions to be detected and avoided. *Id.*

421. *See* NATHAN J. MULLER, WANS TO LANS: THE COMPLETE MANAGEMENT GUIDE 13–18 (2003) (discussing token ring technology).

going back to Coase. It was a fair approximation of reality in the past. Today, however, frequency blocks are no longer the only mechanism for exploiting spectrum. A property regime limited to frequency would preclude many uses that increase capacity and value of spectrum, such as wideband underlay.[422] The trouble is that the more degrees of freedom there are, the more complex the transactional environment. Coase himself acknowledged that, "[w]hen the transfer of rights has to come about as a result of market transactions carried out between large numbers of people or organizations acting jointly, the process of negotiation may be so difficult and time-consuming as to make such transfers a practical impossibility."[423]

Property advocates themselves inadvertently confirm this point. Kwerel and Williams, in advocating a "big bang" auction mechanism for propertizing spectrum, describe several aspects that would be efficient to incorporate into the auctions, such as combinatorial bidding, which are too complex for current software.[424] And this is just for initial reassignment of existing frequency blocks! The better the property system at taking into account the alternative uses of spectrum, the more potential transactions, and hence the greater the transaction costs. This is also a reason property advocates propose that initial property rights track existing FCC licenses, even though those licenses may have inefficient or outdated boundaries.

The De Vany and Minasian proposals for output-delineated spectrum rights were efforts to develop better rights configurations, but as a result they create new problems and complexities.[425] Property advocates today cite these works religiously, yet despite the wealth of recent spectrum scholarship, there have been no serious attempts to update their decades-old proposals. The property camp seems to have concluded that moving to a property system for spectrum as quickly as possible is more important than working through the thorny matter of getting that system right. Once the market is in charge, they assume, the magic process of Coasian bargaining

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422. Though in theory a spectrum property owner might be able to enter into an underlay agreement, the property regime would not provide the necessary tools to make such an agreement work. *See supra* notes 241, 289.

423. Coase, *supra* note 3, at 29. Coase thought such situations called for "special regulations" directly allocating spectrum uses, alongside the property rights mechanisms that would prevail elsewhere. *Id.*

424. *See* KWEREL & WILLIAMS, *supra* note 79, at 16–17 (acknowledging "technical and operational limitations" involved in the recommended two-sided simultaneous auction with package bidding).

425. *See* LEVIN, *supra* note 46, at 94 (stating that the "principal problem in grounding a market system on rights defined as signal outputs derives from the external effects" which introduce "considerable uncertainty" as to how much "of any user's radiation rights he can expect to utilize successfully"); MUELLER, *supra* note 46, at 30 ("It is often difficult to monitor the actual output pattern of a transmitter without knowing the antenna heights and location, power, input, and transmission method.")

will right all wrongs. There is, however, no guarantee this will happen, for reasons Coase himself identified.[426]

Transaction costs are a mirror of interference. The more complicated and uncertain a concept interference is, the more difficult it is to determine ahead of time the efficient configuration of duties to prevent interference. Prior to Coase, interference was seen as an absolute barrier to flexibility in assignment of wireless transmission rights.[427] Government had to manage spectrum and limit private actors, because the alternative was chaos.

One of Coase's major contributions was his recognition that interference boundaries could be set through property rights rather than government management, because each rights holder would have incentives to both exploit and police its spectrum.[428] Coase's proposed solution, however, was based on the contemporary view of interference when he proposed it. Interference was still thought to necessitate exclusivity in spectrum.[429] The less we think of interference as a high and rigid barrier, and the more we see it as a phenomenon that technology is gradually conquering, the more the transaction cost ledger favors commons.

Consider what might have happened had the FCC adopted Coase and Herzel's proposed spectrum property regime in the 1950s. In those days, wireless services offered to the public meant broadcasting. Exclusive property rights in spectrum would therefore have been broadcast rights. The interference boundaries would have assumed central transmission towers with passive receivers, and the systems deployed would have in fact looked like that. Owners could happily buy and sell spectrum in this broadcastopia.

Ten or twenty years later, let us assume, AT&T decides the cellular telephony technology it has developed is ready for commercial

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426. Coase noted:

> This discussion should not be taken to imply that an administrative allocation of resources is inevitably worse than an allocation by means of the price mechanism. The operation of a market is not itself costless, and, if the costs of operating the market exceeded the costs of running the agency by a sufficiently large amount, we might be willing to acquiesce in the malallocation of resources resulting from the agency's lack of knowledge, inflexibility, and exposure to political pressure.

Coase, *supra* note 3, at 18; s*ee also* Coase, *supra* note 124, at 15 (noting that market operating costs are so high that they prevent many transactions that would be carried out in a world in which the pricing system worked without cost); De Vany et al., *supra* note 46, at 1507–08 (acknowledging that the costs of negotiating and exchanging spectrum property rights may be quite high relative to their value).

427. *See* Coase, *supra* note 3, at 12–13 (describing the general view that mass interference in radio transmissions required regulation by the federal government); Nat'l Broad. Co. v. United States, 319 U.S. 190, 213, 215–17 (1943) (emphasizing the need for centralized government regulation of radio transmissions in upholding certain chain broadcasting regulations implemented by the FCC).

428. *See* Coase, *supra* note 3, at 25–29.

429. *See id.* at 25–26.

deployment.[430] To introduce cellular service, AT&T must purchase spectrum from an existing owner, who is by definition a broadcaster. What AT&T needs, however, is not a right to build a broadcast tower in one geographic location, but the ability to erect two-way cellular towers across the country. It is not clear that AT&T could acquire those rights at any price.[431] Mobile telephony, which today generates more revenue than broadcast television, would have no place in broadcastopia. The property system would be efficient on its own terms, but transaction costs would mean it was heavily suboptimal in the aggregate social welfare terms that matter.[432]

What about low-power unlicensed devices, such as those permitted under the FCC's Part 15? Broadcasters' property rights would give them exclusive control over "their" spectrum, so the Part 15 devices would be prohibited. Makers of low-power devices could negotiate to pay a spectrum owner for an "easement," but those direct and transaction costs would raise the price of their equipment. It would make many such systems impractical, because they could not transmit on the same frequencies everywhere in the country. The problem gets worse with technologies such as ultra-wideband. Aggregating easements from the large number of rights holders involved would be a practical impossibility. Scholars have labeled this scenario the anticommons.[433]

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430. Bell Labs in fact first demonstrated the basic technical approach of cellular telephony in the 1940s. JAMES B. MURRAY, JR., WIRELESS NATION: THE FRENZIED LAUNCH OF THE CELLULAR REVOLUTION IN AMERICA 19 (2001). However, such a network would not have been commercially viable at that time. *See id.* at 20 (noting a continued lack of sufficient spectrum despite technological improvements during the 1950s and 1960s).

431. *See* Jon M. Peha, *Spectrum Management Policy Options*, IEEE COMM. SURVEYS, Fourth Quarter 1998, at 1, 4 ("It is therefore quite unlikely that a block of spectrum would emerge nationwide for cellular unless it was created by a single company.").

432. In the real world, it took Craig McCaw and other entrepreneurs years to string together national cellular telephony networks, even though the spectrum was already designated for that purpose and each geographic market had only two cellular operators. *See* MURRAY, *supra* note 430, at 231–50 (describing the piecing together of the nationwide cellular network).

433. *See* Michael A. Heller, *The Tragedy of the Anticommons: Property in the Transition of Marx to Markets*, 111 HARV. L. REV. 621, 623 (1998) (describing the anticommons as a situation in which a scarce resource is "prone to underuse" because "multiple owners are each endowed with the right to exclude others . . . and no one has an effective privilege of use"); Hunter, *supra* note 99, at 444 (proposing that legal propertization of cyberspace is leading to a tragedy of the anticommons). Benkler applies the anticommons argument to wideband underlay. *See* Benkler, *supra* note 6, at 63–64. Benjamin takes issue with Benkler's claim, asserting that if the problem is that owned spectrum bands are too narrow to accommodate ultra-wideband, the initial allocation can simply use wider bands. Benjamin, *supra* note 134, at 2016. This *deus ex machina* approach ignores the reality that whatever property rights system is adopted will have some initial license parameters based on foreseeable transactions at that point in time. Wider bands may allow for more wideband underlay, but future variants of UWB may call for even wider transmission bands. Furthermore, the wide bands of property rights would make other types of underlay more difficult, such as interweaving in guard bands between frequency blocks. Bigger blocks means fewer border areas between owned blocks. No matter how good the regulator is at assigning initial property rights, it will not be able to anticipate all the subsequent possibilities. It faces precisely the informational problem that Coase first identified as the fatal flaw in the current government licensing approach.

Perhaps the courts would read a Part 15 underlay into the preexisting property rights. The analogy would be the decision that, even though land rights theoretically extend forever above and below the ground, airplanes need not negotiate overflight rights with individual landowners. This is an easy case because the benefits of allowing aviation are so clear, and the interference with the landowners' notional property rights so theoretical. We cannot simply assume that courts will reach the right result in the spectrum context. When the default rule is private ownership and the new underlay service is not yet commercially available (which it could not be until it is authorized), courts are likely to err on the side of the incumbent property owners.

The transaction costs of dispute resolution and monitoring are similarly complicated to calculate.[434] Faulhaber and Farber assert that such costs are higher in a commons because "courts will be more efficient in dealing with the familiar territory of property rights."[435] As I have explained, however, this would not necessarily be the case. Whatever the legal regime, administrative transaction costs will depend on how effective and settled the dispute resolution regime is. Costs will be higher at first under either system, as parties explore the boundaries, and adjudicators develop precedent.

E. Easements

The final counter to the commons position, Faulhaber and Farber's proposed noninterfering easement, is of a different character from the others.[436] The easement is an insurance policy. It concedes that commons may be a viable approach, and therefore mandates commons alongside the property rights allocation. Faulhaber and Farber present the easement as a simple adjustment to the property regime that achieves the best of both worlds.[437] On the contrary, a noninterfering easement is a radical limitation of the core exclusive rights in a property system. It means that rights are always exclusive . . . except when they are not. And they are not wherever a parallel transmission is considered noninterfering.

The easement is, in effect, the universal entry privilege I propose above. Far from being a reason to choose property as the overarching legal

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See Coase, *supra* note 3, at 18 (noting that a regulator cannot be in possession of all relevant information concerning how radio frequency might be used).

434. Faulhaber and Farber call these "indirect transaction costs." *See* Faulhaber & Farber, *supra* note 5, at 212. Benkler calls them "administrative costs." *See* Benkler, *supra* note 6, at 56–57.

435. Faulhaber & Farber, *supra* note 5, at 212.

436. *See id.* at 208–09 (proposing that the ownership of a frequency be subject to a "noninterference easement" thus allowing others to use the frequency as long as they did not meaningfully interfere with the owner's transmission).

437. *See id.*

paradigm, it is a reason to scale back the bundle of rights granted in those situations where the property regime applies.[438]

Faulhaber and Farber's choice of wording is unfortunate. An easement is a legal concept plucked from the law of real property. Importing it into spectrum policy reinforces the inaccurate analogy between spectrum and land.[439] Calling the easement "noninterfering" is also problematic, because no transmission can be proven to avoid interfering with all other transmissions.[440] "Noninterfering easement" connotes something akin to a land owner's deed specifying that the public can drive on a road passing though his or her property. Even on their home turf of property law, easements are not so simple, as any first-year law student can attest.

The easement concept implies that the spectrum owner is the primary rights holder, and the easement is an intrusion that it must tolerate if it suffers no harm. If the burden of proof is solely on the potential user of the easement to be noninterfering, the easement may not be viable. The property owner has every incentive to put up artificial limits on the easement or claim interference. In the CDMA vs. UWB example I outline above, the cellular operator could crowd out the UWB systems at any time by making its equipment more sensitive. The noninterference restriction is effectively a choice to protect the cellular network, even if that is the economically inefficient choice.[441] Unless, of course, the easement boundary is subject to a legal regime such as I propose in Part IV, at which point the easement looks much larger than Faulhaber and Farber envision.

The easement as Faulhaber and Farber present it effectively chooses the surgeon over the confectioner in Coase's illustration.[442] That may be the right outcome in some or most cases. To assume that it is, though, is to make a leap not supported by the evidence. The problem here is similar to the one of dedicated unlicensed parks amid owned spectrum, something Faulhaber and Farber also bring up.[443] Neither government nor the spectrum owner

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438. The fact that property rights can accommodate an easement does not say anything about the choice of whether to designate frequency bands for exclusive or unlicensed use. That choice, as Benkler explains, depends on the relative economics of two competing industry structures and the network architectures they generate. *See* Benkler, *supra* note 6, at 62.

439. *See* White, *supra* note 53, at 21 (explaining the analogy between spectrum and land).

440. *See* Hazlett, *supra* note 53, at 374 (admitting that "[a]ll wireless communication implies some level of potential deterioration of valuable signals").

441. If, as is likely, the licensed system operates at high power and the easement is for low-power devices, the high-power system will increase the computational complexity for the unlicensed network to find the efficient transmission path, thus increasing its costs. *See* Benkler, *supra* note 6, at 45 (explaining that "computational complexity of communicating" is related to "the total electromagnetic din in the vicinity").

442. *Id.* at 63–64 (noting that "defin[ing] the operating parameters of open wireless networks based on the sensitivities of the property-based services" is a choice "to make the world safe for physicians and constrained for confectioners").

443. *See* Faulhaber & Farber, *supra* note 5, at 213–14 (describing "parks" as set-aside spectrum blocks which are opened to general use subject to "rules laid down by the owner of the 'park'").

knows ahead of time how the easement will be used. So there is no way to calculate the benefit or optimal boundaries of the easement.

One alternative is to make the interference protection implied by the easement mutual. Easement users could have some rights against the spectrum owner, just as it has against them. The effect would be similar to the "Part 16" rules that Apple proposed for the U-NII band, under which unlicensed devices would collectively enjoy the same protection against out-of-band interferers as licensed systems.[444] The FCC rejected Apple's idea.[445] Benkler argues such a rule should be adopted broadly for unlicensed devices.[446] Merely doing so, however, does not indicate where the boundary should be drawn when rights overlap. The equivalent statement that I have the right to swing my arm until it connects with the bridge of your nose is the beginning of the legal analysis, not the end.

Faulhaber and Farber properly define the easement not just as a low-power underlay, but as a general privilege to transmit where that transmission would not excessively burden other systems.[447] An adaptive or cognitive radio that exploited temporary holes in owned spectrum would be subject to such an easement, for example. If in fact a majority of spectrum frequencies are unused at any given time, as the Shared Spectrum survey found,[448] this portion of easement would in fact be larger than the entire scope of exclusive property rights.

If the easement is a serious proposal, not a hypothetical bone tossed toward the commons, there must be a viable mechanism to determine its boundaries. Benkler, for example, proposes an expanded version of the Faulhaber and Farber easement, which he calls underlay and interweaving rights.[449] Benkler's easement would have two constraints. Systems would have to use power low enough to not "appreciably affect the information flow" of incumbent devices deployed as of that date.[450] They would also be required to incorporate automatic sensing of licensed systems and mechanisms to vacate the band when such transmissions appear.[451]

As I detail above, we can go further. The unlicensed system is not a necessarily subordinate use; it is a competing projection of property rights. The incumbent user of the band has legitimate reliance and expectation interests that must be weighed against any claim that a competing unlicensed use is more efficient. These interests, however, are not absolute, especially

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444. Benkler, *Building the Commons*, *supra* note 55, at 336.

445. *Id.*

446. *See id.* at 392 (arguing that the FCC "should reconsider the decision not to employ a 'Part 16' model").

447. Faulhaber & Farber, *supra* note 5, at 208–09.

448. NEW AM. FOUND. & SHARED SPECTRUM COMPANY, *supra* note 14, at 3.

449. *See* Benkler, *supra* note 6, at 80.

450. *Id.*

451. *Id.* at 80–81.

at the margins. When technological limitations made sharing of spectrum frequencies difficult, a blanket rule privileging incumbents made some sense. As that constraint is more and more fully lifted, however, exclusive rights become a greater and greater drag on efficiency.

VI. Transition Possibilities

Ultimately, commons and property come together as equals. They are different shades in the rainbow of possible use rights that can be accorded to wireless communications equipment. Neither should exist at the sufferance of the other, though participants in the market should have some ability to choose among them. The option of buying exclusive rights or participating in a commons should be a choice spectrum users can make, just as they must choose what service to deliver and what technology to employ. The presence of more substitutes is what will make spectrum effectively less scarce, even as usage increases. The more ways there are to avoid the messy process of dispute resolution by simply routing around conflicts, the more likely participants will choose that route.

The policy challenge today is how to achieve such a result, given the many deep uncertainties I have outlined. If we knew all the situations in which property rights or commons were more efficient, we could simply mandate that world. But we do not know that, nor can we. And any solution that is correct today will be wrong tomorrow as usage and technology change. Therefore, caution and experimentation must be part of the agenda for moving forward. There is nothing wrong with trying out property rights in spectrum, but there is everything wrong with acting as though property rights are the only solution, everywhere and for the end of time.

The legal states for wireless communications can be defined in terms of two variables: whether entry is open to any conforming device or controlled by a rights holder, and whether the boundaries of the state are fixed ahead of time by law or evolve through the interactions of participants.

TABLE 2: POSSIBLE LEGAL ARRANGEMENTS

	Exclusive	Open
Fixed Boundary	Licensing, Property	Commons
Open Boundary	Subdivision	Supercommons

Before the emergence of the commons critique, the spectrum debate focused almost entirely on the top left quadrant of the table. Both government licensing and property rights involve exclusive control of a defined allocation. That is why moving from licensing to property seems so temptingly simple. Government simply must transmute heavily encumbered licenses into permanent fee simple ownership of the same assets. The idea that there might be other ways to slice the spectrum pie, using techniques such as wideband underlay, occasionally cropped up. De Vany, for example, argued in 1996 that property rights would allow owners to share their spectrum with what he called "broad band broadcaster[s]."[452] The boundary between the high-power and low-power uses would not be fixed in the allocation of property rights; it would evolve through negotiation.[453] This was at most a side discussion, though, not the primary argument for the property regime.[454]

The commons critique revealed that there was another dimension that neither government licensing nor property rights took into account. Smart digital devices backed by technical standards can coexist without exclusivity, as WiFi and UWB demonstrate. Open entry encourages different business models, with equipment manufacturers taking the place of centralized infrastructure builders. It also allows for uses that may better achieve the normative goals of democracy, diversity, and autonomy.

My goal in this Article has been to fill in the final quadrant. The supercommons has both open entry and open boundaries. It is the white space around the other forms that have been the subject of the debate. Transmissions that are neither exclusive nor confined to bounded spaces have always been defined as impermissible interference. In many cases, they are. As technology increases the scope of possibilities for wireless communication, however, the spectrum white space grows to the point at which it can be a viable platform in its own right. Even if the supercommons is not exploited, its existence helps sharpen our understanding of the scarcity and transaction cost tradeoffs among the property and commons forms in the various possible manifestations.

Going forward, we should proceed along two tracks. Fixed-boundary frequency bands should gradually be converted to both exclusive property rights and commons, with mechanisms for reversibility at some future point. With over 90% of spectrum below 3 GHz still subject to service-specific licenses, even a relatively small shift could have significant economic consequences.

A commons may be more difficult to reverse than a time-delimited property right, but it is not impossible to move from a commons to

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452. *See* De Vany, *supra* note 291, at 14. Broadband broadcasting, which I refer to as wideband underlay, is an ironic term. Broadcasting is broad in its reach to a wide audience who receive the same programming, but it does so by sending a high-power signal through a relatively narrow wireless channel.

453. De Vany, like other property advocates, was too sanguine that such subdivisions would occur. *See, e.g.*, *supra* note 417. This is the private park scenario raised by Faulhaber and Farber, which I address above. *See supra* subpart V(C).

454. Strictly speaking, subdivision of property rights is only partially an open-boundary form of communication. The subdivision can be no larger than the bounded property right itself. This is another case of the inherent tradeoff in an exclusive-rights regime: Some activities must be prohibited through correlative duties as the price of assigning a right.

something else. The FCC has in the past reassigned private microwave users, who share licensed spectrum under a regime that has elements of a commons.[455] The more devices there are operating in the commons, the harder it will be to declare those devices illegal and turn the band over to an exclusive owner. However, more devices mean the commons is more valuable. If a commons has failed, either because it has too few users or because it has descended into a tragedy of over-use, reassigning it to another use would not cause much of a loss for users.[456] Though there would be a cost and a time lag, there is no reason the FCC could not order certain unlicensed devices shut down—in effect, it will order virtually every household in America to upgrade its television sets when analog broadcasting ceases.[457]

Simultaneously with its expansion of bounded property and commons uses, the government should begin to open up the supercommons. At first, stringent limits including sensing and avoidance capability, strict liability for interference, insurance or bonding requirements, and remote shut-off capability could be required. As Benkler proposes, "anything goes" spectrum could also be set aside as an experimental space.[458] The limits on the supercommons could be removed over time, either on a set schedule pursuant to defined milestones or based on petitions from potential equipment or service providers. The other option is to start with a supercommons that has less severe backstops, but to do so with more constraints on how devices can operate. For example, the newly minted property rights or commons could be tied to a strong supercommons underlay or interweaving privilege. This would give the bounded users notice that they may have to share with others at the margins and would net this restriction on their rights against the benefits they receive at the same time.

VII. Conclusion

The goal of spectrum policy is to maximize national welfare derived from wireless communications. Welfare involves some measure of efficiency, which means optimizing the amount and economic value of communications that occur. The capacity of wireless systems is a function of their architecture and equipment, which are themselves shaped by legal rules.

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455. *See, e.g.*, Redevelopment of Spectrum to Encourage Innovation in the Use of New Telecommunications Technologies, 9 F.C.C.R. 1943, ¶¶ 2, 5 (1994) (describing previous microwave band reallocations).

456. If the government paid off the aggrieved users of the band, the result would be similar to a buyback or compensated taking of spectrum that had been turned into private property.

457. *See* David Lagesse, *Find the Perfect Picture*, U.S. NEWS & WORLD REP., Nov. 25, 2002, at 66, 67 (indicating that when the analog television signal is shut off per FCC order in 2007, televisions without either a digital tuner or a converter will not work).

458. *See* Benkler, *Building the Commons*, *supra* note 55, at 391–94.

Welfare also involves values such as autonomy, diversity, and democracy, which are not always reducible to dollar amounts.[459]

The actions that are properly the subject of spectrum policy are actions of individuals. The issue is whether users can operate certain kinds of devices. Those devices may be built to specifications defined by service providers, technical standards bodies, or hobbyist groups. The device in question may be a five-hundred-foot broadcast tower or a mobile phone that fits in a shirt pocket. Individual use of those devices generates collective value in the form of communications capacity and revenue from services or equipment. As a general matter, the more individuals who can participate in wireless communications, and the more they can do with their devices, the more value will be produced.

Coase himself hinted at such a user-centric perspective. After pointing out that spectrum is no more a resource susceptible to allocation than sound or light waves, he observed that, "[t]o handle the problems arising because one person's use of a sound or light wave may have effects upon others, we establish the right which people have to make sounds which others may hear or to do things which others may see."[460] These are not exclusive or possessory property rights. They are individual privileges to act and rights to be free from certain invasions by others. Their boundaries are determined dynamically by law and custom.

At any point in time, there exists a theoretically optimal arrangement of wireless devices. This would be a situation in which the marginal value of any change would be less than the marginal cost. It is impossible to determine ahead of time what this arrangement is. It will vary over time depending on technical capabilities, existing systems, and demand. It may not be the arrangement that passes the most bits, since some bits are more valuable than others. Nonetheless, the optimal arrangement would generally be one that utilizes spectrum as fully and efficiently as possible.

The status quo is far from the optimal arrangement, because it leaves large portions of spectrum fallow. Property rights in spectrum would be an improvement, but only to a point. Their inherent exclusivity would systematically prevent many possible avenues from being explored. Unlicensed bands open up further opportunities, but remain tied to

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459. This is not to say that normative and economic values cannot be connected. For example, Tom Hazlett argues that property rights, by better aligning economic incentives, will better serve First Amendment interests than the current governmentally managed approach. *See* Thomas Hazlett, *Physical Scarcity, Rent-Seeking and the First Amendment*, 97 COLUM. L. REV. 905, 937–38 (1997) (presenting evidence that the FCC's abandonment of the requirement that radio stations provide "nonentertainment" programs actually led to the desirable First Amendment outcome of a greater diversity of radio station formats). Coming from the other direction, Benkler constructs an economic argument for commons approaches, based on comparative institutional patterns of information collection and preference articulation. Benkler, *Building the Commons*, *supra* note 55, at 383–88, 390–91.

460. Coase, *supra* note 3, at 33.

frequencies. The supercommons around traditional communications techniques opens up the final frontier of wireless. By shifting from regimes that require explicit permission for new transmission techniques to one that uses dynamic boundary-setting mechanisms, the supercommons would, over time, allow the wireless communications ecosystem to move toward the theoretical ideal.

The outcome of the spectrum debate is extremely important. In the years to come, the uses and importance of wireless communication will only grow. As radios become cheaper and more flexible, they will be incorporated into many products and processes that today are unconnected. More than eight billion microprocessors are shipped every year, a number exceeding the population of the earth, yet less than 2% of them are networked.[461] And though virtually every household in America has at least one television, only tens of broadcast stations are available through the air and a couple hundred through cable or satellite.

A vast opportunity lies between those hundreds of channels and hundreds of millions of users, as well as between those millions of networked devices and billions of microprocessors. A new world of communication awaits. Its coastline is only now being mapped; the extent of the hidden continent and its territorial riches remain to be discovered. Now is not the time to fear mythical dragons on the electromagnetic high seas.

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461. Patrick Gelsinger & Bob Metcalfe, Remarks at the Intel Developer Forum (Feb. 21, 2003) (transcript available through Intel) (estimating that less than two—and maybe even less than one—percent of the eight billion microprocessors shipped each year are networked), *available at* http://www.intel.com/pressroom/archive/speeches/gelsinger20030221.htm.