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Issues Related to the Commission's Spectrum Policies	)	ET Docket No. 02-135
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To: The Spectrum Policy Task Force

COMMENTS OF PROFESSORS GERALD R. FAULHABER AND DAVID J. FARBER

Professors Gerald R. Faulhaber and David J. Farber, both of the University of Pennsylvania, submit the enclosed paper as a comment in response to the Spectrum Policy Task Force's invitation for recommendations to improve the Commission's Spectrum policies.*

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As experts in the field of wired and wireless telecommunications, we recognize that the current method of managing the electromagnetic spectrum by administrative fiat has reached the end of its useful life. As the Task Force recognizes, and we support, reform has become a necessity. We also note that while economists have been recommending for years the use of property rights and markets to allocate spectrum, engineers have more recently been recommending making spectrum a commons, on the basis of new technological developments, a very different allocation regime. We show in the enclosed paper that these two approaches can be reconciled to achieve both the benefits of both the market and the new technologies. We trust that our ideas may prove useful to the Task Force.

Respectfully submitted,

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* See Public Notice, "Spectrum Policy Task Force Seeks Public Comment on Issues Related to Commission's Spectrum Policies," ET Docket 02-135, DA 02-1311 (June 6, 2002)("Spectrum Policy Notice").

SPECTRUM MANAGEMENT: PROPERTY RIGHTS, MARKETS, AND THE COMMONS

Gerald R. Faulhaber and David Farber*

Introduction

Since 1927, the electromagnetic spectrum has been allocated to uses and users by the Federal government, covering broadcast radio, microwave communications systems, broadcast television, satellites, dispatch, police and national defense needs, among many others. Assignees receive a license to broadcast certain material (say, taxi dispatch) at a specified frequency and a specified power level (and perhaps direction). For many purposes, this license is time-limited, but with a presumption of renewal; in fact, radio licenses are almost always renewed. Licensees can only use the spectrum for the specified purpose and may not sell or lease it to others.

Economists since Ronald Coase (1959) have argued strongly and persuasively that allocating a scarce resource by administrative fiat makes little sense; establishing a market for spectrum, in which owners could buy, sell, subdivide and aggregate spectrum parcels would lead to a much more efficient allocation of this scarce resource. The Federal Communications Commission (FCC) has gradually been allocating more spectrum for flexible use and since 1993 has been using auctions to award most new spectrum licenses. However, this experiment in bringing market forces to bear to allocate radio spectrum has been applied to only about 10 percent of the most valuable spectrum. Economists continue to press for "marketizing" spectrum as the surest means to use this important national resource efficiently (White (2001)).

Meanwhile, substantial strides have been made in radio technology, including wideband radio (such as spread spectrum and ultra wideband (UWB)), "agile" radio (one of several applications of software defined radio (SDR)) and mesh networks (including ad hoc networks and other forms of peer-to-peer infrastructure architectures). The developers of these technologies note that the products based on these technologies undermine the current system of administrative allocation of exclusive-use licenses, and call for an "open range," or commons, approach to the spectrum that would do away with exclusive use. "Removing the fences," in this view, will lead to more efficient use of the spectrum.

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While both economists and radio engineers believe the present system of spectrum allocation is inefficient and wasteful, they appear to have diametrically opposed views of what should replace it. Economists seek to unleash the power of the market to achieve efficient outcomes; engineers seek to unleash the power of the commons to achieve efficient outcomes. Which is right?

We argue in this paper that this is a false dichotomy, based on a misunderstanding by some economists of the new radio technologies and a misunderstanding by some engineers of the flexibility of property rights and markets. We show that there are several property rights regimes that can simultaneously support both markets and the rapid diffusion of the new radio technologies, leading to a far more efficient allocation of this important and limited national resource.

Early Radio History: From Innovation to Government Allocation[1]

At its earliest inception, radio was seen as useful primarily for marine communications: ship-to-shore telephony. The failure to heed disaster calls from the Titanic in 1912 and the failure to fully realize the naval benefits of wireless in World War I created a public sentiment to improve the maritime uses of wireless communications, leading to the US Navy's efforts to cartelize the industry in 1919-1921.

Broadcast radio seems to have arisen spontaneously in 1921, when the first broadcast stations in New York and Pittsburgh went on the air, reaching thousands of hobbyists with crystal radios. The popularity of broadcast radio spread very quickly, and its commercial possibilities were realized almost immediately. However, the problem of interference was recognized early. If two (or more) broadcasters in the same city chose to transmit on the same (or very close) frequency, then each interfered with the other's signals and radio listeners were treated to cacophony. This was good for no one, and in the early years, a *de facto* property right standard of "priority in use" arose; quite simply, the first user "owned" the frequency, and subsequent users had to broadcast elsewhere. This property right was supported by the Department of Commerce and by 1926 was recognized by several courts.

In 1926, Herbert Hoover, Secretary of the Commerce Department, ordered that the Department stop supporting priority in use claims following two unfavorable court decisions. The result was rather chaotic; in major radio markets, interference became the norm as new firms attempted to poach on the frequencies of popular radio stations. In the resulting outcry, Congress passed the Radio Act of 1927, which established the Federal Radio Agency (FRA) with the responsibility of stewardship of the spectrum and the sole right to determine what various frequencies could be used for and who could use them. In the ensuing years, virtually every country in the world emulated the US by establishing a national agency solely in charge of allocating spectrum to uses and assigning it to users.

[1] The historical material presented here is drawn from Hazlett (1998), to whom the authors are indebted for his work in spectrum economics spanning over a decade, and from Benkler (1997), who presents a somewhat different view of the early history of radio.

All national agencies gather every three years at the World Radiocommunications Conference to discuss and resolve radio spectrum problems across administrative boundaries.

In the US, the Communications Act of 1934 created the Federal Communications Commission (FCC), vesting in it the FRA's spectrum allocation authority[2] (and abolishing the FRA). Since its inception, the FCC has interpreted its authority as the nation's spectrum manager rather broadly. Until quite recently, it imposed an equal time rule on broadcast networks and stations, by which if one candidate for office received air time then all candidates for that office must receive the same air time. Currently, the FCC also has the authority to review all corporate mergers and acquisitions that result in the transfer of radio licenses; the standard governing this review is a rather general "public interest" standard.

The standard procedure (until quite recently) was that an individual or firm wishing to utilize spectrum for a specific purpose license for a particular frequency in a particular location applied to the FCC for a license that covered only that purpose, frequency and place. After public notice, anyone else could also apply for the same frequency and location; should there be more than one applicant, a comparative hearing was held to determine which applicant was "more suitable" to discharge the public interest obligations of license-holding. Numerous critics have charged that this process could be politically influenced; one of the more notorious cases concerns the radio licenses obtained by Lyndon Johnson in the 1940s while he was a Congressman, which licenses became the foundation of his personal fortune (see Caro (1991)). Applicants were issued licenses for specified purposes; a license for taxi dispatch could not be used for ham radio, for example. Further, the license was limited to ten years, although issued with the presumption of renewal. Recently, renewal has become as easy as sending the FCC a postcard, but in the past license renewals could be and were challenged.

The award of the license did not grant the licensee any property rights in the spectrum beyond that of the license. The licensee could not use it for any purpose other than that specified in the license. If the licensee were purchased, or merged with another firm, the transfer of the license had to be approved by the FCC.

More recently, the FCC and Congress have retreated from the comparative hearings model. After a brief foray into licensing analog cellular licenses by lottery, Congress gave the FCC authority to conduct auctions for licenses for commercial services, excluding broadcasting. (Currently, all mutually exclusive FCC licenses except those used for satellite and public safety services are subject to auction). A number of auctions have since been held, raising over $14 billion for the US Treasury.[3] Again, the auction winners do not actually own the spectrum, but merely the license to operate mobile or fixed service (excluding broadcasting). The FCC (nor NTIA) does not assert ownership

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[2] The Commerce Department retained control over all spectrum used by the Federal government. This authority is now vested in the National Telecommunications and Information Agency (NTIA) within Commerce.

[3] http://www.fcc.gov/auctions/summary

of the spectrum, but does retain all rights to control it, including the issuance, conditioning and revocation of licenses; however, a recent ruling by a bankruptcy court in the NextWave case[4] ruled that a spectrum license is considered an asset of the firm and the FCC has no primacy over other creditors in reclaiming this particular asset. This would suggest that the FCC's residual control of all spectrum licenses is not absolute. Additionally, spectrum licenses granted to satellite systems have been explicitly excluded from the auction process[5].

The results of this process are not difficult to predict. Holders of spectrum are unwilling to give it up, even when they are unable to make use of it. For example, the FCC's experience in the 1950s with UHF television assigned 330 Mhz of spectrum to this use.[6] The experience was not successful, and this band is extremely underutilized. However, license holders are unable to use the spectrum for any other purpose (such as wireless telephony) and are unwilling to give it back (see footnote 37). Thus, this prime spectrum provides little value to consumers, while other uses (such as wireless telephony) claim to be in a "spectrum drought." The political nature of spectrum allocation is illustrated by Congress' direction to the FCC[7] to allocate spectrum to the broadcast industry for DTV (digital television), which has allocated channels 2-51 for this purpose.[8] The broadcast industry appears to be stoutly resisting the deployment of DTV and yet it is unwilling to give up the spectrum Congress gave it for this purpose. Again, valuable spectrum provides little value to consumers while other uses are starved for spectrum.[9]

There are several efforts underway at the FCC to improve this highly inefficient use of the spectrum. "Flexible use" is a policy initiative in which spectrum license holders are permitted to use their spectrum for products not specified in their original license. For example, if flexible use were applied to the UHF channels, then UHF license holders could use their spectrum for wireless telephony (or any other use).[10] Nextel is an entrepreneur that has already taken full advantage of flexible use, offering cellphone service using spectrum from the taxi dispatch band. "Band managers" would permit the licensing of spectrum to firms who could then lease this spectrum to others on commercial terms.[11] The FCC is also engaged in band clearing, in which current license holders are offered spectrum in other bands to give up their current allocation that could be more constructively deployed in other uses. Currently, the UHF channels 52-69 are targeted for band clearing.

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[4] NextWave Personal Communications Inc. v. FCC, 254 F.3d 130 (D.C. Cir. 2001). The FCC has appealed this ruling to the Supreme Court; the issue remains unsettled as of this writing.
[5] ORBIT Act, Public Law 106-180, 114 Stat. 48 (2000).
[6] By way of comparison, the FCC auctioned a total of 120 Mhz (in each metro area) for PCS use.
[7] Balanced Budget Act of 1997. U.S. Public Law 105-33, 111Stat 258,105th Cong.,1st sess., 5 August 1997
[8] 13 FCC Rcd 7418 (1998)
[9] Hazlett (2001) presents a thorough and carefully documented history of FCC spectrum decisions, illustrating the systematic inefficiencies of the administrative process with extensive case studies.
[10] Kwerel and Williams (1992).
[11] FCC, 2000 *Second Report and Order*, Service Rules for the 746-764 and 776-794 MHz Bands, and Revisions to Part 27 of the Commission's Rules, WT Docket No. 99-168, FCC 00-90 (rel. March 9, 2000).

Despite the recent moves toward more market-based spectrum allocation, the dominant mode of managing the spectrum is administrative fiat. Perhaps the closest analogy to the US's current approach is that of GOSPLAN, the central planning agency in the former Soviet Union. GOSPLAN drew up plans for every sector of the Soviet economy, determined how much of each scarce input was required for each industry and each factory, and then issued orders to each factory as to how much it was to produce and to whom it was to be shipped. GOSPLAN was subject to intense lobbying by powerful factory bosses regarding quotas and shipments, and allocations were politically mediated. While the FCC only controls the electromagnetic spectrum, it has operated in a very similar manner, and subject to the same political pressures. It should be no surprise that both GOSPLAN and the FCC processes have had similar results: woeful inefficiencies and wasted resources (see, for example, Kwerel and Felker (1985) and Kwerel and Williams (1992)).

The basics of the system we use today were established when the most important use of the spectrum was broadcasting and the range of usable spectrum was about 1% of what it is today. Few would argue that this system is optimal today, but many may lose if the system were changed. The system is so embedded in how we use the spectrum that change is practically unthinkable. Current licensees received scarce spectrum years ago at zero cost from the government under the expectation that it would be theirs forever. These licensees include not only TV broadcasters and telephone companies using microwave relay systems, but police and fire departments, Department of Defense, taxi dispatchers and paging companies. While zero-cost transfers represent a windfall gain to many licensees, to many others it is a component of their public service obligation that they could not otherwise afford. Is this a system that is admittedly highly inefficient yet with so many stakeholders that it cannot be changed?

The Economists' Critique

Ronald Coase The seminal contribution of economists to the issue of spectrum allocation was made by Ronald Coase (1959). Coase was awarded the Nobel Prize in Economics in 1991, and in his Nobel autobiography, wrote of this work:

> I made a study of the Federal Communications Commission which regulated the broadcasting industry in the United States, including the allocation of the radio frequency spectrum. I wrote an article, published in 1959, which discussed the procedures followed by the Commission and suggested that it would be better if use of the spectrum was determined by the pricing system and was awarded to the highest bidder. (Coase, 1991)

To an economist, this critique is as natural for the FCC's method of allocating a scarce resource as it was for the Soviet Union's method of running its economy. The market is a far more powerful and efficient allocator of resources than administrators and bureaucrats can ever be, no matter how knowledgeable and well intentioned. Efficient markets can realize their magic because they are highly decentralized processors of information.

Prices are determined by buyers and sellers interacting in the market, to ensure that demand and supply are equated. The ability of the market price to capture all the information regarding supply and demand is far greater than that of a centralized planner no matter how sophisticated their planning and allocation tools.

Coase's critique seems, in retrospect, blindingly obvious. For almost all activities in the US economy we rely on markets to allocate resources, and markets work somewhere between pretty well and extremely well. Why is spectrum allocated using this wildly inefficient, Soviet-style means of administrative fiat? Coase's solution was to create sufficient property rights in spectrum so that it could be sold to private owners who would then be free to buy, sell and lease spectrum. In legal terms, ownership of spectrum would be ownership in fee simple[12]. Spectrum could be aggregated or subdivided, according to the needs of customers as expressed through the market. As a result, all frequencies would move to their highest valued use. For example, owners of inefficiently utilized UHF channels would have both the ability and incentive to sell or lease their spectrum to wireless telephony firms, or even become such firms themselves.[13] The price at which such transactions occur would reflect the demand and supply for spectrum; since certain frequencies are particularly useful for certain in-demand applications, these frequencies might well command a price premium relative to other frequencies, as the market dictates.[14]

Fundamental to the efficiency of markets is scarcity. If resources are not scarce, if consumers can pick their food off trees that are never exhausted and if there is infinite bandwidth, then there is simply no need to markets, which have costs to organize, administer and maintain. Early hunter-gatherer cultures existed in such a world of plenty; unfortunately, as populations expand, the previously plentiful becomes scarce and people

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[12] Fee simple is the most common type of ownership (usually applied to real estate, more generally any ownership) that allows the owner to have unlimited control over a property. *Black's Law Dictionary* (6th ed., St. Paul, Minn.: West Publishing Co. at p. 615, 1990) defines fee simple as follows: "A fee simple estate is one in which the owner is entitled to the entire property, with unconditional power of disposition during one's life, and descending to one's heirs and legal representatives upon one's death intestate. Such estate is unlimited as to duration, disposition, and descendibility."

[13] Ownership generally confers two social benefits: (i) the owner has an incentive to deploy his or her assets in a way that maximizes the value of that asset, including selling or leasing it, which ensures that the asset is employed in its most valued use; (ii) the owner has a stewardship incentive to improve the asset (or not let it depreciate) if that increases its net value, such as improving land (in some cases, net value may be increased by permitting the property to depreciate). Spectrum ownership would satisfy the first but not the second condition, as it is neither improvable nor depreciable. While ownership permits spectrum assets to move to their highest valued use, the lack of a stewardship function may lead spectrum owners to be viewed as mere *rentiers* or "middlemen," an economic function historically held in low regard by the general public.

[14] In some cases, a use may be highly valued publicly but not be amenable to private production. For example, PBS is a public broadcasting network that produces TV shows that might otherwise be produced but have some public benefit and so receives both governmental and charitable support. There are, of course, other examples of worthy endeavors that require governmental or charitable support, such as live opera. In a market model, PBS (or a similar service) would buy its spectrum with government/charitable funds if the sponsoring organizations believed this to be the best use of their funds for the public benefit. If they believed some other use superior, then PBS may not survive. But this is a decision best taken by this venture's sponsoring organizations.

must find a way to allocate these scarce resources. In our own time, we have seen the oceans undergo the same transformation, as fisheries historically treated as an international commons became overfished and stocks have had to be allocated. Over the long haul, costly trial and error has demonstrated that when resources are scarce, markets are the most efficient way to allocate these resources. Grand experiments with government (rather than market) allocation of economic resources have ended badly, to say the least.[15]

Markets have also shown themselves to be particularly friendly to innovation, as owners of assets strive to make their property more valuable through the use of new technology.. Restricted licensing of spectrum, however, has the opposite effect. Since a licensee can only use his or her frequencies for their designated purpose, the incentives to innovate for a licensee are mitigated. An existing license holder may have incentives to innovate to increase the capacity of its frequency band if it can thereby serve more customers. For example, current licensees of satellite bands may have incentive to convert these bands to terrestrial digital cellular to make more efficient use of this spectrum. But since they are barred from different uses, innovation is limited only to existing authorized uses so that licensees' incentives to innovate are less than they otherwise would be.

As with any social change, transiting from a government-assigned licensing regime to a market regime almost always involves costs to incumbents who have large stakes in the existing system. As mentioned in the previous section, there are many beneficiaries of the current system and they can be expected to resist strongly any solution that involves taking back their long-held assets. We address this question in "Transitioning to Markets: A Modest Proposal," below. For the remainder of this section, we analyze a market-based system ignoring for the moment the problems of actually getting there.

As many college freshmen learn in Econ 1, not all markets work perfectly, and there is an extensive theory of "market failure."[16] One such "failure" that can arise from unrestricted use of property is a "spillover," in which one property owner's use creates costs (or benefits) to others. For example, a factory may produce pollution that is costly to others; alternatively, the owner of an apple orchard creates a positive spillover for the beekeeper next door (and vice versa). In the case of spectrum, spillovers in the form of out-of-band power in adjacent frequencies are important, and can generally be controlled by the careful definition of property rights. In today's regime, spectrum licensees operate under a set of technical restrictions regarding power and place of emission, and possibly direction and time of emission. In a property rights regime, these restrictions would be codified in the property rights of the frequency owner, who would then be subject to civil penalties should he or she violate these restrictions. In fact, such restrictions are often

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[15] The government must provide the essential infrastructure of laws, regulations, and courts to ensure that markets can perform their job of allocating resources well. But government provision of the market infrastructure is different than government substituting for the market.

[16] Such failures include public goods (such as national defense and the justice system), information asymmetries (such as consumers' lack of knowledge about drug efficacy), natural monopolies (such as electric power distribution), and spillovers (such as pollution or network effects). Of these possible market failures, ***only*** spillovers appear to be present in the case of spectrum (although the *use* of spectrum may have public good aspects, such as Part 15 spectrum).

codified in property rights and laws. My right to use my automobile is restricted by speed limits; my right to use my real property is restricted by noise and nuisance statutes of my state, county and local municipality. Property rights in spectrum would be similarly constrained, and in fact we already know what the constraints are: they are largely defined by the technical restrictions in current licenses. These licenses may also include both use restrictions and equipment restrictions that would *not* be included in property rights. The spillover of interference in adjacent bands can thus be eliminated by suitably constraining each owner's property right to use his or her frequency, exactly as we do today. Therefore, the spillovers associated with out-of-band out-of-area frequency emissions can be fully controlled through the appropriate and careful definition of the owner's property rights; emitters who violated these restrictions could be sued by those who suffered from the resultant spillovers for damages and perhaps penalties.

Interference From the economic perspective, radio interference is the spillover that is the primay rationale for government control of the spectrum. It is the interference spillover that requires limitations on the property rights of ownership in a market regime. While we focus on the property rights of the transmitters of radio energy, the problem of interference involves both transmitters and receivers. Restrictions on transmitters include in-band power restrictions, so one transmitter doesn't interfere with a transmitter at a distant location, and out-of-band power restrictions, to control emissions in frequency bands in use by others. But these constraints are based on the ability of the intended *receivers* to filter out spurious signals. For example, early TV receivers had little ability to reject power spills from adjacent TV broadcast bands. As a consequence, "guard bands" of spectrum were designated between each usable bands so that out-of-band power leakage would not impinge on nearby signals. The use of guard bands is wasteful of spectrum today, but was necessary given the technology of the time. Because they employed unsophisticated tuners, early TV sets were relatively inexpensive. Today the ability to discriminate and filter out-of-band power leakage is very inexpensive to build into TV sets. However, the wasted spectrum is still there, "protecting" TV sets, so television set manufacturers have no incentive to install more sophisticated tuners. The inefficiency of spectrum use is locked in because of receivers, not transmitters, require the use of guard bands.[17]

Today's technical rules on interference are likely to become tomorrow's property rights in spectrum. They are based on a balancing of the current technology of both transmitters and receivers. As the technology has evolved, the current licensing system has not been particularly successful at reclaiming valuable spectrum by changing the rules. An important question for any property rights regime is how well it permits property rights to evolve with technology.

Enforcement All property rights must be enforceable if they are to be meaningful. Today's licensees must be able to enforce their licenses, and if ownership of spectrum is permitted, owners must have a way to enforce their property rights.

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[17] In fact, all modern TV sets have digital filters, simply because they are now cheaper and produce a better picture quality than the older filters.

Typically, property rights are enforced by the rights-holder lodging a complaint against an alleged infringer. This might be a simple call to the police that a stranger is trespassing on my land and refuses to leave. It could be a patent holder filing suit in court against another party accused of infringing on his or her patent. Under the current system, a licensee complains to the FCC who may then investigate the complaint and, if appropriate, punish the infringer. In an ownership regime, the rights-holder brings a civil suit against the infringer.[18] In certain cases, such as patent law, special courts are available for adjudicating such cases because of the specialized knowledge required. In a spectrum ownership regime, the FCC could retain an enforcement role, or this role could be subsumed by special "spectrum" courts, or by the general court system. Thus, there are a variety of enforcement models available for an ownership regime. Which venue is most appropriate depends upon the transaction costs of each. The general court system has the great benefit that it is ubiquitous and available locally anywhere in the country. However, if special expertise is required to litigate spectrum claims because of technical complexity, then special courts or the FCC may be needed, albeit more costly. If property rights are sufficiently simple and clear, then the general courts may be the preferred venue.

Assumptions underlying fee simple ownership Since the earliest days of broadcast, the use of spectrum by licensees has properties that are facilitated by a fee simple property rights regime (and facilitated, less efficiently, by the current licensing regime). These properties are:

> *High power* Within the relevant geographic region, emission is at a high enough power that more than one emitter at the same (or similar) frequency will cause damaging interference to the signal of at least one emitter. In many cases, broadcasters emit 24 hours a day, 7 days a week, and non-interfering frequency sharing has not been possible.
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> *Dedicated Frequencies* Most broadcasters emit at a particular frequency (or a limited set of frequencies) so that simple receivers can easily locate them.

Under these assumptions, dedicating certain frequencies to high-powered licensees/owners is an efficient response to the interference problem. The difference between a fee simple property rights regime and the current licensing system is that a market-based regime is a far more powerful mechanism to achieve an efficient allocation of the scarce resource of spectrum, as it harnesses the self-interest of owners rather than relying on bureaucratic processes. However, technology has not been standing still, and new technologies have begun to undermine these assumptions of high power and dedicated frequencies.

The Engineer's Critique

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[18] Public enforcement, such as the police, is usually only available if there is an immediate threat to life or property.

Since 1938, the FCC has used its "Part 15" rules to permit the unlicensed use of certain "intentional emitters," such as garage door openers and cordless phones.[19] Such unlicensed emitters have been constrained to operate only within certain frequency bands and at relatively low power. These limits are enforced by requiring the manufacturers of emitting devices to certify their products as having been tested and found to be within the FCC's frequency and power limits. Manufacturers are required to submit their devices to the FCC or an FCC-approved testing lab. The FCC may sample the product for compliance. Certification is required for imported as well as domestically produced electronic products. While there are opportunities for cheating the system, the consensus within the industry and the FCC[20] is that type certification has generally worked well at controlling interference, and industry cooperation on device design to control interference has been successful.

The openness of Part 15 spectrum has also promoted innovation in spectrum use. Within the FCC constraints, engineers and scientists have developed systems for spread spectrum technology into cordless phones, wireless broadband networks into neighborhoods (such as Metricom's Ricochet service)**,** short-range wireless LANs and wireless home networks (such as "WiFi"). Not surprisingly, radio engineers have lauded the openness of Part 15 spectrum as a boon to innovation.

Further, many have noted that Part 15 spectrum has property rights akin to that of a commons: an asset available for the use of all, with common restrictions governing use restrictions for all.[21] If innovation has been so forthcoming in a commons environment of unlicensed use, then why not extend the commons environment to the entire spectrum? Advocates of this approach compare the level of innovation that has occurred under this commons model with the much more disappointing level of innovation under the current licensing regime, which they sometimes refer to as a private property regime (which it clearly isn't).

Engineers point to two recent developments that would seem to make use of the commons model especially well: ultra-wide band (UWB) radio and software-defined radio (SDR). These two applications show great commercial promise, and appear on the surface to be incompatible with both the existing licensing model as well as a property rights market-based model. We discuss each in turn:

Wideband This form of 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

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[19] Part 15 rules were originally adopted to cover "wireless phonograph," a device whose time has not yet arrived. It was later used to govern "unintentional emitters," such as televisions and personal computers, whose operation caused the emission of electromagnetic radiation. The rules limited both the power and the frequency of the emissions of such devices

[20] John Reed, Senior Engineer, Technical Rules Branch, FCC, personal conversation 4/10/02.

[21] We oversimplify; restricted sharing is permitted in certain other bands, in which low power devices are permitted to emit radiation in licensed bands.

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 off lots of power for lots of bandwidth. The power of the emission is extremely low;[22] 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, 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. In a property rights market regime, UWB signals would also appear in frequencies owned by others, even if not detectable.[23]

Perhaps the clearest analogy is the right of an aircraft to pass over my home. As the property owner, I do not have the right to forbid aircraft to do so, nor may I charge them a fee to do so. However, aircraft regulations require that aircraft not fly lower than 1000 ft. over any obstacle within 2000' so as not to create a noise or safety nuisance.[24] The property rights of aircraft owners and pilots are restricted so as not to interfere (by noise or safety) with my property right to enjoy my home.[25] In a similar vein, the FCC's recent ruling on UWB limits the power of emissions across the frequency band so as not to interfere with licensees' rights to use their frequencies.

Agile Radio This is a form of software defined radio (SDR), a term that covers a rather

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

[23] 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.

[24] Title 14, Code of Federal Regulations, Section 91.119 of the General Operating and Flight Rules

[25] Note that the current property right regime for real property could well be modified to permit homeowners to restrict aircraft overflight rights or set a price for each overflight, perhaps dependent upon altitude. There would clearly be a cost to such a system (see our discussion below regarding the tragedy of the anticommons), but only justifiable if airspace were a scarce resource, subject to congestion. Currently, airspace is regulated for safety and congestion concerns by the FAA (in the US) so a price system based on overflight rights is neither necessary nor particularly efficient.

broad category of devices and includes any device in which the received radio signal is processed by software. "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. Both transmitter and receiver must be agile for this system to function. For example, in principal 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,[26] 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 of original band. Provided the agile radio switches its emissions to another band, it need not interfere with the ham band. 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 (or owners, in a property rights market regime).

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. For many purposes, static allocation is the efficient solution; AM-FM and 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.

Mesh Networks 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[27] in a neighborhood could communicate (possibly at high bandwidth) with a Neighborhood Access Point (NAP) that could connect directly into the Internet (or possibly the telephone network).[28] Computers out of the immediate range of the NAP could connect to the NAP using other computers as relay points, thus extending its range through the use of single or multiple relay "hops" via the other computers in the network. 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, much as the Internet currently operates.

Mesh networks use much less power than conventional systems which need every computer to reach a central antenna. Mesh networked computers need only reach the

[26] 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.
[27] 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.
[28] A current example of a mesh network is Metricom's Ricochet network (now emerging from bankruptcy) which had many thousands of users in multiple cities at its peak. Metricom was based on ideas and patents of Paul Baran (see http://www.ricochet.net).

computer next door, and thus need 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 actually increase their capacity as the geographic density of users increases; in other networks (such as cellular), increasing density actually decreases available capacity because of interference.

New Technology and Property Rights

While the new technology opens up new opportunities for efficient use of spectrum, using either of these technologies appears to violate the license rights of current licensees. It also appears to be incompatible with a property rights market regime as well. Proponents of these technologies claim that they should be deployed in the context of a commons model, in which all can use the spectrum whenever they want, as long as we adopt simple rules to keep out of each other's way. In this view, property rights are the problem, not the solution; "building fences" of property rights violates the commons principle.

It is understandable that the developers of these new technologies hold the view that these innovations are likely to deploy most quickly and effectively in a commons regime. After all, much of the research was conducted within the Part 15 unlicensed spectrum, which is a commons regime. Further, the new technologies appear to use spectrum in new ways that don't easily fit into the legacy business model of high-powered dedicated frequency broadcasting. Why adopt a legacy-driven property rights model when the new technologies promise an end to scarcity? In this view, the commons model is best suited to the new technologies.[29]

Central to the choice between a property right regime or a commons regime are (i) scarcity and (ii) transaction costs. If a resource is scarce in that many people contend for its use, then a commons regime will be afflicted with the "tragedy of the commons," in which the resource is overused; in spectrum terms, we experience interference. In the face of scarcity, a property rights regime will function to ration the scarce resource; the resource will have a positive price and contention for it is resolved in the market. However, if the resource isn't scarce, then a commons regime works quite well without incurring the cost of a property rights regime. Further, if a property rights regime is imposed where scarcity is not present, the price of the resource at the margin falls to zero.[30]

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[29] A number of technical and legal scholars have made this argument persuasively, including Lessig (2001), Benkler (1997), Jackson (1999), Ikeda (2002), and Reed (2002).

[30] In the case of a property rights regime for spectrum, this does not mean that *all* spectrum would carry a zero price; there may be legacy uses of certain frequencies in certain locations that would continue to carry a high price. But it does mean that should spectrum not be scarce, then *some* spectrum would be available at a near-zero price.

The structure and magnitude of transaction costs determine the boundary between efficient regimes. If transactions costs of a property rights regime are quite high, then the costs of the tragedy of the commons must be quite high indeed to justify using a market regime. If the costs of a property rights regime are relatively low, then it is likely more efficient than a commons regime even at low levels of contention costs.

In order to focus on these central issues, we first examine two property rights regimes that appear to release both the power of the market and the power of the new sharing technologies to improve the efficiency of spectrum use.

Fee simple ownership with non-interference easement[31] In this regime, individuals and corporations would be able to buy, sell and lease specific frequencies in specific locations subject to power (and other technical) limitations, and would possess the right to emit at any time *without interference*. Other emitters could use this spectrum, but only on condition that they not *meaningfully* interfere with the owner's right to clear broadcast. Thus, UWB emitters that maintained power levels below the noise threshold would be non-interferers. Agile radio emitters that vacated a frequency within (say) one microsecond after the frequency owner began broadcasting would be non-interferers. Conversely, either a UWB emitter exceeding its power ceiling or an agile radio emitter taking too long to vacate is an interfering user and becomes subject to penalties.

In this regime, spectrum would be owned but subject to an easement that any and all users that did not meaningfully interfere with the owner's right to the spectrum could not be excluded from using the spectrum. In effect, this easement creates a commons at all frequencies and in all locations of a special type: non-interfering uses only.

Enforcement under this regime would require that UWB and agile radio emitters transmit a unique identifier (similar to identifiers built into computer network interface cards) and frequency owners could monitor and record violations. Penalties could be assessed much as traffic violations are handled; it is likely that third-party collection agencies would arise to handle these violations on behalf of owners. Such monitoring would result in costs to owners. Fines for violations could recompense owners for these expenses.

Pure fee simple ownership In this regime, individuals would be able to buy, sell and lease specific frequencies in specific locations subject to power (and other technical) restrictions, and would possess the right of *exclusive use*. Other emitters could use this spectrum, but only upon payment of a fee to the owner. Sharing fees could cover a range of options, from a long-term lease for the entire band to agile radio non-interfering use. The prices would vary, depending on the nature of the lease arrangement, with non-interfering uses such as agile radio most likely priced the lowest. Agile radio users could negotiate long-term use of a band ("forward contract") or negotiate band use at the moment of use ("spot market"). We would expect agile radio users would negotiate with various band owners in both markets. Prices in the two markets would generally differ.

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[31] We use the term "easement" somewhat freely, to indicate a restriction on ownership that specified others may use the property for specified purposes under specified conditions.

In the case of spot markets for spectrum, transactions costs are likely to be significant, as owners would have to monitor *all* uses, not just interfering uses.[32] Just as agile radio transmitters would be required to broadcast a unique identifier, owners would have to broadcast their price for use. Agile radio transmitters could thus "shop" for the least expensive frequencies.[33] It is likely that third-party collection agencies could manage the flow of lease revenues from users to owners, which may well involve thousands of lessees making very small payments each to thousands of lessors. However, there exist institutions that can handle this problem at minimum transactions cost, even without the magic of computers. A similar situation arises in the payment of royalties owed to musicians every time a song is played on the radio or in a jukebox. There are two associations, BMI and ASCAP, that monitor radio playlists and jukebox records, bill the responsible parties and send the receipts to the owners of the music. A similar arrangement is likely to be successful for band use micropayments as well. However, such a real-time spot market system will only arise if the transaction costs of owners is less than the value of the spectrum to lessors.

This regime would generally have higher direct transactions costs than the easement regime, and may be somewhat less encouraging of innovative non-interfering uses. The magnitude of indirect transactions cost is less clear; litigation regarding the use of the easement may well be extensive and costly.

These two property rights regimes focus on the *emitters* of radio energy; how about the *receivers*? The introduction of new technology in one band may only be possible if receivers in adjacent bands can accommodate the new technology, which may require a costly upgrade. For example, if legacy receivers had inexpensive tuners that picked up emissions in neighboring bands, then technologies that uses those bands would only be non-interfering if the legacy tuners were upgraded to filter out their emissions. We noted above that in the case of many receivers in adjacent bands, this could be infeasible if the new service providers had to convince owners of legacy receivers in adjacent bands to upgrade. However, the current radio industries have been successful using voluntary standard-setting among manufacturers. This model focuses on the manufacturers of receivers rather than end-customers, in particular on the chip manufacturers whose products constitute the core of both receivers and transmitters. If the industry can agree that (say) the introduction of agile radio is likely to result in more business for all participants, but at the cost of increasing filtering capabilities for receivers in adjacent bands, then chip manufacturers may agree to establish enhanced standards for new receivers (for these adjacent bands) effective immediately. If the average life of such a

[32] Obviously, such measuring and metering devices do not exist today, as there is no use for them in the current licensing regime. The technology to create such devices is well within today's state of the art; if produced in volume are likely to be low cost. However, they do represent a transaction cost to operating a market system.

[33] This plan is quite similar to that suggested by Eli Noam, "Spectrum Auctions: Yesterday's Heresy, Today's Orthodoxy, Tomorrow's Anachronism," *J. Law & Econ*, **XLI** (Spring), 765. Noam's plan involved a government-operated central monitor and market-making computer to clear all transactions. We envision each owner implementing such a system (if economically feasible). See also a critique of this plan by Thomas Hazlett, "Spectrum Flash Dance: Eli Noam's Proposal for 'Open Access' to Radio Waves," *J. Law & Econ*, **XLI** (Spring), 765.

receiver is (say) three years, then the agile radio service providers could begin using their technology in bands adjacent to the interferees after (say) twice the average receiver life, or six years, assuming that most receivers in the field at that point incorporate the enhanced standards.

The use of voluntary industry standards appears to have worked successfully in computer hardware and software. As new bus architectures have been developed in the PC market, software developers and peripheral manufacturers produce to the new standard while maintaining backward compatibility for some period of time. Eventually, compatibility of complementary products with sufficiently old systems is dropped, and the technology moves on. We believe this model is likely to work in the wireless world as well.

Military and Public Emergency Spectrum Use This unique use places unique demands on spectrum management. During an earthquake or defense contingency (local or national), there is no time to ask permission or negotiate with other parties; military and public emergency personnel need to have immediate preemption capabilities for spectrum capacity substantially larger than their everyday administrative needs. Under the current system of allocating spectrum, this requires that the maximum amount of spectrum be allocated to these uses, even though it is hardly ever used. Using agile radio technologies, this spectrum can be made available to others for routine use, with the contractual proviso that military and public emergency users have an absolute and immediate preemption right to the spectrum. There is a strong precedent for this; all private broadcast and cable systems can be immediately preempted by civil defense authorities who can commandeer their spectrum as part of the nation's Emergency Alert System,[34] which has a history of over half a century.

Transactions cost and the Tragedy of the Anticommons There are two forms of transaction costs of concern: (i) direct transaction costs of spectrum buyers and sellers; (ii) indirect transaction costs of dispute resolution. Disputes regarding interference will arise in either a commons regime or the two property rights regime; it is likely that courts will be called upon to resolve such disputes, and it is likely that courts will be more efficient in dealing with the familiar territory of property rights. However, the property rights with easement may require extensive litigation prior to establishing clear easement rights. We thus view pure ownership as having the lowest indirect transaction costs, ownership with non-interfering easement as next lowest indirect transaction costs, and commons as the highest indirect transaction costs.

Direct transaction costs show the opposite ordering. A commons regime has almost no direct transaction costs as no one is paying anyone.[35] The ownership regimes will incur costs for normal transactions among parties leasing or selling spectrum, which are

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[34] See http://www.fcc.gov/eb/easfact.html for a description of the Emergency Alert System.

[35] This may not be true; if the government is the controller of the commons, it may assess a fee to all users to cover administrative expenses, including dispute resolution costs.

unlikely to be significant.[36] However, transactions between owners and users of the newer technologies may have higher direct costs if buyers and sellers prefer a spot market. In this case, equipment capable of identifying and negotiating electronically within microseconds would need to be deployed. The technology and cost of this equipment is likely to be commensurate with the technology and cost of the advanced devices themselves. The capabilities of an agile radio, for example, are similar to the capabilities of devices required to identify and negotiate with multiple customers at very high speeds. Whether or not a spot market would be preferred over longer term contracts is not clear. The cost of the enabling devices for spot markets may well affect their popularity.

A more serious problem is that of the tragedy of the anticommons, a phrase coined by Heller (1998). If property has *too many* owners, each of which must agree before the property can be put to effective use, then each owner may attempt to "hold up" the other owners for a greater share of the rewards to effective use, thus barring the deployment of the property. Heller and Eisenberg (1998) applied this to patents in biomedical research, and in Heller (1999) he outlined a general theory of the boundaries of private property. Benkler (1997) uses the idea of the anticommons in the context of radio spectrum to argue that the transactions cost of a property rights regime may be prohibitive for the new technologies if legacy owners assert ownership rights.

The argument is perhaps clearest in the case of UWB. Suppose that the spectrum is exhaustively sold, so that an individual or firm owns each frequency band in each locality. Now consider a UWB transmitter, which requires the use of hundreds of these frequency bands (albeit at very low power) to transmit its signal. If the UWB transmitter is required to negotiate a contract with every single owner, and cannot broadcast until every single owner agrees, then the transaction costs are indeed quite high and the transmitter unlikely to be successful. The problem is much less severe for agile radio; if only half the owners agree to transmit short signal bursts from one agile radio to another, this is more than enough. Not every owner must agree, and therefore there is no "hold up" problem. Note also that this problem does not arise at all in the ownership with easement regime.

The tragedy of the anticommons ensures that the direct transaction costs for the pure ownership regime may be particularly high for UWB. For this reason, we favor the ownership with easement regime over the pure ownership regime.

Ownership and the Commons Establishing property rights in spectrum is often portrayed as eliminating the commons (Benkler (1997), Reed (2002), Ikeda (2002)); this is not the case. Commons (and more generally sharing) can exist within an ownership regime; our recommended ownership regime with an easement for non-interfering uses establishes such a commons via the easement. Should it be necessary to have a commons for potentially interfering uses, the most obvious avenue is for the Federal government can

[36] Such transactions occur in all other sectors of the economy: the owner of a factory in New Jersey (or of 20 Mhz of spectrum in New York City) may sell this asset to another party as a normal commercial transaction.

purchase a block of spectrum (which it then owns) and open the band to general use under terms and conditions similar to Part 15 (for example). In fact, any state or local government can do the same thing, establishing a "park" in which users are completely free to use the spectrum without permission provided they follow the rules laid down by the owner of the "park." This is perfectly analogous to public lands, such as National and State Parks, National and State Forests, and municipal parks. Further, private foundations could establish such "parks;" for example, there are many horticultural parks open to the public that are maintained by private foundations. Local neighborhood cooperatives could achieve the same end, possibly requiring a one-time or monthly fee for use. Similarly, private firms could establish such "parks," charging a one-time or monthly fee for use. We would expect that manufacturers of mesh network devices, for example, may choose to "prime the pump" by establishing spectrum parks in various localities to increase their equipment sales.

Any or all of these mechanisms would permit mesh networks to flourish. The authors cited above have alleged that an ownership regime is fundamentally incompatible with the deployment of mesh networks. In the paragraph above, we count at least six ways in which mesh networks can flourish in the ownership regime with non-interfering easement. While we agree with these authors that mesh networking is an exciting new technology that may well shape the future of communications, we have demonstrated that their assertion regarding mesh networking's incompatibility with an ownership regime is incorrect.

Scarcity, markets, and new technology Both economists and engineers agree that the current licensing regime has led to grossly inefficient use of the spectrum resource. If the ownership with easement regime is universally adopted, the alleged "spectrum drought" will almost surely turn into a "spectrum flood," as large amounts of underutilized spectrum come into the market. Current inefficient uses such as UHF TV[37] will come to market quickly once a market regime is in place, with more than enough bandwidth to satisfy immediate demands. Based on this presumption, we conclude that *in the short run*, excess demand will likely turn into excess supply, except in certain especially useful frequency bands. In this situation, *the price of spectrum at the margin is likely to be zero* (or very close to it).[38] This short-run excess supply occurs as a result of markets eliminating current inefficient uses. While this may not be good news to cellular carriers who have spent billions on bandwidth made scarce by government regulation, it is good news to the consuming public and we should welcome it. Under either regime, the artificial scarcity created by the current licensing regime is eliminated.

[37] At present, UHF stations are broadcasting and virtually no one is watching; the reason is the FCC's "must carry" rule: any local station doing over-the-air broadcasting must be carried by local cable television. Therefore, any station broadcasting, even though no one is watching the over-the-air broadcast, get carried on cable TV, where lots of households are watching. We would propose that the FCC grandfather the "must carry" rule for all currently broadcasting stations; without requiring them to continue this unnecessary activity.

[38] Not *all* spectrum will be priced near zero; for example, FM radio station frequencies and cellular wireless frequencies will continue to command a premium. Our assertion is that *some* spectrum will be available at low cost.

We do not expect this short-run excess supply to last. New uses of radio spectrum should come on stream fairly quickly, promising to fill this newly available spectrum. But we also expect the new technologies of UWB, agile radio, and mesh networks to come on stream in parallel, and these technologies will again result in excess supply of spectrum, certainly for the medium term. In the long term, we expect that new uses for radio spectrum will utilize the spectrum fully, and the demand and supply of this important resource will come into balance. The demand for spectrum is likely to grow very rapidly; in the not-too-distant future, this new "unlimited bandwidth"[39] would become limited indeed, as demand grew to meet the available supply. The nature of the market changes, and spectrum bandwidth now becomes a scarce resource; not now, but in the future.

In a long run world of spectrum scarcity (real this time, not the artificial scarcity of government allocation), prices are no longer zero and the commons model breaks down. Agile radios will find the next frequency they hop to is busy, as is the next, and the next, and so forth. As the airwaves congest, the best solution will be the market, as it is for virtually every other economic good or service. In the long run, therefore, the commons portion of the spectrum (including the non-interfering easement) will be highly congested, and many users will migrate toward owned spectrum to ensure access and quality. In a world of real spectrum scarcity, owners will invest in metering gear and charge users a positive price, ensuring that the spectrum is allocated, in real time and otherwise, to its highest valued use.

Pure commons regime How would a pure commons regime work? Unfortunately, high power dedicated spectrum uses are likely to be a fixture of any system for a long time, and such uses fare poorly in a commons model as there is no guarantee of non-interference from other high power dedicated frequency users. If a commons regime were to be adopted, this would reproduce the radio world of the early 1920s. If *all* users were forced to undertake a costly upgrade to agile radio (or UWB, if feasible), then a commons regime may be workable in the short run, as long as scarcity is not an issue. However, as new devices and new uses proliferate, spectrum scarcity will become reality. There still is a limited amount to go around, and at some point it will get used up. This is especially true of "sweet spot" spectrum that is particularly good for certain popular services such as cell phones. In this long run view, a commons regime is quite limiting, and another regime change to markets will be required.

Is it likely that in the long run spectrum will indeed become scarce? While today's massive underutilization of spectrum suggests that markets and new technology may increase available spectrum by orders of magnitude, we have no doubt that clever

[39] The pre-1996 Internet community was particularly fond of the "unlimited bandwidth" vision of the Internet. Everything could be free, it was argued, because the bandwidth of the Internet was virtually unlimited. Post-1996, the phenomenal growth of Internet traffic quickly dispelled the notion of unlimited bandwidth; new applications engendered new demand that quickly exhausted what had appeared to be unlimited supply, and then some. Similarly, we have great faith in electronic engineers and entrepreneurs to create a demand for spectrum that will fill every nook and cranny of it.

engineers and aggressive marketers will find ways to fill that spectrum with new and useful gadgets that we all must have. We believe the long run answer is clear: ways will be found to use all the spectrum we can make available, and eventually it will become scarce.[40]

Conclusion A market-based ownership with non-interfering easement regime is compatible with the deployment of UWB, agile radio and mesh networks. In the short run, we believe this regime is likely to free up so much spectrum that this resource will be in excess supply. In the long run, as this resource becomes better utilized and spectrum becomes scarce, we expect that owned spectrum becomes more attractive as a superior method to manage scarcity.

Transition to a Market-based Regime

Our paper thus far has compared the "end-states" of two regimes: the current licensing regime, the ownership with non-interfering easement regime, and a commons regime, without discussing how the ownership regime could actually be obtained in the context of spectrum politics. We argue above that the market-based regime has more attractive economic properties than either the commons regime or the current licensing regime, especially the real-time leasing regime in the long term.

Any transition plan from the current regime to a market-based regime inevitably will create winners and losers. Losers, of course, will oppose the transition, and winners may favor it but seek even greater gains. In other words, the process is essentially political and the transition must be structured to ensure that all or most stakeholders are not harmed.[41] We thus take the world as it is (warts and all) and seek a politically viable transition plan to a more efficient regime.

Defining property rights Constructing the bundle of rights that constitute property in spectrum must be done with great care, and must precede any attempt to institute markets. In particular, the scope of property must be economically viable in order to avoid the tragedy of the anticommons. But it must not be so large as to encourage market dominance. DeVany et al. (1969) discussed in detail how to define property rights in their seminal article, and is an excellent starting point for this exercise. White (2001) is also useful in this regard. Generally, these authors recommend that technical constraints regarding time, area (including power limitations) and frequency should constitute the

[40] A more subtle point is that technological advances can increase the efficiency with which we use spectrum. But if more spectrum is available at zero cost, then it doesn't pay to invest in using spectrum more efficiently. Only as spectrum becomes scarce (as it is now, artificially, and as it will be in the future, for real) does it pay to invest in more efficient use.

[41] Inevitably, that means perceived inequities that have been built into current system will not be "corrected." Some may view certain current licensees as undeserving of reward, either because they received their licenses through questionable political dealings or from corporate power. We believe that moving toward a more efficient regime of spectrum allocation is far more important than correcting for perceived inequities in the current allocation of licenses.

property bundle. Additionally, our recommended option of a non-interfering easement requires a careful definition of what constitutes interference.

Determining this bundle of rights promises to be a daunting task with technical, economic and political components to that task. The measure of difficulty can be assessed by noting the intensity of the recent debate at the FCC regarding appropriate power and interference levels for ultra wideband deployment. Getting the bundle perfect is not necessary, as mistakes can be remedied by private contracts later. However, getting the bundle approximately correct is important so that post-market bargaining is more efficient.

Broadly speaking, current licenses constitute economically viable bundles, and the technical requirements of these licenses would be an excellent starting point for a property rights bundle. However, current licenses also have use restrictions and in some cases actual equipment restrictions. Such restrictions should not be incorporated into the property rights bundle. In some cases, the current license is tightly tied to a particular use; for example, point-to-point microwave licenses are geographically restricted so that they can be used for little else except microwave, thus limiting their marketability. Such anomalies may need correcting before adopting a market-based regime.

Getting to market We present this proposal in broadest conceptual outline, without pretense that the technical details have been worked through. We do not claim authorship of this proposal; this transition plan has been put forward by Kwerel and Williams (2001) of the FCC. We endorse this plan as a starting point for a “win-win” transition to the market-based technology-friendly regime we believe we need.

The main features of this transition plan are: (i) it moves from a government allocation scheme to a market-based regime; (ii) it is wholly voluntary on the part of current license holders; (iii) incentives are provided so that current licensees will place their current license asset into the market; and (iv) it eliminates all use restrictions and keeps all technical restrictions as limits on the eventual owners’ property rights.

The process:

1. The FCC and NTIA announce that in one year’s time, an auction will be held for all spectrum technically available for broadcast, including all government-held spectrum for defense, police, fire and other public safety uses, and “white space” spectrum held by the FCC.
2. Each licensee may choose to place its spectrum in this auction; it need not do so, but if it does not, then for a period of five years it is prohibited from taking advantage of buying, selling or leasing spectrum and will continue to be limited to its licensed use.
3. A licensee may place its spectrum into the auction simply by notifying the FCC of its decision.

4. The auction is held; any party can bid on any spectrum band it wishes, including part of an existing spectrum license.[42] If its bid is accepted, *the current licensee receives the full bid payment*. The successful bidder acquires ownership in fee simple (under whichever of the two regimes discussed in the previous section) with no restrictions on use but all technical restrictions.
5. No current licensee is required to accept a bid for spectrum it has placed in the auction; it has the "right of first refusal," and may keep the spectrum regardless of the bid.[43] If the licensee accepts the bid, *then the entire bid is paid to the existing licensee.*
6. If the current licensee decides to keep all or part of the frequency band of his license, it becomes his property (under the ownership with non-interfering easement regime previously discussed); all use restrictions are lifted, all technical restrictions remain. The owner is now free to buy more spectrum, sell all or part of his or her existing spectrum or lease its spectrum for any length of time.
7. After this "big bang" auction, we expect an active secondary market in spectrum to arise, in which owners of spectrum can trade freely. The FCC (and NTIA) would exit the spectrum management business altogether (except possibly for certain enforcement duties).

The purpose of holding the auction of all spectrum at the same time is to ensure liquidity; there is enough spectrum available that bidders can be assured of getting what they want and selling what they want. Additionally, the single auction becomes a salient event, capturing the attention of top corporate managers. This ensures that top management becomes aware that they may be able to capitalize their spectrum license asset to improve shareholder value. Spectrum managers further down in the organization may have no such incentive, preferring simply to hold on to their jobs as experts in FCC regulations. With top-level corporate attention, it is more likely that spectrum would end up in the auction.[44]

Government role The role of the Federal government in this "big bang" auction is twofold: (i) to conduct the auction, and (ii) to participate in the auction as a buyer or seller to own blocks of spectrum for (a) governmental purposes, such as defense, and (b) public spectrum, or commons, for use by anyone. We envision the FCC conducting the auction; it has more operational expertise in this function than any other agency in the

[42] It would be preferable for bidders to be permitted "combinatorial" bids, in which they may bid on a combination of existing licenses. See http://wireless.fcc.gov/auctions/31/releases/milgrom_reply.pdf for a description of combinatorial bidding in the context of licenses for wireless communications.
[43] It would appear that there is no economic reason to hold spectrum back from the auction, as the current incumbent always has the right to refuse all bids. This is correct; incumbents are better off placing their spectrum into the auction than not. The holdback option gives all incumbents a pure "no change" option, and can help focus managers and shareowners on the benefits of using the auction process to value their asset and possibly monetize it.
[44] A similar situation obtains in the public sector. A police chief has little incentive to put his or her excess public safety band in an auction; however, his mayor and city council might consider a partial sell-off of police bandwidth a good budgetary tradeoff.

world. We envision an operating arm of the Federal government (perhaps the Department of Commerce) deciding how much spectrum is needed for governmental purposes and for public commons purposes, as directed by Congress. After the auction, the government can go to the secondary market if it needs more or less spectrum for its purposes. Thus, the extent of public spectrum held as a commons is a political decision made in the broader context of a property rights-based regime.[45]

Most important, there would seem to be few if any losers from participating in this process. Current holders of spectrum licenses would be afforded the opportunity to capitalize some or all of their assets; if they chose not to do so, they now own these assets and can use, sell or lease them as they wish in the future. Those who are not current licensees but who require spectrum for their business plans now have the opportunity to buy it on the open market. No one is forced to put their spectrum at auction; but if they choose not to do so, they cannot take advantage of the new regime for five years. Everyone is better off participating in this process rather than not.[46]

We note the similarity of our proposal to that of Lessig (2001), who also proposes a mixed system of property and of commons. We arrive at our solution from a property base, while Lessig appears to arrive at his from a regulatory base. Nevertheless, we arrive at similar recommendations from very different bases, suggesting a common ground between market advocates and commons advocates.

Conclusion

In this paper, we considered property rights regimes and a commons regime in spectrum as alternatives to the current licensing regime, which appears to lead to substantial inefficiencies in spectrum allocation. We noted that economists have favored a market-based regime while engineers have favored a commons-based regime to promote new technologies. We show that there is a property rights market-based regimes that unleash the power of the market and unleash the power of the new technologies to efficiently allocate spectrum that is likely to meet our needs for the near-term future. The presumed dichotomy between the market-based and the commons-based views has been resolved, so that both objectives can be realized. We also outline a transition process to achieve the desired regime outcome that is a “win-win” for all stakeholders, and could be politically feasible. The change to a property rights regime is likely to lower the cost of spectrum substantially, in many cases to zero. Both a commons model and a market model can co-exist it would seem, at least until spectrum becomes truly scarce.

[45] Our proposal is perfectly analogous to land use. All land in the US is owned, and the Federal government is the largest owner of land in the country. Some of this land is owned for government business and much is owned as a public resource. How much land is committed to each use is a political decision, implemented through real property markets.

[46] However, the process may result in some parties being made worse off, compared to the existing regime. For example, if we are correct that the price of spectrum at the margin will decline, then parties with large investments in current licenses will see the price of their asset decline.

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