THE QUESTION OF SPECTRUM: TECHNOLOGY, MANAGEMENT, AND REGIME CHANGE

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ABSTRACT

There is general agreement that the traditional command-and-control regulation of radio spectrum by the FCC (and NTIA) has failed. There is no general agreement on which regime should succeed it. Property rights advocates take Ronald Coase's advice that spectrum licenses should be sold off and traded in secondary markets, like any other asset. Commons advocates argue that new technologies cannot be accommodated by a licensing regime (either traditional command-and-control or property rights) and that a commons regime leads to the most efficient means to deliver useful spectrum to the American public.

This article reviews the scholarly history of this controversy, outlines the evolution of FCC thinking, and parses the question of property rights vs. commons into four distinct parts: new technology, spectrum uses, spectrum management, and the overarching legal regime. Advocates on both sides find much to agree about on the first three factors; the disagreement is focused on the choice of overarching regime to most efficiently and effectively make spectrum and its applications available to the American public. There are two feasible regime choices: a property rights regime and a mixed licensed/commons regime subject to regulation.

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The regime choice depends upon four factors: (1) dispute resolution, (2) transaction costs, (3) tragedies of the commons and anticommons, and (4) flexibility to changing technologies and demands. Each regime is described and analyzed against these four factors. With regard to pure transaction costs, commons may hold a small advantage. For all other factors, the property rights regime holds very substantial advantages relative to the mixed regime. I conclude that the choice comes down to markets vs. regulation as mechanism for allocating resources.

INTRODUCTION

The use of the electromagnetic spectrum for telecommunications and other functions has traditionally been closely regulated by government agencies in most countries. In the U.S., television and radio broadcasting, microwave transmission, cellular and cordless phones, CB and family radio, amateur (ham) radio, and more recently WiFi and other home networking technologies all operate under frequency assignments, power constraints and location restrictions established and enforced by the Federal Communications Commission (FCC).[1] This system was established by the 1927 Radio Act, initially administered by the Federal Radio Agency and then by the FCC since its inception in 1934. Generally, broadcasters of radio energy must apply for and receive a license,[2] which sets forth restrictions on the frequency, power limit, and perhaps direction and time of day that the licensee is permitted, and also sets forth the specific use permitted by the license, such as FM broadcasting, cellular telephony, taxi dispatch, and so forth. These licenses are generally time-limited, but there is a strong presumption of renewal of the license at its expiration.

The rationale for maintaining this extensive licensing system is *radio interference*. Interference occurs when two or more signals of the same (or similar) frequency and power arrive at a receiver simultaneously, and the receiver cannot distinguish between the wanted signal and the

1. The National Telecommunications and Information Agency of the Department of Commerce manages all federally operated spectrum, such as used by the Department of Defense, Federal Aviation Agency, and so forth. The FCC regulates all other spectrum.

2. As we shall see in detail below, the FCC has also set aside important frequency bands for unlicensed use, such as cordless phones, garage door openers and WiFi.

interfering signal(s). In the early days of radio, conflicting broadcasters in the same geographic area interfered with each others' signals, so that listeners could not enjoy their preferred broadcasts. By assigning broadcasters to specific frequencies in specific localities and limiting their broadcast power, the FCC created an interference-free space in which listeners could hear their preferred broadcaster. Specifically, the FCC allocated broad swaths of frequency to particular uses, such as radio broadcast, taxi dispatch, and police and fire services. Within each swath and in each locality, particular users were licensed to use specific frequencies, such as a radio broadcaster or a police department. Thus, the use of the frequency was also constrained; taxi dispatch services, for example, could not be used by radio broadcasters. This frequency/location/power/use allocation mechanism was a feasible approach for early radio to solve the interference problem, and has remained so up until recently, as new technologies are becoming available.

The purpose of this paper is to review the current state of the property rights vs. commons debate, to parse the question into its constituent parts in order to clarify where the disputants agree and where the disputants disagree, and to focus attention on the four key properties of the overarching legal regime: dispute resolution, transaction costs, tragedies of the commons and anticommons, and flexibility for changes in technology and demands. Part I reviews the history of spectrum management and the evolution of the academic debate surrounding it. Part II examines practical considerations of the FCC concerning property rights, commons, and non-interfering easements. The reader well-versed in this ongoing debate may skim these sections without loss, moving quickly to Part III, which parses the problem into areas in which commons and property rights advocates agree and the one area (the overarching legal regime) in which they do not. Part IV assesses the merits and drawbacks of each regime in terms of transaction costs, dispute resolution, and flexibility to respond to future changes in technology and demands. Part V contrasts the differing regimes in the light of three hypotheticals. I conclude that a property rights regime is substantially superior to a commons regime using these criteria.

I. THE EVOLUTION OF THE SPECTRUM MANAGEMENT DEBATE

The history of spectrum management since the earliest days has been amply documented elsewhere;[3] I give only the bare outlines of that

3. *See* Ellen P. Goodman, *Spectrum Rights in the Telecosm to Come*, 41 SAN DIEGO L. REV. 269, 282 n.34 (2004) (summarizing several versions of this history). *See also* Yochai Benkler, *Overcoming Agoraphobia: Building the Commons of the Digitally Networked Environment*, 11 HARV. J.L. & TECH. 287, 298 (1998); Gerald Faulhaber & David Farber,

history, relevant to the purposes of this paper.

The command-and-control system of administrative allocation of frequency/location/power/use spectrum licenses was and is the dominant form of spectrum management regime throughout the developed world. As the uses of radio multiplied, the FCC and regulators around the world allocated and assigned spectrum for AM-FM radio, analog (and later digital) television, microwave communications, garage door operators, cordless phones, industrial and scientific purposes, amateur (ham) radio, airport and aircraft radar, CB radio, and a host of other applications. Such licenses were granted on the basis of the licensee operating "in the public interest," a rather elastic standard with widely varying interpretations over time. Conditions were often applied to the granting of such licenses, such as build-out requirements; licenses could be revoked if these conditions were not met. In practice, however, the grant of a license was a grant in perpetuity, and was quite difficult for the FCC to recover should spectrum needs change.[4]

As might be expected, this highly inflexible bureaucratic allocation mechanism has given rise to huge inefficiencies, noted by virtually all scholars and by the FCC itself.[5] The administrative licensing mechanism was initially challenged in a seminal article by Ronald Coase,[6] in which he questioned why licenses should be allocated by administrative fiat and suggested that radio licenses should be bought and sold like any other scarce commodity in our economy. In this

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Spectrum Management: Property Rights, Markets, and the Commons, *in* RETHINKING RIGHTS AND REGULATIONS: INSTITUTIONAL RESPONSES TO NEW COMMUNICATIONS TECHNOLOGIES, (Lorrie Faith Cranor & Steven S. Wildman eds., 2003); 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 (2001).

4. *See* JONATHAN E. NEUCHTERLEIN & PHILIP J. WEISER, DIGITAL CROSSROADS 225-60 (2005).

5. For example, in the 1950s, the FCC designed the experiment of UHF television, committing 330 Mhz of frequency space in locations around the country, in the hopes of fostering localism in broadcasting. This experiment failed; however, as there are hundreds of license holders throughout the U.S. that continue to hold onto these licenses, and so the spectrum cannot be used for any other purpose. *See* Faulhaber & Farber, *supra* note 3, at 197. The value of this underutilized spectrum can be inferred from the fact that the entire frequency bandwidth devoted to digital wireless cellular service is no more than 180 Mhz. Opening up the current UHF band to wireless could almost double the capacity of the U.S. wireless industry. Additionally, studies by Agilent Technology of the power spectrum in Santa Rosa, CA show that aside from the fairly narrow digital wireless bands and the WiFi band, virtually all the spectrum between 1.5 Ghz and 3.0 Ghz is almost completely unutilized. And a recent study in Brussels, Belgium finds similar vast underutilization of spectrum in a major European city. *See* Patrick S. Ryan, *Some Tests of Spectrum Usage in Brussels, Belgium*, DROIT & NOUVELLES TECHNOLOGIES (Sept. 28, 2004) (Belg.), *available at* http://ssrn.com/abstract=603581.

6. R. H. Coase, *The Federal Communications Commission*, 2 J.L. & ECON. 1, 25–26, 35–38 (1959).

model, radio licenses would be owned by the licensee, who would have the right to use, exclude use by others, buy, sell, lease, subdivide and aggregate the license. Coase asked the obvious question: why should this valuable commodity be allocated by a regulatory agency, as if the U.S. were a planned economy? Why not treat licenses as we do every other good in our market economy, and let it be bought and sold? In that way, the market would assure that radio licenses would migrate to their highest valued use, rather than migrate to those whose political and bureaucratic power was strongest.

Apparently, this question was not quite so obvious to others at the time. Although Professor Coase was later awarded the Nobel Prize in Economics, his idea of marketable spectrum licenses was considered radical in the extreme at the time, bordering on the crackpot. Indeed, in 1959 the FCC invited Professor Coase to testify about his proposal for market allocation of radio spectrum rights. FCC Commissioner Philip S. Cross asked the first question: "Is this all a big joke?"[7] A University of Chicago colleague called this "an insight more fundamental than we can use."[8] Eventually, Coase's idea took root.

Coase's insight was that substantial inefficiencies would result from government allocation of this valuable commodity, a fact now firmly documented, both in the U.S. and abroad.[9] He accepted that the unit of transaction was the frequency/locality/power/use[10] license (as indeed there were no other options at the time); his remedy was to replace the administrative bureaucratic allocation mechanism with discipline of market allocation.

Coase's ideas did not take root until much later, and only then incompletely: the U.S. Congress permitted the FCC to conduct auctions of spectrum licenses in 1993, and the FCC held its first auction in 1995.[11] Other countries have followed suit. However, these licenses are as constrained in that once won at auction they cannot be bought and sold without FCC review and permission. However, the partial adoption

7. Hazlett, *supra* note 3, at 337.

8. Goodman, *supra* note 3, at 270 (citing Harry Kalven, Jr., *Broadcasting, Public Policy and the First Amendment*, 10 J.L. & ECON. 15, 30 (1967)).

9. *See* Thomas Hazlett, *Liberalizing US Spectrum Allocation*, 27 TELECOMMS. POL'Y, 485-99 (2003), *available at* http://www.manhattan-institute.org/hazlett/TP.TWH.8.03.pdf.

10. Professor Coase seems to have not included "use" in his definition of a marketable spectrum license, relying only on frequency, location, and power. Later advocates of marketable licenses have adopted this approach. A much more complete proposal for defining complete property rights in spectrum licenses is contained in 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 (1969) (proposing a frequency/location/power paradigm and time as well, assuming time sharing of licenses, with no use restrictions).

11. New Zealand and India preceded the U.S. in employing spectrum auctions.

of Coase's ideas is perhaps best viewed in the broader sweep of policy thinking of the latter half of the 20th century, towards market-based allocation mechanisms and away from administrative and regulatory allocation mechanisms, popularly referred to as deregulation. This mode of economic thinking has become something of the received wisdom in policy circles, both in the U.S. and abroad. The partial acceptance of Coase's ideas concerning market-based allocation of spectrum licenses coincided with the acceptance of market-based approaches over regulation approaches to policy issues.

A. Round 1: Market Allocation of Licenses vs. Commons

During the 1990s, a number of economic scholars published a series of articles elucidating and elaborating the idea of market-based spectrum license allocation, maintaining a gentle pressure on the public policy process to move in this direction.[12]

In sum, economists have sought a regime change: from administrative bureaucratic allocation of licenses to market allocation of licenses. They have done so for the simple Coasian argument put forward in 1959: to vastly increase the economic efficiency of the use of this important resource.

However, a challenge to this reform proposal came from a group of technologists and legal scholars who agreed with the economic critique that regulation had resulted in great inefficiencies, but sharply disagreed with the market-based remedy. They noted that new technologies permitted new forms of interference avoidance that did not rely on the frequency/location/power paradigm. Instead, these new technologies would use processing power and real-time avoidance systems to solve the interference problem without the restrictions of frequency/location/power licenses. Advocates of this approach argue that a commons regime is far more appropriate than a license/property regime for these new technologies, and they predict tremendous spectrum abundance through the use of these new technologies in a commons environment. Technologists and legal scholars (and indeed some economists) also seek regime change: from administrative

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12. Thomas W. Hazlett, *Assigning Property Rights to Radio Spectrum Users: Why Did FCC License Auctions Take 67 Years?*, 41 J.L. & ECON. 529, 534 (1998); Evan Kwerel & Alex D. Felker, Using Auctions to Select FCC Licensees (FCC Office of Plans and Policy, Working Paper No. 16, May 1985), *available at* http://www.fcc.gov/Bureaus/OPP/working_papers/oppwp16.pdf; Gregory L. Rosston & Jeffrey S. Steinberg, *Using Market-Based Spectrum Policy to Promote the Public Interest*, 50 FED. COMM. L.J. 87, 93 (1997); Pablo T. Spiller & Carlo Cardilli, *Towards a Property Rights Approach to Communications Spectrum*, 16 YALE J. ON REG. 53 (1999); Lawrence J. White, *"Propertyzing" the Electromagnetic Spectrum: Why It's Important, and How to Begin*, 9 MEDIA L. & POL'Y 19 (2000).

bureaucratic allocation of exclusive licenses to a commons regime, a radical approach that appears to be supported by these new technologies.[13]

Two technologies and one architecture of particular interest are: (i) agile radio (sometimes referred to as cognitive radio, one of a general class called software-defined radio); (ii) ultrawideband; and (iii) mesh networks.[14]

1. Agile Radio

"Agile" radios are devices in which a radio can determine if a specific frequency band is currently in use, emit in that band if not, and switch to another band in microseconds if another user begins to emit in that band. Agility may be hardwired into a device, but it may also occur in the form of software defined radio (SDR), a term that covers a rather broad category of devices and includes any device in which the received radio signal is processed by software.[15] Both transmitter and receiver must be agile for this system to function. For example, in principle an agile radio transmitter could use an empty ham radio band (or government military band) to communicate with an agile radio receiver; should a ham operator (or military user) start using that band, the transmitter would shift to another band within microseconds (the receiver presumably shifting as well, according to a pre-arranged script) and the agile radio communication could continue while the ham operator used the original band. Provided the agile radio switches its emissions to another band, it need not interfere with the ham band.[16] As long as there are sufficient frequency bands so that the agile radio pair can always find an unused band, agile radio achieves a more efficient use of bandwidth without interference with existing licensees.

Agile radio creates this increased efficiency by *dynamic* allocation of spectrum, rather than the current *static* allocation approach, common to both the current licensing regime and a property rights regime.[17] For many purposes, static allocation is the efficient solution; AM-FM and

13. The first writings to call for this regime change are, inter alia, LAWRENCE LESSIG, THE FUTURE OF IDEAS 221–22 (2001); *and* Benkler, *supra* note 3.

14. This technology description is taken from Faulhaber & Farber, *supra* note 3, at 193, 205-07.

15. An excellent non-engineering description of this technology appears in David Marsh, *Software Defined Radio Tunes In*, EDN 52 (Mar. 3, 2005), *available at* http://www.edn.com/contents/images/505082.pdf. My thanks to David Farber for bringing this article to my attention.

16. Current technologies that use "listen before talk" may not completely avoid interference with agile radio. Some form of "get permission before talk" may be necessary.

17. *Within* a licensed frequency band, the licensee may use dynamic allocation; in fact, conventional cellular systems today multiplex many users on a common group of channels dynamically.

TV broadcasting of continuous content to the existing huge base of relatively simple receivers will be a very important spectrum use for years to come, and static allocation works perfectly for this application. But dynamic allocation for certain uses can improve the efficiency of spectrum allocation, perhaps dramatically. In light of the inefficiencies of the current licensing regime, this would appear to be an important improvement. Note, however, this is not without cost; dynamic allocation not only requires substantially more sophisticated transceivers but may also use frequency space for needed signaling purposes.

Agile radio is not without problems. Currently, if a licensee experiences interference, it has only a few neighbors who are likely causing that interference, and can easily check out the source of the interference and take action to suppress it. But since agile radios may be able to transmit anywhere in the spectrum, an interfering agile radio may evade detection and identification, so that victims of its interference have no clue as to the responsible party. Although some have called this "opportunistic" radio, perhaps "hit and run" radio is more deserved. It may be the case that technology will eventually fix this problem, but it appears to be very far from being fixed at this writing.

2. Wideband

Wideband radio emissions can be used for a variety of purposes, including ground penetration, through-the-wall imaging, and short-range "radar" for vehicles. It can also be used for two-way communications. The most successful wideband application today is spread spectrum, used in many cordless phones. This technology allows a signal to be "spread" across a range of frequencies, trading off power for bandwidth. Ultra-wideband (UWB) operates similarly but in a more extreme form. The signal to be transmitted is captured in small time intervals (about 1 microsecond) and the signal is converted to a set of very short pulses (about 1 picosecond) and these pulses are broadcasted over a very wide bandwidth (greater than 1 GHz); the broadcaster emits this picosecond pulse in a time slot every microsecond at very low power; the receiver (which must be synchronized) picks up the low power signal over this wide bandwidth, and converts it back to (a very good approximation of) the original signal.

UWB radios essentially trades lots of power for lots of bandwidth. The power per unit of bandwidth of the emission is extremely low;[18] for most purposes, it is part of the background radio noise, and non-UWB receivers that are designed to reject noise would not recognize the signal,

18. With the exception of ground-penetrating radar (GPR), which is quite powerful and would be an interfering use if not pointed into the ground.

so there is no interference with high-powered broadcasters. The useful range of UWB at these power levels is rather short, at most a mile or two. Interference with other UWB emitters is unlikely; emitters more than, say, five miles apart can use the same transmit time slot without interference with each other, and there are many time slots. Additionally, UWB is fault-tolerant, in that the frequency pattern transmitted in the picosecond burst can suffer some degradation and the original signal can still be recovered.

On the other hand, the bandwidth of the UWB signal spans a large fraction of the total frequency available to all, and appears (if undetected) at many frequencies for which licensees hold exclusive use.[19] Some license holders that purchased their licenses at auction have objected that UWB is a violation of their frequency license, regardless of the fact that it cannot be detected or otherwise interfere with their use of the license.[20]

3. Mesh Networks

Wireless mesh networking is a wireless architecture that can use different forms of radio transmission, including UWB, agile radio, even cellular. A mesh network of, say, computers[21] in a neighborhood could communicate (possibly at high bandwidth) with a nearby computer similarly equipped that could connect directly into the Internet (or possibly the telephone network).[22] Indeed, the connection may pass through many computers before connecting to the Internet, relaying the connection from one mesh point to the next, and the next. To help establish the mesh, wireless Network Access Points (NAP) could be seeded throughout the mesh region as relay points, in addition to the existing computers. Apart from the few NAPs required to seed the network, there is no infrastructure such as cables or fiber optics needed for mesh networks. The wireless devices themselves form the network,

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19. Note that UWB radio could broadcast at much higher power and have a greatly extended range; however, that would lift emissions out of the noise and become an interfering use. Even now, certain existing low power uses such as Global Positioning System (GPS) receivers claim UWB can cause interference with their systems if operated at somewhat higher power levels than recently approved by the FCC.

20. Comments of Sprint Corp., to the *Public Notice* in Spectrum Policy Task Force Seeks Public Comment on Issues Related to Commission's Spectrum Policies, 10–11, ET Docket No. 02-135 (July 8, 2002), *at* http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6513201188.

21. Mesh network architecture can be used not only for computers but also for voice and indeed any radio transmission; it can also be used with a mix of transmission technologies, such as agile, UWB, cellular, CB radio, etc.

22. A current example of a mesh network is Metricom's Ricochet network (now emerging from bankruptcy) which had some thousands of users in multiple cities at its peak. Metricom was based on ideas and patents of Paul Baran (*see* http://www.ricochet.net). Ricochet is NAP-based rather than peer-to-peer based.

much as the Internet currently operates.

Mesh networks use much less power than conventional systems which need every computer to reach a central antenna. A mesh networked computer need only reach the nearest networked computer, and thus needs less power. The architecture takes full advantage of the relay capabilities of the mesh devices to lower power requirements and therefore minimize interference problems. Because of this, mesh networks are claimed to actually increase their capacity as the geographic density of users increases, a claim dependent upon a smooth distribution of devices and an absence of bottlenecks that may not obtain under field conditions. In other networks (such as cellular), increasing density actually decreases available capacity because of interference.

If mesh networks are so wonderful, one might ask why do we not see them in practice? In fact, mesh networks have a number of very practical difficulties that must be overcome before they are field-practical. (i) The density of devices in a geographic area must be relatively high in order for low-power mesh networks to hop from device to device. This is a particular problem for a new service in which device densities are necessarily low. It is also a particular problem for a mobile service in which device density changes minute to minute as devices move around. (ii) Owners of devices must be willing to leave their devices connected and powered in order to act as a relay for others. However, being a relay has no immediate benefit and drains battery life, giving users an incentive to "free ride" and not provide relay functions. (iii) Communications are likely to travel over many links before they reach their destination, resulting in delays. Human conversation is highly sensitive to such delays and mesh networks are unlikely to be useful for voice traffic.[23] These problems may yet be overcome with new technology, but nothing on the immediate horizon suggests solutions to these problems.

4. Technology Assessment

The potential for these new technologies to vastly improve the efficiency of spectrum use is very promising. However, there are three points to keep in mind in evaluating the role of these technologies. First, none of these technologies are currently deployed in a commercial setting; they exist in theoretical papers, lab results, and early field tests.[24]

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23. Delay in transmission is called "latency" in engineering. Certain applications, such as voice telephony, require very low latency to be useful. Other applications, such as e-mail, do not.

24. In fact, each of these technologies as they exist today has technical and operational difficulties that prevent its early deployment. UWB is perhaps closest to deployment, but is a very low power service, and thus only appropriate for services in which transmitters and

Second, while these technologies may enable a commons regime (if they completely supplant existing technology), they are perfectly capable of deployment in the context of a licensing/property regime; they are a necessary but not sufficient condition for a commons regime. Third, there are many applications for which the new technologies are simply an unnecessary expense: TV/radio broadcasting, airport radars and a host of other high-powered dedicated uses are much better served via exclusive licensing. This is not to imply that these technologies will not become increasingly important; they certainly will. But it does mean that (i) this will not happen tomorrow; (ii) they can work their efficiency magic in either a commons regime or a property regime; and (iii) they are very unlikely to supplant exclusive licenses for all or even most uses.

The enthusiasm of the early work on commons and the new technologies suggested that all of wireless communications could be managed as a commons regime, doing away with all exclusive use and permitting users to self-manage their own frequency spaces through voluntary limited commons and protocol agreements among manufacturers. The early papers suggested that there may be some limited role for regulation, to ensure the proper functioning of the commons, but that this regulation was to be "light." The commons was to be largely self-regulating, drawing on ideas of communities managing a resource for mutual gain. There were to be no intermediaries, such as cell phone companies or other service providers. Services would be provided by the users and the devices they used, and interference would be controlled using protocols embedded in hardware.

This vision appears strikingly similar to the pre-1995 Internet of John Perry Barlow, and the early authors certainly come from this tradition. There are several related policy ideas that commons authors share, such as opposition to copyright and other intellectual property mechanisms, and a general concern over the degradation of the intellectual commons in American life.[25] These writings have a strong

receivers are quite close. Agile radios (indeed, software defined radios) are still rather costly to produce, and the protocols needed to behave well in an opportunistic setting are still on the drawing board. (*But see* Marsh, *supra* note 15, for a thorough analysis of SDR's problems and prospects). Mesh networks is actually a rather old idea; the Internet itself can be thought of as a mesh network, albeit not a wireless mesh. In order for a mesh network to provide an acceptable quality of service to its customers, there must be a fairly dense deployment of communicating devices and/or NAPs. This is difficult to guarantee with mobile devices, where density (devices/mi^2) can vary dynamically. Additionally, the use of many relay points in the mesh prior to connecting to the Internet or telephone network can introduce delays that are unacceptable to latency-sensitive applications such as voice. Again, this is not to say that these problems cannot be solved; it is to say that they won't be solved tomorrow and these technologies may well yield less than today's theoretical models promise.

25. *See* LESSIG, *supra* note 13, for a powerful statement of this vision, of which spectrum commons is but a small part.

tenor that ownership (of spectrum license, of copyrights, of patents. . .), especially by corporations, leads to exclusion and resource underutilization, while commons ensures full access untrammeled by profit-seeking intermediaries.[26] The commons is asserted to be a superior mechanism for encouraging free speech, although no proof is offered for this highly debatable proposition.[27] Similar arguments are used to illustrate how the Internet, the quintessential commons, is being taken over by corporations.[28]

In "Round 1" of this conflict of ideas, economists approach spectrum management as the next battle of market forces against *dirigiste* regulation. Technologists and some legal scholars approach spectrum as the next battle to save the commons and "public spaces" such as the Internet and public domain writings against rapacious corporations. In both cases, spectrum management is part of a larger intellectual and policy agenda; unfortunately, the topic has become something of a battleground for the larger issues. This paper has a much more modest objective: to focus on the spectrum management issue exclusively, with the normative goal of achieving efficient and effective mechanisms for deploying spectrum resources to the American people. I find much merit in both of the "big ideas," but this paper is about spectrum management only; there is no larger agenda.

B. Round 2: Non-Interfering Easements

In 2001-2003, the spectrum management issues were joined in a series of conferences and moot courts, in which property rights vs. commons conflict was hotly debated. Several papers grew out of this ongoing debate.[29] But the overall picture was accommodation: commons advocates recognized that there was a continuing need for dedicated

26. *See* LAWRENCE LESSIG, FREE CULTURE (2004).

27. Consider, for example, the ability of an individual caller to CNN's "Larry King Live" television show to make her views known to the world and to that evening's high-powered guest, compared to the paltry audience reachable via a cable system's public access channel. The former venue is a private network carried over private cable systems or licensed broadcast TV, to a huge audience. The latter venue is an open access commons, which most viewers avoid like the plague.

28. *See* LAWRENCE LESSIG, CODE AND OTHER LAWS OF CYBERSPACE (1999).

29. On the commons side, *see, e.g.*, Yochai Benkler, *Some Economics of Wireless Communications*, 16 HARV. J. L. & TECH. 25, 82–83 (2002); Stuart Buck, *Replacing Spectrum Auctions with a Spectrum Commons*, 2002 STAN. TECH. L. REV. 2 (2002), *available at* http://stlr.stanford.edu/STLR/Articles/02_STLR_2/article_pdf.pdf; 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, 778–80 (1998). On the property rights side, *see, e.g.*, Stuart Minor Benjamin, *Spectrum Abundance and the Choice Between Private and Public Control*, 78 N.Y.U. L. REV. 2007 (2003); Faulhaber & Farber, *supra* note 3; James B. Speta, *A Vision of Internet Openness by Government Fiat*, 96 NW. U. L. REV. 1553, 1572 (2002) (reviewing LESSIG, *supra* note 13).

spectrum for applications such as radars and AM-FM broadcasting, so that the regime of the future must accommodate both licensed exclusive use spectrum and commons spectrum. Professor Benkler[30] suggested that the FCC oversee a ten-year experiment, managing licensed spectrum and commons spectrum side by side, until it became clear which alternative was superior. Property rights advocates noted that the success of unlicensed spectrum[31] set aside by the FCC suggested that the regime of the future must accommodate unlicensed use. In particular, Faulhaber-Farber proposed a commons-type structure within a property rights regime in the form of a *non-interfering easement* applicable to all (or most) license property, in which the property owner must accept the use of his frequency/location/power license by anyone who does not interfere with his own use (which has absolute priority).[32] For example, low-power UWB would be covered by this easement, to the extent that it operates under the noise floor[33] and creates no interference.[34] Agile radio would also be covered to the extent that agile users leave a frequency band within microseconds of the owner initiating the use of this band, and otherwise cause no interference. Both sides also recognized that there were very substantial uncertainties regarding the future development of both wireless technologies and the uses for wireless, and any regime adopted had to be capable of adaptation as these uncertainties resolved themselves in the coming years. The only feasible regime was one that was flexible enough to adapt to change. Neither commons nor exclusive licenses could be ruled out at this time.

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30. Benkler, *supra* note 29.

31. I use the term "success" advisedly; a true success would involve a demonstration that the net benefit of unlicensed use exceeds the net benefit of deploying the same spectrum in other licensed uses (such as cellular telephony). While we have some estimates of both market value and social value of licensed spectrum, we have no such estimates for unlicensed spectrum. In this instance, "success" is defined modestly: unlicensed spectrum seems to work for its intended use.

32. Faulhaber & Farber, *supra* note 3, at 208-09. In principle, a market in spectrum rights could achieve the same goal; opportunistic users could bargain in real time with license owners for temporary underlay rights. However, the transaction costs of such a real-time pricing system for opportunistic uses seem excessive; the non-interfering easement would avoid these costs, although the easement is not without costs. A very similar proposal is made in Benkler, *supra* note 29, at 55.

33. Note that the actual level of the noise floor, below which signals are unintelligible, is not a constant of nature; it may depend upon the sensitivity and selectivity of the assumed receivers of the signal.

34. This would appear to be similar to the FCC's Interference Temperature proposal, which proposes using "white space" between the noise floor and the "usable" floor in licensed spectrum for unlicensed use. *See* Establishment of an Interference Temperature Metric to Quantify and Manage Interference and to Expand Available Unlicensed Operation in Certain Fixed, Mobile and Satellite Frequency Bands, *Notice of Inquiry & Notice of Proposed Rulemaking*, 18 FCC Rcd. 25,309 (2003). The proposed non-interfering easement is agnostic regarding the particular noise level, and is neither and endorsement nor a rejection of the interference temperature proposal.

In this Round, several "tragedy" arguments surfaced. Property rights advocates criticized commons advocates for ignoring the "tragedy of the commons," which arises when a free resource is over-used and over-congested. The classic example is open ocean fisheries, such as the Grand Bank off the coast of Newfoundland, traditionally the richest fishery in the world. As the technology of fishing improved, commercial fishermen increased their catch dramatically and eventually depleted the resource almost completely. Since the fishery commons was available to all, no one was responsible for the overall health of the resource; the incentive of each individual fisherman was to take as much as possible from the resource, because if they didn't someone else would. Commons advocates argued that the new technologies freed up so much spectrum that it would be abundant; scarcity would be a thing of the past, and there would be enough for all. The tragedy of the commons would not occur because spectrum would be so abundant. Further, protocols embedded in device hardware would ensure against interference and the tragedy of the commons.

Commons advocates also alluded to the "tragedy of the anticommons," a problem that occurs with private property.[35] Suppose a town or developer wants to put together a large parcel of land for a project, such as a beachfront walkway or a shopping center. This requires the aggregation of land; since the land is usually contiguous parcels, the town/developer must deal with certain buyers, who are likely to hold out for a large payment, recognizing that the project can only happen if they agree. In the context of spectrum, the anticommons problem appears to preclude the aggregation of small parcels of contiguous spectrum into larger swaths that may be required for a government to provide a commons. This is actually a re-badging of the "holdup" problem, well-known in both law and economics, and it suggests that market transactions of private property can be quite difficult in the case of aggregation.

Round 2 thus moved the opposing sides somewhat closer, but neither could claim a conceptual breakthrough. The concept of a non-interfering easement appeared to add something novel to the mix.[36] What is perhaps more important is that both sides recognized the importance of transaction costs and dispute resolution in determining the

35. *See* Michael A. Heller, *The Tragedy of the Anticommons: Property in the Transition from Marx to Markets*, 111 HARV. L. REV. 621 (1998). An economic model of the anticommons is in James M. Buchanan & Yong J. Yoon, *Symmetric Tragedies: Commons and Anticommons*, 43 J. L. & ECON. 1 (2000).

36. While the easement concept was novel to the debate, it is very similar to the well-established concept of secondary allocation, in which a licensed or unlicensed device can use a frequency band provided it caused no interference. There are minor differences between the two concepts, but this approach is neither radical nor untested.

optimal regime for the future of spectrum. This changed the tenor of the debate from philosophical/ideological to practical and results-oriented. At the end of the day, what matters is how effectively either regime gets spectrum into the hands of those who value it most. Commons advocates claimed that a market in licenses would have large transaction costs and dispute resolution would be very costly. Property right advocates noted that commons advocates had yet to address the problem of transaction costs and dispute resolution in a commons system, but simply hoped that a regulator would resolve all such problems, without addressing the costs of regulation. While the "tragedies" of commons and anticommons were raised, there was no resolution. However, this round of writings simply suggested that this was the appropriate research agenda if we wished to make progress on determining the better regime for spectrum management.

C. Round 3: Practicality of Property Rights and Commons Regimes

The current Round 3 of papers, of which this paper is one, attempt to drill down into the detail of how property rights and commons would actually work, considering issues of future flexibility, transaction costs, and dispute resolution.[37] While by no means free of ideology, the papers of Round 3 are more focused on problem solving and less concerned with lofty visions of how the world ought to be. Werbach, for example, proposes his supercommons as a way for exclusive licenses and commons to cohabitate, but with a strong preference for commons.[38] Goodman is more focused on dispute resolution; her most valuable contribution is a very thorough analysis of how nuisance law is an inefficient mechanism for dispute resolution, presumably in a property rights regime.[39] She recommends regulation of a combined licensed and commons spectrum.

II. THE FCC'S FORAY INTO PROPERTY RIGHTS, COMMONS, AND NON-INTERFERING EASEMENTS

The FCC was not insensitive to this debate; indeed, the Commission had instituted changes in the traditional command-and-control licensing model decades ago. One of the earliest and best known

37. *See, e.g.*, Stuart Minor Benjamin, *Spectrum Abundance and the Choice Between Private and Public Control*, 78 N.Y.U. L. REV. 2007 (2003); Goodman, *supra* note 3; Thomas Hazlett, *Property Rights and Wireless License Values* (AEI-Brookings Joint Center., Working Paper No. 04-08, Mar. 2004), *at* http://ssrn.com/abstract=519602; Kevin Werbach, *Supercommons: Toward a Unified Theory of Wireless Communications*, 82 TEX. L. REV. 863 (2004).

38. *See* Werbach, *supra* note 37.

39. *See* Goodman, *supra* note 3.

was CB radio, a personal wireless communication service that did not require owners of CB equipment to be licensed in order to broadcast and receive. The FCC set aside 40 voice channels in a frequency band that could be shared by anyone with FCC-approved equipment. All conversations were public in that they could be heard by anyone with a CB receiver. Early users of the service, primarily professional drivers, developed social protocols to facilitate effective sharing of the limited channels. The service became wildly popular in the mid-1970s, with sales increasing by a factor of ten, but by the end of the 1970s its popularity had waned. A number of other services were introduced in the 1970s and 1980s in so-called *unlicensed* spectrum, such as cordless telephones, garage door openers, and wireless weather stations (in which an outdoor sensor unit, mounted on the roof or outside wall of a home, communicated wirelessly with an indoor display unit). Most of these services were offered using "Part 15" devices, limited to certain frequency bands. They share a number of properties: (i) no license was necessary for a user to operate the device; (ii) a relatively small number of manufacturers produced the actual radio emitters, each of which was type-certified by the FCC; and (iii) perhaps most important, power levels were quite low. This latter property was crucial to the control of interference; users would not want their cordless phone conversations picked up by their neighbor's cordless phone, nor would they want their garage door opener to open their neighbor's garage door.[40]

In fact, frequencies devoted to Part 15 devices became a focus of innovation. New technologies could be tried out without making a substantial commitment to obtain licensed spectrum first. Perhaps the best-known success in this unlicensed spectrum is WiFi, a high-bandwidth short-range (100-250 ft) wireless technology which has become a standard for wireless home networking. It is also offered in public spaces, such as coffee shops, airports and hotels. Some municipalities have announced plans to deploy WiFi "hotspots" on utility poles and allow residents to access the Internet for free (or at low cost).[41]

The successful deployment of WiFi is a strong argument that a commons approach, in which interference is controlled by hardware, can

40. Apparently, even these low power levels were not sufficient to eliminate all interference. The FCC adopted a novel technology, spread spectrum, for use with 900 MHz cordless phones to secure phone calls (though this technology was strongly contested at the FCC). Garage door opener firms adopted a technique called "rolling codes" to eliminate opening neighbors' garage doors. Both these approaches presaged the technologies mentioned above: ultrawideband and agile radios. And both approaches suggest that there may be private means of resolving interference problems using technology rather than licenses, a key point of the commons advocates.

41. *See* Wireless Philadelphia Executive Committee Briefing, *at* http://www.phila.gov/wireless/briefing.html (last visited Oct. 8, 2005) (describing Philadelphia's well-publicized WiFi initiative).

work. The FCC has indeed been a "light" regulator of the unlicensed spectrum; it specified only frequency and power limits, and let the market decide what devices and what protocols would be deployed. In recent years, the FCC has dedicated new frequency bands for unlicensed use, and has indicated its intent to continue to do so.[42]

On a parallel track, the FCC has also moved strongly in a pro-market direction. Of course, the success of the auctions for PCS cellular services is the best-known market initiative, and the FCC continues to roll out new spectrum at auction. But the initial licenses sold at auction were still of the traditional form: they could not be bought, sold or leased without explicit FCC permission, and their use was tightly restricted: cellular licenses could not be used for TV broadcasting, and vice-versa. The FCC has been moving to relax both these constraints. A recent Report and Order seeks to establish an active secondary market in spectrum licenses by making FCC approval of such transfers virtually automatic (provided these transfers do not involve public safety).[43] The FCC also seeks to establish rules for band managers; firms that would hold the spectrum license and lease part or the entire spectrum to others.[44] Additionally, it has increasingly included "flexible use" in its service definitions, allowing licensees substantial freedom to deploy their licensed spectrum, provided they still abided by the technical (frequency/location/power) limits.

The FCC has also initiated consideration of the non-interfering easement concept suggested by Faulhaber-Farber,[45] at least in the context of ultrawideband. In this proceeding, the FCC is considering whether to authorize opportunistic uses of licensed spectrum when not being used by the licensee.[46]

The FCC also established a Spectrum Policy Task Force to take a broad look at spectrum management and to make recommendations to the Commission. It specifically examined the two options of property rights with markets, commons, as well as the traditional command-and-control regulation.[47] The Report recommends that all three models have a place in the overall FCC regulatory spectrum strategy: (i) continuing to allocate some spectrum at auction while relaxing constraints on use and

42. *See, e.g.,* Additional Spectrum for Unlicensed Devices Below 900 Mhz and in the 3 Ghz Band, *Notice of Proposed Rulemaking*, 19 FCC Rcd. 7545 (2004).

43. Promoting Efficient Use of Spectrum Through Elimination of Barriers to the Development of Secondary Markets, *Report & Order & Further Notice of Proposed Rulemaking*, 18 FCC Rcd. 20,604 (2003).

44. *See id.*

45. *See* Faulhaber & Farber, *supra* note 3.

46. *See* Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems, *First Report & Order*, 17 FCC Rcd. 10,505 (2002).

47. *See* FCC, SPECTRUM POLICY TASK FORCE REPORT, ET Docket No. 02-135 (2002), *at* http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-228542A1.pdf.

encouraging secondary market (essentially, simulating a true property rights model); (ii) continuing to allocate spectrum bands for common use, especially in the higher frequencies; and (iii) for certain legacy uses, such as TV broadcasting and public safety, continuing command-and-control.[48] Of course, the overarching legal regime would be regulation; both market-based licenses and unlicensed spectrum would still be subject to regulatory oversight and government allocation of spectrum.

This suggests that the traditional regulatory regime, universally despised by virtually all commentators and apparently the FCC itself, is being replaced by a regulatory regime that will contain within it both commons-managed spectrum and property rights/flexibly licensed managed spectrum (along with a legacy command-and-control sector, at least for some time). Should these trends continue, it is likely the end-state of this evolution is *end-state regulation* (as distinct from traditional regulation) which, in brief consists, of a regulator overseeing all spectrum, of which a large fraction is flexibly licensed-managed, a large fraction is unlicensed commons-managed, and a diminishing fraction is traditionally regulated. In the flexibly licensed-managed spectrum, licensees would own the licenses and could buy, sell, lease, subdivide and aggregate licenses, and use their spectrum for a wide range of uses at their discretion. They may also be subject to a non-interfering easement. The commons-managed, unlicensed spectrum would be subject to continued regulation as it is today. As conditions changed, the FCC could adjust the assignment of spectrum to commons vs. property rights, could change the rules under which each commons-managed patch of spectrum was governed, and may even change the property rights of licensees should they deem it necessary. For example, the Spectrum Policy Task Force Report suggests that the FCC may impose a "good neighbor" policy of "group[ing] technically compatible systems and devices in close spectrum proximity"[49] in order to increase efficiency of spectrum use.[50]

48. *See id.*

49. *See id.* at 22.

50. Although a transmitter may have a license to transmit only within a specified frequency band, its transmission may interfere with receivers in adjacent bands, either because the transmitter's power "leaks" into the adjacent band or because the receivers in the adjacent band cannot filter out the power emitted by the transmitter within its own band. Both transmitters and receivers are equipped with band-pass filters, devices that limit the power transmitted outside the required frequencies or limit what is received outside the required frequencies, but such filters are not perfect. For example, a low-powered use in a frequency adjacent to a high-powered use may experience interference, especially with poorly tuned receivers. Thus, interference is a function of both the quality of the receiver and the quality of the transmitter.

III. PARSING THE PROPERTY RIGHTS VS. COMMONS DEBATE

This debate has been positioned as "property rights vs. commons;" it has also been positioned as new technology (favoring commons) vs. legacy technology (favoring licensing).[51] In this section, there appear to be (at least) four levels of the "property rights vs. commons" debate: *new technology, spectrum use, spectrum management*, and the *overarching legal regime*. Each is discussed in turn:

A. *New Technology*

Much of the power of the commons advocates' argument is that the latest technology enables, indeed may demand, a commons approach to spectrum. The arguments adduced include agile radio and ultrawideband as requiring a commons, and use of WiFi as a new technology introduced in the unlicensed space as the commons success story. They also suggest that the deployment of mesh networks can lead to increases in bandwidth per user as the number of users increase.

It is noted above that these new technologies have some way to go to demonstrate they are as transformative as their advocates claim, but let us *arguendo* assume the truth of their assertions. Does this imply that new technologies only arise in an unlicensed environment, or that technological innovation is more likely to arise in a commons? Does this imply that these new technologies can only be accommodated by a commons regime? In both cases, the answer is no. Regarding the environment of innovation, there have been extraordinary advances in cellular technology in antenna design and bandwidth utilization, spurred by competition and spectrum scarcity (albeit regulation-induced). There is also very obvious innovation in cellular handsets and data capabilities in this market, suggesting that innovation has many outlets, not merely that of the commons. Regarding the deployment of these new technologies in a licensed regime, Faulhaber-Farber's non-interfering easement concept suggests that a small tweak on an exclusive licensing

51. Another dimension along which battle lines seem to have been drawn is analogy: is spectrum like land, or is it like air? Commons advocates argue the latter is the correct analogy, and conclude that since air is a common resource and is so managed, so must spectrum. They allege that property rights advocates are led to error through the use of the land analogy. In fact, this dimension has more to do with disciplinary differences than with the dispute itself. Legal scholars traditionally argue from analogy, and it is often the case that once the profession settles on the right analogy, the issue is decided. Economists, on the other hand, view analogy essentially as a teaching aid and not a research tool. What spectrum is "like" is largely irrelevant to economists; what matters are its basic underlying physical and economic properties. It is these properties, rather than analogies, which drive the economic logic. The fight over the correct analogy is not a fight that economists understand or care about, and this paper will not engage in this fight.

regime can easily accommodate these technologies.[52] In sum, these new technologies neither require a commons regime for their (as yet to develop) deployment, nor do they demonstrate the superiority of unlicensed spectrum as a source of innovation.

As a general rule, there is a demand side and a supply side to technological innovation. The demand side of innovation is the new products that can be offered with innovation or cost savings realized via the innovation; in either case, the demand side is driven by adding value for customers. The supply side of innovation is the cost of deploying the technology; the supply side is driven by the investment needed for deployment. Generally, we would anticipate that a property rights regime would be less risky for new service introduction as the entrepreneur would not face the risk of congestion, especially by copycat imitators using the same commons frequency band. Indeed, the more successful the new service, the greater is the risk of congestion from copycats in the commons. In addition, we would anticipate that a property rights regime gives strong incentives to adopt innovations that economize on spectrum, as this represents a direct benefit to license holders.

In a commons regime, there is no individual incentive to economize on spectrum; who would pay for an innovation that conserves on spectrum that is free to all? On the other hand, unlicensed spectrum has the advantage that the entry costs (apart from the innovation itself) is virtually free; the innovative entrepreneur need not purchase spectrum in order to offer service. Of course, in a market system, an innovator without ready capital could rent spectrum rather than buy it, thereby reducing entry costs. On balance, then, the demand side of innovation favors a property rights regime while the supply side could be argued to favor a commons regime (although a market system can go far to reducing entry costs).

Generally, we would expect that innovations with great novelty but very uncertain customer value would find unlicensed spectrum a more attractive entry option, while innovations with more promise of customer value would find licensed spectrum a more attractive entry option. A more likely outcome is that new innovators may deploy a trial service in unlicensed spectrum, and upon demonstration that the business model works the entrepreneur could migrate the service to licensed spectrum.

52. High-powered unlicensed agile radios almost surely will require some form of cooperation with licensees in order to avoid interference At the very least, the potential for opportunistic use is likely to require that licensees monitor and record opportunistic users to ensure they operate within parameters. Additionally, there are other technical problems that are difficult to solve without explicit cooperation of licensees, which may require equipment and cost mandates on licensees to accommodate easements for high-powered users.

This has already occurred with the firm Clearwire, which offers wireless broadband Internet access. Originally, Clearwire offered service in the unlicensed 2.4 Ghz (ISM) band. After proving its technical and business plan, Clearwire has moved to licensed spectrum in the 2.5 Ghz (ITFS) band.[53] It currently offers wireless broadband Internet access in four U.S. cities using licensed spectrum.

Although the new technologies have been touted as enabling a commons regime, there are problems with using both high-powered agile/cognitive radios and low-powered mesh networks simultaneously in an open commons. Generally, a commons is open to all users, high-powered and low-powered (up to a certain power limit). Even if the high-powered transmitter (such as an FM broadcaster) used agile/cognitive transceivers to avoid "collisions" with other high-powered transmitters, it is unlikely they could avoid interfering with low-power systems. The high-power agile/cognitive radios using the "listen before talk" protocol may not even detect many of the low-power systems using the commons and therefore not be able to avoid interfering with them. I refer to this as the *power mix* problem.[54] It is easy to solve the power mix problem in a property rights regime, as the license holder decides who and how the frequency band is to be used, within its overall power limit. In a commons regime, the power mix problem appears only solvable by resorting to an intrusive command-and-control regulatory regime. But this is exactly what we already have with current FCC regulation, with well-known and unfortunate results.

53. Marcia Martinek, *Clearwire Picks Raze for First Licensed Trials*, WIRELESS REVIEW, (Sept. 21, 2001), *at* http://wirelessreview.com/ar/wireless_clearwire_picks_raze/. Similarly, Metricom, a company noted by commons advocates to have started a business in unlicensed spectrum, migrated to licensed spectrum as their business matured (to little avail; the firm has failed twice). *See* Hazlett, *supra* note 3.

54. There are potential solutions to this problem. Low power systems could be agile radios themselves, since they can detect both high- and low-power transmissions in the relevant range; of course, this implies extra expense to low power systems simply to avoid high-powered system interference. It is also possible to restrict how many high-powered users are transmitting within a given commons band to ensure that the low-power users have sufficient bandwidth. More drastically, a specific frequency band can be earmarked for low power only, simply by setting a low overall power limit. But again, these options imply an intrusive regulatory solution: who decides the low power protocols for agile radio? Who decides how many high powered transmitters will be allowed in a particular commons band? Who decides which commons should be dedicated to low power only? None of these solutions is particularly good, and all require a regulator to determine the protocols used and possibly to undertake flow control of users and traffic into the commons. Experience has amply demonstrated that regulatory disputations over protocols are both excessively long and excessively costly. Alternatively, if some commons are designated for low power only, the regulatory disputation over how-much-is-low-power-only vs. how-much-is-open-commons would likewise be excessively long and excessively costly.

B. Spectrum Use

The current array of wireless applications is simply dizzying, from cellular phones, broadcast TV and radio, WiFi, public safety radio, scientific and medical equipment to GPS systems. These applications are high power, low power, one-way broadcast, two-way interactive, people-to-people voice and data, machine-to-machine, occasional vs. constant use, and all combinations thereof. Some uses are particularly suited to exclusive use, such as high powered radar in constant use, TV and radio broadcast (again, in constant use). Some uses are particularly suited to commons, such as low powered occasional uses such as garage door openers, cordless phones and home networking. And this is not the end; the uses of wireless are likely to continue their growth, as demands for new services are discovered and developed in the U.S. and abroad. But this expanding set of uses favors neither a commons approach nor a property rights approach. Indeed, it is the realization of this breadth of uses that has led advocates on both sides of this dispute to agree that both a commons and an exclusive use licensing approach somehow need to coexist for the foreseeable future.

At a deeper level, the appropriateness of licensed vs. unlicensed spectrum management depends upon scarcity vs. abundance. Commons advocates are fond of likening spectrum to the ocean, in which passing ships need only simple rules to avoid collisions. There is no need to establish property rights in the ocean to avoid collisions. But is the analogy correct? It depends upon several factors: (i) avoidance using simple rules is easy because the ocean is essentially limitless; (ii) detection is easy with onboard radar; and (iii) ship passings only occur every few days. If we slightly modify the analogy to large ships navigating in rivers and harbors, the situation changes radically: (i) avoidance is much more difficult as rivers and harbors are tightly constrained; (ii) radar in close quarters is rather cluttered and less useful; (iii) ship passings occur every few minutes. Not surprisingly, the rules also change; ship captains are not allowed to navigate within harbors and ship traffic is very tightly controlled by a harbormaster. As the environment becomes more constrained and potential interference becomes greater, a much higher degree of control is required. Applying this lesson to spectrum, the high demand for using spectrum suggests this is a harbor, not an ocean. To make matters even more contentious, we note that in the ocean/harbor analogy, avoiding collisions is in everyone's interest. In spectrum, a rogue user may gain a large (albeit temporary) advantage by breaking the rules. An example would be using excessive transmission power for ensuring the message gets through clearly to very distant receivers, but in doing so, causing excessive interference for other users. The ocean analogy is seductive but very unrealistic.

The current successful implementation of commons spectrum use is Part 15 (unlicensed) frequency bands, such as cordless phones, garage door openers, and WiFi. In this restricted frequency space, the FCC has adopted a rule that essentially makes the spectrum like the ocean: it imposes a strict power limit on transmitters. Each transmitter then creates interference over such a small geographic area (e.g., the inside of a house) that interference is almost defined away. For these uses, power limits in no significant way affect the functionality of the devices, yet the interference problem is solved. For services in which low power destroys functionality (such as airport radars and police radio), a commons approach becomes either impossible or costly, and exclusive use is a more efficient management approach.

It should also be noted that applications currently deployed in unlicensed spectrum could as easily be deployed in licensed spectrum should a market for licenses develop. For example, garage door openers currently operate in Part 15 unlicensed spectrum, a model which is quite successful. However, if licenses were available in regional and national markets, firms that produced garage door openers could purchase small frequency bands (since this is a very narrowband service) throughout the country and design their transmitters for their purchased frequency. Most likely, an industry trade association could purchase the spectrum, which would then be shared among its members (a form of limited commons). Thus, this service (and others like it) can work equally well under either licensed or unlicensed management.

C. Spectrum Management

This term denotes the operating management of specific frequency bands. For example, is the frequency band licensed or unlicensed? Are there rules governing the use of the spectrum (such as use constraints for licensed bands or power limits for unlicensed bands)? Who sets and administers the rules? Are there social norms among the users that control on-air behavior, such as CB radio and ham radio? Is there a payment for use of the band? If so, to whom? If licensed, does the licensee exclude other users? If unlicensed, do user groups exclude others?

Under the current regime, both licensed and unlicensed frequency bands are subject to rules, beyond the frequency/location/power bundle of rights. In the case of unlicensed bands, these rules may be built into the hardware but they are nevertheless real. Some years ago, cordless phones were available that advertised a "50 mile range." While the claim was exaggerated, the actual range was far beyond the usual cordless phone range, for the simple reason that the phones were emitting power far in excess of that mandated by the FCC rules. These were foreignmade power-boosted phones bootlegged to dealers in the U.S. who could sell them as "superphones;" very valuable to their owners but causing interference with others. Alarmingly, these phones caused some interference to air traffic control radars. The same phenomenon occurred in CB radio during its popularity peak; it was fairly easy to buy a "souped up" CB radio, or indeed to alter an existing radio to illegally boost power. While beneficial to the owner of the altered radio, it greatly increased interference with other CB users.

While early advocates of the commons suggested that commons would be self-managing and require no rules imposed by governments or private parties, there is now general acceptance that some rules for unlicensed bands are required, although commons advocates prefer "light regulation" to accomplish this.[55] There is also the suggestion that for some bands, users may well organize themselves, enforcing self-adopted rules through non-legal mechanisms. In fact, this has occurred in the amateur radio band,[56] in which a group of dedicated users follow historically adopted practices and face group sanctions should they not follow these practices. This closely parallels self-policing in other well-defined groups of commons users, such as cattle ranchers in the western U.S. who use public lands to graze their cattle.[57] Far from being rule-free, such arrangements are usually quite complex and even formal.[58]

The point here is that there will be rules; the only question is who establishes and enforces the rules. Will the rules be set by a private licensee, by a government regulator such as the FCC, or a user/producer group such as ham radio operators or garage door opener manufacturers? While one might speculate that rules set by user groups or manufacturers are more beneficial than rules set by private or regulatory controllers, there is no reason to believe this is the case. User groups and manufacturer groups often have motivations that may not coincide with the well-being of the entire group of users or potential users and may be quite inefficient. For example, manufacturers could adopt rules that

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55. *See* Werbach, *supra* note 37; Goodman, *supra* note 3.

56. Amateur radio is in fact a licensed band; in order to receive a license, a user must pass a test on general radio knowledge including demonstrating proficiency in Morse code. Although Morse code is virtually never used in today's ham radio environment, it acts as a barrier to entry for casual users, resulting in a self-defined elite of radio that helps it observe and monitor the group's adopted rules of behavior.

57. *See* ROBERT C. ELLICKSON, ORDER WITHOUT LAW: HOW NEIGHBORS SETTLE DISPUTES 15-64 (1991) (pointing out that in a community in which parties have long-term relationships, norms of cooperation can be enforced by reputation building. If parties are unknown to each other, or otherwise anonymous, then the incentive of each party is to be a selfish short-run profit-maximizer, as reputation sanctions are ineffective).

58. Examples of pure commons in which there are no rules do exist. For example, public domain literature can be published by anyone without payment of royalties or any other restriction. In this case, the use of a book or article in the public domain does no damage to any other party, so untrammeled access is efficient.

constitute entry barriers to new competitors, thus preserving oligopolistic market power. The assertion that there will be rules in any spectrum now seems to be accepted by both sides to the dispute.

Another issue is the price at which spectrum will be made available. Early commons advocates took their cue from current unlicensed spectrum, in which there is no charge for spectrum use.[59] Of course, there is a charge for the devices that use the spectrum, such as the cordless phone and the WiFi access point. Further, there is a cost: since the FCC is the current monitor and enforcer of its own standards, it expends resources to make the rules and to enforce the rules. For example, during the CB radio craze of the mid-1970s, the FCC was receiving about 35,000-50,000 complaints per year, usually from owners of TV sets complaining of broadcast interference.[60]

The costs to establish the rules and then enforce them could be substantial, and there is no reason to expect that taxpayers would continue to bear these costs. Moreover, there are opportunity costs of spectrum use: the Part 15 frequency bands have many alternative uses, such as cellular telephony. Thus, users of unlicensed spectrum are imposing an opportunity cost on the economy, even if there is no actual cash flow. User fees (similar to those charged for many other public services, such as National Parks) may be a more appropriate way to cover these costs. The point here is that the property rights vs. commons debate is not about price. Commons advocates are quick to point out that this is not about "getting free stuff." It appears the "free/not free" is not really part of this debate.

The core of the argument for commons seems to be open access to all. Commons advocates assert that exclusive use licensing will necessarily lead to, well, exclusion. Only licensees will have access to the licensed band, and others will be excluded. In a commons, everyone will have access. Yes, there will be rules, and there may even be a price, but open access to all is the touchstone of the commons argument.

Is it true that commons always implies open access? As a general rule, not all commons are necessarily open to all. For example, cattle grazing on "open" public lands is often quite limited by rules. A non-member will generally not be able to drive up with five head of cattle to let them graze on such lands, as it constitutes a limited commons. But it is certainly the case that Part 15 use of the 2.4 Ghz band for WiFi is indeed open to all, and this is what commons advocates have in mind.

Is it true that exclusive use licenses necessarily lead to a closed

59. This is not quite true; some retail establishments that offer WiFi service on their premises often require a fee for usage.

60. Telephone Interview with George R. Dillon, Assistant Chief, FCC Enforcement Bureau, (Jan. 8, 2004).

system? There are cases in which this is true: an airport operating a radar system will not share its spectrum with anyone else, nor will an FM radio station. However, much spectrum held by licensees is actively marketed by those licensees in order to attract as many users as possible. Consider, for example, cellular telephony. Each wireless carrier offers to provide service to anyone; no one is refused (although billing arrangements may vary). Carriers offer flexibility regarding handsets; a check of Verizon Wireless' website revealed the firm offering twenty different handsets from seven different manufacturers, with a wide variety of features and functions.[61] It is hard to imagine access more open.[62]

But the commons advocates rely on the Internet's "end-to-end" principle,[63] in which anyone may launch any application they wish on the Internet.[64] But this is not observed in radio; any device intended for use in the spectrum must either be controlled by a licensed user or be type-certified by the FCC.[65] This is not simply a meddling regulator; devices which do not meet standards may well cause harm to other users. Approval of devices is the norm in unlicensed bands. In the PCS cellular band, the licensee determines what devices it approves. This is a bit more restrictive (and a great deal more efficient) than type-certification, but it is difficult to build a case for open access in unlicensed as compared to licensed based on this small difference.

In fact, current PCS cellular services are quite close to what the FCC has termed "private commons,"[66] privately licensed spectrum made available to all (under conditions determined by the licensee). The only

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61. *See* Verizon Wireless website, *at* http://www.verizonwireless.com/b2c/index.jsp (last visited on June 27, 2005).

62. Note that if "open access" is indeed the same as "anyone can use it", then this is simply common carriage, a principle that has been used in telecommunications and utility regulation for over a century, hardly a revolutionary development.

63. *See* J. H. Saltzer, et al., *End-To-End Arguments in System Design*. 2 ACM TRANSACTIONS ON COMPUTER SYSTEM 277, n.4 (1984).

64. If the application doesn't use the existing protocols of TCP/IP it will not work, and will do no one any harm. If a new wireless application doesn't use the existing rules and protocols, it may work and it is likely to cause others harm, through interference. The Internet is not like wireless in this regard.

In fact, the very openness of the Internet has led to its own "tragedy of the commons." The ability of anyone to develop an application and distribute it over the Internet becomes much less wonderful when that application is a virus or worm that can infect computers worldwide in hours or minutes. The anonymity of the Internet becomes less wonderful when that anonymity (plus low cost distribution) fills users' mailboxes daily with hundreds of spam e-mails. The great promise of the Internet is in danger of being undermined by these activities, but they are a product of its openness; it is a tragedy of the commons.

65. Even experimenters must acquire an experimenter's license in order to transmit and experimental device.

66. *See* Promoting Efficient Use of Spectrum Through Elimination of Barriers to Secondary Markets, *Report & Order & Further Notice of Proposed Rulemaking*, 19 FCC Rcd. 17,503, 17,506 (2004).

difference is that the FCC envisions that the licensee would not provide infrastructure, using instead a low-power mesh network architecture. But the openness and availability of diverse technologies appears the same. The only difference appears to be whether the system's infrastructure is contained within the user device or not.

Hence, both licensed and unlicensed spectrum will be subject to rules. In unlicensed bands, the FCC (and possibly device manufacturers) will set the rules; in licensed bands, the licensee will set the rules. The issue is not whether there will be rules or not; the issue will be who sets the rules. Additionally, it is likely that both licensed and unlicensed frequency bands will carry a price, unless explicitly subsidized by the government. [67] The role of open access, strongly emphasized by commons advocates, may actually be well-served in certain licensed bands such as cellular telephony, for the simple reason that licensees find it most profitable to offer services to everyone on similar terms and conditions, although this latter point may be more controversial.

Are there differences in management between property rights/licensed and commons/unlicensed? In fact, the differences are rather profound. In the licensed arena, both private and public agents may hold licenses. For example, police departments, the military, and Federal Aviation Agency air traffic control may hold licenses, as well as TV and radio broadcasters, cellular telephone firms, and cable TV firms. The licensee may use its license exclusively; for example, cable TV network providers use satellite radio channels to transmit TV shows in real time (or on delay) to their various franchisees. Broadcast networks also use satellite channels to distribute material to affiliates. They use these channels continuously and have no interest in sharing. Likewise, air traffic control is not interested in sharing its frequencies. But licensees could also open their spectrum to everyone, such as occurs in cellular, or to some subset of users, such as aeronautical radio (in which only members can use the spectrum). Government licensees[68] can choose

67. *See* Brett M. Frischmann, *An Economic Theory of Infrastructure and Sustainable Infrastructure Commons* 89 MINN. L. REV. 917, 925-26 (2005) (stating "[t]his does not mean, however, that access is free. We pay tolls to access highways, we buy stamps to send letters, we pay telephone companies to route our calls across their lines, and so on. Users must pay for access to some (though not all) of these resources. Nor does it mean that access to the resource is unregulated. Transportation of hazardous substances by highway or mail, for example, is heavily regulated. The key point is that the resource is openly accessible to all within a community regardless of the identity of the end-user or end-use." But as noted above, this is simply common carriage, not a "commons.").

68. Under the current regime, the government doesn't actually hold a license to Part 15 spectrum. But if a property rights regime were in place, the government (in fact, state and local governments as well as the Federal government) would hold licenses to any spectrum offered under Part 15 rules. In essence, the government would "own" the commons, much as it owns public lands today.

to open their spectrum to all, such as Part 15, or to some, such as ham radio operators. Thus, a property rights regime could accommodate both private and public ownership of licenses and could accommodate exclusive use and various forms of open access spectrum, including government-managed commons.

A commons regime, however, has virtually no other management option than . . . commons. Exclusive use is not possible, nor is private licensing. A commons regime is forevermore government controlled and non-exclusive. As a result, spectrum devoted to property rights/licensed has a rich set of management options available, including government-owned and managed commons.[69] Spectrum devoted to commons has only one management option: commons, subject to regulatory oversight. On the management flexibility dimension, a property rights regime has a decided advantage. This suggests that some form of licensing will be with us for the indefinite future.

D. Overarching Legal Regime

Moving from the micro view to the macro view, I examine the core of the dispute: the overarching legal regime which governs spectrum. The analysis thus far suggests four possible legal regimes: (i) traditional command-and-control regulation; (ii) end-state regulation, as described above;[70] (iii) a property rights regime; and (iv) a commons regime.

Since traditional command-and-control regulation is the regime from which all reformers, both academic and practical, flee, it can be removed from further consideration. Today's regime is far enough away from traditional regulation that a reversion to it is not a serious policy option. The commons regime, while attractive to some, is lacking in flexibility that virtually all disputants agree is necessary. If the overarching legal regime is a commons, then there is no management option for exclusive use, either public or private; since many uses are most efficiently deployed using exclusive use, a commons regime must also be removed from consideration.

The two serious contending regimes are a property rights regime and an end-state regulatory regime. The two regimes are compared on four dimensions: (a) dispute resolution; (b) transaction costs; (c) the

69. To be perfectly clear, under a property rights/licensed regime, a government (at any level, or any other entity) can own a swath of spectrum and permit others to use it, subject to their rules and regulations. For example, New York City land is governed by a property rights regime, and yet there is a large and important commons in the middle of Manhattan: Central Park. The presence of Central Park in no way compromises the property rights regime governing real estate in New York; the City of New York owns the park and chooses to manage it as a commons available to all, under their rules and regulations. It is in this sense that a property rights regime can accommodate commons usage.

70. *See supra* p. 127.

tragedies of the commons and anticommons; and (d) flexibility to adapt to changing technology and changing demands. These comparisons are made using simplifying assumptions: (i) transition issues are ignored; (ii) the regimes are assumed to be in long run equilibrium; and (iii) the technologies discussed above[71] are assumed to be fully mature and available in the market at reasonable cost. This is not to say that transitions, both economic and political, are not important; we applaud the extensive work at the FCC focused on transition.[72] This is also not to say that the technologies described above as yet-to-be-deployed are guaranteed success; but assuming their success makes the case for a commons (and for a non-interfering easement) rather stronger. These caveats are extremely important. It could be that the transition to a preferred regime is very costly or politically impossible; in which case we must settle for second-best. In this paper, I take the view that it is important to understand what the preferred target regime is, and why it is preferred, so that an informed decision regarding transition and its costs can be made.

The actual mechanics of how legal regimes work is messy and uncertain. While property rights advocates assume that the costs of a property rights system (dispute resolution, transaction costs, etc.) are low to nil, this need not be the case; cost must be identified and estimated. Likewise, commons advocates assume that if commons are not totally self-regulating then "light" regulation will solve the problem, all at low cost. Again, this is surely not the case; the costs must be identified and estimated.

IV. REGIME CHANGE—FINDING THE ANSWER

In order to assess which regime will lead to more efficient use of spectrum, we examine each of the four issues: dispute resolution, transaction costs, tragedies of the commons and anticommons, and flexibility to changing technologies and demands. This requires that the properties of both regulation and markets be made explicit, so that a comparison on these four dimensions is possible. I first make clear precisely what the differences are between a property rights regime and an end-state regulation regime, followed by a brief overview of the regulatory process and its expected outcomes. I then examine how each of the four issues is expressed in the two regimes; I find that the property

71. *See supra* pp. 130-33.

72. *See* EVAN KWEREL & JOHN WILLIAMS, A PROPOSAL FOR RAPID TRANSITION TO MARKET ALLOCATION OF SPECTRUM (Federal Communications Commission Office of Plans and Policy, Working Paper No. 38, November 2002), *at* http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-228552A1.pdf.

rights regime outperforms the end-state regulation regime in almost every regard.

A. *Property Rights vs. End-State Regulation: What's the Difference?*

A brief statement of the differences between the two candidate regimes is in order prior to a comparison of their characteristics.

1. Property Rights

Specific rights governing transmission of radio energy and freedom from impinging radiation are defined for each frequency band and geographic area, and licenses are owned by either private individuals or firms, or by public agencies. The licensee has the right to operate radio systems within the constraints imposed by the license; she may buy additional licenses, sell the license, subdivide the license, and rent/lease all or part of the license. A licensee may use the licensed spectrum for its exclusive use; it may also use the spectrum to offer services involving other parties (customers) either with or without charge. Such uses include commons-type open access. If a licensee's spectrum is available to others, such as a cellular phone system or a WiFi-type home networking system, the licensee (public or private) may establish whatever rules, regulations, and obligations on users it deems fit, within the overall constraints of its license. In this regime, behavior *within* the bounds of a license is governed by the licensee, be it private, corporate, or governmental. Behavior *among* licenses is governed by the market, supported by the courts for dispute resolution.

2. End-State Regulation

Specific rights governing transmission of radio energy and freedom from impinging radiation are defined for each frequency band and geographic area, and the regulator (e.g.,, the FCC) specifies which bands and areas are to be licensed and which bands are held in common as unlicensed. Changes in the allocation between licensed and unlicensed would also be under the control of the FCC. Licenses are owned by licensees and can be bought, sold, subdivided, aggregated, and leased by licensees. However, disputes among licensees would continue to be resolved, as today, by the regulator. The FCC would be able (but not likely) to modify the terms of licenses or even revoke them. Frequency bands held in common would be individually managed by the FCC, and may differ in operating characteristics permitted and may be limited in who may use these bands and/or what uses are permitted in the bands. Disputes among users of the commons would be resolved, as today, by the regulator. Further, selection of protocols and formats to be used to avoid interference would be decided by the FCC, as it does today. The FCC would also control the boundaries among commons uses as well as between commons and licensed uses. The FCC would be able (but not likely) to impose use restrictions for either licensed or unlicensed bands. In this regime, the FCC would have much the same power as today to designate frequency bands as licensed or unlicensed, change these allocations over time, resolve disputes in both licensed and unlicensed, and set the rules and obligations for commons/unlicensed spectrum. The only difference with today's regime is that licensees would have much greater freedom to buy, sell, subdivide, aggregate and lease their licenses. In all other respects, regulatory authority would remain in place.

In brief, the critical difference is the role of regulation. In the property rights regime, regulation is largely replaced by careful construction of property rights to avoid interference, operation of the market, and support of the judiciary for dispute resolution. Today's regulators are relegated to setting rules and regulations only in frequency bands for which they are the licensees, and their power is no more than that of any other licensee. In the end-state regulation regime, the regulator continues its overarching role of allocator of frequencies, arbiter of protocol and technology choices, and adjudicator of disputes, as it does today. The regime does offer licensees much greater freedom to use the market to buy, sell, and lease their licenses, which of course would still be subject to ultimate regulatory control.

B. A Short Course in the Theory and Practice of Regulation

Because regulation is the defining characteristic of the end-state regulation regime, an understanding of regulation[73] is required. Is "light regulation" even possible? I argue that "light regulation" is an oxymoron; it is not an equilibrium outcome of the political forces that drive regulators, especially in commercially important markets.

And regulation is above all political, subject to forces of producers large and small, consumer and user groups, unions, the U.S. Congress, even economists and technologists. If a regulator has jurisdiction over particular markets and technologies, it has the potential to use the coercive power of the government to intervene in markets. This power is highly valued by market participants, and they will lobby the regulator to intervene on their behalf, at the expense of their competitors. Such

73. I use the term "regulation" to denote the presence of a permanent governmental body that has been delegated authority to establish and enforce rules concerning core economic decisions of firms in specific markets or market activities, including price, quality, standards, entry and exit, and other such rules and obligations. In this context, I do not consider the courts to be involved in regulation.

lobbying is not only targeted at the regulators, it is also targeted at legislators (either state or Federal) that control the regulators budgets and can enact laws overturning regulatory rulings. The regulatory process is designed to listen to all sides, consider carefully the merits as well as the power of the lobbying participants and the likelihood of a successful court challenge, and reach a conclusion, often after years of comment, reply comment, deliberation and reconsideration. Participants use the regulatory/political/judicial process strategically to achieve corporate or group objectives.

As an example, consider the ongoing FCC case of Nextel Communications, a cellular (SMR licensed) carrier operating in the 800 Mhz band.[74] This band is adjacent to a police radio band, and police around the nation were claiming interference from cellular traffic in the Nextel band. Nextel proposed that it would move to another band to avoid interference, and the FCC appeared to agree. This rather simple transaction would appear straightforward; however, the proceeding has been ongoing for the last two years, and has attracted 2,445 comments and reply comments from parties far beyond the 800 Mhz band. Most instructive was Verizon Wireless' demand that Nextel should be forced to bid for the spectrum at auction (even though it had already paid for its 800 Mhz spectrum it was now being forced to abandon).[75] Verizon Wireless, a competitor to Nextel, was pursuing the interests of its shareowners in its use of the regulatory process to disadvantage a competitor; it is blameless here. Rather, the problem lies with the regulatory process, which permits parties outside the transaction (which after all is between Nextel and public safety agencies) to have an influence over the outcome. This interpretation of Verizon Wireless' actions is supported by the fact that it reached a business agreement[76] with Nextel to drop all lawsuits if Nextel agreed to let Verizon Wireless use its successful copyrighted "push-to-talk" label for its own services.[77] In sum, it was profit maximal for Verizon Wireless to use its lobbying abilities in a dispute in which it had no direct interest to gain a commercial advantage.

But surely, it might be thought, instructing the FCC (or whatever

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74. *See* FCC, ABOUT 800 MHZ BAND RECONFIGURATION, (Jan. 12, 2005), *at* http://wireless.fcc.gov/publicsafety/800MHz/bandreconfiguration/about.html.

75. It might be argued that Nextel could sell its interest in the 800 Mhz band in order to buy other spectrum at auction. In fact, Nextel had paid for its spectrum in every expectation it could use it. In the event, it was the collective ability of the nation's police forces to lobby to shut down Nextel that made this spectrum valueless; should Nextel have tried to sell it, it would have no takers since the spectrum is now unusable for high powered SMR applications.

76. *See* Ken Belson, *Verizon and Nextel Agree to Drop Lawsuits*, N.Y. TIMES, Nov. 3, 2004, at C12.

77. *Id.* After Verizon Wireless dropped its objections, the FCC approved Nextel's re-banding plan.

regulator there is) to regulate "lightly" would eliminate these problems. Unfortunately, this is not the case. Market participants who can successfully lobby the regulator or Congress will do everything they can to force a regulator to intervene in their markets because the participants can then use their power to achieve market outcomes favorable to themselves, generally at lower cost than actually serving customers. It is the participants who will force the regulator to expand from light regulation to the usual pervasive regulation, often by enlisting Congressional support. This is why "light regulation" is an oxymoron; as long as a regulator of a market exists, participants will push the regulator to expand its writ so that participants can enjoy the market advantage that comes from successful lobbying. The conclusion is clear: *light regulation is not a real option.*[78]

There are some frequency bands in which the FCC's hand has been very light; garage door openers and outside home weather stations, for example. But there were very substantial disputes over the introduction of spread spectrum technology in cordless phones, for example; it appears that if the market does not involve a great amount of market value and there are no technological changes involved, then minimal regulation may emerge.

Generally, there is no reason to suspect that regulation under the end-state regulation regime will be much different than it is today, except licenses will be much easier to transact under this regime. But the same forces operating in today's regulated environment will continue to operate in the end-state regulation regime and will be mediated in much the same way. In sum, *as long as there is a regulator to complain to, market participants will complain and the regulator will be forced to respond. The scope and intensity of regulation inevitably expands to meet the demands of market participants.*

Could some form of regulation be used in a property rights regime as a specialized court for dispute resolution? If expertise in wireless issues is needed, perhaps retaining regulation for dispute resolution makes some sense. But as we have just seen, dispute resolution is a function in which regulation performs particularly poorly, and becomes a backdoor by which regulation re-enters, as market participants manipulate their actions to accord with the regulator's interests as expressed in dispute resolution cases. In fact, the need for technical expertise by courts or

78. If light regulation were a feasible option, one would expect that it would exist in some jurisdiction in some industry. The commons advocates have yet to disclose the existence of light regulation in the real world in markets where substantial value is at stake. Perhaps the most telling evidence is that the most successful U.S. deregulations (airlines and motor freight) were very quickly followed by the abolition of the regulating agencies (Civil Aeronautics Board and Interstate Commerce Commission). Had these agencies survived, there is little doubt that market participants would have figured out a way to get them to resume their regulating ways.

regulators to enforce property rights is a signal that the property rights are too complex and too complicated for normal people to understand. The problem is solved, not through specialized courts or regulators, but via simple, clear, measurable conditions on spectrum licenses.

As inefficient as regulation can be, is it necessarily worse than a market system which uses the judiciary for dispute resolution? Clearly, the disastrous consequences of asbestos litigation suggest that there may be worse things than regulation. But a simple comparison of long-run outcomes should frame the issue: spectrum has been allocated by regulation for over seventy years and very large swaths of frequencies are not in use, even though the demand for spectrum is quite high. Land, on the other hand, has been allocated by the market via property rights with dispute resolution by the courts for centuries, and yet we do not see large swaths of real property lying empty and unused in the presence of high demand for it. Likewise, dispute resolution of commercial disputes via commercial law, while costly, have not resulted in large swaths of the economy being paralyzed by allocative inefficiencies. This simple efficiency test suggests that the costs of regulation really are significantly higher than market mechanisms for allocating resources.

C. Dispute Resolution

Disputes take several forms. A classic dispute over a specific interference problem was described above in the case of Nextel in the 800 Mhz spectrum. Another form of dispute could be the introduction of a new technology, such as wideband. A third form of dispute could be over standards and protocols, in which one or more parties wish to change an existing standard or protocol and need a means of ensuring that all parties move to the new standard.[79]

It is easy to assess how an end-state regulatory regime will handle disputes; it will handle them pretty much as it does today. The Nextel 800 Mhz dispute was discussed above; this is a case involving licensed spectrum. Unless the end-state regulatory regime explicitly moves to court-enforced property rights for the spectrum under licensed management, we can expect the FCC to continue to resolve disputes between licensees in much the same was as the Nextel 800 Mhz dispute was resolved.

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79. Werbach argues that dispute resolution in his "supercommons" will occur via some form of tort which he does not completely specify. Given that a regulator would continue to have overarching authority of all spectrum, both licensed and unlicensed, it is very unlikely that the locus of dispute resolution will change. The FCC will continue to resolve disputes, using rules rather similar to those in place today. Since the regulatory process is very unlikely to change, it is safe to assume that at least in unlicensed bands the FCC will continue to resolve disputes. *See* Werbach, *supra* note 37.

In the case of unlicensed spectrum, the FCC regulatory process has also established a track record relating to new technology introduction. This is particularly important to the commons argument, since the FCC cannot step back from dispute resolution in unlicensed spectrum in the end-state regulatory regime. In her excellent article, Ellen Goodman notes: "For example, it took three years and two rulemakings for the FCC to change its ex ante controls for unlicensed operation to allow new, nonconforming technologies into the unlicensed bands."[80] The footnote that follows explicates this long drawn out affair of regulatory cut and thrust involving the introduction of a new technology into a commons regime.[81] It would appear that even in commons-managed spectrum, the regulatory process is not particularly friendly to new technology introduction. But in the future commons, this scenario will no doubt be the norm; again, "light regulation" is an oxymoron.

Several commons advocates have suggested that social norms can develop within communities to ensure that individuals behave cooperatively (i.e., no pirate transmitting devices) or be subject to group sanctions.[82] The reference is Robert Ellickson's famously colorful study of ranchers in Shasta County, CA, based on the theory of repeated games, which suggested that norms of cooperation (such as the "tit for tat" strategy) can emerge within stable communities.[83] But Ellickson makes clear that this only occurs within stable communities in which actions among neighbors are seen as part of a pattern of repeated play, where sanctions for uncooperative behavior can be imposed on future stages of play.[84] In the wireless context, this applies to cooperation standards among ham radio operators, a fairly homogeneous group who know who is who in the ham community. It does not apply in mass markets such as CB radio in the 1970s, where players are anonymous and cannot be disciplined by other users.

But even when there are user communities that interact over long time periods, Ellickson's view regarding the likelihood of cooperation, based on Axelrod's work in the early 1980s,[85] is overly rosy. Later work in sequential game theory proves Ellickson's allegations about the likelihood of cooperation are incorrect on a couple of counts: (i) "tit for

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80. Goodman, *supra* note 3, at 376.

81. *See id.* at n. 348.

82. *See* Benkler, *supra* note 3, at 361; Philip J. Weiser & Dale N. Hatfield, *Policing the Spectrum Commons*, 74 FORDHAM L. REV. (forthcoming 2005), *at* http://ssrn.com/abstract=704741.

83. *See* ELLICKSON, *supra* note 57.

84. *See id.*

85. Much of Axelrod's work is based on articles the author published in 1980-81, very early days in the development of modern game theory. S*ee* ROBERT AXELROD, THE EVOLUTION OF COOPERATION (Basic Books 1984).

tat" is not an equilibrium strategy[86] in the repeated play prisoner's dilemma game; (ii) while cooperative equilibria do exist,[87] they are not unique; non-cooperative equilibria also exist. Evolutionary game theory suggests that if the cooperative equilibria require investments, then it is likely that they will be unstable compared to non-cooperative equilibria.[88] Commons advocates have used Ellickson and the ensuing legal literature on norms[89] to suggest that social norms and mores can act as a substitute for regulation.But the more careful application of game theory by Mahoney and Sanchirico proves this bias toward cooperative norms is misplaced;[90] we rely on it at our peril. Moreover, in a commons regime, the number of "neighbors" is likely to be large and their relationship is unlikely to be long term, so cooperative equilibria are unlikely to exist. Realistically, in commons or markets, court-enforced law or regulation is a necessity whenever cheating could be profitable short-term. Reliance on social norms is romantic but fanciful.

But surely in practice industry groups would find it in their interest to cooperate? Unfortunately, this is not the case. Goodman continues: "Even when industry groups are responsible for agreeing to protocols that the regulator merely approves, standard setting has often proved to be staggeringly slow and acrimonious."[91] The footnote that follows explicates the lengthy proceedings involved in setting standards for digital television.[92]

Unfortunately, the commons presents a special difficulty in dispute resolution. In a property rights regime, each licensee has only a few neighbors, those that would be most affected by a violation of the license terms and conditions. In a commons regime, there could well be thousands of users of a particular commons. If a particular user decides to "cheat," perhaps using an illegal transmitter with much higher power than permitted in the commons, this will interfere with other users.

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86. The correct equilibrium concept for sequential games is Subgame Perfect Nash Equilibrium. Such equilibria ensure that sanctions are optimal for other players to impose on strategy deviants, thus ensuring strategic discipline that supports the equilibrium. Paul Mahoney and Chris Sanchirico provide a lucid explanation in the legal scholarship literature. *See* Paul Mahoney & Chris Sanchirico, *Norms, Repeated Games and the Role of Law*, 91 CAL. L. REV. 1281 (2003).

87. *Id.*

88. *See* Paul Mahoney & Chris Sanchirico, *Competing Norms and Social Evolution: Is the Fittest Norm Efficient?*, 149 U. PA. L. REV. 2027, 2059 (2001).

89. *See* Eric Posner, *The Regulation of Groups: The Influence of Legal and Nonlegal Sanctions on Collective Action,* 63 U. CHI. L. REV. 133 (1996); Richard H. McAdams, *The Origin, Development, and Regulation of Norms*, 96 MICH. L. REV. 338, 352 (1997).

90. The evolutionary psychology literature suggests a non-game-theoretic mechanism in which cooperation is a possible equilibrium. *See* Amy Wax, *Evolution and the Bounds of Human Nature*, 23 LAW & PHIL. 527 (2004).

91. Goodman, *supra* note 3, at 376-77.

92. *See id.* at 377 n. 349.

However, since the interference impinges on many users, there will be a free rider problem with enforcement. Who will bother to file a formal complaint to the FCC, when everyone expects someone else to undertake the costly complaint process? If commons users are given the right to sue the interferer, the problem becomes even worse.[93] Who will bring a costly suit against the interferer when everyone expects someone else to bring the suit? This is the *enforcement tragedy of the commons*: with lots of commons users affected by the interference, no one user has an incentive to enforce their commons rights.

In a property rights regime, the specification of the property rights becomes critical. Following De Vany,[94] I assume that at a minimum each license has a location, a frequency band, and power levels specified; additionally, a license could also be limited by time of day or direction (relevant for satellite reception, e.g.). It is useful to think of both location and frequency as an allotted space in which the licensee's power across the boundaries of this space are explicitly restricted.[95] For example, power emissions into adjacent frequency bands would be specified,[96] and power emissions across a geographic boundary would also be specified (in watts/m^2).[97] In both cases, the power limits may be expressed statistically: emissions across a geographic boundary should be no greater than *x* watts/m^2 no more than *y*% of the time.[98] These restrictions on transmitting in one frequency band and location become rights for those in adjacent frequency bands and locations. Goodman argues persuasively that the use of nuisance law to resolve spectrum property disputes would be costly and inefficient.[99] Therefore, I propose that license restrictions would have the force of trespass law; should a licensee violate one of its restrictions, its neighbors could obtain injunctive relief without a showing of damages. Could these restrictions be enforced by neighbors? Should a licensee detect interference, either it

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93. As suggested by Werbach. *See* Werbach, *supra* note 37, at 938-39.

94. *See* De Vany, *supra* note 10.

95. *See* KWEREL & WILLIAMS, *supra* note 72, at 42-44 (discussing flexible license rights).

96. This limitation could be specified to "roll off," so that e.g., 80% of out of band emissions would be within 0.5 Khz of the frequency band border, 95% must be within 1.0 Khz of the border, etc.

97. It is more convenient to express power limitations at the transmitter; however, it is actual power impinging across a geographic boundary that is the relevant measure for interference in an adjacent location.

98. This specification may also include the height of the measuring antenna: e.g., ". . .no greater than *x* watts/m^2 no more than *y*% of the time measured no higher than *z* m above ground." Clearly, effective enforcement requires the right to be fully specified, cover (almost) all contingencies, and be measurable.

99. Nuisance law cases require a determination of damages as well as a balancing of interests among the parties. This is the basis of Goodman's finding that nuisance law imposes substantial inefficiencies. *See* Goodman, *supra* note 3, at 326-59.

or a third-party measurement service could objectively measure and record violations. In fact, it may make such measurements routinely, without waiting for allegations of interference violations.

The "bright line" trespass rule together with the ease of measuring violations suggests that courts would find dispute resolution straightforward:[100] technical evidence of violation is presented, no damages need to be proved, no balancing of interests is required, and an injunction follows.[101] In fact, in such a trespass law regime, few cases would ever reach the court since the outcome would be foreordained. Only the cases with questionable evidence would move forward. Thus, simple dispute resolution should be a relatively low cost. This avoids Goodman's costly nuisance law issues.

But not all interference cases result from license condition violations. Radio waves can do unexpected things and more sophisticated forms of interference may occur, although this should be unusual. In these cases, in which a licensee experiences interference from another licensee who is operating within his property rights, several alternatives are possible. One option is "neighborly" bargaining. As the commons advocates point out, neighbors often figure out means of resolving disputes without recourse to the courts, especially in the presence of long term relationships ("repeated play" in game theoretic language). But neighborly bargaining works in a property rights regime as well as a commons regime, perhaps even better because there are likely to be fewer (and more familiar) neighbors. Such could be the case here, and in cases where such interference occurs, neighborly bargaining is likely to be the first line of dispute resolution. A second option is more formal dispute resolution, including the courts (in the form of nuisance law) or arbitration. In fact, binding arbitration should be considered an option, should this prove to be the most efficient dispute resolution of these spectrum nuisance cases. Since these cases are likely to require specialized knowledge of radio technology, specialist arbitrators are likely to be knowledgeable and effective as against generalist judges and

100. No doubt a court would be loath to issue an injunction if a licensee emitted out of band power 1% over its permitted limit for 1 second, without a showing of damages. If the property right were written specifically acknowledging the right of injunctive relief without a showing of damages, it is likely the courts would settle on a threshold level of intrusion that would call forth an injunction.

101. The way boundary rights are defined now in flexible licenses requires neither measurements nor the existence of "interference" per se. They are enforced either by equipment type acceptance or by calculations using standard propagation models and technical data that licensees must provide. Also, violations of current boundary limits (like trespass on land) are enforceable now even if there is no harm from interference to a licensee's services. Telephone Interview with John Williams, Spectrum Policy Task Force Member, FCC Office of Plans and Policy (Mar. 10, 2005).

juries.[102]

Failing neighborly bargaining and the courts (or arbitration), an aggrieved licensee has the option of selling his license and moving elsewhere. Now should this be suggested for the settling of land disputes, this would clearly be inappropriate, as landowners may have strong emotional attachments to their homestead or large capital investments that are specific to this property. In spectrum, it is not likely that any licensee will have strong emotional attachments to their spectrum. But what about capital investments? Surely investing in transmitter and receivers (which may actually be owned by your customers) at a certain frequency band makes moving to a different band very costly. However, in the new world of software-defined radio (which we assume to be fully mature) frequency changes in a transmitter can be made quite simply with a flip of a software switch. A frequency change in customer-owned equipment is easily updated over the air in a software-defined radio world. Even today, cellular telephones receive software updates over the air, patching themselves remotely. In this future technological environment, transmitters and receivers will have no long term attachments to particular frequency bands and moving from one to another should be easy.[103] If a licensee has insuperable problems with its neighbor, it can simply move away at low cost to a new set of neighbors.[104] With a rich market in licenses, finding a new place to locate should be no more difficult than finding a new house or apartment. The problem of the anticommons simply does not arise.

If non-interfering easements are granted within the property rights

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102. Whether or not arbitration is more efficient than litigation or is more or less fair is a matter of dispute within the legal scholarship literature, which is not addressed in this paper. *See* Lisa B. Bingham, *Mandatory Arbitration: Control Over Dispute-System Design and Mandatory Commercial Arbitration*, 67 L. & CONTEMP. PROBS. 221 (2004). Lewis L. Maltby provides a discussion on the fairness of arbitration in employee-employer disputes, in which empirical results are quoted, ". . .compare[ing] the size of the awards in AAA arbitration proceedings to the size of awards in state court employment cases. The median AAA award was $63,120, while the median state court award was an almost identical $68,737." The mean of court awards was considerably higher than the mean of arbitration awards, suggesting that occasional very high jury awards lent a certain lottery aspect to litigation for plaintiffs not present in arbitration. *See* Lewis L. Maltby, *Employment Arbitration and Workplace Justice*, 38 U.S.F. L. REV. 105, 115 (2003).

103. Note that the ability of licensees to swap spectrum using markets is far less demanding than the technology of agile radio, in which spectrum may be swapped every few seconds rather than every few years. A user interested in switching frequency bands will of course be limited in her choices to bands whose license property rights match their needs; not all bands will necessarily do.

104. It is possible that the licensee may incur a loss in selling her current license, if it were the case that her interference troubles with neighbors would carry over to the next owner. For example, if a homeowner acquires a new neighbor that is noisy and obnoxious (but not illegally so), she can move, but it is likely the price of her home will reflect the negative aspects of her current neighbor.

model, the same principle applies. For example, an opportunistic agile radio would have the right to broadcast in a licensed band if the licensee is not using it; the agile radio has the obligation to ascertain if it is being used before broadcasting.[105] The agile radio would also be required to vacate the band within, say, 5 milliseconds of the licensee starting use of the band. Failure of the agile radio to comply would be a trespass violation, and an injunction issued against this particular agile radio using this band again. In this special case of opportunistic use of licensed spectrum, agile radios would be required to broadcast an identifying number to ensure that violators can be identified.[106]

Dispute resolution costs in a property rights model are thus held low by (i) using trespass law to enforce licensee restrictions; (ii) using neighborly bargaining where possible; (iii) using nuisance law in litigation or arbitration as a backup; and (iv) if all else fails, relocate at low cost.

D. Transaction Costs

Commons advocates point out that markets for licenses have costs: buying and selling a license involves costs which would not be incurred in a commons regime. Both Benkler[107] and Werbach[108] note that transaction costs in a property regime are likely to be large and thus suggest the rejection of a market-based property rights regime for that reason (among many others), while neither author offers evidence of large transaction costs nor do they even define "large."

In the recent past, spectrum transactions have been difficult to execute because of regulatory limitations, and so have been more costly than would be the case in a full property rights market. Even so, a great many transactions occurred; Nextel, for example, purchased over 40,000 SMR licenses to put together its national network, apparently not overwhelmed by transaction costs.[109] A number of large wireless firms bought, sold and swapped spectrum around the country in order to build their national networks, again apparently not overwhelmed by transaction costs,[110] in spite of the difficulty of transacting an FCC

105. Quite recently, the FCC issued a ruling permitting "smart" (i.e., agile) radios, taking care to ensure that such radios do not interfere with licensees use of spectrum. *See* Facilitating Opportunities for Flexible, Efficient, and Reliable Spectrum Use Employing Cognitive Radio Technologies, *Report & Order*, 20 FCC Rcd. 5486 (2005).

106. Should such services become popular, then they may acquire "squatters rights;" even though they infringe on licensees, it may be difficult if not impossible to evict them.

107. Benkler, *supra* note 29, at 57.

108. Werbach, *supra* note 37, at 961.

109. *See* Thomas W. Hazlett, *Is Federal Preemption Efficient In Cellular Phone Regulation?*, 56 FED. COMM. L. J. 155, 193 tbl. 8 (2003).

110. Analysts suggested that the broker fee for arranging such sales was approximately

license. The empirical evidence suggests that the transaction costs of spectrum in the late 1990s did not prevent a very active market in spectrum licenses, even though these costs are greater than would be expected in a full property rights market.

There does not appear to be publicly available data on the pecuniary costs of transacting spectrum licenses. However, the costs can be easily bounded from above and below. For example, Internet stock brokerage services are willing to trade at $10-13 per trade brokerage commission.[111] Of course, the stock market has very high volume and very competitive brokerage services, so this commission is likely a lower bound. The market is more likely to be similar to the real estate market in terms of volume and transaction speed. Generally, the real estate market has very high transaction costs, so it is useful as an upper bound on spectrum license costs. Typically, brokerage commissions are 5%-6%. Based on a sample of forty real estate transactions in Maryland and Delaware, I estimate the pure transaction cost at 0.8% in Delaware and 0.62% in Maryland.[112] This upper bound appears to be a rather modest transaction burden, particularly if a full property rights market drives down brokerage costs to under 3%, as seems likely. The pecuniary costs of transacting spectrum licenses does not appear to be a significant hindrance to the market.

Benkler suggests that one important transaction cost comes from the difficulty of predicting the value of a frequency band in markets with uncertainty, which certainly describes spectrum markets. However, this assertion flies in the face of the fact that many markets not only thrive in the presence of uncertainty, they actually *are* markets for uncertainty. Capital markets (stocks, bonds, futures, options, etc.) and commodity markets are obvious examples. In fact, almost every asset market bears elements of risk and uncertainty, yet asset markets generally perform quite well. The assertion that uncertainty about returns would in any way discourage markets runs counter to every piece of evidence concerning the performance of asset markets. The evidence concerning recent transactions of spectrum licenses also runs counter to this assertion.

Werbach also mentions monopoly as a problem with markets,[113] a view shared by many commons advocates. In fact, it would appear that

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3%.

111. *See* E-Trade Financial, U.S. Commissions and Fees rate sheet *at* https://us.etrade.com/e/t/home/generalgen (last visited Oct. 8, 2005).

112. Based on a sample of 40 real estate transactions; pure transaction costs include all settlement fees and title insurance. They do not include broker fees (uniform at 5% or 6%), financing and mortgage company fees; or state and county transfer taxes (which are unique to real estate).

113. Werbach, *supra* note 37, at 929, 950.

commons advocates believe that the natural state of markets is monopolization. In fact, the empirical evidence supports the opposite. Currently, the spectrum use with greatest market value is cellular telephony, presumably the likeliest candidate for this alleged monopolization. Yet the Department of Justice and the FCC recently concluded that the industry was competitive enough to permit the merger of AT&T Wireless and Cingular, with only minimal requirements for divestitures. If monopoly doesn't exist in wireless today, does it exist in markets that are similar to what a full property rights market in spectrum licenses would be, such as asset markets? National asset markets, such as markets for financial products, are famously competitive. Even localized asset markets, such as real estate markets, are notably free of monopoly.

The assertion that spectrum markets would be monopolized simply cannot be supported by the evidence. In fact, most existing monopolies owe their privileged status to government protection (either current or the recent past). Telephone, electric power distribution and cable TV all gained their strong market power as regulated monopolies. This is not to say that most markets are perfectly competitive in the ideal conceptualization of introductory economics. But rivalrous behavior and aggressive competition, such as in cellular telephony, appears to be the norm in U.S. markets that we all experience daily.

Lessig makes a similar point in noting that a perfectly competitive market must price each use of spectrum at every second at its marginal cost, including opportunity and congestion cost.[114] Since this is clearly impossible (on transaction cost grounds), economic efficiency cannot be achieved and so a commons is preferable. This argument strains credulity. Almost no real world markets fit the ideal conceptualization of perfect competition. In communication markets such as wired and wireless telephony and Internet, pricing is almost never precisely marginal cost. In fact, it is usually flat-rate priced (such as local wired telephone service, Internet service) or priced in "buckets" (such as wireless service). While this doesn't meet the ideal conceptualization, these examples are the result of competitive market forces responding to what customers want. These markets are working just fine and no economist would recommend they be dismantled because they do not meet an ideal conceptualization.

E. Tragedies of the Commons and Anticommons

Commons advocates respond to the problem of the tragedy of the commons by noting that users (or manufacturers of devices) are able to

114. *See* LESSIG, *supra* note 13.

come together to solve their communal problems outside the context of law. Examples include a successful self-imposed code of conduct for amateur radio and the ability of ranchers grazing open range to develop a complex set of rules and protocols for use of the commons grazing land.[115] They also suggest that some "light" regulatory oversight may be needed to enhance these self-organizing systems. It is certainly correct to assert regulatory oversight is required. As previously noted,[116] game theory suggests self-governance is a likely outcome only when a small number of players interact over a long period of time. Otherwise, anonymous and temporary users will have incentives to break the rules for their own advantage, as occurred in CB radio. Continued regulatory oversight and enforcement is necessary to control this; however, FCC enforcement was not sufficient to solve the problems of CB radio in the late 1970s.[117] One response to a tragedy of the commons is for users to request more capacity. As the 2.4 Ghz band becomes more crowded, commons advocates call for more (and better) bandwidth to meet their needs. Of course, if the new technologies are as bandwidth-conserving as commons advocates assert, then there would be little need for new bandwidth; unlicensed users could operate within the allocated bands. In general, in the end-state regulatory regime, congestion in unlicensed bands would call forth regulatory intervention, with its attendant costs, delays and uncertainty.

In a property rights regime, the problem is the tragedy of the anticommons. If bigger blocks of spectrum are needed and cannot be obtained by conserving bandwidth within an existing license, it would appear necessary to negotiate with adjacent licensees in order to obtain needed bandwidth. It would appear adjacent licensees may "holdup" the licensee in need of more spectrum, hoping to extract as much of the rent of the new project from the acquiring licensee.[118] But what is the underlying cause of the anticommons problem? The problem only arises if two properties are satisfied: (i) location-specificity and (ii) contiguity. If I wish to aggregate property around my existing home, then I have no choice about location: it must be where my home is located. I also have no choice about what properties I must acquire: they must be contiguous

115. *See* ELLICKSON, *supra* note 57 (discussing subsequent scholarship).

116. *See supra* p. 142.

117. Enforcement need not be vested in the FCC; VHF marine radio is an unlicensed system in use by almost all boaters and both formal and informal protocols seem to be followed by millions of recreational boaters. The fact that marine police and the US Coast Guard monitor VHF channels no doubt has a disciplining effect.

118. If there is only one other licensee, then the project should go forward, as the only bargaining is over who gets the rents. The anticommons problem arises when there is more than one party on the opposite side, and each party holds out to capture all the rents. In this case, unless the parties on the opposite side can somehow organize themselves, the project will not get done and no one receives rents: hence, the tragedy of the anticommons.

to my current property. A similar problem faces a developer of a shopping mall: there may be only one location that is most suitable for the mall, and the developer must purchase not only that property but all contiguous properties, leading to the holdup problem. A beach town may wish to construct a walkway on its beach, but if the land is owned by private property owners, no other land will do, and it is all contiguous. In this case, the town may choose to solve the holdup problem using eminent domain, a cumbersome and costly process at best.

But in spectrum, neither location-specificity nor contiguity need apply. As previously noted, in the new world of software-defined radio (which we assume to be relatively low cost), frequency changes in a transmitter can be made quite simply with a flip of a software switch.[119] A frequency change in customer-owned equipment is easily updated over the air in a software-defined radio world. Further, spectrum need not be contiguous; receivers need not be listening on just one frequency but be "smart" enough to monitor and receive multiple frequencies. I refer to this as the *anti-anticommons* principle. In this case, commons advocates have been drawn in by the analogy to land; the anticommons is a problem most acute in land. It is not a problem in spectrum, at least with the technologies promised by the commons advocates. Solving the holdup problem in a property rights regime is as simple and low-cost as shopping for new spectrum.

Although contiguity is not crucial for most applications in a world of cheap software defined radio, it is crucial (or at least important) for at least one technology: ultrawideband (UWB). As described above, UWB is now licensed as a very low power service (below the noise floor) which uses a very large swath of spectrum, 1 Ghz or more. While it is not absolutely essential that this swath of spectrum be contiguous, it certainly reduces the cost of UWB if it is. In my previous work with David Farber, I suggested that in a property rights regime a *non-interfering easement* could be granted in *all* licensed spectrum, in which any non-interfering use (such as UWB) could use licensed spectrum without permission provided the licensee was not using the spectrum or would not be interfered with by the use in question.[120] UWB was the anticipated use for such easements (called "underlay" rights in FCC-ese). However, it was anticipated that (high power) agile radio could also use any licensed spectrum that was not in use by the licensee, provided it could vacate the spectrum within milliseconds of the licensee commencing use (called "overlay" rights in FCC-ese). Further analysis suggests that the transaction costs and potential for abuse of agile radio's use of a non-interfering easement may prevent its deployment.

119. *See supra* p. 144.
120. *See* Faulhaber & Farber, *supra* note 3.

Nevertheless, the concept of a non-interfering easement within a property rights regime certainly would accommodate the functionality for which commons advocates champion the commons solution. In other words, the non-interfering easement with a property rights model *is* the commons. It is with some surprise I note that having offered the same functionality of a commons within a property rights regime, the commons advocates continue to argue for a commons regime *instead* of a property rights regime. Commons advocates are apparently unwilling to accept the "win-win" proposition of non-interfering easements within a property rights regime that gives them virtually everything they claim they want.[121]

F. Flexibility to Respond to Changes in Technology and Demands

New technologies meeting new demands occur regularly in wireless without requiring modifications or changes in existing rules. For example, WiFi is a new technology meeting a new demand (for in-home networking) that fits well within the Part 15 rules at 2.4 Ghz, and was introduced seamlessly. Similarly, the extraordinary advances in cellular technology were introduced well within the cellular license rules and were integrated seamlessly. However, some technologies may not fit so easily; commons advocates argue that both UWB and agile radio do not fit into the classic licensing model, although introducing the minor change of non-interfering easements into the property rights model appears to solve that problem. But new technologies, unimaginable today, may also be disruptive of either commons rules or property rights licenses. How robust is either regime to disruptive technology?

There are several ways in which a new technology can impinge on existing arrangements: (i) a new protocol or standard could be introduced into wireless, such as spread spectrum in the 900 Mhz band in the 1980s; (ii) a new technology may require more or less power than existing rules permit; (iii) a new technology may require more or less bandwidth than existing bands permit; (iv) receiver technology may become more or less sensitive to interference; or (v) new technologies may require opportunistic or very low power use of existing licensed or unlicensed bands, such as agile radio or UWB.

121. This is not to say that non-interfering easements are obviously easy and costless to implement. Permitting alternative uses of licensed spectrum by random transmitters raised serious and difficult questions regarding methods of ensuring true non-interference, monitoring for non-interference, enforcement and identification issues that cannot be ignored. Should these problems be more costly to solve than the social value of the easement, clearly the easement concept should not be implemented.

1. New Protocols/Standards

The introduction of spread spectrum for cordless telephones under regulation and the adoption of standards for digital TV, discussed by Goodman,[122] are good models for how well the end-state regulatory regime would handle new protocols and standards in both licensed and unlicensed bands. This suggests disruptive protocols or standards are not likely to fare well in the end-state regulatory regime.

By contrast, in the property right regime, licensees are free to adopt new standards and protocols without seeking regulatory approval.[123] Market adoption of new standards is never a smooth process and may result in inefficiencies.[124] However, there is little evidence that regulatory standard setting is an improvement, especially given the opportunities for rent-seeking in the regulatory standard setting process.

2. Flexible Power Limits

If a new technology reduces the power limit required for a particular use, there is little incentive for individual users in an unlicensed band to adopt this new technology. Manufacturers of devices using unlicensed spectrum have some incentive to introduce power-conserving technologies, as it means they may be able to sell more devices. But this incentive is muted in that its introduction means that all manufacturers can sell more devices, leading to a free rider problem. These problems are not present in licensed bands; licensees have the incentive to introduce power-conserving technologies as they are the immediate beneficiaries of it. They may even choose to sell off some capacity should this occur.

If the new technology increases required power, then the end-state regulatory regime faces difficult negotiations in both licensed and unlicensed bands. Neighboring bands might be required to increase the quality of their receivers to tune out additional out of band power and neighboring locations might be required to do the same. In existing unlicensed bands, a changeout of all devices may be required to accommodate the new technology. Alternatively, a new unlicensed band

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122. *See* Goodman, *supra* note 3, at 376-77.

123. The theory of regulation discussed above suggests that regulation provides a mechanism by which competitors can seek to disadvantage innovators from adopting new technologies. The openness of the regulatory process ensures that anyone can object to any proposal to introduce technology that requires regulatory approval. Further, the theory also suggests that the scope of regulation will expand to cover new technologies should these innovations be perceived as a threat to other market participants. These institutional mechanisms are simply not present in the property rights model.

124. *See* Stanley M. Bensen & Joseph Farrell, *Choosing How to Compete: Strategy and Tactics in Standardization*, 8 J. ECON. PERSP. 117 (1994).

could be established for the new technology if one were available. At best, these options are likely to be quite difficult, take a very long time, and may not be successful. In a property rights model, a licensee who wished to use the new power-increasing technology could engage in neighborly bargaining with licensees in adjacent frequencies and locations. This bargaining would include possible payments to neighbors to adjust to higher power levels, or the buyout of the neighbors' licenses. Should this fail, the licensees could buy new spectrum licenses covering enough bandwidth and enough locations to enable it to deploy the new technology, as is implied in the anti-anticommons principle. However, the application could be location-specific, in which case options for deployment are more limited.

In sum, technologies that decrease power requirements are more likely to be deployed and exploited in a property rights regime rather than the end-state regulatory regime. Technologies that increase power requirements are in general more difficult to deploy in either regime, but are somewhat more likely to find success in the property rights regime.

3. Flexible Bandwidth

If the new technology enables applications to use less bandwidth than previously, the analysis of the previous section on power also applies. The incentives to deploy the technology in unlicensed bands is somewhat muted. In licensed bands, licensees have incentives to economize on bandwidth, not only to increase the use of their license but also to sell or lease any unneeded bandwidth.

If the technology increases bandwidth needed for applications, then the end-state regulatory regime may observe that existing unlicensed bands become more congested, leading to a tragedy of the commons. The regulator can respond to this by purchasing licensed spectrum and converting it to unlicensed spectrum, or it could impose new rules and limitations on users and manufacturers restricting the use of the new technology. Again, we would expect that regulatory resolution of this conflict would be costly and lengthy, and possibly not successful.

In the property rights regime, licensees who wish to expand their bandwidth to take advantage of the new technology can engage in neighborly bargaining with their neighbors to accept higher levels of out of band power, or they may negotiate the purchase of neighboring bands. Failing this, licensees can choose to sell their current spectrum and move to a new, larger frequency band at relatively low cost, as argued above. In fact, they may purchase several contiguous bands and aggregate them. The same mechanism would apply in the end-state regulatory regime, except that a competitor may petition the regulator to intervene on its behalf to halt this market transaction.

Thus, bandwidth-conserving technologies are more likely to be deployed in a property rights regime than in the end-state regulatory regime, as licensees can internalize the benefits of the innovation whereas users and manufacturers in unlicensed spectrum are handicapped in this regard. Bandwidth-increasing technologies are likely to lead to a tragedy of the commons in unlicensed spectrum, calling for regulatory intervention with its attendant costs, delays and uncertainty. In contrast, deployment of such a technology in a property rights regime calls for license aggregation: buying the licenses of adjacent licensees. Recalling the principle of the anti-anticommons, this should be both simple and low-cost.

Even without the deployment of software-defined radio, the evidence suggests that spectrum can be aggregated. The aggregation occurred during the 1990s, when a number of large wireless firms that owned licenses in some metro areas wished to expand their networks to have national scope. This required them to purchase specific frequency bands in specific locations, generally from other cellular companies, to fill out their networks. More dramatically, Nextel purchased over 40,000 SMR licenses nationwide to obtain nationwide coverage. In both situations, the firms managed to solve the holdup problem and put together nationwide networks. This process took time and money, but it did not stop any of the firms involved.[125]

Lastly, what might occur if the bandwidth devoted to different management options needs to change? For example, it could be that commons-managed spectrum is wildly successful and needs to be expanded at the expense of property rights-managed spectrum. In the end-state regulatory regime, the decision becomes regulatory; the regulator would have to decide how to value commons spectrum (as there would be no market price), how much spectrum to convert to commons, what bands were most appropriate, and then purchase the required licenses at market (and subject to holdup problems). It would then have to decide what commons uses would be permitted to use the newly available spectrum, including power limits and protocols. Each of these decisions could be expected to be costly, delayed and highly uncertain.

In a property rights regime, licensees that held their bands for open

125. The holdup problem is particularly severe in land, where developers must acquire contiguous land at a particular site for a successful project (indeed, almost all examples of the holdup problem used by commons advocates are based on land). Even here, aggregators have come up with interesting and compelling solutions: an aggregator can make a (generous) "all or nothing" offer to landholders, stipulating that individual offers are contingent upon all offers being accepted. In established neighborhoods, for example, such offers can change the social dynamic among neighbors from common resistance and holdups to common acceptance and social sanctions against holdouts. My thanks to Hon. Stephen F. Williams for this observation.

access would find their market value increase and seek to purchase new bandwidth licenses to expand their services. Alternatively, current spectrum licensees could also assess the market value of open access spectrum and choose to convert their current spectrum to open access. Included in this group of potential agents would be government (at any level) that could purchase licenses and convert them from exclusive use to commons use, if there were sufficient political demand for this. On the other hand, it could be that spectrum devoted to open access is less valuable than exclusive use spectrum; we would expect that licensees of commons spectrum would convert their frequency bands from commons to exclusive use, much the way an owner of an apartment building may convert the building from rental units to a condominium. This market-driven process would provide much clearer signals regarding the value of moving spectrum to or from open access/unlicensed to exclusive use.

In sum, the property rights regime is likely to adjust rather easily to technology and demand changes necessitating changes in required bandwidth. The end-state regulatory regime can rely on market mechanisms to be flexible for licensed bands, but is liable to encounter tragedy of the commons problems in unlicensed bands, which can only be resolved by regulatory interventions that are costly, delayed and uncertain. The overall allocation of bandwidth from commons to property rights and back is likely to be difficult in the end-state regulatory regime and relatively automatic in the property rights regime.

V. SOME ILLUSTRATIVE HYPOTHETICALS

In order to illustrate how each regime would operate in practice, I consider three cases in which an individual, firm or agency would operate within each regime, comparing the costs and benefits of each regime for each of the three cases: a full time exclusive use broadcaster, a two-way communication service (voice or data) and a municipality with public safety needs.

A. Case A: Broadcasting

A firm or individual wishes to operate a high-powered transmitter to broadcast entertainment (such as FM radio or TV) or other full-time exclusive use (such as an airport radar) in an SMSA (or nationally).

1. Property Rights Regime

The firm or individual purchases a spectrum license in the open market for the necessary bandwidth, power and location(s). This is almost identical to the purchase of a radio station (or network of radio stations) in today's market. If the operator wished to use the existing base of inexpensive receivers, it would be limited to broadcasting in bands the "dumb" receivers could tune in. However, the operator could choose to broadcast at any frequency it chose, provided "smart" receivers were available which could detect the new signal.[126]

If an immediate neighbor (in geographic space or frequency space) claimed that the operator was operating outside the power bounds specified in its license, the operator could hire a third party technical firm to verify that it was in compliance with its license (or not), and appropriate action be taken. Note that the number of neighbors is small.[127] In frequency space, there are only two immediate neighbors, on either side of the licensee's band (although in some cases non-adjacent bands could be affected, the number of "neighbors" remains small). In geographic space, only licensees in the three or four contiguous MSAs are immediate neighbors.[128] This could involve fixing a problem if it exists (requesting a grace period from the neighbor), or notifying the neighbor that the firm is in compliance. In this case, should the immediate neighbor decide to bring suit, the third party firm's data could be used in the firm's defense.

If the firm is in compliance but the neighbor is legitimately suffering interference as a result of the firm's broadcasting, the two neighbors would engage in neighborly bargaining. As neighbors with a fairly long term relationship, we would expect such bargaining would be successful; each neighbor would have an interest in maintaining a cordial relationship with the other to ensure that future problems can be resolved at low cost. Failing successful bargaining, the party suffering interference may attempt to bring suit under nuisance law, in which case the court must balance relative economic harms and costs of remediation. It is likely, however, that a court would find a transmitter operating within its

126. The "smart" radio would have radio stations such as "Power 99" or "Smooth Listening." In each city, this station might be broadcasting on a different frequency, or the frequency in a particular city may change over time. The "smart radio" would receive a download, perhaps once a day or whenever it was turned on, updating the local frequencies of all entertainment broadcasters, much as DNS servers in the Internet download update DNS information from the Internet root servers periodically, so that they may direct traffic appropriately for new servers and discontinued servers.

127. The interference detection problem is made more difficult if a non-interfering easement is present. A licensee may need to monitor its licensed spectrum to ensure that opportunistic users such as agile radios stay within their easement limits. This monitoring could be continuous or only in response to regular interruptions; the firm itself could do the monitoring or it could hire a third party monitor to detect and record out-of-easement power emissions. Under a property rights with non-interfering easement regime, agile radios would likely be required to broadcast an identifier so that infringers could be tracked and prosecuted. *See supra* p. 130.

128. If the licensee significantly violates its licensed limits, it could impinge on more distant bands and locations. But as a general rule, the immediate neighbors suffer the most significant interference and have the greatest incentive to complain and/or bring action.

license parameters not to be creating a nuisance. If the issue is still not resolved, the party suffering interference either mitigates the interference by upgrading receivers or purchases a spectrum license in a different band.

2. End-State Regulatory Regime

If the radio and TV bands continue to be allocated by the regulators to exclusive use, then the firm or individual will most likely purchase an existing radio or TV license and would proceed as today. If the firm or individual chooses to purchase other frequencies to which today's "dumb" radios or TVs are not tuned, then the firm would have to rely on customers adopting "smart" radios, as described previously.[129]

Dispute resolution in the exclusive use portion of the spectrum would likely remain with the FCC. There is ample evidence regarding the speed and efficacy of the FCC dispute resolution process, in particular its bias in favor of incumbents and the open nature of proceedings that permits intervention by competitors and other rent-seekers.[130] In essence, today's regulatory regime of dispute resolution is duplicated in the end-state regulatory regime, with all its attendant costs and biases.

It is not at all clear how entertainment broadcasting could work in a commons regime. Broadcasting is typically high-powered; even using agile/cognitive technology (a substantial expense for both broadcasters and users) in an open commons, the power mix problem ensures that low-powered users would suffer interference. Only further intrusive regulation could resolve this problem, and it would still be unattractive to broadcasters.

3. Case A Conclusion

A broadcaster could function well in a property rights regime, but would be more likely to encounter competition. Broadcast licenses would no longer command economic rents (unless there was an identification of a particular frequency with a brand name, such as "Power 99" in Philadelphia). In the end-state regulatory regime, broadcasters would function much as they do today in the exclusive use portion of the spectrum, and still be subject to FCC dispute resolution. They are unlikely to be able to function at all in a commons regime. The exclusive use licenses in the end-state regulatory regime promise the transactional flexibility of the property rights regime but continue regulatory dispute resolution, allocation of spectrum between exclusive

129. *See supra* pp. 129-30.
130. Goodman, *supra* note 3, at 376-77.

use and commons, regulatory selection of protocols and standards, and lobbying and other rent-seeking activity, with its attendant excessive delays and excessive costs.

B. Case B: Two-way Communication Service (voice/data)

A firm, individual or government agency wishes to establish a two-way communication system within one or more locations. This case includes a very broad array of systems. One example is systems designed for customers of the firm to use, such as a cell phone system or a wireless computer data system.[131] This would involve a localized wireless network accessing a landline network that connects with other wireless and wireline communication systems. Typically (but not always), such systems are open to all customers, decentralized and often use multiple antennas within an area. A second example is systems designed for a firm/agency's employees to use for internal communications. This would include such examples as police radio, fire radio, taxi dispatch, and firms with locally dispersed employees, such as construction firms or delivery firms. Typically (but not always), such systems are closed to all but the operating firm, have a central focal node, such as a dispatcher, and often use a single antenna within an area.

Both types of systems are similar enough so that their options under a property rights regime are roughly the same and their options under an end-state regulatory regime are roughly the same. In fact, some systems, such as Nextel's cell phone *cum* walkie-talkie system, fit both categories.

1. Property Rights Regime

The firm selling to end-customers would purchase sufficient frequency space in all locations; if the same frequency bands were available in all locations, then the firm could use fairly simple user devices, much like today's cell phones. If not, the firm could buy different frequency bands in different locations and require the use of smart phones by its customers to enable the phones to switch frequency bands in each city. Otherwise, the system would operate as today's cell phone systems work: the firm would attempt to attract as many customers as possible, offering them a wide variety of user devices (phones or PC cards for data services) and a wide variety of payment plans. The firm could choose to deploy a technology using multiple antennas that connect into the national telephone system (or the Internet, if data), or they could deploy a peer-to-peer mesh network, in which the infrastructure is contained within the user devices themselves,

131. Examples of such data systems include GPRS, 1*x*EVDO, WiFi and WiMax.

obviating the need for an antenna infrastructure. Typically, a *service* firm would deploy a system with infrastructure, establishing rules of use and acceptable user devices, while a *device* firm would be more likely to deploy a mesh network, building rules of use and protocols into the individual devices. In either case, the firm would hold the licenses for the frequencies and locations necessary for the system to work.

In the case of a mesh network deployed within a licensed frequency band and location, the user devices could be designed so that they could use up to the maximum permitted power level if the density of users was low and the nearest user device (which would be the relay point) was many miles away. As the density of users increased, the power levels could be reduced, since the nearest user device may only be several feet away. This ability to vary power depending on the density of the network enables a mesh network to be economically viable at low device densities. As the density increases, power can be reduced, leading to what David Reed has called *cooperation gain*.[132] However, this cooperation gain can only be achieved at fairly high device densities, and its benefit is severely limited if the required multiple "hops" to complete a message results in unacceptable delays (latency). Within a property rights regime, a mesh network may trade off cooperation gain by using higher powered devices to reduce latency problems (fewer hops) and handle lower device densities.

Interference problems among users within a frequency band can be managed by the licensee, perhaps by updating software within the permitted devices and controlling the number of devices sold in a particular location if necessary. Whether the licensee is operating a mesh network or a more traditional communications network with an antenna infrastructure, it is the licensee that is responsible for policing its own spectrum to ensure that interference does not occur, and has the legal authority to take action if necessary. Further, it is in the interest of the licensee to offer an acceptable level of interference (generally low but not necessarily zero) to attract and retain customers in the context of a competitive market.

If the immediate neighbors complain of interference due to out-of-license power emissions from the licensee's customers, both the licensee and his neighbors have the same options available as in Case A; each can hire a third-party monitor to detect, measure and record the presence or absence of out-of-license emissions. If a suit is brought, the records of the third-party monitors should be decisive in reaching a swift decision,

132. Comments of David P. Reed, to the *Public Notice* in Spectrum Policy Task Force Seeks Public Comment on Issues Related to Commission's Spectrum Policies, ET Docket 02-135 (July 8, 2002), *at* http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6513202407.

suggesting it is unlikely that most cases would actually be tried. If the neighbor suffered legitimate interference from the licensee operating within his license constraints, then the neighbor and the licensee could engage in neighborly bargaining; since they have an ongoing relationship as neighbors, it is likely such bargaining would be successful. Otherwise, the neighbor could bring suit under nuisance law, in which the court would decide on the basis of relative harms. If this does not resolve the issue, the neighbor can take mitigating action (such as buying new receivers) or move to other spectrum. Of course, this would involve changing the frequencies of both transmitters and receivers; but this could be realized using over-the-air system updates for smart phones.[133]

2. End-State Regulatory Regime

Deployment of a two-way voice or data communications system in the end-state regime offers both opportunities and problems. A *service* firm could provide a system with infrastructure within the exclusive use portion of the spectrum simply by purchasing the spectrum. Such an operation would be almost identical to offering cellular phone service today, except that service providers would have greater freedom to purchase spectrum in an open market with few of today's constraints. This would also entail continued FCC oversight and dispute resolution. One recent example of how convoluted and costly is this oversight and dispute resolution is the current Nextel band relocation case, discussed earlier.[134]

Could a service firm deploy a system with infrastructure in a commons spectrum? This would seem unlikely; as such systems usually depend upon high power (as do cellular systems today). If the system were deployed in an open commons, it would certainly require agile radios in order to avoid interference with other high-powered users. But it would also be subject to the power mix problem, and would likely interfere with low-powered users, which it would be unable to detect. Only if the low powered users deployed agile technology would they manage to avoid interference from high-powered users such as a cellular-type system. This would, of course, impose a cost on low powered users

133. Even with today's not-very-smart cell phones, information can be downloaded over the air to each phone, updating roaming information.

134. *See supra* pp. 138-40. Another example of a dispute before the FCC whose resolution was very costly and long-delayed is the NextWave case, involving disputed payments for auctioned licenses for spectrum to be used for wireless telephony. After two trips to the Second Circuit and one trip to the DC Circuit the case was eventually decided by the Supreme Court after five years; during this period, the disputed spectrum was not used in any way to benefit the public. *See* FCC v. NextWave Pers. Commc'ns Inc., 537 U.S. 293 (2003), *available at* http://caselaw.lp.findlaw.com/scripts/getcase.pl?court=US&vol=000&invol=01-653 (briefly discussing history of the case).

they would not have to bear if only low powered users were permitted. This suggests that a regulator may have to segregate commons for high-powered users from commons for low powered users, which again involves regulatory decisions which are likely to be disputatious, lengthy and costly. Additionally, operating a cellular-type system in an open commons, even using agile radios, subjects the system operator to the risk of congestion in the band; since it does not own the band and it is open to all, it cannot guarantee to customers a particular service level (dropped calls, failure to connect, etc.), and therefore cannot guarantee to investors that its business model will be viable in the future if and when congestion may occur.

A *device* firm would be more likely to deploy its system as a mesh network in a commons or in exclusive use spectrum. In the case of the commons, however, low power constraints on transmitters imply that only a high device density can support the service (since transceivers must be close together to act as relays for each other at low power). It is unclear how such a system could get started; obviously a new system will have a rather low device density, and thus be unworkable. It is also likely that latency problems could occur in such low power networks if many hops are required to transmit information. The deployment of mesh networks in a low powered commons environment is problematic. On the other hand, the device firm could certainly deploy its system in the exclusive use portion of the spectrum simply through direct purchase.

In the end-state regulatory regime, the communications service would still be subject to FCC dispute resolution, should interference occur. If cheating (such as using a pirate radio) is beneficial to the cheater even if costly to other commons users, there is a potential enforcement tragedy of the commons. This need not be the case of all such commons. For example, many Part 15 devices today work together quite well; there is no benefit to users of garage door openers or to users of inside/outside weather stations to increase their power. But CB radio during the late 1970s offers an example in which pirate devices caused substantial interference for the simple reason that it was in the interest of the pirate to increase power and the likelihood of enforcement was quite low.

3. Case B Conclusion

Two-way communications services from a service firm with antenna infrastructure are unlikely to be offered in a commons environment; the power mix problem may work against this high-powered use. The property rights regime appears to be their natural métier, as evidenced by today's highly successful cellular service. Device firms offering mesh networks are likely to find the variable-powered property rights regime preferable to the low-powered commons regime, in that the former allows them to solve the device density problem. As above, the exclusive use licenses in the end-state regime promise the transactional flexibility of the property rights regime but continue regulatory dispute resolution, allocation of spectrum between exclusive use and commons, regulatory selection of protocols and standards, and lobbying and other rent-seeking activity, with its attendant excessive delays and excessive costs.

C. *Case C: Public Safety*

A municipality wishes to establish (more likely, to continue) police, fire and emergency radio services for its public safety agencies. The demands of public safety agencies for radio spectrum are rather unique: at most times, the need is for administrative and isolated emergency traffic among mobile units and headquarters, using relatively little bandwidth. However, at times of civil disturbance or catastrophe, the needs change dramatically; many units are simultaneously deployed and must coordinate activities within and sometimes between agencies. The bandwidth requirements for public safety may increase dramatically at these times, and the ability of public safety agencies to protect and serve the public depends critically on having sufficient bandwidth, free of interference, to communicate instantly. Negotiations are not possible and compromise is not an option; clear communications requiring multiples of the normal bandwidth requirements are essential.

1. Property Rights Regime

Municipalities have already been allocated spectrum in today's regime and would be most likely to keep it under the new property rights regime. The amount of bandwidth allocated for public safety tends to be the maximum bandwidth needed for public emergencies; as a result, much of the bandwidth allocated for public safety lies fallow. Municipalities could adopt two strategies to improve their spectrum efficiency without compromising their mission goals. Under the first strategy, municipalities could adopt new digital technologies for transmission and reception which could reduce their bandwidth needs. They could then sell off the unneeded spectrum to others, covering the cost of the new equipment while helping the municipal finances. Ownership of the license ensures that municipalities have the incentive to engage in this mutually beneficial trade. Under the current regulatory regime, they do not.

Under the second strategy, in order to use their normally spare capacity, municipalities could also sell rights to others to use their spectrum during non-emergency periods using special cognitive radios.

During an emergency, a signal would be broadcast that would shut down all non-emergency spectrum use,[135] so that all available bandwidth would be used for emergency traffic only.[136] Examples of potential customers for these overlay rights would be construction firms and delivery companies. Municipalities would benefit by receiving revenues for the spectrum they control when they do not need it, and users willing to tolerate interruptions get access to spectrum at lower cost. Ownership of the license ensures that municipalities have the incentive to engage in this mutually beneficial trade. Under the current regulatory regime, they do not.

Should the licensees create interference by violating the license terms, or receive interference from a neighboring licensee violating its license terms, recourse to the courts would be direct, and third-party monitors could generate evidence regarding adherence by the parties to license terms. Because of the life-or-death nature of public safety services, neighbors violating their license terms may be subject to criminal as well as civil penalties. Interference caused by neighbors operating within their license terms could be handled by neighborly bargaining or by bringing suit under nuisance law, should that fail. Alternatively, either party can sell their spectrum and move to a different band.

Users of underlay spectrum could also violate the conditions of use, perhaps using an unauthorized device that did not turn off on command (just as a motorist today may refuse to yield the right-of-way to an emergency vehicle); they would then be subject to civil and perhaps criminal penalties (as is the unyielding motorist today) for such violations.

If the municipality wishes to move to a newer system, it may need less bandwidth or more. If it needs less, it can move to the newer system and sell off the unneeded bandwidth to help offset the cost of the new system. If it needs more bandwidth, it can bargain with its neighbors to buy a license for a contiguous band or it can buy a license for a non-contiguous band and use software defined radios to manage the use of multiple bands within a single device.

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135. The municipality could require that only certain devices be used in this underlay spectrum, which devices would have hardware embedded that would turn them off upon receipt of the "off" signal broadcast by public safety officials.

136. If a non-interfering easement is adopted for all spectrum including public safety, then the overlay right discussed here would be senior to the "free" overlay right of the non-interfering easement. Specifically, the owner of the overlay right discussed could broadcast as long as there was no emergency, and it would have an absolute right to transmit over anyone using the non-interfering easement. Only if the public safety agency *and* the owner of the underlay right were not transmitting could an agile radio use the non-interfering easement in this band.

2. End-State Regulatory Regime

Public safety agencies would likely prefer to use exclusive use spectrum in this regime, taking advantage of the transactional capabilities outlined above. The only difference would be the continued oversight of the FCC and that dispute resolution would remain a regulatory function. The current proceedings regarding the interference issues in the 800 Mhz band involving Nextel and public safety agencies is a clear case study demonstrating the excessively long and excessively costly regulatory dispute resolution.

Using the commons for public safety seems highly undesirable. Public safety radio is generally high-powered, and thus could cause the power mix problem if used in an open commons. If public safety radios are used in a high power commons only, then they would have to be agile, and yet still be subject to possible congestion or tragedy of the commons. A public emergency when life and limb are in danger is no time for a police radio to be blocked by a teenager using an agile phone to download pictures from Penthouse Magazine during a traffic burst. While commons advocates may claim this is unlikely, whose life are we willing to bet on this?

3. Case C Conclusion

A property rights regime is quite friendly to public safety use, even permitting costs to decline, and additional revenues to be realized, for municipalities. In the end-state regime, using a commons for public safety radio is undesirable; in a public emergency, first responders must be able to access the bandwidth they need without competing with other users of the commons. As above, the exclusive use licenses in the end-state regime promise the transactional flexibility of the property rights regime but continue regulatory dispute resolution, allocation of spectrum between exclusive use and commons, regulatory selection of protocols and standards, and lobbying and other rent-seeking activity, with its attendant excessive delays and excessive costs.

CONCLUSION

This paper lays out in some detail what we can expect from regulation based on evidence, and also lays out a legal framework for a property rights regime. It analyzes each regime on the basis of the four factors. For one of those factors, the end-state regulatory regime has the advantage, at least in commons-managed spectrum: there are no transaction costs associated with buying, selling or leasing spectrum. In the case of the property rights regime, the evidence suggests that these transaction costs are likely to be rather small, and therefore not a decisive issue. For all other factors, the property rights regime appears to dominate the end-state regulatory regime.

The new technologies have been a driving force in this debate, and without exception these technologies hold much promise. However, these technologies do not favor one regime over the other. These technologies enable the commons, in the sense that they help solve the tragedy of the commons (interference) problem, but they support property rights, in the sense that they help solve the holdup (tragedy of the anticommons) problem. The technologies cannot tell us the regime to choose, but they do make it easier to implement either regime.

It is important to recall that the focus of this paper is the evaluation of two "end-state" regimes, while ignoring costs associated with transitioning from today's regime to the preferred end-state regulatory regime. The economic and political costs of transition may differ greatly between the property rights regime and the end-state regulation regime, and these transition costs are important in making a good regime choice. But it is beyond the scope of this paper to undertake the task of analyzing these costs.

Ultimately, the choice of an overarching legal regime comes down to a choice between regulation and markets. There is much evidence about the economic performance of regulation, not the least from FCC regulation over the past 70 years. Markets in spectrum licenses are small and very imperfect; yet the existing spotty evidence suggests they work moderately well. The fears of commons advocates of monopoly, holdup problems and huge transaction costs simply don't withstand careful analysis. The conclusion is clear and inescapable.