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# Optimal Abolition of FCC Spectrum Allocation

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On November 2, 1920, U.S. radio broadcasting edged into the marketplace when Westinghouse's KDKA station in Pittsburgh, Pennsylvania, aired reports of the presidential election held that day. By year-end 1922, some 500 broadcast stations were on the air. "Priority in use" airwave rights were enforced by the Department of Commerce. But on July 8, 1926, Commerce Secretary Herbert Hoover announced that, in response to conflicting court opinions, the Department would no longer enforce broadcasting rights. Stations became free to jump wavelengths, and many did. Within seven months, some 200 new stations emerged. The resulting chaos demanded a remedy. In November 1926, the *Chicago Tribune*'s WGN obtained a court injunction against an interloper, protecting its use of a frequency under common law. But neither policymakers nor the large commercial stations saw this as the preferred solution. In December 1926, Congress passed a statute requiring all broadcasters to waive any vested rights in frequencies, and in February 1927 the Radio Act established the Federal Radio Commission. Evolving into the Federal Communications Commission in 1934, the agency would administratively determine what use could be made of airwaves according to "public interest, convenience, or necessity"—a standard put forward by the fledgling National Association of Broadcasters (Dill, 1938).

The 1927 legislation represented a bargain between policymakers, who obtained influence over programming (including such regulations as the "equal time rule" and, later, the "fairness doctrine"), and radio station owners, who enjoyed rent protection via regulatory barriers to entry (Hazlett 1990, 1997, 2001a). Consumers were not well-represented in this legislative bargain: in fact, one of the first actions taken by the Federal Radio Commission was to reject an expansion of the

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broadcasting band that would have accommodated hundreds of additional stations. Moreover, the Federal Radio Commission soon forced many small broadcasters off the air. The Commission structure also illustrated overarching political influence; for example, the FRC was required by law to divide the United States into five geographic regions and to issue an equal number of radio licenses in each region, despite population and demand differences across the regions.

Critics soon began to ask whether regulation of the airwaves was serving the public interest. An early study by the Brookings Institution concluded that the Federal Radio Commission was the most politically-charged agency yet to appear in Washington (Schmeckebier, 1932). A University of Chicago law student named Leo Herzel (1951, 1952, 1998) provocatively argued that airwave rights be auctioned rather than assigned by fiat. Ronald Coase (1959), impressed by the essay, proposed a general regime of spectrum property rights. But when Coase was asked to testify at the Federal Communications Commission, the first question a commissioner asked was, "Tell us, Professor, is this all a big joke?" (Coase, 1998).

The idea of liberalizing airwave regulation gradually gained ground among scholars, only to be rebuffed in the political process. In 1976, FCC commissioner (and now University of Virginia law professor) Glen O. Robinson argued for reforms that included competitive bidding for licenses, a suggestion that led two other commissioners to respond that auctions had about as much chance as "the Easter Bunny in the Preakness" (Robinson, 1978). In 1978, the Chairman of the U.S. House Communications Subcommittee, Lionel van Deerlin (D-CA), introduced a bill to abolish the FCC, replacing it with a "Communications Regulatory Commission" permitted to assign licenses by auction and to regulate only "to the extent marketplace forces are deficient." The legislation failed.

But by the 1980s, the wireless marketplace was in fundamental realignment. The seminal event was the introduction of cellular telephony. Mobile phone service had existed since the 1940s, but a fixed number of channels—for example, 12 in New York City—were shared. One channel was required for each call, such that no more than 12 conversations could occur at once.[1] Cellular systems reduce signal power, linking phones short distances to local relay points or "base stations." The area around each station—a "cell"— hosts phone calls on each channel, while other cells do likewise, reusing spectrum. With hand-offs, users roam across cells. A band that hosted only 12 calls at one time now hosts thousands, with capacity limited only by the cost of "cell splitting."[2]

[1] In 1976, 543 subscribers shared these twelve metropolitan New York channels, with another 3,700 customers on the waiting list. Service was poor with circuits frequently jammed (Calhoun, 1988, p. 31).

[2] Digital technologies soon increased the communications capacity of cellular systems, as well. Through time division multiple access (TDMA), a link is shared by multiple calls that send digital information in short, alternating bursts (lasting a small fraction of a second) that are unnoticed by users but which stack additional communications. With code division multiple access (CDMA), digital information for multiple calls is transmitted throughout a given band, but coded such that the recipient receives just the information intended for them. Overlapping coded links yield denser bandwidth use and are generally referred to as "spread spectrum."

Cellular technology was designed at Bell Labs in 1947, but no spectrum was allocated for this use. Finally, an FCC proceeding began in 1968, ultimately allocating 50 MHz of spectrum to two licenses (25 MHz each) per market. Assignments, mostly by lottery, occurred in 1984–86 (urban–suburban markets) and 1988–89 (rural markets). A specific analog technology was initially mandated, but a 1988 reform permitted carriers to adopt the digital standard of their choosing. In general, cellular operators were given far more discretion over system architecture and business models for their spectrum use than had ever been granted radio or TV broadcasters.

Liberal reforms continued in the 1990s, when competitive bidding was adopted for the assignment of wireless licenses. By 2001, at least 27 countries, including New Zealand, the United States, India, the United Kingdom, Germany, Italy, Turkey, and Brazil had auctioned permits (Hazlett, forthcoming). For discussions of the U.S. experience with auctioning spectrum rights in this journal, see McMillan (1994) and McAfee and McMillan (1996). For the international experience, see Klemperer (2002).

License auctions improve assignments, reducing political discretion and placing rights in the hands of the parties most productive at employing them (Cramton, 2002). Still, spectrum allocation remains in the hands of regulators, who continue to determine, case by case, how particular airwaves can be used. Even with the most liberal rules now in place, generally for mobile phone networks, the overwhelming proportion of economically important bandwidth is reserved for limited and specific uses, unavailable for market allocation. An innovator seeking spectrum access to these bands cannot purchase frequency rights, but must petition for a "public interest" ruling.

Meanwhile, the modern information economy continuously suggests valuable new uses for radio spectrum. We are already some generations along in the evolution of spectrum-based services. Broadcast TV and radio, once dominant, have been eclipsed both within the mass media, where cable, satellite, and Internet delivery platforms have emerged, and in the wireless sector, where mobile telephony now dominates. For example, U.S. TV broadcasting in 2006 accounted for revenues of about $40 billion, while cable and satellite TV saw video subscription receipts of approximately $64 billion ($93 billion overall) and cellular carriers generated service revenues of $118 billion.

This paper begins with a tour of the radio spectrum, what it is, and how it is allocated. It discusses problems that have occurred with administrative allocation, and makes the case that the control of the Federal Communications Commission over the allocation of spectrum should be abolished. A general allocation of property rights, permitting any wireless operations within an owner's frequency space, would substitute for regulatory determinations. Broad distribution of exclusive rights would enable competitive markets to discover optimal deployments. All types of spectrum use and all manner of spectrum owners—including firms, industry consortia, nonprofit organizations, or public agencies—can be efficiently accommodated within such a regime. In fact, the legal devices for this transition have already been tried and tested.

## An Economical Tour of the Electromagnetic Spectrum

The electromagnetic spectrum is an input into wireless communications. From satellite television to garage door openers, emitting radiation through the electromagnetic spectrum can create valuable outputs. How can this natural resource be most efficiently used?

Consider a television broadcasting service. Video transmitted over-the-air can cheaply deliver valuable content to households, but that simultaneously makes it difficult for another video signal to be transmitted on the same channel to standard TV sets in the area. The U.S. analog standard adopted by the FCC in 1941 delivers one program in a 6 MHz band. The same frequency space can, using digital formats, deliver five to ten pictures of similar clarity or, alternatively, one or two programs in high-definition. Alternatively, a single 6 MHz channel allocated TV band spectrum could economically be used to supply, say, broadband service connecting computer users to the Internet. The wireless broadband option is effectively eliminated, however, under the digital TV standard adopted in the United States, where TV stations (to retain their licenses) must transmit high-powered video broadcasts across the entire 6 MHz band.

Since transmission rules are fixed by law, a TV broadcaster will tend to emit too much power and to underutilize spectrum-saving techniques. Were the broadcaster to enjoy frequency ownership, on the contrary, it would profit by investing in improved receivers (allowing, say, both an over-the-air TV signal and two-way Internet access in the same band) or substituting TV signal delivery by cable and satellite.

Yet the TV band reflects the quintessential traditional approach to spectrum management, which asserts that government must control frequency use to limit "harmful interference." The resulting "state property" or "administrative allocation" regime (Lueck and Miceli, 2006) undertakes that planning in two basic steps (Robinson, 1985).

The first is *spectrum allocation*, in which wireless services that can be delivered on a given slice of spectrum are defined, along with permitted technologies and business models. Moreover, market structure is determined by the creation of licenses and the bandwidth allotted to each. Other sorts of regulations often obtain as well. Since 1927, for instance, U.S. broadcasting licenses have included prohibitions on foreign ownership.

The second stage is *rights assignment*, distributing licenses to users. The U.S. initially used "beauty contests" in which spectrum was simply handed to politically preferred parties, then moved to lotteries in the 1980s, and then to auctions in the 1990s (Hazlett, 1998). In certain unlicensed bands, like those used for cordless

*Table 1*
**Spectrum Bands**

| *Band* | *Frequencies* | *Services (partial)* | *Approximate time use began* |
|---|---|---|---|
| Medium frequencies | 300 KHz–3 MHz | AM radio | 1920s |
| High frequencies | 3 MHz–30 MHz | short wave radio | 1930s |
| Very high frequencies (VHF) | 30 MHz–300 MHz | FM radio, broadcast TV | 1940s |
| Ultra-high frequencies (UHF) | 300 MHz–3 GHz | broadcast TV, mobile phones, cordless phones, wifi (802.11b/g), WiMAX, paging, satellite radio | 1950s |
| Super high frequencies (SHF) | 3 GHz–30 GHz | fixed microwave links, wifi (802.11a), cordless phones, satellite TV, "wireless fiber" | 1950s (microwave)<br>1970s |
| Extremely high frequencies (EHF) | 30 GHz–300 GHz | short-range wireless data links, remote sensing, radio astronomy | 1990s |

phones or wi-fi, spectrum use is regulated by behavioral restrictions such as power levels and technology standards (limiting the types of radios used to those approved by regulators).

The history of wireless testifies to a continual discovery process. When Guglielmo Marconi demonstrated the first radio in 1895, he assumed that only one signal could be successfully transmitted per area. Frequency division was then developed, permitting multiple links across distinct bands. A range of techniques were found to improve the geographic targeting of signals, limiting spillovers and enabling more spectrum reuse. The advent of sophisticated signal processing then allowed very low-power signals spread widely across bands to convey useful communications while politely disrupting little else. Martin Cooper (2003), often called the "father of the cell phone," characterizes a century of technological progress in wireless as a steady doubling of capacity every two years. In other words, potential transmissions increased about a million-fold in the half century from 1900 to 1950, and then another million-fold to 2000.

Such productive gains flow from progress on both the *intensive margin*, getting more communications out of given frequencies, and the *extensive margin*, using new (usually higher) frequencies. This second path is illustrated in Table 1.

Bands useless for communications in one period have become prime conduits in the next. Conversely, bands that appear fully utilized under particular rules may yield abundant new opportunities under others. For instance, when a 1990 license was awarded to permit use of 6 MHz for airplane telephone service, it was reported that the FCC had "handed out the last remaining substantial portion of prime radio waves" (Kriz, 1990, p. 1660). That report reflected the conventional regulatory wisdom of the day, but since that time some 150 MHz has been allocated for Personal Communications Services (PCS), 90 MHz for Advanced Wireless Services (AWS), and 108 MHz for 700 MHz licenses—all in the prime frequencies below 3 GHz. Auctions for the PCS and AWS licenses raised in excess of $25 billion. In each instance, new communications capacity was made possible by reorganizing band use, employing new technologies and shifting existing traffic to other bands or fixed links, like fiber optic cables.

Different frequencies feature distinct natural properties, altering their usefulness. Many valuable applications are less expensive to supply using VHF (very high frequency) or UHF (ultra-high frequency) bands, where signals are easily received through walls, fog, rain, or foliage, and attenuate relatively slowly and reliably. These bands are considered "beachfront property" for mobile telephony, video, or WiMAX, an emerging wireless broadband service sometimes called "Wi-Fi on steroids." Table 2 notes some economically important allocations.

## The Sluggishness of Administrative Allocation

The central tension in spectrum allocation pits economics against engineering. In a market with well-defined property rights, such conflicts melt. Resource owners employ engineers to reveal options for business ventures linking investors, technologists, device makers, and service providers. Spillovers between spectrum owners are adjudicated by parties that gain wealth from cost-effectively resolving disputes. Under administrative allocation, however, resource decisionmakers do not know what economic values are possible and do not internalize gains from finding out. Instead, they pursue rules to *minimize harmful interference*. This lacks a balancing test for evaluating trade-offs. Indeed, simply restricting productive activity reduces interference, and regulators rely much too heavily on this approach in policing airwaves.

The overarching entry barrier in wireless is the boilerplate term, "technical reasons." In managing spectrum, there is always an engineering rationale for deterring entrants or blocking new technologies, as any wireless application prompts possible conflicts with other spectrum users. Moreover, under administrative allocation, competitive entrants must prove that they will advance the public interest. Incumbents enjoy financial incentives to oppose these petitions, publicizing potential spillovers.

Competition suffers, as in similar proceedings conducted by the now defunct Civil Aeronautics Board and Interstate Commerce Commission. To illustrate, I first focus on the broadcast television spectrum band, the mother lode of productive—and vastly underutilized—radio spectrum.

*Table 2*
**U.S. Revenues and Bandwidth for Selected Wireless Applications**

| *Service* | *Frequencies* | *Total MHz* | *Annual revenues* |
|---|---|---|---|
| AM/FM radio | 520–1610 kHz; 88–108 MHz | 21 MHz | $20 billion (2006) |
| Satellite radio | 2.320–2.345 GHz | 25 MHz | $1.6 billion (2006) |
| TV broadcasting | 54–806 MHz (67 channels, 6 MHz each) | 402 MHz | $40 billion (2005) |
| TV sets | | | $20 billion (2005) |
| TV broadcasting after 2009 digital transition | 54–692 MHz (49 channels, 6 MHz each) | 294 MHz | n.a. |
| Satellite TV | 12.2 GHz–12.7 GHz | 500 MHz | $25 billion (2006) |
| Mobile Telephony | 800 MHz, 900 MHz, 1.8 GHz, 1.9 GHz | 190 MHz | $118 billion (2006) |
| Mobile handsets and network infrastructure | | | $42 billion (2005) |
| Mobile telephony: additions | 1.7 GHz, 2.1 GHz, 700 MHz | 152 MHz | licenses being issued 2007–08 |
| Unlicensed wireless LANs (local area networks) | 900 MHz, 1.9 GHz, 2.4 GHz; 5.1–5.8 GHz | 129.5 MHz (555 MHz @ 5 GHz) | $1.6 billion (2005) |

**The Underutilized Television Band**

The current U.S. television band encompasses 402 MHz: 67 channels allotted 6 MHz each. This band, allocated by the FCC for television between 1939 and 1953, is extremely valuable for transmitting voice, data, and video. Now, 1700 full-power television stations broadcast in 210 television markets. The average of eight stations per market represents just 12 percent (8 out of 67) of the total slots set aside.

The justification for letting this valuable spectrum go largely unused is that "taboos" (vacant channels) serve as buffers between signals, improving reception. This does limit interference, but in an inordinately expensive manner (Crandall, 1978). The government's anti-interference rules are overly conservative, sacrificing valuable competition for tiny gains in signal quality.

Moreover, numerous technical and organizational fixes would, at trivial cost, permit far more broadcast channels (or other services). Since the early 1970s, for instance, analog filters costing only a few dollars would permit standard TV sets to receive all (67) TV channels. But "technical reasons" pursued by regulators have ignored the cheaper solution and focused almost solely on the more expensive. "As a result, throughout the United States there is more unused 'white space' than occupied channels, even though the white space could be used without creating harm to any user. For instance, Robert Pepper, Chief of Policy Development for the Federal Communications Commission, observed that even in Los Angeles, the city with the most broadcast television channels, only 196 MHz are occupied, leaving large amounts of valuable 'white space'" (Aspen, 2004, p.15).

Other regulatory choices waste spectrum, too. For example, a key 1952 decision (the "TV Allocation Table") planned for only enough broadcasting opportunities to support three national networks. DuMont, a fledgling fourth network broadcasting on temporary licenses, argued for high-powered regional licenses. This would have allowed the 12 VHF channels (with better propagation characteristics than UHF) to support four or more national networks. Regulators rejected that course in favor of "localism," dotting the country with low-powered stations in more local markets. This political solution was supported by Congress and the three large networks. The resulting triopoly, following the 1955 death of the DuMont network, lasted for over three decades.[3]

Indeed, the entire U.S. cable television industry in the United States—accounting for over $40 billion in annual video revenues for operators (National Cable and Telecommunications Association, 2007)—can be viewed as a reaction to these limits. Cable television systems constructed "spectrum in a tube" to deliver programming valued by viewers but blocked by regulators.

Were the allocated bandwidth efficiently used, the average U.S. household could have enjoyed scores of analog channels decades sooner. In Italy, courts opened entry into broadcasting in the 1970s. Hundreds of television stations sprang up, and Italy became the most densely "TV stationed" in the world (Noam, 1992). A generation later, the Italian regulatory agency boasted, "The Italian radiotelevision market is typified by the absence of cable TV, which was compensated with the total liberalization of the radiotelevision sector in 1976" (AGCOM, 2001).

The television band, while increasingly valuable for delivering other services, is largely obsolete for its current purpose. About 87 percent of households pay cable or satellite TV operators to opt out of the "free" broadcast system. Beginning in the

[3] About 100 "experimental" television licenses had been issued up until 1948, and were offering broadcast TV services for CBS, NBC, ABC, DuMont, and other programmers. A freeze on licenses was then imposed by the FCC until an overall plan for distributed licenses was developed, which finally came in 1952. The DuMont network opposed "localism" and advanced its alternative plan which would have increased the number of competitors able to reach national (or near-national) audiences. Localism was popular with Congress, however, and with the incumbent TV networks excepting DuMont, and that approach was adopted with the assignment of about 500 TV licenses.

mid 1980s, however, another rationale for protecting the existing spectrum allocation was developed: "advanced television." In 1987, the FCC considered a request from public safety officials and a radio manufacturer to release several little-used TV channels for cellular-type services (Brinkley, 1997). To thwart the reallocation, broadcasters asserted that while many channels might appear vacant, they were needed for "advanced television." Although "high definition" TV was only an idea and digital TV was not yet invented, the FCC found that a transition was in the public interest. It froze unused TV channels.

Fast-forward to the FCC's current plan, where the 402 MHz TV band (67 channels) is to be trimmed to 294 MHz (49 channels) in February 2009, when analog broadcasts are slated, by statute, to end. Digital signals are well-behaved and compact—a 6 MHz channel transmits five or ten standard quality TV programs, against one via analog; but they will still be allotted a vast swath of bandwith, nearly three-fourths of the old analog allocation. Moreover, $1.5 billion in federal vouchers has been authorized to fund digital off-air tuners (which allow reception of digital broadcasts without cable of satellite connections), subsidizing broadcast television for another generation. For only a slightly larger investment, all nonsubscribing TV households could be connected to cable or satellite (Hazlett, 2001b). A complete exodus from broadcast television would permit orders-of-magnitude improvement in consumer surplus (Hazlett and Munoz, 2004). If allocated to flexible-use licenses, the digital TV spectrum could host a wide range of additional voice, broadband, and video networks, as well as innovative applications yet unknown.

**Some Proposals to Free the TV Spectrum**

However efficient the demise of traditional broadcasting, FCC rules effectively freeze television stations in place. Transitioning broadcasts to alternative platforms would result in license revocation. Given this, the great majority of channels will continue to simply serve as vacant "taboos," yielding the value of a vestigial organ.

A number of proposals aim to salvage the television band. The ideas are not mutually exclusive. I briefly sketch a few here.

One plan would require stations to "co-locate" their transmitters, where stations in a given market transmit from the same physical place. Co-location saves stations money via shared tower costs. More importantly, it enables even cheap TV sets to differentiate between signals broadcast on adjacent channels. Digital transmissions also permit different programs to be broadcast simultaneously, so-called "digital multiplexing." The combination of co-location and multiplexing could deliver 50 standard-definition broadcasts (or ten high-definition signals) using only roughly 50 MHz of contiguous bandwidth. The roughly 250 MHz remaining in the television band could then be allocated to flexible-use licenses and auctioned off.

A second approach would issue "overlay rights" yielding new licensees broad discretion to use unoccupied frequencies while respecting the rights of incumbents, who would be grandfathered to continue operations. Overlay rights trigger several important responses. Entrants can productively utilize vacant bands. In addition, entrants can negotiate with existing users, moving them to where they are less expensive to accommodate—to other frequencies within the band, to those outside the band, or to fixed links—or entrants can just buy out existing users. Finally, overlay licensees are eager to see that the property rights of existing licensees are defined in an expeditious manner. The costs of any delays are internalized.

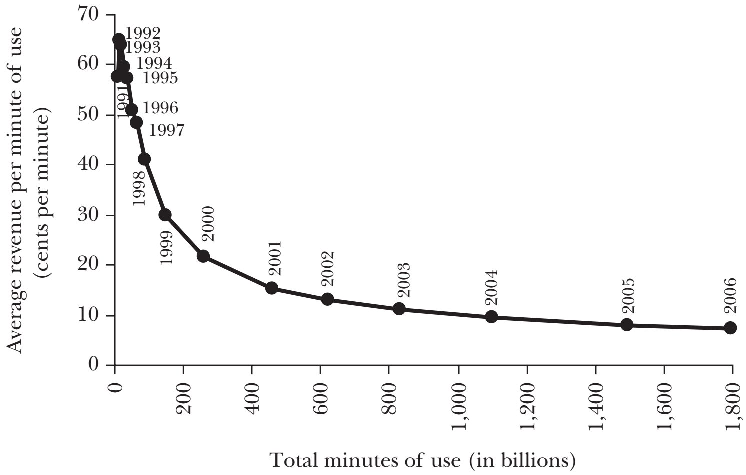
The then-Chairman of the Senate Commerce Committee, Sen. Larry Pressler, proposed overlay rights to reallocate television spectrum in 1996. Today the proposal could be applied by allocating, say, five nationwide licenses of about 60 MHz each, assigning them by auction. Hold-out problems with incumbents can emerge, but can be mitigated via a variety of institutional options, including mandates for binding arbitration. Moreover, problems become tractable when an interested party is empowered to bargain, replacing a public agency defining "interference" as an administrative exercise. For example, PCS licenses auctioned beginning in 1995 were encumbered by thousands of point-to-point microwave users, incumbents that had thwarted government efforts to relocate them for years. Policymakers finally resolved the stand-off by grandfathering the incumbents and issuing overlay licenses for PCS. The strategy worked. Entrants expeditiously moved incumbents, clearing bands for mobile phone use (Cramton, Kwerel, and Williams, 1998).

A third plan would cede full use of the "white space" to incumbents, the existing broadcast television stations. Interference between licensees would cease to be an issue, given the financial integration of assets (Demsetz, 2003). If TV stations truly believed that the best way to avoid interference was to continue leaving "white space," they would continue operating as is. In reality, if individual TV stations had the power to use or sell the white space, they would modify spectrum use to capture new opportunities.

A fourth proposal is to allocate the "white space" between digital TV channels for low-power devices under the unlicensed model. Existing television stations would continue existing broadcasts, while regulator-approved devices would be allowed to transmit on a "non-interfering" basis. The FCC has considered rules for such devices since 2002, but has yet to approve any unlicensed radios. If and when they do, the existing pattern of television broadcast transmissions will become even more difficult to reorganize rationally. Unlicensed users of the band will be widely dispersed and their interests fragmented. Those possessing undefined "white space" rights will be unable to contract for efficient reorganization, locking-in the broadcast television spectrum allocation.

Spectrum property rights open entirely different pathways. Take the liberal licenses auctioned in 2003 to, respectively, Aloha and Crown Castle. Both companies developed mobile television services using their licensed frequencies. But trials of Aloha's HiWire in Las Vegas, as well as Crown Castle's Modeo in New York City, suggested that their services would be uncompetitive against a third rival—Qualcomm's MediaFlo. By late 2007, both Aloha and Crown Castle had suspended their

*Figure 1*
**Prices and Outputs for U.S. Cellular Telephony, 1991–2006**




*Source:* Semi-Annual Wireless Industry Survey, Cellular Telecommunications & Internet Association (CTIA), except minutes of use in the second half of 2006, which is collected from Wireless Quick Facts, CTIA.

mobile television build-outs and reassigned their spectrum rights, which analysts anticipate will be redeployed for, respectively, wireless broadband and satellite radio. In contrast to the traditional television band allocation, where stiff opposition from incumbent licensees *still* protects spectrum blocks set aside for television circa 1950, de facto spectrum owners welcome (and finance) emerging options.

A fifth proposal would pay cable and/or satellite television operators to deliver broadcast stations' programs and sweep all 294 MHz clean. With 98 percent of U.S. households passed by cable and virtually 100 percent falling within the footprint of two satellite TV systems, the approximately 15 million TV households that rely on over-the-air broadcasting for TV reception could be served at low incremental cost. The one-time connection charge for new households averages under $300 (Hazlett, 2001b), implying aggregate transition costs of less than $4.5 billion.

The social value of 294 MHz of cleared TV band spectrum is orders of magnitude higher. All mobile telephony had access, through 2006, to under 200 MHz of spectrum (of lower quality than the television band). This market, however, generated revenues of $150 billion in 2006, and produces annual consumer surplus exceeding that amount (Hausman, 2004). Figure 1 displays historical price–quantity pairs, with price proxied by average revenue per minute and output defined as annual aggregate minutes of use. Incremental bandwidth generates further surplus, of course, reducing retail prices and expanding capacity for new applications (Hazlett and Munoz, 2004).

The gaping inefficiencies in the allocation of TV spectrum have long been apparent to economists (Minasian, 1975; Crandall, 1978; Levin, 1980; Owen, 1999). Some economists and communications scholars have persuasively suggested that the "public interest" scheme for granting TV broadcast licenses, coupled with severe restrictions of communications output, violates the free speech clause of the First Amendment (Owen, Beebe, and Manning, 1974; Bazelon, 1975; Pool, 1983; Benjamin, 2002; Yoo, 2003). The underutilization of spectrum reduces both efficiency and freedom.

### Other Examples of Administrative Delay

For years, satellite TV operators, licensed to use 12.2 GHz to 12.7 GHz, lobbied to block a potential entrant's application for a competing license. The applicant had developed a way to share satellite frequencies, delivering about a 100 video channels via terrestrial broadcasts beamed from a northern point in each TV market. Dishes receiving signals from the two incumbent operators aim towards the southern sky to receive signals from geosynchronous orbit satellites (that "hover" over the equator) and would continue to work unimpeded. Still, incumbent firms noted that a few satellite TV subscribers whose dishes were not well-aligned might have to re-adjust them. Even when the potential entrant offered to identify and fix such problems at its expense, the incumbents countered that *any* degradation was unacceptable. The promising technology was held up for nearly a decade.[4]

Another paradigmatic example of wasteful spectrum use via administrative allocation occurred with unlicensed personal communication services (U-PCS). In the early 1990s, Apple Computer petitioned the Federal Communications Commission to set aside additional bands to operate cordless phones and to link office computers (Apple, 1991). The Commission responded by allocating 30 MHz, mandating that devices use low power and "listen before talk" algorithms to coordinate traffic. But for a decade the plan failed to generate virtually any economic activity; indeed, 10 MHz devoted to data did not result in a single device being approved for use by the FCC. Meanwhile, the adjacent 120 MHz allocated to licensed PCS hosts about half the service provided 240 million U.S. mobile subscribers.

Endemic underutilization of radio spectrum is the historical legacy of the administrative system. FM radio was deterred by FCC rules for nearly three decades (Hazlett, 2001a). Cellular telephony was conceptually developed in the 1940s but not licensed until the 1980s (Calhoun, 1988). Current restrictions block thousands of low-power FM stations (Hazlett and Viani, 2005), and deter WiMAX (Brito, 2007) next-generation wireless broadband. In short, the administrative allocation

[4] When the Federal Communications Commission finally auctioned licenses for MVDDS (multichannel video and data distribution service) in 2004, incumbent cable and satellite operators emerged as high bidders for the licenses. The applicant, whose request for a license assigned without an auction was denied, did not bid.

of spectrum has hampered technological progress, underutilized spectrum, and produced anticompetitive outcomes.

## Property Rights for Spectrum Markets

Market allocation of radio spectrum was the policy recommendation of Coase (1959). Yet scholars who first attempted to formulate the enabling mechanism of property rights in frequencies (Coase, Meckling, and Minasian, 1963; Levin, 1968; DeVany, Eckert, Meyers, O'Hara, and Scott, 1969; Minasian 1975) met with limited success. Experience illuminating how such markets would function was scarce. Today, however, data on spectrum rights regimes abound. One body of evidence comes from the U.S. experience with liberal licenses for cellular networks; another from countries that have adopted more general spectrum property regimes.

### Spectrum Property Rights in Cellular Networks

U.S. cellular licenses permit licensees wide latitude to choose the services they provide, the prices they charge, the technologies they deploy, and the business models they adopt. This practice distinctly departs from traditional spectrum policy. "[T]he Personal Communications Service (PCS) permits any fixed or mobile use and technology, whereas the Television Broadcasting service is quite narrowly defined both in the nature of the use permitted and the technology" (Kwerel and Williams, 2002, p. 4). Cellular licensees do not possess title to frequencies, but their license rights are defined so broadly as to imply de facto spectrum ownership. As Reed Hundt (1999, p. 98), FCC Chair from 1993–97, boasted: "We totally deregulated wireless."

The spectrum available under this permissive regime constitutes about 7 percent of prime frequencies under 3 GHz (Kwerel and Williams, 2002, p. 32). This total rises to about 12 percent with the Advanced Wireless Services (AWS) and 700 MHz licenses now being assigned. In addition, 190 MHz (about another 6 percent) allocated for the use of video transmission by educational institutions in the 1960s has seen significant regulatory reform over the past decade. Two-way data services are now permitted, and many institutions have leased their license rights to private companies. Clearwire, a wireless broadband provider that went public in 2007, is constructing a network with these licenses. Strong demand exists for far more bandwidth, however, and opportunity costs (as measured by the value of current deployments) are exceedingly modest.

One straightforward approach to reform would simply increase the amount of spectrum allocated to flexible-use licenses. This approach is being pursued by the deregulatory-minded spectrum regulator in the United Kingdom, Ofcom. In late 2004, the agency adopted a plan to expand the bandwidth allocated to liberal licenses from about 11 percent of frequencies under 3 GHz to 69 percent by year

2010. This process was triggered by a report commissioned by the Labour government (Cave, 2002).

Such reforms need not wait for regulators to "clear" bands. Overlay rights create economic agents who internalize gains from rationally reorganizing wireless use, a process used in PCS and AWS licensing. Qualcomm, which purchased UHF license rights subject to the grandfathering of analog TV stations on Channel 55 until the February 2009 digital switch-over, has paid dozens of stations to vacate the frequency early, freeing bandwidth for MediaFlo.

### Liberal Regimes

Some countries have, in addition to implementing auctions for wireless license assignments, adopted general rules granting de facto spectrum ownership. These categorically permit licensees (not just cellular operators) virtually any use of spectrum. New Zealand (1989), Australia (1992, 1997), Guatemala (1996), and El Salvador (1997) have instituted rudimentary property regimes (Hazlett, forthcoming). In the case of Guatemala, the law extends de jure property rights.

Markets and regulatory processes have been orderly in these countries, and outcomes in retail markets salubrious. El Salvador and Guatemala both allow mobile phone networks to utilize far more spectrum than other Latin American countries, with the result that competition is relatively intense, output high, and prices low (Hazlett, Ibarguen, and Leighton, 2007). In Australia, liberalization invited technological innovation, and multiple wireless broadband providers operated there for years before gaining access to markets in other countries (Buckman, 2005).

The International Telecommunications Union is a United Nations agency that seeks to coordinate telecommunication services across countries. The ITU offers a standardized licensing scheme that can be generically altered to grant licensees permission to modify operations—selecting their own services, technologies, or business models—using bandwidth allocated to the license. El Salvador did this in its 1997 statutory reform. Hence, standard allocation schemes can form the basis of liberal property rights regimes.

## Can Spectrum Rights Be Practically Defined?

It was long argued that spectrum did not admit to ownership because legally clear definitions of bandwidth boundaries were impossible to craft (Smythe, 1952; Melody, 1980). Despite the demonstrated operation of markets with de facto spectrum ownership, similar concerns are still raised. For example, Goodman (2004, p. 274) explores mechanisms to define "interference," which she describes as "the eight hundred pound gorilla in the spectrum policy debate." She notes that "interference between spectrum users was the rationale for government regulation of spectrum in the first place," and proceeds to outline elaborate approaches to the problem. "Given this complexity," she writes, we should not "be quick to throw over the administrative role in spectrum management."

**Engineering and Economics in Property Definition**

The complexity of spectrum rights is, in an engineering context, real. Hatfield and Weiser (2006, p. 1) explain:

> [D]efining rights to use spectrum is far more difficult than ordinarily suggested. Problems such as geographic spillover and adjacent channel spillover make it much more difficult to define rights to spectrum and to determine how to measure when those rights have been transgressed. Unlike the case of real property, which is measured in two or three dimensions, there are as many as seven dimensions by which electromagnetic frequency can be measured, and the best way to measure these dimensions remains unsettled.

Of course, technical difficulties are not unique to spectrum rights. Property lines can also be difficult to draw in other contexts such as water rights, oil reserves, and intellectual property, and yet institutions arise in each of these areas to enable private ownership. Moreover, difficulties in defining spectrum rights apply just as much to regulators as they do to private actors. Indeed, regulators have enormous difficulty defining spectrum rights, resolving dilemmas with delays, rigid restrictions, and overconservatism in use rules—mandating scores of TV channels go unused, for instance, as a substitute for more clearly defined channel boundaries. The question is not whether property lines are difficult to precisely draw, but whether the allocation decisions of regulators are superior to those of spectrum owners grappling with the same phenomena.

In contract law it is recognized that agreements generally lack completeness. Courts nonetheless resolve disputes as if contracts covered all contingencies, under the logic that society is better off when productive activity can commence without the "exhaustive" definition of all rights and responsibilities (Scott and Triantis, 2005).

In a similar vein, efficient spectrum rights convey imperfect boundaries. Yet, so long as they facilitate transactions that "out-optimize" administrative allocation, they increase the social value of spectrum. This bar is a low one, and the evidence is overwhelming that private spectrum ownership scales it.

**Practical Spectrum Rights with Some Interference**

In the 1920s, prior to the 1927 Radio Act, spectrum conflicts were largely handled by common law rules enforced by the U.S. Department of Commerce. Priority-in-use established a given station's rights, and entrants either bought existing facilities or negotiated time-sharing agreements to gain new access (Hazlett, 1990, 1997). This regime was abandoned in favor of administrative allocation in the Radio Act. Given the short time for the law to develop and the limited wireless applications then available, many spectrum ownership questions remained unanswered.

However, practical spectrum rights have since been defined and adopted. Australia delineates spectrum "cubes," frequency spaces lacking service or technology specifications and assigned by auction (Hazlett, forthcoming). More ambitiously, Guatemala defines spectrum properties with the following parameters: 1) frequency, 2) geography, 3) hours of operation, 4) maximum emitted radiation within in the band, and 5) maximum emitted radiation at the geographical edge. Where these specifications create conflicts claimed to be damaging by other parties, the law specifies arbitration governed by strict time limits. The approach underscores the fact that technical specifications by regulators can be largely replaced by well-designed dispute resolution mechanisms.

In the United States, cellular markets suggest how exclusive spectrum rights help deal with spillover effects. Because an intense degree of spectrum sharing in cellular markets is so seamlessly adjudicated, it often goes unnoticed. Yet it is exceptionally useful in providing insights about how property rights are utilized.

First, millions of cellular customers share frequencies, "interfering" with each other by making phone calls or data connections. However, the potential interference does not lead to endless squabbling. Instead, we observe network coordination of cellular infrastructure, technology, handsets, applications, and access pricing. These menus reduce rates at off-peak times or for low-bandwidth communications such as text messaging. Networks then compete on service quality, with reductions in "calls blocked" and "calls dropped" tending to increase subscribership and profits.

Second, cellular carriers host multiple networks. Operators supply voice, data, and mobile video by optimizing frequency space and its radio complements. Some applications are provided via vertical integration, and some via third-party vendors that access the network (and its licensed frequencies) under negotiated agreements. Hence, subscribers to Blackberry or Palm personal digital assistant services connect over airwaves controlled by cellular networks, with spectrum access arranged by interfirm contracts. The On-Star emergency vehicular service also operates this way. Again, interference is not seriously contentious. Rather, quality of service is specified by agreement, and policed via competition between providers.

Third, carriers sell large increments of network access to mobile virtual network operators which, in the United States, are unregulated. Firms such as Tracfone (seven million subscribers) or Virgin Mobile (four million) do not possess cellular licenses or wireless facilities. Their customers, who potentially "interfere" with a carrier's (direct) customers, are nonetheless served by these networks under wholesale agreements specifying quality of service.

Fourth, when emissions spill between wireless networks—a not uncommon situation given that the carriers are allocated adjacent spectrum, which is heavily used—the issue is typically resolved by voluntary work-outs (like repositioning links or upgrading receivers). With properly aligned incentives, obstructionist tactics do not deter entrants but pose liabilities for the obstructionist, including potential future encroachments from encroached-upon neighbors. This experience mirrors the success of PCS overlay rights in producing negotiated settlements. The FCC rules set limits on interference—but the parties are then permitted to bargain. This approach has long been the case in satellites and microwave systems. Such transactions have even succeeded when the FCC has elected not to supply a starting definition of harmful interference (Williams, 1986).

Fifth, cellular markets manage technology transitions routinely. The analog-to-digital migration is illustrative. Cellular licenses originally mandated an analog standard. In 1988, however, the FCC permitted operators to deploy the digital system of their choice. Little immediate change occurred. But when competitive PCS licenses were issued in 1995, incumbent operators moved tens of millions of analog cellular subscribers to digital handsets. With freedom to control the 25 MHz allocated their licenses, carriers deployed new technologies in their base stations, subsidized compatible handsets, and gradually made more spectrum available for digital traffic. Interference was not an issue, despite conflicts between analog and digital users. In 1995, there were 30 million analog subscribers. By 2007, there were fewer than one million, as against about 240 million digital (Cellular Telecommunications & Internet Association (CTIA) 2007; Davidson, 2007); also in 2007, the FCC's analog-to-digital TV transition entered its twenty-first year.

In sum, millions of users access licensed spectrum without having licenses themselves. Secondary market transactions supply frequencies and the complementary infrastructure that makes spectrum valuable. Cellular carriers stack multiple services and networks within the bands they control, and monitor their quality. When spillovers diminish quality of service, cost-effective solutions are pursued. Subscribers choose among the competitive options.

Interference is an integral part of wireless communications—if you're doing things right—because it implies that at least some airwaves are being well utilized. A regulatory system that seeks to assure interference never occurs is doomed to underutilization, even if rent seeking did not so reliably turn "technical reasons" into anticompetitive barriers. Rather than implement new government rules to police interference in more ambitious ways, the pro-consumer policy reform is to release more bandwidth—through auctions, grandfathering, and liberalization enabling all uses and technologies—to more owners.

Administrative allocations, focusing on technical determinations, often miss simple economic solutions. Take the situation where there are two wireless users, *A* and *B*. *A* emits radiation that is extremely valuable to its customers, difficult to control, randomly encroaches on *B*'s allotted frequency space, and does substantial harm to *B*'s customers. The damage, however, is not easily detected or attributed to *A*. The standard regulatory result will tie the regulatory agency in knots for years, and will then produce an outcome where rules rigidly dictate what *A* and *B* may do with wireless applications.

Alternatively, productive economic solutions are available. One would impose binding arbitration with short time constraints under existing FCC "interference" criteria. Another would be to combine the interests into an $A+B$ license, assigning equity to existing licensees on the basis of appraised valuation. Of course, businesses commonly divide spectrum rights by sharing profits, as noted in the stacking of various cellular applications and networks.[5] When a network, say Sprint-Nextel, provides services for Virgin Mobile users, Sprint is essentially sharing its spectrum (and network) with Virgin and its customers. The parties do not partition spectrum into distinct bands and then define what constitutes interference between them. Participants in these market transactions use financial instruments in lieu of bandwidth division because the parties internalize the costs of defining property rights.

Demsetz (2003) stresses that transaction costs are often considered exogenous when, in fact, they are highly sensitive to how rights are defined. An important way to reduce spillovers in spectrum is to reduce borders, assigning relatively broad rights subject to competitive market structure. By focusing on technical interference delineation, however, regulatory rulemakings produce highly contentious disputes over entirely too many boundaries.

## Has Technology Made Spectrum Property Rights Obsolete?

Some argue that new technological developments have rendered private property rights to spectrum passé. For example, Werbach (2004, p. 867) writes: "The property approach made sense in 1960, but is now questionable." The prototypical example features the emergence of Wi-Fi devices, which use unlicensed spectrum to create local area networks. Millions of homes and enterprises have Wi-Fi networks, enabling wireless access to DSL connections or other links to the Internet. Noting innovations that allow radios to detect and then transmit via idle bands, Lessig (2001, p. 78) writes of a "spectrum commons" that permits nonexclusive access tempered only by "etiquettes" or "protocols"—rules no more intrusive than "behav[ing] like a (good) neighbor sharing a telephone party line."[6] U.S. regulators have recently seized on the argument to increase allocations of unlicensed spectrum.

A healthy academic literature considers how changing circumstances alter optimal property rules (nicely summarized in Lueck and Miceli, 2006). Here, the question is: Have advanced technologies, yielding enhanced opportunities for wireless activities to be coordinated by smart technology, reduced the case for exclusive spectrum rights? In

[5] This is literally done in the case of Virgin Mobile, with the venture half-owned by Virgin and Sprint, the wireless carrier whose licensed frequency space is used by the service.

[6] Protocols for line-sharing are, electronically speaking, ancient. Party lines in rural markets are still remembered by some, and telecommunications systems, wired and wireless, have relied on queuing algorithms for access to available bandwidth for decades. Trunking, developed in 1947, allows a radio to scan across multiple channels, selecting one that is available (unoccupied) to make a call.

a word, *no*. To understand why, consider developments in three areas: unlicensed bandwidth, technology adoption, and spectrum usage patterns.

**Unlicensed Bands**

It is incorrect to assert that Wi-Fi devices "rely on utilizing frequencies that no one controls" (Benkler, 2002, p. 30). In fact, wide-ranging regulatory constraints are imposed to limit potential conflicts (Jackson, Pickholtz, and Hatfield, 2006). Government controls unlicensed spectrum via equipment approvals, sharply restricting emission levels (separating users to help avert a tragedy of the commons) and effectively excluding most potential wireless activity. This ability to exclude mirrors that of a private property owner, but the incentive structure and feedback mechanisms are quite distinct.

There are two broad methods of awarding resource appropriation rights (Smith, 2002). One approach, "governance," effectively treats spectrum as state property and sets behavioral rules for users. Usage can be limited to licensees (as with traditional licenses), or they can be nonexclusive (as with unlicensed devices). The alternative approach is "exclusion," which defines a space and delegates further appropriation rules to an owner. The issue is not "unlimited" use of unlicensed spectrum vs. the restrictions of property owners, but the means by which exclusions are chosen. The state can do it directly or delegate the function to private property owners competing in the marketplace.

The governance of unlicensed spectrum limits the power of radio signals to enable localized wireless applications like cordless phones or remote controls. But decisions as to whether additional (or less) unlicensed bandwidth would be efficient, or whether a technology transition would collectively aid users, are made by the regulator. The infirmities of administrative allocation remain (Faulhaber, 2006) because costs and benefits are not internalized by decisionmakers. Moreover, the value of excluded opportunities is not revealed, as spectrum transactions are preempted.

It is argued that unlicensed bands host abundant economic activity without interference, demonstrating that technology has triumphed over exclusive property rights. First, the assertion is factually incorrect. Unlicensed wireless entrepreneur Tim Pozar writes: "A properly engineered and designed network will be useful longer than one that isn't properly designed, but it still may have a limited lifetime, as noise or interference from other users will increase" (Pozar, 2003; see also Lemos, 2007). Second, the absence of interference does not suffice to produce an efficient outcome. Note the experience with U-PCS, where FCC rules for "polite" protocols deterred virtually any use of 30 MHz for a decade. There, unlicensed spectrum rules produced a tragedy of the commons via *regulatory* interference. Third, unlicensed equipment regulations protect local wireless device use by limiting the range of signals. This restriction is not cost-free. A great many wireless networks, technologies, and applications are thereby excluded. Regulators have no reliable way to measure the value of these lost opportunities against the gains created for local device usage.

Most basically, unlicensed spectrum is efficiently accommodated under a private property system. Firms could acquire frequencies and dedicate them for use by approved devices, charging equipment makers license fees (similar to the way in which patent owners charge for intellectual property inputs) (Kwerel and Williams, 2002, p. 31). Cellular networks demonstrate how privately owned bands operate as "commons," where owners coordinate with device manufacturers to make radios accessing a given band, while building network infrastructure that makes such devices valuable.[7]

Spectrum rights need not be held entirely in the private sector. Public or nonprofit agencies may acquire spectrum property just as occurs with public parks, museums, roads, and other institutions (Kwerel and Williams, 2002, p. 7). Spectrum markets improve such choices by introducing transparency and revealing the value of alternative opportunities. More fundamentally, a unifying property regime eliminates "case by case" allocations for each new wireless application, removing the regulatory bottleneck. In a world of liberal spectrum access, new technologies would have ready access to market-priced spectrum. The opportunity cost of access for new competitors—including those possibly supplying additional "commons"—would fall dramatically.

**Technology Adoption**

A variety of technologies have been said to coordinate economic activity without exclusive frequency rights; it is said these technologies disrupt markets and revolutionize the optimal structure of property rights. The widely cited example is "spread spectrum" (Gilder, 1995; Lessig, 1999), but other technologies credited include time division multiplexing (Benkler, 1998), smart antennas (Gilder, 1995; Werbach, 2004), software-defined radio (Werbach, 2004), directional beaming (Werbach, 2004), and mesh networks (Benkler, 2002).

Yet each of these advanced technologies has been developed and deployed using exclusive spectrum rights. Spread spectrum CDMA (code division multiple access) and time division multiple access (TDMA) are the primary technologies used in digital mobile phones accessing licensed spectrum, and serve over 2.8 billion subscribers worldwide. Array antennas, which dramatically increase spectrum reuse by pinpointing the intended target of a wireless link, are widely used in these cellular systems. The first FCC-approved software-defined radio, produced by Vanu, was for use in cellular networks.

Spectrum ownership provides powerful incentives to conserve spectrum, increasing network capacity so as to generate additional revenue. For example, the

[7] While carriers typically charge subscription fees, models mimicking unlicensed device use are possible. Indeed, a portable book-reader sold by Amazon.com downloads content via the high-speed wireless connections provided by Sprint. Customers pay for books, newspapers, or magazines, but not for access.

radios used in CDMA mobiles dynamically adjust power 800 times per second, searching for the lowest power level that will maintain a connection. In the unlicensed 2.4 GHz band, Wi-Fi users lack spectrum ownership incentives and do not undertake such costly efforts to create additional capacity (Peha, 2000).

**Spectrum Usage Patterns**

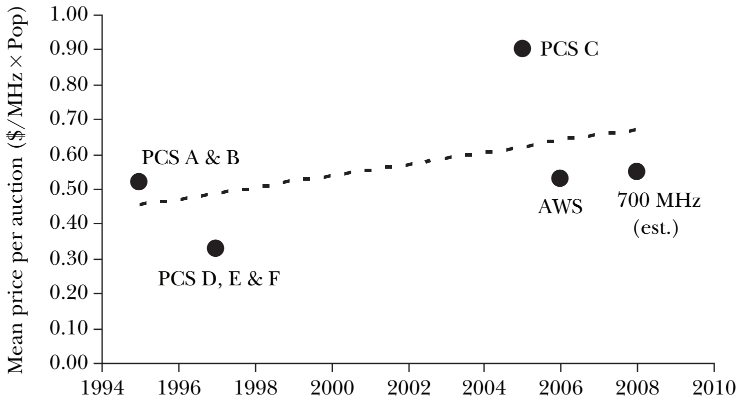
Perhaps the source of greatest organizational complexity in wireless lies in the creation of cellular infrastructure, which involves large irreversible investments complementing radio spectrum. Sales of cellular network equipment sales—base stations and handsets—amounted to $202 billion internationally in 2005, as against $3.1 billion for local area wireless networks (Morgan Stanley, 2005, pp. 18, 20). This disparity in investments complementing licensed versus unlicensed spectrum substantially *overstates* the stand-alone utility of unlicensed spectrum as a substitute for exclusive rights. Wi-Fi routers use unlicensed spectrum to link users to wide-area broadband networks that are largely supplied via privately owned "spectrum in a tube."

If new technologies operating on unlicensed bands were actually disruptive to the logic of exclusive spectrum rights, market activity would show evidence of a shift in usage patterns. Wireless investments would migrate to unlicensed bands. That transition has not been observed.[8] Moreover, the competitive threat posed by unlicensed applications would devalue licenses. Yet, as shown in Figure 2, the average license price, adjusted for population in the service area and bandwidth, has held largely steady in the face of the heralded technology changes.

Over the past decade, U.S. regulators have allocated hundreds of MHz for additional unlicensed use, yet it has generated relatively little economic activity. Very substantial investments, in contrast, continue to be made by wireless operators gaining new exclusive rights, often bidding billions of dollars for the privilege. In 2006, for instance, T-Mobile spent $4.2 billion for AWS licenses, and then embarked on a $2.7 billion construction project to build a nationwide wireless broadband network. This strategy was to compete with similar systems already launched by its three major rivals. No investment approaching this scale has been observed using unlicensed airwaves. So far as it can be determined, the marginal value of liberally regulated exclusive spectrum rights dominates the value of additional unlicensed bands (Hazlett and Spitzer, 2006; Coleman Bazelon, 2006). What is more important is that a spectrum property regime efficiently accommodates both.

[8] Wireless carriers are deploying dual-mode handsets, however, allowing subscribers to access local wireless networks seamlessly (via Wi-Fi). This practice economizes on the cost of new base stations, required when cell-splitting is undertaken to provide additional network capacity. It also provides customers with low-cost access when within range of fixed broadband connections, as in homes served by cable modem or digital subscriber line service.

*Figure 2*
**Mean Prices for U.S. Mobile Wireless Licenses, 1995–2008**
*(points on the graph show blocks (licenses) sold during different FCC auctions)*




*Note:* Prices are average winning bids for FCC auctions of cellular-like licenses. 700 MHz auction prices are Congressional Budget Office estimates. Mean price per auction is the average license price, adjusted for population in the service area ("Pop") and bandwidth (MHz). "PCS" are personal communication services. "AWS" are advanced wireless services.

## Conclusion

Moving from administrative allocation of spectrum rights to a system based on property rights and markets does not require radical policy surgery or de novo construction of ambitious regimes. A number of real-world property rights models are available from which to choose, based both on U.S. experience with cellular networks and on the experiences of other countries like the United Kingdom, New Zealand, Australia, Guatemala, and El Salvador.

Spectrum markets offer at least two broad advantages. First, replacing case-by-case administrative rules with generalized ownership rights eliminates regulatory delays and persistent underutilization of spectrum. Instead of waiting for public interest determinations from agents who internalize neither gains from innovation nor losses from warehousing, innovators are free to purchase inputs. The resulting rivalry yields competitive benefits for consumers and spurs technological advance by lowering the cost of frequency rights.

Second, conflicts are efficiently resolved. The primary dysfunctionality of the administrative allocation regime is the way this regime deals with interference. New applications are routinely thwarted while agencies seek to establish technical spectrum-sharing rules. But trade-offs between the cost of "harmful interference" in one application and the benefits of additional activities in another should be perceived as economic values, not engineering parameters. Regulators responding to political incentives reliably impose rigid use restrictions that prevent efficient utilization of bandwidth. A liberal property regime, conversely, enables economic solutions, squeezing far more value from the myriad wireless alternatives.

Many economists and spectrum experts argue that private spectrum rights outperform administrative allocation (Huber, 1997; White, 2000; Hazlett, 2001a; Owen and Rosston, 2001; Kwerel and Williams, 2002; Hazlett, 2003; Faulhaber, 2005; Baumol and Robyn, 2006). In 2001, "37 Concerned Economists" urged the FCC to "liberalize existing licenses, permitting any service or technology within the frequency space explicitly or implicitly allotted the license; exhaustively allocate unoccupied radio bands to licenses granting flexible spectrum use rights, assigning such licenses by competitive bidding; [and] eliminate direct regulation of wireless markets, deferring to antitrust law" (Rosston and Hazlett, 2001).

This policy recommendation stands as a simple plan for incremental reforms that would dramatically benefit society. Ultimately, however, wiser use of the spectrum will be driven less by academic arguments than by the flood of productive wireless opportunities available to the modern information economy. Spectrum regulation took a very large step towards property rights when cellular networks eclipsed broadcasting as the dominant wireless sector, and now liberal frequency markets dot the globe. Other markets, and national regimes, will follow. Before long, the transition to standard property institutions will be only a modest leap. In a few decades, the idea of administrative allocation of radio spectrum will be a quaint historical episode.

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