



School of Law

THE CASE FOR LIBERAL SPECTRUM LICENSES: A TECHNICAL AND ECONOMIC PERSPECTIVE

**Thomas W. Hazlett, Professor
George Mason University School of Law**

**Evan T. Leo, Partner
Kellogg, Huber, Hansen, Todd, Evans & Figel**

**George Mason University Law and Economics
Research Paper Series**

10-19

This paper can be downloaded without charge from the Social Science
Research Network at http://ssrn.com/abstract_id=1585469

THE CASE FOR LIBERAL SPECTRUM LICENSES: A TECHNICAL AND ECONOMIC PERSPECTIVE

Thomas W. Hazlett¹ and Evan T. Leo²

March 23, 2010

The traditional system of radio spectrum allocation has inefficiently restricted wireless services. Alternatively, liberal licenses ceding de facto spectrum ownership rights yield incentives for operators to maximize airwave value. These authorizations have been widely used for mobile services in the U.S. and internationally, leading to the development of highly productive services and waves of innovation in technology, applications and business models. Serious challenges to the efficacy of such a spectrum regime have arisen, however. Seeing the widespread adoption of such devices as cordless phones and wi-fi radios using bands set aside for unlicensed use, some scholars and policy makers posit that spectrum sharing technologies have become cheap and easy to deploy, mitigating airwave scarcity and, therefore, the utility of exclusive rights. This paper evaluates such claims technically and economically. We demonstrate that spectrum scarcity is alive and well. Costly conflicts over airwave use not only continue, but have intensified with scientific advances that dramatically improve the functionality of wireless devices and so increase demand for spectrum access. Exclusive ownership rights help direct spectrum inputs to where they deliver the highest social gains, making exclusive property rules relatively *more* socially valuable. Liberal licenses efficiently accommodate rival business models (including those commonly associated with unlicensed spectrum allocations) while mitigating the constraints levied on spectrum use by regulators imposing restrictions in traditional licenses or via use rules and technology standards in unlicensed spectrum allocations.

JEL Classification: H23, K11, K23, L14, L51, L96, O3, P48

Key Words: radio spectrum allocation; wireless licenses; unlicensed spectrum; property rights; mobile telecommunications policy; “spectrum commons”

¹ Professor of Law & Economics and Director, Information Economy Project, George Mason University. Prof. Hazlett received his Ph.D. (Economics) from the University of California, Los Angeles, formerly held faculty positions at the University of California, Davis, Columbia University, and the Wharton School, and served as Chief Economist of the Federal Communications Commission. He is the co-author of PUBLIC POLICY TOWARDS CABLE TELEVISION (MIT, 1997).

² Partner, Kellogg, Huber, Hansen, Todd, Evans & Figel, P.L.L.C. Mr. Leo received his J.D. from The George Washington University. The authors express their appreciation to Charles Jackson for helpful technical comments, and thank Mary Ann Endo for invaluable research assistance. All liability remains with the authors.

I. INTRODUCTION

A great information policy debate rages. While the world marvels at the emergence of vast wireless networks, now serving nearly five billion global subscribers,³ many leading policy advocates in the United States have concluded that ceding to mobile networks *de facto* ownership of the airwaves through cellular licenses is a barrier to innovation and social progress. Latching on to the examples of cordless phones, Wi-Fi, and Bluetooth, they credit unlicensed bandwidth – spectrum without exclusive ownership rights – as a Petri dish for disruptive technologies. These advocates extrapolate these examples as a template for restructuring the airwaves. Exclusive spectrum rights are obsolete, they claim; expanding “spectrum commons” would be more economically productive. Federal regulators have begun accepting this argument, shifting policies to favor allocations of unlicensed spectrum.

This Article evaluates the economic and technical arguments underlying this choice of regulatory regimes. It first traces the path from traditional licenses, which systematically squandered valuable wireless opportunities, to reforms creating liberal licenses. Next, we examine the claim that advanced wireless technologies can effectively eliminate spectrum scarcity and, with it, the social utility of exclusionary rules for access to airwaves.

We show that interference between radio signals is real and that conflicts between rival users are expensive. To productively use spectrum inputs for one set of applications or technologies constrains what such inputs can supply for alternatives. New and improved spectrum-sharing technologies do not eliminate these trade-offs, but instead increase the value of communications and *further exacerbate* the competition for airspace. Overwhelming marketplace evidence demonstrates that liberal licenses promote beneficial social coordination, uniquely shifting spectrum to innovative uses, organizing investment in large-scale network infrastructure, and creating complex contracts permitting intensive spectrum sharing. Indeed, exclusive frequency rights are so broadly accommodating that they efficiently supply “spectrum commons,” just as public parks are most productively provided within the context of private ownership of real estate.

II. RIVAL SPECTRUM MODELS

The U.S. mobile phone industry has achieved remarkable success. More than 270 million Americans – roughly 87 percent of the population – purchase wireless service.⁴ The nation’s wireless carriers spend over \$20 billion a year building network infrastructure; about \$16 billion more is spent on handsets and other wireless devices. U.S. companies like Qualcomm and Motorola have developed leading-edge wireless technologies sold throughout the world. Firms like Apple, Palm,

³ Gary Kim, *Five Billion Mobile Subscribers by End of 2010: What Role for Fixed Networks?* TMCNET (Feb. 25, 2010); <http://4g-wirelessevolution.tmcnet.com/broadband-stimulus/topics/fixed-networks/articles/76859-five-billion-mobile-subscribers-end-2010-what-role.htm>.

⁴ Cellular Telecommunications & Internet Association, *Wireless Quick Facts* (data as of Dec. 2008) (“CTIA Wireless Facts”), http://www.ctia.org/media/industry_info/index.cfm/AID/10323. The term “wireless service” is used interchangeably with “mobile service,” “cellular service,” and “CMRS” (Commercial Mobile Radio Service, the FCC’s official service designation) in this Article.

and Research in Motion (Blackberry) have amassed leading positions as device and application suppliers without owning wireless infrastructure, by contracting with carriers who do. Application providers such as Yahoo!, Google, Twitter, and ESPN, while also lacking wireless assets, have likewise been able to reach mass market audiences through partnership with wireless firms. The U.S. wireless industry as a whole generates more than \$148 billion in revenues per year⁵ – more than broadcast and cable television combined.⁶ According to some estimates, the industry creates more than \$150 billion per year in additional consumer benefits.⁷

Radio spectrum is a key input to the wireless industry. Licenses issued by the Federal Communications Commission enable firms to exercise control over designated airwaves; the nature of the spectrum rights granted affects the volume, quality, cost, and scope of services that can be provided to customers. Through 2008, mobile networks could access only about 194 MHz,⁸ just 7 percent of the prime bandwidth below 3 GHz. (This is range most economically viable for broadcasting and mobile services, and is considered “beachfront property.”) In September 2006, Advanced Wireless Service (AWS) licenses representing an additional 90 MHz of frequency space in the 1.7 GHz and 2.1 GHz bands were auctioned, the U.S. Treasury collecting \$13.7 billion.⁹ These frequencies were encumbered by a wide range of government users, were not generally available to licensees through 2008,¹⁰ and are gradually being deployed since.¹¹ In March 2008, the FCC

5 See *CTIA Wireless Facts* (annualized incremental capital investment \$20.1B in 2008).

6 Compare *CTIA Wireless Facts* with IBISWorld Industry Report, *Television Broadcasting: U.S. Industry Report*, <http://www.ibisworld.com/industry/retail.aspx?indid=1261&chid=1> (IBISWorld estimates that television broadcasting revenue totaled \$36.8 billion in 2008), and National Cable & Telecommunications Association, *Industry Data*, <http://www.ncta.com/Statistics.aspx> (Kagan Research estimates cable revenue totaled \$86.3 billion in 2008).

⁷ Jerry A. Hausman, *Cellular, 3G, Broadband and WiFi*, in R. Cooper and G. Madden, eds., *Frontiers of Broadband, Electronic and Mobile Commerce* (Physica-Verlag, 2004), 9-25. See also Roger Etner, Cellular Telecommunications & Internet Association (CTIA), *The Increasingly Important Impact of Wireless Broadband Technology and Services On The U.S. Economy: A Follow Up To The 2005 Ovum Report On The Impact Of The US Wireless Telecom Industry On The US Economy*, at 2 (2008), http://files.ctia.org/pdf/Final_OvumEconomicImpact_Report_5_21_08.pdf. (estimating that by 2016 the wireless industry will help bring about \$427 billion per year in productivity gains, more than the productivity gain currently provided by the motor vehicle and pharmaceutical industries combined).

⁸ Rysavy Research, *Mobile Broadband and Spectrum Demand*, <http://www.rysavvy.com> (Dec. 2008), p. 23 (Rysavy, *Spectrum Demand*). For a detailed description of mobile (and other) allocations under 3 GHz, see Evan Kwerel & John Williams, *A Proposal for a Rapid Transition to Market Allocation of Spectrum*, Federal Communications Commission OPP Working Paper No. 38 (Nov. 2002) (Kwerel & Williams, *Big Bang*).

⁹ Federal Communications Commission Press Release, *Auction of Advanced Wireless Service Licenses Licenses Closes* (Sept. 20, 2006). Due to regulatory lags, AWS bandwidth was not generally available to licenses until well into 2007 or even 2008. There is also a lag between the time licenses are assigned and networks are built. T-Mobile, the largest AWS bidder, first began serving customers using these frequencies in May 2008. See Katherine Noyes, *T-Mobile's 3G Network Touches Down in NYC*, TECHNEWSWORLD (May 5, 2008); <http://www.technewsworld.com/story/62876.html?wlc=1235087208>.

¹⁰ Rysavy, *Spectrum Demand*, p. 23.

¹¹ Comments of T-Mobile USA, Inc. to the National Telecommunications and Information Administration, U.S. Department of Commerce, *In the Matter of Relocation of Federal Systems in the 1710-1755 Frequency Band, Review of the Initial Implementation of the Commercial Spectrum Enhancement Act*, Docket No. 0906231085-91085-01 (Aug. 21, 2009); http://www.ntia.doc.gov/comments/2009/CSEA/T-Mobile_CSEA_NOI_Comments_8-21-09.pdf.

conducted further auctions for the use of 52 MHz in the 700 MHz band, collecting another \$19.6 billion in winning bids.¹² The 700 MHz frequencies were occupied, in part, by analog TV broadcast stations which were switched off June 12, 2009 as part of the transition to digital television.¹³ These frequencies are largely being held for deployment in emerging “4G” (Fourth Generation) wireless services offering far higher data speeds and capacities than existing wireless broadband networks.¹⁴

The recent FCC sales of new wireless licenses will bring the total amount of licensed spectrum available to mobile carriers in the U.S. up to levels comparable to those in the European Union. By 2001, EU regulators had issued mobile licenses allocating an average of about 266 MHz per country, about 50 percent higher than the amount then allocated in the U.S.¹⁵ The recent AWS and 700 MHz auctions bring the U.S. total up to about 360 MHz available for mobile service,¹⁶ but EU countries are now preparing to make major new allocations that will extend the leap-frogging.¹⁷

¹² Federal Communications Commission Press Release, *Statement by FCC Chairman Kevin J. Martin* (Mar. 18, 2008).

¹³ In 1997 the FCC assigned each TV station a new digital TV broadcasting license, placing the digital stations on channels 2-51 so as to allow the remaining channels assigned to TV broadcasting (52-69) to be later reallocated. By regulatory mandate, stations were broadcasting in digital formats on their new digital channel assignments by 2002. The end of analog broadcasting on TV Channels 52-69 had been mandated by Congress to occur Dec. 31, 2006, but contained conditions unlikely to be met in the vast majority of markets. Long delays were anticipated. Hence, in the Digital Transition and Public Safety Act of 2005 Congress set Feb. 17, 2009 as the new analog switch-off date. Just days before the deadline, however, Congress, responding to a request from the new Obama Administration, voted to delay the switch-off until June 12, 2009. This deadline held. Ending analog TV broadcasting on channels 52-69 made 108 MHz (6 MHz per channel) available for reallocation. Some 70 MHz of this “digital dividend” was allocated to liberal licenses auctioned by the FCC in 2002, 2003 and 2008.

¹⁴ Gary Kim, *4G Wireless Evolution - Verizon Promises 5 Mbps to 12 Mbps LTE Speeds*, TMCNET (Dec. 7, 2009); <http://4g-wirelessevolution.tmcnet.com/topics/4g-wirelessevolution/articles/70469-verizon-promises-5-mbps-12-mbps-lte-speeds.htm>.

¹⁵ Thomas W. Hazlett and Roberto E. Muñoz, *Spectrum Allocation in Latin America: An Economic Analysis*, 21 INFO ECON & POL’Y 261 (June 2009).

¹⁶ See Blair Levin *et al.*, Stifel Nicolaos, *What 700 MHz Winners Can Do with Their Spectrum*, at 4 (Apr. 15, 2008). These totals do not include spectrum to “fixed” broadband services, such as the 3.5 GHz band in Europe, and the 2.5 GHz band in the U.S. While these wireless services are being adapted for mobile use, the migration – undoubtedly promising as a future source of competition – is yet nascent. Clearwire is developing a nationwide wireless broadband network using WiMax technology delivered over 2.5 GHz frequencies. There is potentially some 190 MHz available for use there, divided between EBS (Educational Broadband Services) licensed held by non-profit (mostly educational) institutions and BRS (Broadband Radio Service) licenses held by commercial operators. Transaction costs associated with re-aggregating the dispersed, truncated, and conflicting transmission rights have been formidable. See Thomas W. Hazlett, *Spectrum Tragedies*, 22 YALE J REG 242 (Summer 2005) (“Hazlett, *Spectrum Tragedies*”). As of year-end 2008, Clearwire reported about 400,000 U.S. subscribers, while cellular carriers accounted for over 25 million high-speed access subscribers. *Clearwire Reports Fourth Quarter and Full Year 2008 Results*, Clearwire website (Mar. 7, 2009); <http://newsroom.clearwire.com/phoenix.zhtml?c=214419&p=irol-newsArticle&ID=1263228&highlight=>. Federal Communications Commission, *High-Speed Services for Internet Access: Status as of December 31, 2008*, Industry Analysis and Technology Division, Wireline Competition Bureau, (Feb. 2010), p. 9; http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-296239A1.pdf.

¹⁷ “Ofcom, the regulator in United Kingdom, is in the process of reallocating 355 MHz of spectrum for commercial wireless services, which would bring the U.K.’s total up to 710 MHz... Similarly, in Germany, 340 MHz of spectrum has been identified for reallocation, which will bring the total up to 645 MHz...” Comments of CTIA-The Wireless Association submitted to the Federal Communications Commission, In the Matter of In the Matter of Implementation of Section 6002(b) of the Omnibus Budget Reconciliation Act of 1993, WT Docket No. 09-66 (Sept. 30, 2009), pp. 82-3.

To meet the perceived U.S. deficit, the FCC has announced that it “recommends making 500 megahertz of spectrum newly available for broadband by 2020, with a benchmark of making 300 megahertz available by 2015.”¹⁸ The goal is ambitious; previous experience suggests that even much smaller allocations take much longer to implement.¹⁹

Cellular licenses were issued in the U.S. between 1982 and 1989, PCS licenses beginning in 1995.²⁰ These latter awards represented a paradigm shift in the authorization of spectrum use, rejecting the traditional regime crafted for and typified by broadcasting licenses. For radio and television stations, licensees receive narrowly crafted operating permits that define the service they can provide, the technology they may employ, the physical location where they must place transmitters (and transmitter height), and the business model (advertising-based, non-subscription) they must use. A TV broadcaster cannot, for example, forego video transmissions and instead use its licensed spectrum to provide high-speed internet service.

Wireless phone licenses – and particularly PCS licenses – were the first major implementation of two fundamental policy innovations: (1) awarding licenses by competitive bidding, abandoning assignments by regulatory fiat or lottery²¹; and (2) permitting licensees wide discretion in using allotted frequency space.²² Auctions were efficiency-enhancing,²³ but the latter policy was of much greater significance for consumer welfare.²⁴ With licensees free to choose services, technologies, architectures, and business models, market forces could for the first time optimize radio spectrum use. The emergence of vigorous economic activity, including high levels of network investment, led regulators to adopt liberal licenses as the new standard for wireless services.

In parallel to the evolution of the liberal license model, a second distinct FCC policy regime also was developing. Traditionally, the FCC set aside bands for “unlicensed” use by low power, short-range radios – remote controls, short-range security systems, and baby monitors, for example. Such

¹⁸ Federal Communications Commission, National Broadband Plan: Connecting America (Mar. 16, 2010), p. 26; <http://www.broadband.gov/download-plan/>.

¹⁹ Spectrum for cellular telephone service was first formally sought when the FCC opened a rule making on the matter in 1968. Licenses, two per market, were finally assigned by lottery in the 1983-89 period. These licenses were allocated 25 MHz each (50 MHz total). PCS spectrum was first requested at the FCC in 1989. Auctions assigned the first licenses in 1995 but, with many fits and starts, completed in 2005. Total spectrum allocated to the PCS licenses was 120 MHz.

²⁰ Thomas W. Hazlett, *Assigning Property Right to Radio Spectrum Users: Why Did FCC License Auctions Take 67 Years?* 41 J LAW & ECON 133 (Oct. 1998) (“Hazlett, 67 Years”). Note that while the U.S. was the first country to widely assign cellular licenses (for analog voice services), EU countries issued 2G (Second Generation) licenses (for digital voice services) in 1989-1992. This was years ahead of the comparable U.S. allocation, for PCS.

²¹ License auctions were first authorized in Section 6002 of the Omnibus Budget Reconciliation Act of 1993. The first spectrum auctions were for PCS awards. Lotteries had been used to assign cellular licenses. See James B. Murray, Jr., *Wireless Nation* (2001).

²² For example, cellular licenses were originally issued with a mandate that operators use a specific analog transmission format (AMPS); there was no mandated format for digital PCS licenses.

²³ Peter Cramton, *Spectrum Auctions*, S. Majumdar, et al., eds., *Handbook of Telecommunications Economics* (North Holland, 2002) (“*Spectrum Auctions*”).

²⁴ See Thomas W. Hazlett & Roberto E. Muñoz, *A Welfare Analysis of Spectrum Allocation Policies*, 40 RAND JOURNAL OF ECONOMICS 424 (Autumn 2009).

unlicensed bands have also been allocated for the use of non-communications devices, like microwave ovens and medical or scientific equipment that emit radiation potentially conflicting with the use of communications systems. The first unlicensed bands were established in 1938.²⁵

In 1985, however, the FCC took a decisive step in authorizing a whole class of new unlicensed devices, eliminating the process of regulatory pre-approval under vague “public interest” criteria. This deregulatory initiative, which began under President Jimmy Carter’s FCC and was implemented under President Ronald Reagan’s, aimed to reduce barriers to entry for new technologies.²⁶ In place of a case-by-case regulatory process, the FCC set forth technical criteria, including power limits, to which new “Part 15” unlicensed devices would need to adhere.²⁷ This policy paved the way for widespread use of unlicensed devices in the so-called Industrial, Scientific and Medical (ISM) frequencies in the 900 MHz (26 MHz), 2.4 GHz (83.5 MHz) bands, and 5.8 GHz (125 MHz). In subsequent years, thousands of unlicensed devices were introduced under the Part 15 framework, including cordless phones and WiFi radios connecting computers in local area networks.²⁸ One of the lead FCC engineers that worked on the regulatory initiative recounts that such devices were neither planned nor anticipated.²⁹

In recent years, the FCC has moved aggressively to allocate more bandwidth to unlicensed (or “license-exempt”) spectrum.³⁰ In 1985, there was 234.5 MHz of spectrum (in the ISM bands)

²⁵ See Kenneth R. Carter, Ahmed Lahjouji & Neal McNeil, FCC, *Unlicensed and Unshackled: A Joint OSP-OET White Paper on Unlicensed Devices and Their Regulatory Issues*, OSP Working Paper No. 39 at 6 (May 2003). Amateur bands (including CB “citizens’ band” frequencies) are organized on a similar basis to unlicensed bands, although radio operators are technically required to be licensed by the FCC. The requirement is loosely enforced. Moreover, licenses help to assure that users comply with FCC rules, and do not cede control of spectrum space. In this sense, unlicensed (amateur) bands have been in use since before the 1927 Radio Act.

²⁶ See Michael J. Marcus, *Wi-Fi and Bluetooth - The Path from Carter and Reagan-era Faith in Deregulation to Widespread Products Impacting Our World*, 5 INFO 19 (August 2009); Kenneth R. Carter, *Unlicensed to Kill: A Brief History of the FCC Part 15 Rules*, 5 INFO 8 (August 2009); Kevin Negus & Al Petrick, [History of Wireless Local Area Networks \(WLANs\) in the Unlicensed Bands](#), 5 INFO 35 (August 2009).

²⁷ See 47 C.F.R. § 15 *et seq.* In addition to the limiting technical constraints, Part 15 requires that an operator accept whatever interference is received and correct whatever interference is caused. Should harmful interference occur, the operator is required immediately to correct the interference problem, even if correction of the problem requires ceasing operation of the Part 15 system causing the interference. See *In the Matter of Revision of Part 15 of the Commission’s Rules Regarding Ultra-Wideband Transmission Systems, First Report and Order*, ET Docket 98-153, ¶ 6 n.2 (rel. April 22, 2002).

²⁸ Devices are regulated under three methods at the FCC: Verification, Declaration of Conformity, and Certification. The latter category relies largely on tests performed by private firms. See FCC Office of Engineering and Technology; <http://www.fcc.gov/oet/ea/procedures.html#sec1>.

²⁹ “In the 1981-85 period when these rules were drafted, wireless LANs were not a common topic of discussion. Indeed, Ethernet and other LAN installations were rare outside technical organizations and unheard of in homes. The deliberations had raised the possibility of ‘wireless data terminals’ as an example, but did not specifically “tilt” in favor of this application in the resulting rules. The Carter and Reagan era faith in deregulation laid the foundation for the future development of a variety of products without the need for government action.” Marcus, *Wi-Fi and Bluetooth*, at 29-30.

³⁰ The rationale for this policy shift was laid out in the FCC’s Spectrum Policy Task Force Report issued in Nov. 2002, and was strongly endorsed by then FCC Chair Michael Powell, appointed by Pres. George W. Bush. See Spectrum Policy Task Force, FCC, *Report*, E.T. Docket No. 02-135 (Nov. 2002); see also Lawrence Lessig, *Technology Over Ideology*, 12.12 WIRED (Dec. 2004); <http://www.wired.com/wired/archive/12.12/view.html?pg=5> (“When Powell took charge, most thought the FCC would quickly launch massive spectrum auctions. The reigning ideology was that spectrum is land, and

available to unlicensed devices.³¹ By 2004, approximately 665 MHz of spectrum in the same frequency range had been allocated to unlicensed use. In comparison, as of that same date, about 385 MHz had been allocated in this range to liberal licenses – an unlicensed-to-licensed ratio of 1.7.³² This tends to be substantially higher than in other countries, where the ratio is generally less than one. See Figure 1.

The U.S. government push favoring unlicensed bandwidth was further seen in an important 2005 decision. Regulators allocated 50 MHz (3650 to 3700 MHz) for terrestrial services including WiMax an emergent wireless broadband technology often referred to as “wi-fi on steroids.”³³ Despite the general use of neighboring frequencies (known generically as “the 3.5 GHz band”) in international markets as licensed spectrum, and the development of WiMax radios using these airwaves by equipment makers, the FCC chose to allocate the entire band for unlicensed (non-exclusive) access.³⁴ This generated controversy even among the major vendors of radios for use in unlicensed spectrum, Intel and Alvarion, which had opposed the FCC’s approach.³⁵ Then, in a much larger and more valuable band where the Commission sought to choose between licensed and unlicensed models, the FCC ruled in December 2008 that the frequencies previously used by analog television broadcasts would be set-aside for the use of unlicensed devices. This decision set aside an estimated 240 MHz of UHF bandwidth in the median U.S. market,³⁶ and brings the total unlicensed allocation to 955 MHz.³⁷ By comparison, as of year-end 2008, approximately 422 MHz had been

that markets allocate land most efficiently. But Powell's FCC quickly sabotaged this idea... Auctions were slowed; spectrum commons were encouraged.”).

³¹ In 2002, the requirement that devices using ISM bands conform to spread spectrum formats was abolished, while power limits and other technical constraints were retained. *Amendment of Part 15 of the Commission's Rules Regarding Spread Spectrum Devices, Second Report and Order*, ET Docket No. 99-231 (Rel. May 30, 2002).

³² See also Hazlett, *Spectrum Tragedies* at Table 2 (comparing 648.5 MHz of unlicensed spectrum to 189 MHz of “flexible use,” licensed spectrum).

³³ George Ou, *How to Waste Perfectly Good Mobile Spectrum*, DIGITAL SOCIETY (March 16, 2010); <http://www.digitalsociety.org/2010/03/white-space-backhauls-a-penny-wise-and-a-pound-foolish/>.

³⁴ *Wireless Operations in the 3650-3700 MHz Band*, First Report and Order (ET Docket No. 04-151 (Rel. March 16, 2005)).

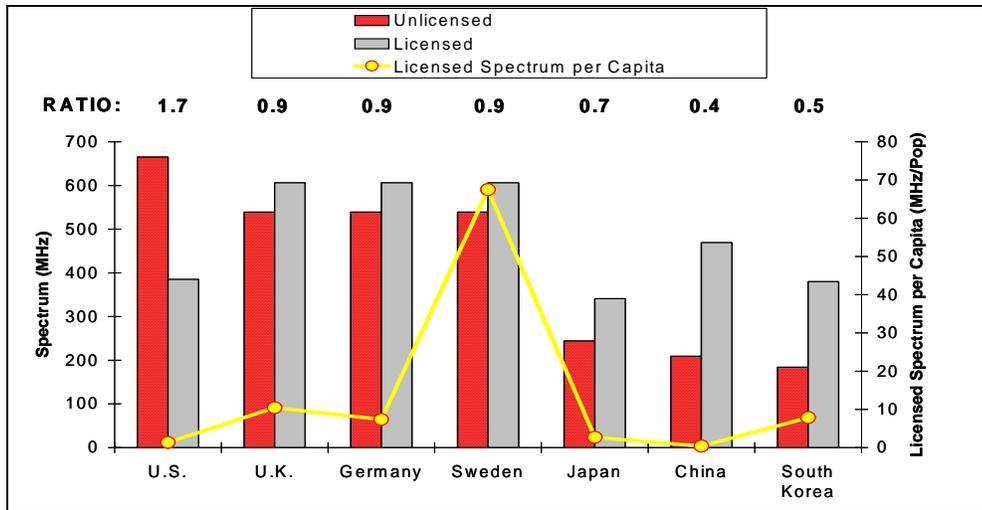
³⁵ See Jerry Brito, *The Spectrum Commons in Theory and Practice*, 2007 STAN TECH L R 1; <http://stlr.stanford.edu/pdf/brito-commons.pdf>

³⁶ Under FCC rules, unlicensed devices will be permitted to access TV band spectrum not occupied by television broadcasters. The average TV market features 8.6 TV stations (there are 1800 full-power stations and 210 TV markets), and each market is allocated 49 TV channels allocated 6 MHz each (294 MHz total). This leaves about 240 MHz for unlicensed use. We note that the bandwidth that would actually be for available for unlicensed devices is much below the 240 MHz set aside. See Michael Calabrese, *Broadcast to Broadband*, IEEE INTERNET COMPUTING (March/April 2008); http://www.newamerica.net/files/Broadcast_to_Broadband.pdf. That is because the FCC usage restrictions, ostensibly employed to protect over-the-air television viewers on the one side and unlicensed device users on the other, leave many unused channels in place to separate rival applications. Moreover, transactions to move TV stations to alternative channels or platforms (cable, satellite, and broadband) so as to efficiently resolve conflicts are impossible to execute given the lack of band ownership under the non-exclusive usage rights issued by the FCC.

³⁷ This total includes 26 MHz in the 900 MHz band; 83.5 MHz in the 2.4 GHz band; 50 MHz in the 3.6 GHz band; 555 MHz in the 5 GHz band; and 240 MHz in the “white spaces” TV band.

allocated to liberal licenses, bringing the ratio of unlicensed to liberal-license spectrum to about 2.3:1.³⁸

FIG. 1. RATIOS OF UNLICENSED TO LICENSED SPECTRUM UNDER 6 GHz (2005)



An influential coalition composed of major technology firms such as Intel,³⁹ Microsoft,⁴⁰ Apple,⁴¹ Cisco,⁴² Google,⁴³ and other computer manufacturers, together with several academics,⁴⁴ has

³⁸ By year-end 2008, some 422 MHz of spectrum was allocated for liberal licenses, although much of it was encumbered. In particular, 700 MHz licenses hosting TV broadcasts ongoing until a scheduled June 2009 analog switch-off. Licensed spectrum allocations are calculated as: 50 MHz (800 MHz cellular), 120 MHz (1.9 GHz PCS), 14 MHz (SMR, 1.9 GHz), 90 MHz (1.7/2.1 GHz AWS), 70 MHz (700 MHz), 78 MHz (2.5 GHz, 13 6-MHz BRS channels). The 30 MHz of WCS spectrum is not included because, while license rules are liberal in terms of services and technologies, emission rules are exceedingly stringent. The WCS licenses, auctioned in 1997, attracted extremely low bids as a result. See Cramton, *Spectrum Auctions*. Ironically, the FCC blocked a 2006 bid by satellite radio licensee XM to buy WCS licenses. With Satellite Digital Audio Radio Service (SDARS) licenses allocated spectrum adjacent to the WCS band, integration of ownership could have easily solved the externality problem. Tony Sanders, *FCC Delay Scotches WCS Merger*, RADIO MONITOR (May 22, 2006); <http://www.allbusiness.com/services/motion-pictures/4479825-1.html>. On how ownership structures impact transaction costs, see Harold Demsetz, *Ownership and the Externality Problem*, in T.L. Anderson & F. S. McChesney, eds. *Property Rights: Cooperation, Conflict and Law* 282 (Princeton Univ. Press; 2003).

³⁹ See, e.g., P. Pitsch, *The Future of Radio Spectrum Policy*, Technology@Intel Magazine (Feb./Mar. 2004), <http://www.intel.com/technology/magazine/standards/st02041.pdf>.

⁴⁰ See, e.g., Comments of Microsoft Corporation at 2-3, *Revision of Parts 2 and 15 of the Commission's Rules to Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz Band*, ET Docket No. 03-122 (FCC filed Sept. 3, 2003).

⁴¹ See, e.g., Comments of Wireless Information Networks Forum, *Apple Computer, Inc. Petition for Rulemaking To Allocate Spectrum in the 5 GHz Band To Establish a Wireless Component of the National Information Infrastructure*, RM-8653 (July 10, 1995).

⁴² See, e.g., Cisco Systems, *Wireless and Spectrum Management*, http://www.cisco.com/web/about/gov/networks/wireless_spectrum_management.html.

⁴³ Stephanie Condon, *Google Launches 'Free the Airwaves,'* CNET NEWS.COM (Aug. 18, 2008); http://news.cnet.com/8301-1035_3-10018917-94.html.

been urging the FCC to expand the unlicensed “spectrum commons.” Advanced low-power radios, they argue, can use embedded sensors and digital intelligence to sense each other’s presence and avoid interfering with each other’s transmissions. In the most aggressive form of the argument, all carriers and consumers should therefore be allowed to transmit radio signals in any frequency band using one of these smart radios.

With this technology in hand, these advocates claim, exclusive, property-like rights in spectrum are obstructive anachronisms. The FCC should therefore designate more frequency bands as unlicensed – *i.e.*, to be used only by FCC-permitted low-power radios. And the FCC should allow anyone to operate low-power transmitters in licensed bands allocated for services provided by broadcasters, wireless phone companies, and others, so long as these “underlay” devices operate below some power threshold set by the FCC, and incorporate smart protocols to avoid interfering with licensed transmissions.

The FCC has been receptive to this vision. In 2002, an FCC-convened task force advocated further use of unlicensed bands.⁴⁵ On the predicate that unlicensed bands have been a “tremendous success,”⁴⁶ the Commission designated several new bands for unlicensed access.⁴⁷ The FCC also authorized underlay rights for ultra-wideband (UWB) radios in bands above 10 GHz, provided they use very low power to leave other communication signals undisturbed.⁴⁸ The FCC further considered authorizing unlicensed devices to access licensed spectrum in its Interference Temperature proceeding, launched in November 2003; the initiative failed, however, and the proceeding was terminated in May 2007.⁴⁹ And the 3650 MHz and TV Band “white spaces” proceedings, mentioned

⁴⁴ See, e.g., Yochai Benkler, *Overcoming Agoraphobia: Building the Commons of the Digitally Networked Environment*, 11 Harv. J. L. & Tech. 287 (Winter 1998); Lawrence Lessig, *The Future of Ideas: The Fate of the Commons in a Connected World* (Random House 2001); Yochai Benkler, *Some Economics of Wireless Communications*, 16 Harv. J. L. & Tech. 25 (Fall 2002); Kevin Werbach, *Supercommons: Toward a Unified Theory of Wireless Communication*, 82 Texas L. R. 863 (Mar. 2004); Kevin Werbach, New America Foundation, *Radio Revolution: The Coming Age of Unlicensed Wireless* at 47 (Dec. 15, 2003) (“Werbach, *Radio Revolution*”); J.H. Snider, *Reclaiming the Vast Wasteland: The Economic Case for Re-Allocating to Unlicensed Service the Unused Spectrum (White Space) Between TV Channels 2 and 51*, New America Foundation Wireless Future Program (Oct. 2005).

⁴⁵ See Federal Communications Commission, *Spectrum Policy Task Force Report*, ET Docket No. 02-135 (Nov. 15, 2002).

⁴⁶ *Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band, Notice of Inquiry*, 17 FCC Rcd 25632, ¶ 6 (2002).

⁴⁷ This includes 2 GHz in the 57-59 GHz band (2000); 255 MHz in the 5.470-5.725 GHz band; 2.9 GHz in the 92.0-94.0 and 94.1-95.0 GHz bands (2003); and 50 MHz in the 3.65-3.7 GHz band (2005). *Amendment of Part 2 of the Commission’s Rules to Allocate Additional Spectrum to the Inter-Satellite, Fixed, and Mobile Services to Permit Unlicensed Devices to Use Certain Segments in the 50.2-50.4 GHz and 51.4-71.0 GHz Bands*, Report and Order ¶ 2, ET Docket No. 99-261, FCC 00-442 (Rel. Dec. 22, 2000); *Revisions of Part 2 and 15 of the Commission’s Rule to Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5GHz Band*, Report and Order, ET Docket No. 03-122, RM-10371 (Rel. Nov. 18, 2003); *Allocations and Service Rules for the 71-76 GHz, 81-86 GHz and 92-95 GHz Bands*, Report and Order, WT Docket No. 02-146, RM-10288, FCC 03-248 (Rel. Nov. 4, 2003); *Wireless Operations in the 3650-3700 MHz Band*, Report and Order, ET Docket No. 04-151, WT Docket No. 05-96 (Rel. Mar. 16, 2005).

⁴⁸ Federal Communications Commission, *Revision of Part 15 of the Commission’s Rules Regarding Ultra-Wideband Transmission Systems, First Report and Order*, ET Docket No. 98-153 (rel. April 22, 2002).

⁴⁹ *Establishment of an Interference Temperature Metric to Quantify and Manage Interference and to Expand Available Unlicensed Operation in Certain Fixed, Mobile and Satellite Frequency Bands*, Order, Order, ET Docket No. 03-237 (rel. May 4, 2007).

above, were clear victories for champions of unlicensed spectrum access, victorious in head-to-head match-ups where the Commission considered whether to apply licensed or unlicensed rules for specific frequencies.

III. WIFI, TELEVISION, AND WIDE-AREA WIRELESS

Much of the case for un-licensing spectrum begins with the argument that broadcast television wastes valuable radio spectrum and that an unlicensed regime can make more productive and efficient use of the spectrum.⁵⁰ For empirical support, commons advocates rely heavily on the success of WiFi, which is now widely used in local area networks, public hot spots, and other applications. Wi-Fi, as one commons advocate puts it, is “the most prominent unlicensed wireless technology available today,” and “a great case study for the impact of dynamic wireless technologies.”⁵¹ Introduced in the late 1990s,⁵² Wi-Fi radios now provide high-speed, digital connections to millions of users using unlicensed bandwidth. TV broadcasters, by contrast, provide video service via exclusive licenses. But TV band airwaves are dramatically under-utilized, littered with “white spaces” where little to no communications travel. Indeed, *all* over-the-air TV reception could be transferred to cable and/or satellite TV systems at a small fraction of the cost of the TV airwaves that would be released for more valuable services.⁵³ Exclusive spectrum rights, we are to conclude, impede innovation and promote inefficient use of the airwaves.

Both ends of the comparison are confused. First, broadcast TV licenses are locked into inefficient market structures precisely because of “command and control” regulation that economists have long condemned as “Gosplan.”⁵⁴ Ronald H. Coase’s classic critique of the FCC focused on these licenses, leading him to recommend adoption of private property rights in spectrum to replace “public interest” assignments by regulators.⁵⁵ Coase’s proposal was considered radical. When Coase

⁵⁰ Paul Baran, *Is the UHF Frequency Shortage a Self Made Problem?* Marconi Centennial Symposium, Bologna, Italy (June 23, 1995); <http://www.interesting-people.org/archives/interesting-people/199507/msg00023.html>.

⁵¹ Werbach, *Radio Revolution* at 22. See also Yochai Benkler, *Some Economics of Wireless Communications*, 16 Harv. J. Law & Tech. 25, 30 (Fall 2002) (“Benkler, *Some Economics of Wireless Communications*”) (noting the “breathtaking growth” of WiFi devices that “rely on utilizing frequencies that no one controls.”); Wireless Broadband Access Task Force, FCC, *Connected & On the Go: Broadband Goes Wireless* at 3 (Feb. 2005) (“FCC Task Force Paper”) (noting the “tremendous success” of WiFi devices).

⁵² Negus & Petrick, *History of Wireless Local Area Networks*.

⁵³ Thomas W. Hazlett, *The U.S. Digital TV Transition Time to Toss the Negroponte Switch*, AEI-Brookings Joint Center for Regulatory Studies Working Paper No. 01-15 (Nov. 2001); Thomas W. Hazlett, *Transition to Yesterday: Subsidizing the Killer App of 1952*, ARS TECHNICA (Nov. 3, 2008); <http://arstechnica.com/old/content/2008/11/dtv-transition-to-yesterday.ars>; Richard H. Thaler, *The Buried Treasure in Your TV Dial*, N.Y. TIMES (Feb. 27, 2010); <http://www.nytimes.com/2010/02/28/business/economy/28view.html>.

⁵⁴ Gerald R. Faulhaber & David J. Farber, *Spectrum Management: Property Rights, Markets, and the Commons*, AEI-Brookings Joint Center for Regulatory Studies Working Paper No. 02-12 (Dec. 2002).

⁵⁵ Ronald H. Coase, *The Federal Communications Commission*, 2 J L ECON 1 (1959).

explained his proposal at a 1959 FCC hearing, the first question posed by a Commissioner was, “Is this all a big joke?”⁵⁶

It was not. Were licensees to freely control the spectrum allocated to their licenses, rather than being granted narrow rights to transmit in ways specified by regulators, these de facto property owners would naturally seek to expand value creation – to make productive use of “white spaces.” It took a quarter century for regulators to (implicitly) start to embrace Coase’s proposal. Beginning with licensing of cellular phone service in the 1980s, carriers were given far more control over the use of their spectrum as compared to radio and TV broadcasting licensees.

Why the shift? Well, for one thing, the political interest in regulating cellular was lower because the content transmitted over cellular networks is private, whereas broadcasting is inherently public, transmitting content influencing social, cultural, and political developments. For another thing, the cost of regulating cellular was much higher. Instead of a single, one-way transmitter, cellular systems involve the integration of literally thousands of base stations and literally millions of handsets, each a receiver and a transmitter moving in space. The increasingly liberal licenses granted mobile phone operators have endowed firms with the ability to design their own services, adapt new technologies, determine network architectures, and experiment with new business models as profit criteria dictate, a radical departure (for allocated spectrum⁵⁷) from the traditional broadcast license.

The historical broadcast license is quite distinct from a liberal license. Licensees are endowed with extremely delimited property rights in spectrum; their specific use permits authorize only a broadcasting service operated according to fixed technical standards and pre-specified service definitions. Licensees cannot allocate the spectrum allocated to their licenses to higher valued uses, even if alternatives are more profitable. The gross inefficiencies that result are not due to licensing, but to truncating private ownership of spectrum rights. As Coase recognized, granting licensees ownership of spectrum, as in broad, “flexible use” permits,⁵⁸ allows market forces to divert spectrum resources to their most socially valuable employments.⁵⁹

On the flip side of the comparison between Wi-Fi and broadcasting, commons advocates misread the market evidence on Wi-Fi. Although highly effective and popular as a method for

⁵⁶ Ronald H. Coase, *Comment on Thomas W. Hazlett*, 41 J L ECON 577, 579 (Oct. 1998).

⁵⁷ The reforms begun with cellular licensing do not constitute full liberalization, in that only modest amounts of bandwidth have been allotted to liberal licenses. More widespread reforms have occurred in other countries. See Thomas W. Hazlett, *Property Rights and Wireless Licenses*, 51 J L ECON 563 (Aug. 2008).

⁵⁸ Kwerel & Williams (2002) use the term *flexible use* as a proxy for exclusive spectrum rights. Hazlett & Spitzer expand the term to EAFUS, *exclusively-assigned, flexible-use spectrum*. Thomas W. Hazlett & Matthew L. Spitzer, *Advanced Wireless Technologies and Public Policy*, 79 SO CA L R 595 (March 2006) (Hazlett & Spitzer, *Advanced Wireless*).

⁵⁹ With colleagues, Coase outlined a detailed policy proposal for private property rights in spectrum in 1962, a considerable feat given the relative dearth of market data to rely on. See Ronald H. Coase, William Meckling, and Jora Minasian, *Problems of Radio Frequency Allocation*, Rand Corp. DRU-RH-1219 (Sept. 1995; originally written in 1962). The efficiency of the approach suggested has, indeed, proven successful as per many economic analyses. Perhaps the most influential source is the 2002 report on spectrum policy commissioned by the Government of the United Kingdom. Martin Cave, *Review of Radio Spectrum Management*, Independent Review Report prepared for Department of Trade and Industry – Her Majesty’s Treasury (March 2002) (“*Cave Report*”), <http://www.ofcom.org.uk/static/archive/ra/spectrum-review/index.htm>.

connecting PCs to broadband networks, fixed, short-range data links are primarily a complement to wide area networks (WANs) rather than a substitute (which may eclipse the alternative in the marketplace). Wi-Fi nodes have flourished in enterprises as high-speed fiber connections became available; similarly, residential adoptions have soared as cable modem, DSL (digital subscriber line), and fiber subscriptions have been extended to U.S. households. In this context, the driver of demand for unlicensed devices is the deployment of the WANs, which rely upon private property rights to “spectrum in a tube.” This causality is more easily seen, perhaps, in the case of cordless phones, an appendage of fixed networks. There, the clarity of the symbiotic economic relationship has generally prevented commentators from asserting that plain old telephone service can more efficiently be supplied using a “spectrum commons.” It would be nonsensical to claim that the use of the edge device (the cordless handset) was in any way undermining the utility of the ownership rights to the fixed network and the bandwidth created by its investors.

Unlicensed frequencies are not “open access” regimes that enable users to appropriate spectrum resources without constraint.⁶⁰ Nor are unlicensed bands organized within a “commons,” where collective resource owners set usage rules to maximize joint returns.⁶¹ Group owners do not set resource-appropriation terms, government regulators do. Trade-offs from adopting different rules are evaluated on behalf of the public. Regulation of unlicensed bands creates non-exclusive use rights, and the conditions imposed exclude particular types of behavior so as to protect others. A high-powered TV broadcast station is not allowed to blast emissions, diminishing opportunities for low-power radios attempting to provide home networking links in the same market. This is intended to limit conflicts between rival users of a scarce resource,⁶² rather than risk resource dissipation due to unproductive competition for rights.⁶³

Property rules are an antidote to “tragedy of the commons.”⁶⁴ Where entirely unrestricted access prevails and scarcity obtains, the marginal user will crowd into the “free” resource even as the cost borne by the group of users exceeds the (new) benefit created. The standard example is an open pasture that becomes “over-grazed” by the owners of cattle, each of whom realizes some gain until the resource is destroyed for all.

⁶⁰ The law and economics literature recognizes four standard property regimes: open access, state property, common property, and private property. See Dean Lueck and Thomas J. Miceli, *Property Law*, in A. M. Polinski and S. Shavell, eds., *Handbook of Law and Economics* Vol. 1 (Amsterdam: Elsevier, 2007), at 183-257. The U.S. spectrum regime has not, strictly speaking, nationalized airwaves or privatized airwaves. Rather, the law is that the public owns the airwaves, with the federal government regulating access so as to protect these public resources. See Thomas W. Hazlett, *The Wireless Craze, The Unlimited Bandwidth Myth, the Spectrum Auction Faux Pas, and the Punchline to Ronald Coase’s “Big Joke”*: An Essay on the Airwave Allocation Policy, 14 HARV JL & TECH 335 (Spring 2001), at 459-61. As a practical matter, this arrangement constitutes state ownership, also known as administrative allocation. Resource use is determined by state regulators, not by private or group owners.

⁶¹ This is the key characteristic of the self-organizing commons studied in such classic works as Elinor Ostrom, *Governing the Commons* (Cambridge, 1990).

⁶² See Harold Demsetz, *Towards a Theory of Property Rights*, 57 AMER ECON REV 347 (May 1967).

⁶³ See Henry E. Smith, *Exclusion versus Governance: Two Strategies for Delineating Property Rights*, 31 J LEGAL STUD S453 (2002)

⁶⁴ Garret Hardin, *The Tragedy of the Commons*, 162 SCIENCE 1243 (1968).

Perhaps because of the compelling manner in which the “over-grazing” problem is formulated, it is often missed that the regulation of unlicensed devices – prescriptions on technology standards and power limits – is just another approach to avert a tragedy of the commons. The regime seeks to permit some behavior and to block incompatible behavior. The proper test of social efficiency is not whether “interference” has been reduced or eliminated, but whether the most valuable outcomes obtain.⁶⁵

Three implications arise. First, anarchy does not reign. The power limits and technology restrictions imposed by regulators protect some applications and users at the expense of others. Scarcity is not eliminated; indeed, the effort to advance what Benkler labels a “well regulated commons”⁶⁶ is itself a rejection of open access. Allocating spectrum for unlicensed usage necessarily excludes certain wireless alternatives, implicating trade-offs that need not be made in the case of true resource abundance.

Second, tragedy of the commons may obtain even when there is little or no interference between users. Markets that experience over-utilization yield the most widely recognized “tragedy,” but rules to mitigate resource dissipation can easily result in under-utilization, which is equally inefficient. Such an outcome includes the instance where investments in technology, infrastructure, or economic organization – say, paying incumbents to move their wireless operations – are socially efficient but fail to occur due to the lack of spectrum ownership. Market failure of this sort has clearly occurred in unlicensed bands, such as U-PCS, where spectrum allocated for over a decade to data transmissions saw not a single device approved for use by the FCC.⁶⁷

Third, even when abundant use is made of unlicensed bands, the allocation may be socially destructive. For example, unlicensed rules may exclude services that are more valuable than the protected activities. Equivalently, the social value created in the use of unlicensed devices may be achieved more economically by via exclusive spectrum rights, provided either by market competitors or via the acquisition of bandwidth by a non-profit organization supplying a “spectrum park.” The active secondary market in spectrum access vividly demonstrates how device makers can, rather than request unlicensed allocations for the use of their radios, contract with mobile licensees exercising de facto spectrum ownership. Apple arranges for its iPhone customers to access radio spectrum via bulk contracts it arranges with carriers (in U.S. and internationally). Amazon sells its Kindle book reader with embedded wireless functionality (for digital content downloads) by contracting (in the U.S.) with the Sprint phone network. General Motors operates an emergency OnStar radio service by contracting with Verizon Wireless.⁶⁸ The market supplies radio spectrum and network services

⁶⁵ Coase, *FCC*, at 27.

⁶⁶ Yochai Benkler, *Overcoming Agoraphobia: Building the Commons of the Digitally Networked Environment*, 11 Harv. J. L. & Tech. 394 (Winter 1998).

⁶⁷ See, e.g., Kenneth R. Carter, *Policy Lessons from Personal Communications Services: Licensed vs. Unlicensed Spectrum Access*, 15 COMMLAW PERSPECTUS 93 (2006), at 97 (footnotes omitted) (“[I]n 1993 the... the FCC assigned PCS spectrum both by licenses awarded in competitive bidding auctions and through an unlicensed model... it is hard to argue that licensed PCS has not been a huge success at lowering prices and spurring competition with cellular service. Conversely, unlicensed PCS has at best been a very late bloomer, and at worst, dead.”).

⁶⁸ John W. Mayo & Scott Wallsten, *Enabling Efficient Wireless Communications: The Role of Secondary Markets in Spectrum*, INFO ECON & POL’Y (forthcoming) (“Mayo & Wallsten, *The Role of Secondary Markets*”); http://www.gcbpp.org/files/Academic_Papers/EnablingWirelessCommunicationsJuly2009.pdf; Thomas W. Hazlett, *The*

(with infrastructure complementary to frequency spaces) for an extremely wide range of applications, rival application providers bidding against each other for available resources. To the degree that spectrum inputs with exclusive ownership rights are made available by regulators, the standard economic optimization results.

IV. WI-FI: THE STARBUCKS FALLACY

The Wi-Fi standard for wireless, high-speed, local-area networks was ratified in 1999.⁶⁹ By 2002, global annual sales of Wi-Fi equipment had exceeded \$1 billion;⁷⁰ by 2006, such sales reached an estimated \$3.8 billion.⁷¹ The secret of Wi-Fi's success, commons advocates maintain, is that the standard defines low-power, spread-spectrum devices that can operate "without the requirement of spectrum licensing to prevent interference."⁷² With Wi-Fi, "there is no need for service providers, cell towers, controlled hardware markets, or expensive spectrum licenses."⁷³

While WiFi was taking off, comparable wireless data services offered in licensed bands were allegedly doing "exactly the opposite."⁷⁴ Although wireless phone companies eventually began offering high-speed data services, these networks cost ten times more,⁷⁵ and "[n]one . . . has yet become a mass-market success."⁷⁶ WiFi, it is suggested, is superior even to high-speed wireline connections: there is "great consternation in the communications industry" about the inadequacies of DSL and cable modem broadband services, and Wi-Fi service "costs half as much."⁷⁷

Even putting aside the factual predicates (and premature nature) of these arguments,⁷⁸ the comparisons are fatally flawed. First, assuming that unlicensed devices are popular, it does not

Modular Confines of Mobile Networks: Are iPhones iPhone? George Mason Law & Economics Research Paper No. 10-01 (Jan. 2010); http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1533441.

⁶⁹ See Institute of Electrical and Electronics Engineers, Inc. (IEEE), *Get IEEE 802*, <http://standards.ieee.org/getieee802/802.11.html>.

⁷⁰ See Kenneth R. Carter, Ahmed Lahjouji & Neal McNeil, FCC, *Unlicensed and Unshackled: A Joint OSP-OET White Paper on Unlicensed Devices and Their Regulatory Issues*, OSP Working Paper No. 39 at 32 (May 2003) (citing Goldman Sachs).

⁷¹ Bernie Mahon & Louis Gerhardy, Morgan Stanley, *Q1 2006 Global Technology Databook*, at 22 (March 3, 2006) ("*Global Technology Databook*").

⁷² Werbach, *Radio Revolution* at 23.

⁷³ *Id.*

⁷⁴ *Id.* at 22.

⁷⁵ *Id.* at 23 ("[A] Wi-Fi network costs . . . one-tenth as much as a third-generation cellular network.").

⁷⁶ *Id.* at 22.

⁷⁷ *Id.* at 23.

⁷⁸ Licensed wireless 3G services have become extremely popular with the advent of smart phones and other advanced wireless devices, while wireline broadband connections (particularly cable modem and new fiber-to-the-premises networks) now offer speeds up to 100 Mbps, far in excess of what a Wi-Fi connection provides. See *Annual Report and Analysis of Competitive Market Conditions With Respect to Commercial Mobile Services*, Thirteenth Report, WT Docket

necessarily follow that more spectrum should be allocated to unlicensed instead of licensed uses. In 2008, U.S. Wi-Fi devices and cordless phones were out-sold by well over an order of magnitude by digital TV sets, which garnered \$27 billion in sales.⁷⁹ Yet, the airwaves dedicated to broadcast television are severely misallocated because video signals can be delivered more efficiently on alternative platforms, freeing the TV band for more productive employments.⁸⁰ From a social welfare perspective, the relevant policy question is how incremental bandwidth can best create value. In evaluating trade-offs, it is important to recognize that licensed regimes can provide precisely the same applications as unlicensed spectrum. Just as public parks are supplied under a private property regime for land, public, private non-profit, or private for-profit enterprises can host spectrum sharing arrangements.⁸¹ To achieve an efficient outcome, the analysis must determine that the costs of pre-empting alternative liberal license allocations are less than unlicensed benefits. No amount of economic activity in unlicensed bands itself makes the case for allocating more unlicensed spectrum.

Second, as an empirical matter, the social value of the economic activity associated with liberal licenses far exceeds what has been achieved in unlicensed bands. Licensed wide area wireless networks are used by more than 270 million⁸² U.S. subscribers who pay over \$148 billion⁸³ a year and generate at least another \$150 billion⁸⁴ in consumer surplus. Equipment sales tell a similar story. In 2006, global sales for WWANs (wireless wide area networks, using liberal licenses) were about \$225 billion (including handsets); for WLANs (wireless local area networks, using unlicensed

No. 08-27 (rel. Jan. 16, 2009); Saul Hansell, *Cablevision Goes for U.S. Broadband Speed Record*, NY Times (Apr. 28, 2009), <http://bits.blogs.nytimes.com/2009/04/28/cablevision-goes-for-us-broadband-speed-record/>.

⁷⁹ Consumer Electronics Association Press Release, *Consumer Electronics Industry Issues 2009 Forecast* (Jan. 8, 2009) (digital television sets accounted for 15% of the \$172 billion shipment revenues in 2008).

⁸⁰ Hazlett, *Transition to Yesterday*.

⁸¹ FCC spectrum policy experts have noted efficiencies of such an institutional approach:

[When] making decisions about the amount of spectrum allocated to unlicensed use, the government should face the opportunity cost of limiting or foreclosing other use. Just as the government decides how much land to purchase for public parks, it would decide how much spectrum to set aside for unlicensed devices. A market system would also provide the opportunity for private spectrum licensees in flexible bands to compete with the government for the provision of spectrum for low-power devices, just as private facilities that charge admission compete with public parks. Licensees might find it profitable to do so by charging manufacturers of such devices to operate on their spectrum. This would allow private licensees to compete on the technical protocols and other quality factors instead of relying on government or industry committees.

Kwerel & Williams, *Big Bang* at 7.

⁸² Cellular Telecommunications & Internet Association (CTIA), *Semi-Annual Survey of Wireless* (2008); http://files.ctia.org/pdf/CTIA_Survey_Year-End_2008_Graphics.pdf.

⁸³ Cellular Telecommunications & Internet Association (CTIA), *Semi-Annual Survey of Wireless* (2008), http://files.ctia.org/pdf/CTIA_Survey_Year-End_2008_Graphics.pdf.

⁸⁴ Hazlett & Muñoz, *Welfare Analysis*. Professor Jerry Hausman produces consistent estimates using a different model. See Jerry Hausman, *Mobile Telephone*, Ch. 13 in Martin Cave, et al., eds., *Handbook of Telecommunications Economics Vol. I* 563, 586 (2002).

frequencies) about \$3.8 billion.⁸⁵ By 2012, analysts expect that smartphone revenues will reach \$66 billion.⁸⁶

FCC statistics for broadband access in the United States tell the same story. While unlicensed bandwidth is available everywhere for the use of Internet Service Providers (ISPs), and while hundreds of WISPs (wireless ISPs) use wireless for this purpose,⁸⁷ they operate in small deployments, usually in rural areas where low population densities ensure minimal interference. The result is that unlicensed frequencies, while useful in providing Wi-Fi as a WLAN appendage in millions of homes or businesses that subscribe to wide area broadband services, are virtually non-existent in supplying WAN services themselves. The FCC recorded only 700,000 fixed wireless customers as of year-end 2007, a total which includes ISPs using licensed as well as unlicensed frequencies, as compared to more than 52 million mobile high-speed data customers (all delivered via licensed spectrum). See Table 1. In addition, the FCC reported about 71 million fixed high-speed connections (cable modem, DSL, and fiber), networks relying on the ownership of spectrum encased in wires. The bottom line; more than 121 million subscribers receive high-speed data service (fixed and mobile) via exclusively owned bandwidth, as against – at most -- just a few hundred thousand subscribers to WISPs accessing the “spectrum commons.”

⁸⁵ Morgan Stanley, *Global Technology Handbook* at 22, 24.

⁸⁶ Jason Armstrong et al, Goldman Sachs, *The Mobile Data Opportunity – Finding the Best Spots in the Food Chain* (Apr. 17, 2008).

⁸⁷ According to the Wireless Internet Service Provider Association, there are 300-1000 WISPs. See http://www.ntia.doc.gov/broadbandgrants/090319/NTIA_031909_1000_1200_session.txt (citing WISPA member saying there are 300-1000 WISPs); Comments of the Wireless Internet Service Provider Association, *A National Broadband Plan for Our Future*, GN Docket No. 09-51 (June 8, 2009); see also WISP Directory, *WISP USA*, http://www.wispdirectory.com/index.php?option=com_mtree&task=listcats&cat_id=73&Itemid=53 (the WISP Directory lists 1,845 WISPs in the US).

TABLE 1. U.S. BROADBAND SUBSCRIBERS (DEC. 2007)⁸⁸

Technology ²	2005	2006		2007	
	Dec	Jun	Dec	Jun	Dec
ADSL	19,515,483	22,584,255	25,412,883	27,561,867	29,451,719
SDSL	368,782	337,412	344,759	319,987	293,974
Traditional Wireline	510,191	610,722	685,939	752,009	592,295
Cable Modem	26,558,206	29,174,494	31,981,705	34,404,368	36,497,284
Fiber ³	448,257	685,823	1,035,677	1,403,729	1,850,695
Satellite	426,928	495,365	571,980	668,803	791,142
Fixed Wireless	257,431	361,113	484,377	586,813	705,014
Mobile Wireless	3,127,670	11,016,520	22,287,749	35,305,253	50,977,914
Power Line and Other	4,571	5,208	4,776	5,420	5,274
Total Lines	51,217,519	65,270,912	82,809,845	101,008,249	121,165,311

The rise and fall of Municipal Wi-Fi networks is also revealing evidence. “Muni Wi-Fi” was widely touted as the next big thing in broadband in 2006 and 2007.⁸⁹ At one point, there were plans to deploy scores of networks covering such major urban areas such as Philadelphia, Houston, Boston, Chicago, Los Angeles, Atlanta and San Francisco.⁹⁰ By 2008, however, virtually all of these plans had collapsed.⁹¹ Access to “free” airwaves were supposed to provide cheap service, but the structure of property rights – with regulatory limitations on power, technology, and the inability to exclude (or, therefore, contract with) potentially rivalrous spectrum users – has rendered the model of limited practical use.⁹² Gradually, this reality has set in. “Story after story after story highlight[s] how wide-area WiFi is a lot more complicated than many in the industry (and the press) would have you believe.”⁹³

At the end of the day, Wi-Fi offers only very limited substitution possibilities for high-speed DSL, cable, fiber, or wide area wireless. As commons advocates themselves acknowledge, it is “a

⁸⁸ Source: Federal Communications Commission, *High-Speed Services for Internet Access: Status as of December 31, 2007* (Jan. 2009), Table 1.

⁸⁹ Robert McChesney and John Podesta, *Let There Be Wi-Fi*, WASHINGTON MONTHLY (Jan./Feb. 2006); <http://www.washingtonmonthly.com/features/2006/0601.podesta.html>.

⁹⁰ Thomas W. Hazlett, *Philadelphia Freedom*, ARS TECHNICA (Dec. 22, 2008); <http://arstechnica.com/telecom/news/2008/12/muni-wifi-fcc-free-wireless.ars>.

⁹¹ *Id.*

⁹² This is why the hundreds of private WISPs did not see such services as profit opportunities, leading community activists and policy makers to seek local government support. The deals struck by municipalities included subsidies, monopoly rights to access street lights (for placement of wireless nodes), or exclusive contracts with public agencies (anchor tenants).

⁹³ Michael Masnick, *Can Mesh WiFi Solve The Net Neutrality Issue?* TECHDIRT (June 20, 2006); <http://techdirt.com/articles/20060620/0318228.shtml>.

short-range technology designed primarily for connections to a nearby hotspot.”⁹⁴ Wi-Fi radios typically operate at such low power that “[e]ven if every home in a neighborhood had a Wi-Fi access point, few of those nodes would *see* one another. . . .”⁹⁵ Wi-Fi devices, in short, rarely interfere with each other because they provide such limited range. The secret of Wi-Fi’s success is the secret of Wi-Fi’s failure. By contrast, DSL, cable modems, fiber, and wireless broadband service (*e.g.*, EV-DO) provide wide-area coverage across cities and markets, cost-effectively scaling to national and international networks.

Some predict, however, that more and better Wi-Fi lies ahead and that radio-frequency (RF) engineering advances will overcome all these limitations. Such range-extending technology includes phased-array antennas, mesh networking boxes that automatically create ad hoc mesh networks with each other, a follow-up standard (802.16) for wireless metropolitan-area-network (“MAN”) technology, and so forth.⁹⁶

There is no doubt that innovative advances will come, but they will not be restricted to use in unlicensed bands. Rapid technological change is the networks using licensed spectrum. Airwaves are agnostic to regulatory regimes; investors are not. Where network owners can optimize a given spectrum space, contracting with those who will share it, they are often able to bring more resources and greater social coordination to bear. This is observed in liberal licensed spectrum, which is being far more intensely developed and utilized, in economic value terms, than spectrum allocated to traditional licenses or unlicensed bands. As U.S. smart phone sales reach \$14 billion per year,⁹⁷ iconic wireless innovations such as the Apple iPhone and RIM Blackberry rely on wide area wireless networks, and the licensed spectrum they use, to revolutionize communications. Hence, as the benefits of using unlicensed spectrum rise, the opportunity costs of taking allocations away from liberal licenses rise *pari passu*.

Which brings us to Starbucks. When eliminating (through government regulation) all options other than low-power radios, exclusive rights in *real estate* may work similarly to exclusive rights in *spectrum*. Users can themselves limit the number of transmitters and/or receivers competing for access to spectrum in corporate offices, on university campuses, and Starbucks coffee shops.⁹⁸ Intel, for example, carefully restricts unauthorized use of unlicensed frequencies within its corporate office

⁹⁴ Werbach, *Radio Revolution* at 39. “Basic WiFi or its variants . . . cannot simply be put into service for last-mile deployments.”

⁹⁵ *Id.* (emphasis added).

⁹⁶ *Id.* at 23, 39; Björn Wellenius & Isabel Neto, *The Radio Spectrum: Opportunities and Challenges for the Developing World* at 7, World Bank Policy Working Paper 3742 (Oct. 2005) (“Other recent innovations include smart radios and antennas, software-defined radios, cognitive radios, and mesh, ad-hoc, or viral networks. As a group, these technologies enable users not to cause insurmountable interference to each other even when transmitting at the same time, in the same place, and on the same parts of the spectrum”)(internal citations omitted); see Fulvio Minervini, *Emerging Technologies and Access to Spectrum Resources: the Case of Short-Range Systems* at 112 – 115, Communications & Strategies (3Q 2007) available at http://mpr.ub.uni-muenchen.de/6786/1/MPRA_paper_6786.pdf.

⁹⁷ The Consumer Electronics Association estimates 2009 U.S. sales of 37 million smartphones, with total revenues of \$14 billion. This is about forty times cordless phone sales. Wi-fi sales are not charted by CEA.

⁹⁸ See Hazlett, *Spectrum Tragedies* at 264-266.

space.⁹⁹ Carnegie Mellon protects the spectrum on its campus by effectively “privatizing the commons,” *i.e.*, carefully selecting what services and users to include in its network (and thereby which to exclude), while adopting technologies and distributing wireless access points to control interference problems.¹⁰⁰ This is not the “end of scarcity,” but the operations of a property system to manage competing, mutually exclusive activities.¹⁰¹ Conflicts still exist, and “open access” would be socially destructive.

In short, regulatory exclusions police Starbucks stores airwaves, limit unlicensed frequencies to the use of cordless phones, wireless routers, or other similar low-power devices. And Starbucks can eliminate further conflicts; instead of invite any and all ISPs to set-up local area networks in its stores, it designates an exclusive provider. Those not paying for service are denied access. The “spectrum commons” has been locally privatized, creating a fee-based service supplied solely by AT&T, one of the nation’s largest mobile wireless carriers.¹⁰² What is clear is that such services provide social value. What remains unclear, given the lack of a market for the spectrum inputs consumed, is that the opportunities consumed by the government’s spectrum allocation do not exceed these benefits. Net social value may well have been higher had companies like Starbucks, AT&T, and Cisco (a large maker of Wi-Fi hotspot routers) been forced to economize on spectrum resources by purchasing them in the market – just as AT&T does when acquiring billions of dollars worth of liberal licenses, making wireless access available to its millions of mobile subscribers.

What works in a Starbucks does not necessarily produce benefits exceeding social opportunity costs. Nor does it scale to other useful wireless applications. Indeed, the rules that allow the beneficial deployment of short range devices in a home or enterprise make the deployment of wide area networks – particularly for services involving the economic and technical complexity of mobile access – extremely problematic. The local Wi-Fi link that connects clustered, fixed users to a WAN relies on private property rights to radio spectrum to transport data to distant networks. Just as the cordless phone depends on, and does not replace, the telephone network, the cordless PC depends on, and does not displace, the wired or wireless wide area network.

⁹⁹ See Mike Chartier, Director Regulatory Policy, Intel, *Local Spectrum Sovereignty: An Inflection Point in Allocation*, Proceedings of the International Symposium on Advanced Radio Technologies, U.S. Dep’t of Commerce, NTIA Special Publication SP-04-409 at 32-33 (Mar. 2004) (“*Chartier, Local Spectrum Sovereignty*”) (“Failure to fulfill the above terms and conditions [for non-IT WLANs] will result in I.T.’s disconnecting and or taking possession of the Experimental W-LAN Access Points.”).

¹⁰⁰ Airspace Guideline for 2.4 GHz Radio Frequency at Carnegie Mellon University, as cited in *Chartier, Local Spectrum Sovereignty* at 33 (“While we will not actively monitor use of the airspace for potential interfering devices, we will seek out the user of a specific device if we find that it is actually causing interference and disrupting the campus network. In these cases, Computing Services reserves the right to restrict the use of all 2.4 GHz radio devices in university-owned buildings and all outdoor spaces on the Carnegie Mellon Campus.”).

¹⁰¹ David Weinberger, *The Myth of Interference*, SALON.COM (March 12, 2003); <http://www.salon.com/tech/feature/2003/03/12/spectrum/print.html>.

¹⁰² See Starbucks, *High Speed Wireless Internet Access*, <http://www.starbucks.com/retail/wireless.asp>.

V. BROADCASTING LICENSES: A BLAST FROM THE PAST

According to the exclusivity critique, the central problem in spectrum is that ownership rights result in the wasting of bandwidth. In any given geographic area, many channels in a licensed system are empty much of the time.¹⁰³ This was not always the case, according to spectrum commons advocates. Licensing was perhaps needed in 1927, but only because the broadcast radios of that era weren't smart. Things are very different today. Technology, they claim, makes once-scarce spectrum plentiful.¹⁰⁴ To prove this proposition, commons advocates have measured "actual usage" in "the most active channels of the broadcast bands... during peak hours in the highly populated, Dupont Circle area of Washington, DC."¹⁰⁵ These measurements are believed to establish that "[m]ost of the spectrum is empty in most places most of the time."¹⁰⁶

But the measurements equate *emitted radiation* with actual usage, disregarding the economic value generated. Under this scale, a broadcast tower emitting a 1,000,000-watt test pattern signal is not a waste of spectrum and electricity but a highly utilized frequency band. And even if spectrum use measurements were correctly done, they would reveal an even more sweeping indictment: the absence of effective airwave ownership cripples the process by which frequency spaces are bid into their highest-valued uses.¹⁰⁷ Administrative allocation leaves regulators in charge of resource choices, meaning that

¹⁰³ Werbach, *Radio Revolution* at 19; Lynette Luna, *Start-up Looks to Jump Start Secondary Spectrum Market*, FIERCEBROADBANDWIRELESS (Mar. 10, 2008), <http://www.fiercebroadbandwireless.com/story/start-up-looks-to-jump-start-secondary-spectrum-market/2008-03-10> (Rick Rotondo, SpectrumBridge's Vice President of Marketing, stated that "... in any given time and place, 80 percent to 94 percent of all allocated spectrum in the U.S. goes unused"); Federal Communications Commission, *Promoting Efficient Use of Spectrum Through Elimination of Barriers to the Development of Secondary Markets*, Notice of Proposed Rulemaking at 2, WT Docket No. 00-230 (Rel. Nov. 27, 2000) ("... radio spectrum may be used inefficiently by its current licensees or even lie fallow, especially in rural areas, limiting availability of valuable services to many"); Michael Calabrese, New America Foundation, *The End of Spectrum 'Scarcity': Building on the TV Bands Database to Access Unused Public Airwaves*, Working Paper No. 25 (June 2009), at 1, ("[I]n every community across the country, large swaths of valuable spectrum lie fallow the majority of the time. This underutilized spectrum represents enormous, untapped, public capacity for high-speed and pervasive broadband connectivity," ... "[S]tudies show that only a fraction of even prime frequencies below 3 GHz are in use, even in the largest cities, at any particular place or time. Federal agencies sit on hundreds of MHz that are unused in most areas; and many private licensees are warehousing spectrum, particularly in rural areas."); See also <http://www.sharedspectrum.com/measurements/#> (showing spectrum occupancy in six east coast locations including New York City, NY).

¹⁰⁴ Werbach, *Radio Revolution* at 21 ("Technology is making the wireless world look more and more like the ocean."); Bruce Fette, *Cognitive Radio Technology* 64 (2006) ("... SDRs and other advanced technologies can potentially alleviate many of the conflicts by making spectrum more plentiful through more efficient access"); U.S. General Accounting Office, *Comprehensive Review of U.S. Spectrum Management with Board Stakeholder Involvement Is Needed* at 9, Appendix III, GAO-03-277 (Jan. 2003) ("[A]dvances in technology could also help to accommodate more services and users").

¹⁰⁵ Werbach, *Radio Revolution* at 8, Figure 2.

¹⁰⁶ *Id.*; Max Vilimpoc & Mark McHenry, New America Foundation & Shared Spectrum Company, *Dupont Circle Spectrum Utilization During Peak Hours* (2003), <http://vilimpoc.org/research/policy/NAF-SSC-Spectrum-Measurement-Results.pdf>.

¹⁰⁷ Gregory I. Rosston & Jeffrey S. Steinberg, *Using Market-Based Spectrum Policy to Promote the Public Interest*, 50 FED COMM L J, 88 (1997); Pablo T. Spiller & Carlo Cardilli, *Towards a Property Rights Approach to Communications Spectrum*, 16 YALE J REG 53 (W 1999); Lawrence J. White, 'Propertyizing' the Electromagnetic Spectrum, 9 MEDIA L &

interest group competition rules the roost. The ugly result is that airwaves are systematically underutilized, maximizing not consumer welfare but the political interests of influential coalitions.

The historical origins of this system are instructive. In 1920, Westinghouse inaugurated the nation's first successful radio station, KDKA, in Pittsburgh.¹⁰⁸ Hundreds of other new stations began broadcasting shortly thereafter. Each transmitter was required to obtain a license from the Department of Commerce under the 1912 Radio Act.¹⁰⁹ While anyone could register for a license, and the Commerce Department had no basis on which to deny it, the agency was permitted to issue the license under terms "minimizing interference."¹¹⁰ In 1922, the Commerce Department established rules for allocating frequency slots on a first-come, first-served basis.¹¹¹ The government then delayed or encumbered new licenses (mandating time-sharing agreements, for example) to effectively protect existing stations from encroachment by entrants.¹¹²

The de facto property system, based on common law principles of *priority-in-use* or *right of user*, successfully launched the emerging medium. By the mid-1920s, and prior to any "public interest" licensing law, radio had become an extremely popular mass-market commodity.¹¹³ Yet key policy makers were not happy with this result, as the first-come-first-served approach severely limited their degrees of freedom. The Secretary of Commerce, Herbert Hoover, was vocal in his support for more administrative discretion, as was Sen. Clarence C. Dill (D-WA), a congressional leader in the area.¹¹⁴

Just as importantly, large incumbent radio stations sought a greater level of security. While priority-in-use protected their signals, it also created a risk of competitive entry. That is to say, new spectrum could potentially be claimed by new rivals. The broadcast stations sought a regulatory solution under which barriers could be legally erected to prevent this; the standard of "public interest, convenience, or necessity" – first suggested by the newly-formed National Association of Broadcasters in 1925 – was such a rule.¹¹⁵ Large commercial radio stations formed a coalition with key policy makers and ultimately gained passage of the Radio Act of 1927, placing radio broadcasting under the new Federal Radio Commission ("FRC").¹¹⁶ The FRC was empowered to license transmitters, assign

POL'Y (Fall 2000); *Comments of 37 Concerned Economists*, AEI-Brooking Joint Center for Regulatory Studies, Related Paper (Feb. 2001); Hazlett, *Wireless Craze*; Gerald R. Faulhaber, *The Future of Wireless Telecommunications: Spectrum as a Critical Resource*, 18 INFO ECON & POL'Y 256 (Sept. 2006).

¹⁰⁸ See IEEE History Center, *Westinghouse Radio Station KDKA, 1920*, http://www.ieee.org/organizations/history_center/milestones_photos/kdka.html.

¹⁰⁹ See Thomas W. Hazlett, *The Rationality of U.S. Regulation of the Broadcast Spectrum*, 33 J.L. & Econ. 133 (1990) ("Hazlett, *Rationality of Broadcast Regulation*").

¹¹⁰ 1912 Radio Act, Public Law. No. 264, 62d Congress (Aug. 13, 1912).

¹¹¹ See Clarence C. Dill, *Radio Law* (National Book Co.: 1938) ("Dill, *Radio Law*").

¹¹² Hazlett, *Rationality of Broadcast Regulation*.

¹¹³ Thomas W. Hazlett, *Physical Scarcity, Rent Seeking, and the First Amendment*, 97 COL L R 905 (May 1997).

¹¹⁴ Hazlett, *Rationality of Broadcast Regulation* at 162-63. Dill was a principal author of the 1927 Radio Act. See also, Dean Lueck, *The Rule of First Appropriation and the Design of the Law*, 38 J.L. & ECON 393 (Oct. 1995).

¹¹⁵ Dill, *Radio Law* at 89.

¹¹⁶ Radio Act of 1927, Pub. L. No. 632, 44 Stat. 1162 (1927). The Interstate Commerce Commission retained authority over common carrier use of radio spectrum.

frequencies, prescribe service limits, and approve the locations and power levels of transmitters according to “public interest” criteria. These policies were carried forward by the Communications Act of 1934, which transplanted the FRC into a newly-constituted Federal Communications Commission.¹¹⁷

Both policy makers and powerful incumbent stations gained from the bargain contained in the 1927 and 1934 acts. Regulators gained considerable control over the operations of licensees, including the ability to influence program content. And because license holders would be restricted to explicitly authorized activities, competition between licensees could be limited. New services, technologies, and business models were barred – forming, effectively, a government-enforced cartel. Later, law and economics scholars would characterize the general arrangement as “Taxation by Regulation.”¹¹⁸ Reducing competition via legal barriers increases profits; regulators then redirect some of the economic gains towards “public interest” expenditures.

FCC spectrum allocation proved bureaucratically tidy but economically inflexible. First, the FCC would zone the real estate. It assigned large blocks of spectrum for particular uses such as AM radio or VHF TV. Then it sliced each block into smaller licenses and assigned them to individual firms. Licensees got no “property rights” in spectrum;¹¹⁹ licenses typically expired after eight years,¹²⁰ and they could not be transferred without Commission approval.¹²¹ Between 1927 and the early 1970s, the FCC promulgated a dense web of rules governing license retention and alienability, transmission and programming rights, signal privacy, and content – rules like the “fairness doctrine” or an obligation to air programs deemed educational for children. Broadcasters, for example, were barred early on from using their main frequencies and facilities to transmit private, addressed messages to specific receivers – essentially telephone or telegraph services.¹²²

The traditional licensing approach results in vast waste of bandwidth precisely because licensees are given no ownership in the underlying spectrum but are instead restricted to specific uses of a radio technology defined by the regulator. Without spectrum ownership, private parties cannot transact to make more valuable use of idle frequencies. The tragedy is not the overuse of the commons, but its underuse.¹²³ In theory, the regulatory agency could prevent this, but it is not vested with real ownership, is unable effectively to finance productive, spectrum-enhancing investments, and receives no reward for generating extra social value. These misaligned incentives create “non-market failure.”¹²⁴

¹¹⁷ 47 U.S.C. 151. The Communications Act and its amendments, including those in the 1996 Telecommunications Act, are posted by the FCC; <http://www.fcc.gov/Reports/1934new.pdf>.

¹¹⁸ Richard A. Posner, *Taxation by Regulation*, 2 BELL J ECON & MGT SCI 1, 22-50 (Spring 1971).

¹¹⁹ See 47 U.S.C. §§ 301, 304, 309(h)(1); see also 1927 Radio Act § 1.

¹²⁰ 47 U.S.C § 307(c).

¹²¹ 47 U.S.C. § 310(d); see also 1927 Radio Act § 12.

¹²² See *Scroggin & Co. Bank*, 1 FCC 194 (1935); *Bremer Broadcasting Co.*, 2 FCC 79 (1935).

¹²³ Or, some call it, a tragedy of the anti-commons. See Michael Heller, *The Gridlock Economy* (Basic Books, 2008).

¹²⁴ Charles Wolf, Jr., *Markets or Governments: Choosing Between Imperfect Alternatives* (MIT Press, 1988). Wolf describes non-market failure as a situation in which the incentives of government policy makers do not reliably produce efficient outcomes, analogous to “market failure.”

Shifting to liberal licenses –granting wireless service providers exclusive rights and broad flexibility to use allocated spectrum – remedies this tragedy, creating the legal institutions to support Coasean contracting. These unleash incentives to invest in complementary assets that improve the productivity of airwaves, creating value for wireless users, some of which can then be captured by spectrum owners. This property structure enables complex organizational efforts, including those involving billions of dollars in risk capital dependent on the actions of millions of customers far into the future.

In sum, the case for un-licensing spectrum today is based on the deficiencies of a broadcast licensing policy established in the 1920s, and largely repudiated by spectrum policies that emerged in the U.S. and elsewhere in the 1980s and 1990s. Broadcasting is no longer dominant, having been eclipsed in value terms by the world of mobile communications. The licenses that enable those markets are sufficiently liberal as to represent *de facto* ownership of radio spectrum. The traditional licensing regime, despite the continued support of political survivalists in broadcasting, is universally recognized as obsolete. Grounded as it is on a critique of the 1927 Radio Act, the case for un-licensing spectrum targets a corpse, oblivious to the thundering herd now dominating communications markets via exclusive spectrum rights.

VI. WIRELESS CARRIERS AND FLEXIBLE LICENSES

One group of “broadcasters” has already completed a very successful transition from the old ways of licensing to the new. Radio dispatch services – used by taxicab companies, for example – once operated much like radio stations, under licenses that narrowly specified the service to be provided and the technology to be used. In 1987, a former FCC lawyer named Morgan O’Brien teamed up with an investment banker and began buying up dispatch companies – and their Specialized Mobile Radio (SMR) licenses – across the country.¹²⁵ Their company, FleetCall, then put forward a plan asking regulators to approve a technical upgrade for SMR licenses: they sought the right to deploy digital instead of analog radios. (The technological innovation would have violated license terms – hence the petition for license modification.)

The license modification also sought permission to use the extra capacity made possible by the technical upgrade for cellular phone calls. Such requests are met with strong opposition from established interests, and are typically deterred; why spend scarce resources on such low-probability payoffs? But Morgan O’Brien believed that his knowledge of the Commission and the timing of this proposal – with the explosion of cellular use and the drift in de-regulatory philosophy – brightened FleetCall’s prospects. Some years and \$2 million in legal fees later (as against an estimated \$20 million for opponents of the requested rule changes),¹²⁶ the underdog received approval.¹²⁷

¹²⁵ See K. Maney, *Nextel’s Morgan O’Brien Kept the Faith and, Boy, Has It Paid Off*, USA TODAY at 3B (Dec. 15, 2004). See also, O. Casey Corr, *Money Out of Thin Air: The Story of Craig McCaw, The Visionary Who Invented The Cell Phone Industry, and His Next Billion-Dollar Idea at 235-48* (Crown Business, 2000).

¹²⁶ Hazlett, *Wireless Craze* at 388, 428.

¹²⁷ See *Request of Fleet Call, Inc. for Waiver and Other Relief To Permit Creation of Enhanced Specialized Mobile Radio Systems in Six Markets*, Memorandum Opinion and Order, 6 FCC Rcd 1533, ¶ 36 (1991) (“*Fleet Call Order*”).

FleetCall adopted a new Motorola technology (iDEN, based on Time Division Multiple Access or “TDMA”), greatly expanding network capacity.¹²⁸ In March 1993, the “taxi dispatch” company renamed itself Nextel.¹²⁹ In 1995, wireless pioneer Craig McCaw invested \$1.1 billion.¹³⁰ Motorola improved iDEN to enable data and fax communications in addition to voice, along with two-way dispatch and paging applications.¹³¹ By 2003, FleetCall had acquired spectrum rights in the 700, 800, and 900 MHz bands,¹³² and was operating one of the largest digital networks in the country.¹³³ It executed a “spectrum swap” with the FCC, reducing interference that its phones caused to adjacent public service (fire, police, etc.) frequencies, receiving spectrum holdings in the 1.9 GHz band.¹³⁴ It then acquired several 2.1 and 2.5 GHz licenses, and established partnerships and roaming agreements giving it national coverage.¹³⁵ In 2005, Nextel – providing push-to-talk walkie-talkie service, wireless data services, wireless Internet access, and short messaging to roughly 17 million customers¹³⁶ – was sold to Sprint for an acquisition price of \$35 billion.¹³⁷

Other wireless carriers acquired their spectrum assets more directly. Verizon Wireless,¹³⁸ AT&T Mobility,¹³⁹ T-Mobile¹⁴⁰ and other mobile networks received cellular licenses – initially issued by the government in lotteries¹⁴¹ – largely through secondary market purchases. The early cellular networks were required to build systems incorporating the analog Advanced Mobile Phone

¹²⁸ *New Motorola Digital Technology Increases Channel Capacity as Much as Six Times, Promises Enhanced Services to Thousands of Customers*, PR Newswire (Sept. 20, 1991).

¹²⁹ See Nextel, *Nextel History*, http://www.nextel.com/en/about/corporateinfo/company_history5.shtml.

¹³⁰ See *Motorola Licenses Radio System, McCaw Invests in Nextel*, Newsbytes (Apr. 5, 1995).

¹³¹ *Motorola Announces Commercial Availability of iDEN Technology Enhancement*, PR Newswire (June 17, 1996).

¹³² See Nextel Communications, Inc., Form 10-K (SEC filed Mar. 27, 2003).

¹³³ Nextel Press Release, *Nextel Completes Another Industry First* (July 29, 2003).

¹³⁴ Roy Mark, *Nextel Finalizes Spectrum Swap*, WI-FIWI-FI PLANET (Feb. 7, 2005); <http://www.wi-fiplanet.com/news/article.php/3469601>; ; *Improving Public Safety Communications in the 800 MHz Band*, Report and Order, WT Docket 02-55 (Rel. Aug. 6, 2004).

¹³⁵ Nextel Communications, Inc., Form 10-K (SEC filed Mar. 15, 2005).

¹³⁶ See Nextel Press Release, *Nextel Reports Strong Results* (July 21, 2005).

¹³⁷ *Sprint to Buy Nextel for \$35 Billion in Major Deal*, CHICAGO TRIBUNE (Dec. 15, 2004); Sprint Press Release, *Sprint Nextel Completes Merger* (Aug. 12, 2005)..

¹³⁸ Verizon was formed from the merger of Bell Atlantic and GTE. Bell Atlantic had previously merged with NYNEX and AirTouch (originally the wireless arm of Pacific Bell). Verizon owns 55% of Verizon Wireless; Vodafone, a global mobile carrier based in the U.K., the other 45%.

¹³⁹ SBC (which had previously merged with Ameritech and Pacific Telesis) jointly owned Cingular with BellSouth (with SBC owning 60% and BellSouth 40%). In October 2004, Cingular merged with AT&T Wireless; by this time, SBC had acquired the long distance operator AT&T. Following the merger, SBC changed its name to AT&T. In 2006, AT&T acquired BellSouth.

¹⁴⁰ T-Mobile was created by the 2000 purchase of U.S. carrier VoiceStream by Deutsche Telekom, a German telecommunications provider spun off from the former state monopoly. *VoiceStream, Deutsche Telekom Seal \$50.7 Billion Deal*, REUTERS (July 24, 2000); <http://www.crn.com/channel/18809269;jsessionid=FX4SMMH2RYNDKQSNLRSKHSCJUNN2JVN>.

¹⁴¹ Thomas W. Hazlett & Robert J. Michaels, *The Cost of Rent Seeking: Evidence from the Cellular Telephone License Lotteries*, 39 SO ECON J 425 (Jan. 1993).

Systems (“AMPS”) standard. In 1988, the FCC relaxed this requirement, allowing operators to upgrade to a digital standard of their choosing, though still requiring that they maintain the old AMPS system as well.¹⁴² That was an important policy pivot which pointed the way to further liberalization.

In 1993, with the FCC getting ready to assign new Personal Communications Services (PCS) licenses, adding competitors to cellular, Congress ordered that all wireless phone rivals be regulated under a unified Commercial Mobile Radio Service (CMRS) designation.¹⁴³ Cellular, PCS, and SMR -- the reinvented taxi dispatcher -- would operate as direct rivals with broad, flexible-use spectrum rights.¹⁴⁴ This codified what the FCC had already begun to implement, pre-empted state rate regulation, and for the first time permitted licenses to be assigned through competitive bidding.¹⁴⁵ Chairman Reed Hundt remarked: “We totally deregulated wireless.”¹⁴⁶

Carriers seized the opportunity to deploy a range of digital voice technologies -- not only TDMA, but also GSM (the standard used most widely in the rest of world), and Code Division Multiple Access (“CDMA”), a rival standard developed by San Diego-based Qualcomm. These technologies have permitted aggressive upgrades over the years to second, third, and fourth generation (2G, 3G, and 4G in industry parlance) systems that have paved the way for innovative wireless services and devices. GSM networks, which AT&T and T-Mobile deploy, have evolved from EDGE to UMTS to HSDPA technology. CDMA networks, which Verizon and Sprint have deployed, evolved from IS-95, CDMA2000 1x, to EV-DO, to EV-DO Revision A. All four wireless carriers have recently begun yet another new upgrade -- to Long Term Evolution (“LTE”) technology, which offers download speeds to mobile handsets of up to 100 Mbps.

This progression occurs seamlessly, without disturbing network users, but requires vast resources: over \$20 billion annually in network capital expenditure.¹⁴⁷ Customers spend billions more per year on handsets -- an estimated \$22.2 billion in 2009.¹⁴⁸ With licensees given wide latitude to choose the technologies deployed and the services offered, firms compete vigorously to improve services, upgrade architectures, cut prices and provide popular platforms for third party content. Market forces compel efficiency of spectrum use in these bands.¹⁴⁹

¹⁴² *Amendment of Parts 2 and 22 of the Commission’s Rules To Permit Liberalization of Technology and Auxiliary Service Offerings in the Domestic Public Cellular Radio Telecommunications Service*, Report and Order, 3 FCC Rcd 7033 (1988) (the “Liberalization of Technical and Auxiliary Offerings” Order of 1988) (“1988 FCC Liberalization Order”).

¹⁴³ Omnibus Budget Reconciliation Act of 1993, Pub. L. No. 103-66, Title VI, § 6002(b)(2)(A), 107 Stat. 312, 393 (1993).

¹⁴⁴ The FCC found that SMR systems providing interconnected service should be classified as CMRS providers. *Implementation of Sections 3(n) and 332 of the Communications Act*, Second Report and Order, 9 FCC Rcd 1411, ¶¶ 90-92 (1994).

¹⁴⁵ See 47 C.F.R. § 24.

¹⁴⁶ Reed Hundt, *You Say You Want A Revolution* 98 (Yale U. Press, 1999).

¹⁴⁷ Skyline Marketing Group, *CapEx Report 2004*, Carrier Data Sheets (2005).

¹⁴⁸ Consumer Electronics Association Press Release, *Consumer Still Buying Consumer Electronics in a Down Economy, CEA Forecast Finds* (July 17, 2009).

¹⁴⁹ Of course, this “property rights” framework is limited both in the extent of the liberalization and in its scope (*i.e.*, allocated spectrum). See Kwerel & Williams, *Big Bang*.

Wireless license auctions have likewise been a success. Since competitive bidding began in 1994, the government has realized \$52.6 billion in receipts.¹⁵⁰ These numbers confirm the obvious: wireless service providers will pay substantial sums to avoid having to operate in a “spectrum commons.” Any firm has the choice to do otherwise, deploying state-of-the-art radios, spread spectrum devices, mesh Wi-Fi networks, or array antennae put forward as exhibits for the proposition that exclusive spectrum rights have outlived their usefulness. Yet, in March 2008, telecommunications firms shelled out \$19.6 billion to acquire exclusive access to 52 MHz of prime frequencies – paying far higher prices than in previous FCC auctions on an adjusted “per MHz-pop” basis.¹⁵¹ That firms reject available “free” spectrum in unlicensed bands and instead bid aggressively to acquire liberal licenses suggests that exclusive spectrum ownership is expected to offer productive efficiencies.

The standard explanation of private property rights in the economics literature is that a grant of exclusive control creates incentives for resource conservation and improvement.¹⁵² Liberal spectrum licenses promote precisely these outcomes. Between 1985 and 2008, cellular networks built approximately 242,000 cell sites,¹⁵³ investing some \$265 billion in the process.¹⁵⁴ CMRS network and end-user equipment evolved rapidly, smoothly transitioning from analog to digital service. Advanced compression technologies and smart antennas have been widely deployed, allowing carriers to pack more and more traffic into given bandwidth. For example, CDMA handsets are programmed to check 800 times per second for the lowest possible power level that maintains a link to the base station; GSM over 1,000 times. Dynamic power adjustment reduces spillovers, allowing more phone calls to be made.¹⁵⁵ These innovations and a host of others have resulted in increasingly intense use of frequency space. In 1993, a 10 km cell served, on average, fewer than seven subscribers per MHz. In 2003, in the same 10 km area, wireless networks averaged nearly 500 subscribers per MHz.¹⁵⁶

Thus, over two decades, great progress has been made in creating exclusive, flexible-use, geographically defined spectrum licenses. CMRS operators have freedom to choose what kind of network equipment to deploy and what services to offer. The approach has also given rise to the regulatory innovation of “overlay” rights. Bands littered with incumbent users, but containing substantially under-utilized “white spaces,” are shared with new, encumbered licenses. The new licensee

¹⁵⁰ Federal Communications Commission, *Statement by FCC Chairman Kevin J. Martin*, News Release (March 18, 2008). The Commission raised \$13.9 billion in the Sept. 2006 Advanced Wireless Services license sale, \$19.6 billion in the March 2008 700 MHz license auction, and another \$19.1 billion for all other licenses.

¹⁵¹ Price comparisons are generally made by adjusting for the bandwidth allocated the license (MHz) and the population in the coverage area of the license (pop). The 700 MHz auction brought an average winning bid of \$1.28 per MHz-pop, while the 2006 AWS auction averaged 53¢. Mindel de la Torre, *U.S. Spectrum Update: 700 MHz Band and Advanced Wireless Services (AWS)*, presentation to Spectrum 20/20 Rendez-Vous 2008 (Ottawa, Canada; May 6, 2008); <http://www.rabc-cccr.ca/Files/Mindel-Mindel1.pdf>. The one large previous auction for broadband PCS licenses, the A-B auction concluded in March 1995, generated total bids of \$7.7 billion and an average price equal to 51¢ per MHz-pop.

¹⁵² Demsetz, *Property Rights*.

¹⁵³ CTIA, Semi-Annual Wireless Industry Survey, http://files.ctia.org/pdf/CTIA_Survey_Year-End_2008_Graphics.pdf.

¹⁵⁴ CTIA database.

¹⁵⁵ *How to Make 3G Work in Europe*, The Economist (Sept. 26, 2002); http://www.economist.com/business/displayStory.cfm?story_id=1353050.

¹⁵⁶ *CTIA Interference Temperature Brief* at 5.

can emit, with broad flexibility, in the allotted frequencies, while respecting the operations of existing users who are grandfathered to continue transmitting. Incumbents are free to “sell out” to the new licensee, moving operations to other bands, fixed links, or ceasing altogether, with the overlay licensee capturing the benefits created.

Overlays effectively cede the task of spectrum reallocation to markets, endowing the overlay licensee with property rights to the fruits of whatever new, innovative band uses it can create. For example, new PCS licensees relocated 4,500 microwave incumbents, paying their moving costs, in order to take full advantage of their spectrum.¹⁵⁷ Likewise, in the 700 MHz band, Qualcomm paid dozens of TV stations on Channels 54, 55, and 56 to accept interference so that Qualcomm’s new mobile TV application, MediaFlo, could launch nationwide service in 2007.¹⁵⁸ Similar overlays are also used in the AWS frequencies, where licenses were auctioned in 2006.¹⁵⁹

No alternative property regime allows such efficiencies. In unlicensed bands, the deal-makers necessary for efficient coordination do not exist, which is exactly why such “commons” must rely on spectrum allocations, power limits, and technology mandates pre-set by regulators. Commons advocates have argued that abundant economic unlicensed activity now takes place in what were formerly considered “junk” or “garbage bands,” useless for productive activity.¹⁶⁰ But liberally licensed bands have likewise often started with “garbage,” and then struck gold by moving thousands of polluters out. The unlicensed bands host valuable applications, but only by powering down, accepting intermittent interference, and living amongst the “garbage.” This not only severely limits the potential of such bands, but also deters certain unlicensed frequencies, including those allocated to U-PCS and to the 3650-3700 MHz band, from providing net social value. Hamstrung by FCC rules and assigned to no owner, these bands are stuck in the bowels of administrative process.

VII. THE QUIET PAST AND NOISY FUTURE

There was no demand for spectrum before 1895 because nobody yet knew how to build a radio. Nobody needed any two years later, either. Guglielmo Marconi had demonstrated the basic engineering, but it would take another thirty years to develop products and business models to move hundreds of broadcast stations and millions of receivers into the mass market – enough radio hardware to spawn the conflicts that impelled the creation of a legal regime to police spectrum access.

To frame this history in terms relevant to the current debate, licenses matter when radio technologies and markets evolve to the point where things get crowded. The commons advocates insist

¹⁵⁷ Peter Cramton, Evan Kwerel & John Williams, *Efficient Relocation of Spectrum Incumbents*, 41 J L & Econ 647 (Oct. 1998).

¹⁵⁸ Thomas W. Hazlett, *A Law & Economics Approach to Spectrum Property Rights: A Response to Weiser and Hatfield*, 15 Geo Mason L. R. 975 (Spring 2008) (Hazlett, *Spectrum Property Rights*) at 1000-1004.

¹⁵⁹ See, e.g., *Spectrum Sharing and Incumbent Relocation Services for AWS Licensees*, Comsearch (April 11, 2008); http://www.commscope.com/andrew/eng/support_document/spec_sheets/network/_icsFiles/afieldfile/2008/04/11/BN_PA_101102_1_EN.pdf.

¹⁶⁰ Philip J. Weiser & Dale N. Hatfield, *Policing the Spectrum Commons*, 74 FORDHAM L REV 101 (2005) (“Weiser & Hatfield, *Spectrum Commons*”) at 101.

that when the technology is smart enough, things *never* get crowded. That story is exactly backwards. Setting aside regulatory barriers, it is the slow arrival of technology that has left some bands relatively empty. Bands that were empty a decade ago are crowded today in large measure because affordable new products have arrived to fill them. Technology is not the solution to spectrum scarcity, but its cause. As wireless technologies become smart, cheap, and ubiquitous, the social value of property rights – helping to create the platforms on which such burgeoning economic activity can be best accommodated – rises.

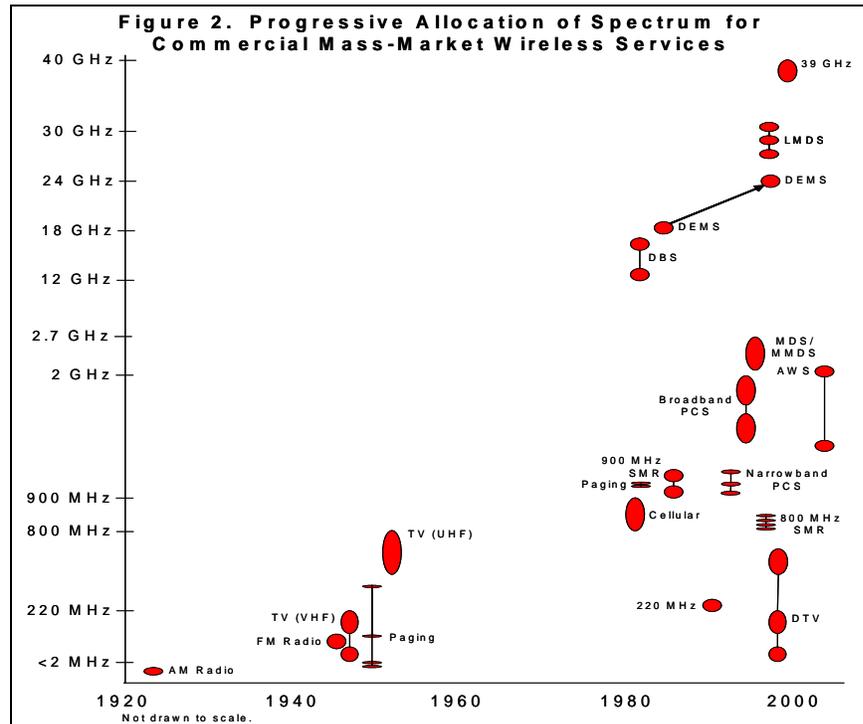
We face lots of spectrum scarcity looking forward. A radio’s power amplifier is the toughest part to build, and the higher the frequency, the tougher it gets. Twenty years ago, no one knew how to build the high-frequency gallium arsenide chip-scale amplifiers that now power many Wi-Fi radios. Wi-Fi radios operate at 2.4 and 5 GHz, and cheap, compact chip-scale amplifiers capable of handling such high frequencies hadn’t been developed until around that time. (To put the technical challenges involved here in perspective, recall that a state-of-the art Pentium microprocessor operates at “only” 3 GHz.) Military research funded the development of this exotic semiconductor,¹⁶¹ and licensed wireless carriers created the mass-market demand by selling millions of cell phones.¹⁶² In that sense, Wi-Fi took a free ride on technological innovation in licensed bands.

Unsurprisingly, the history of FCC licensing has tracked the progressive march of radio-amplifier technology up the frequency ladder – if with significant, wealth-destroying lags.¹⁶³ And the FCC’s allocation of spectrum for mass-market licensed services has largely tracked the frequency-climbing evolution of radios. *See* Figure 2. The amount of usable spectrum continues to expand because engineers continue to push radio frequencies up into higher bands, and radio costs down. The spectrum always looks un-crowded to pioneers at the very top of the ladder. Then, when costs drop and regulatory barriers fall, crowds follow.

¹⁶¹ *See* TRW News Release, *TRW To Fabricate Advanced Integrated Circuits for RF Micro Devices* (Dec. 7, 1993) (“Much of TRW’s [gallium arsenide (GaAs)] chip manufacturing expertise was developed as part of the Microwave and Millimeter Wave Monolithic Integrated Circuits (MIMIC) program sponsored by the Department of Defense’s Advanced Research Projects Agency (ARPA). . . . The MIMIC program was begun in 1987 by ARPA to make GaAs integrated circuits producible, affordable and applicable to a wide range of critical defense system needs.”).

¹⁶² *See, e.g.*, T. Whitaker, *SiGe and CMOS Target GaAs Dominance of Cellular PA Slots*, CompoundSemiconductor.Net (May 2004), <http://www.compoundsemiconductor.net/articles/magazine/10/5/3/1> (“[I]n the largest market segment, [power amplifiers] for cellular handsets, GaAs enjoys almost total dominance, and accounted for well over 95% of handset [power amplifier] revenues [in 2003], according to market research firm ABI Research.”).

¹⁶³ Cellular phone allocations were delayed from the late 1940s, when cellular technology was developed by Bell Labs, until licenses were distributed in the 1980s -- one notable example of regulatory lag. *See* George Calhoun, *Digital Cellular Radio* (Artech House, 1988).



The bands being occupied today have an additional feature: many high-frequency transmissions are easily blocked by physical obstacles, rain, and so forth. DBS satellites, for example, broadcast at 12 GHz. At this frequency, signals are blocked by foliage, so the pizza-sized receiving antennas require a treeless line of sight to the southern sky. Heavy rain can also block these signals. By contrast, the Navy’s ultra-low-frequency radios can communicate with submerged submarines. That high-frequency signals are easily blocked is a perfectly schizophrenic blessing, as the Wi-Fi experience again teaches. One Wi-Fi radio is unlikely to interfere with another when shielding supplied by walls and trees sharply limits its range. But that same limit is what makes it relatively costly to scale Wi-Fi deployments for many applications larger than a Starbucks.

VIII. FROM LMDS TO WIMAX

Consider the evolution of Wireless Metropolitan Area Networks (“WMANs”). These technologies support wireless links that can span distances of up to 30 miles; they can be used to backhaul traffic from local points of aggregation, or to provide last-mile broadband connectivity directly to customers.¹⁶⁴ The first-generation WMAN technologies (LMDS and MMDS, for example) and the second (WiMax and Mobile Fi) were both designed to operate principally in

¹⁶⁴ *FCC Task Force Paper* at 20 (“Wireless Metropolitan Area Networks (WMANs) are point-to-point or point-to-multipoint networks with individual links that not only can span distances of up to 30 miles, which is important for backhaul applications, but also can provide last-mile connectivity in metropolitan environments.”).

licensed bands. Unlicensed bands are viewed as viable alternatives only in the sparsely populated rural locations.

The first major wave of investment in WMAN technologies occurred shortly after passage of the 1996 Telecom Act. Between 1997 and 2000, the FCC licensed several large parcels of spectrum for these services – the 24 GHz band allocated for Digital Electronic Messaging Service (“DEMS”),¹⁶⁵ the 27-31GHz bands allocated to Local Multipoint Distribution System,¹⁶⁶ and the 39 GHz band.¹⁶⁷ These high frequencies provide very large amounts of bandwidth, but signals carry only a couple of miles, and require a clear line of sight.¹⁶⁸ Companies like Teligent, WinStar, and NextLink (later XO) bid aggressively to acquire blocks of spectrum that serve more than 90 percent of the population in 30 U.S. markets.¹⁶⁹ By year-end 2001, these companies had spent over \$10 billion building out their networks.¹⁷⁰ But the radios and receivers capable of handling these high frequencies were still very expensive, and much less reliable than wireline alternatives.¹⁷¹ These first-generation services all failed when Wall Street’s dot-com bubble collapsed.¹⁷²

¹⁶⁵ See *Amendments to Parts 1, 2, 87 and 101 of the Commission’s Rules To License Fixed Services at 24 GHz*, Report and Order, 15 FCC Rcd 16934, ¶¶ 3-4 (2000) (DEMS services were initially allocated spectrum in the 18 GHz band. This allocation was then moved to a different section of the same 18 GHz band. DEMS was finally relocated to the 24 GHz band in 1997.).

¹⁶⁶ See FCC LMDS Factsheet at 1. There are two LMDS licenses issued in each of 493 Basic Trading Areas (BTAs). Frequency Block A licenses are for 1.15 GHz in the 27.5-28.35 GHz, 29.1-29.25 GHz, and 31.075-31.225 GHz bands; Frequency Block B licenses are for 150 MHz in the 31-31.075 GHz and 31.225-31.300 GHz bands. See Wireless Telecommunications Bureau, FCC, *Factsheet for Auction 17 (Local Multipoint Distribution System) (LMDS)*, http://wireless.fcc.gov/auctions/default.htm?job=auction_factsheet&id=17.

¹⁶⁷ See Wireless Telecommunications Bureau, FCC, *Factsheet for Auction 30 (39 GHz)*, http://wireless.fcc.gov/auctions/default.htm?job=auction_factsheet&id=30 (“39 GHz licensees may provide fixed communications including point-to-point and point-to-multipoint communications”).

¹⁶⁸ K. Wanichkorn, Ph.D., *Thailand Rural Wireless Broadband Access Initiative*, presentation before APT Regional Forum for ICT Experts in South-East Asia, Jakarta, Indonesia (Feb. 4-5, 2004) (“High Microwave Frequencies (>10GHz)” work at “[s]hort propagation distances (3-5km) and require line-of-sight.”); A. Langowski, *LMDS Hits the Spot?*, CED MAGAZINE (Feb. 1, 2001), <http://www.cedmagazine.com/ced/2001/0201/id2.htm> (LMDS “systems operate only over short distances.”).

¹⁶⁹ *Id.*

¹⁷⁰ See, e.g., L. Whiteman, *TeraGo Lands \$20M in First Round*, DAILY DEAL (Apr. 24, 2001) (“Winstar spent more than \$6 billion building its network, according to estimates by Boston consulting firm Adventis.”); J. Barthold, *Teligent Faces New Sober Reality*, TELEPHONY (Sept. 16, 2002) (“We had \$2 billion to \$3 billion thrown at us.”) (quoting Teligent Marketing VP, Denise Goldberg); *Infospace Adds to Senior Management Team*, Business Wire (Apr. 2, 2003) (noting that NEXTLINK raised more than \$4 billion in capital).

¹⁷¹ See, e.g., *Intel and Clearwire Forge WiMAX Alliance*, THE REGISTER (Oct. 29, 2004), http://www.theregister.co.uk/2004/10/29/intel_clearwire_wimax/ (“The most critical element in the bursting of the last BWA bubble was the cost of subscriber equipment. . . . [T]he critical stumbling block for Winstar [was] the expensive, proprietary subscriber equipment.” at 25).

¹⁷² M. McCormack, et al., Bear Stearns, *Wireless Broadband: The Impact of 802 Technology* at 17, Exhibit 7.

As markets recovered and radios in these bands improved,¹⁷³ the licenses returned to investors' radar screens.¹⁷⁴ New firms with new business models acquired the licenses in the 24, 27-31, and 39 GHz bands. Companies like First Avenue Networks¹⁷⁵ and IDT¹⁷⁶ began leasing this spectrum wholesale to providers of high-speed Internet access, mobile carriers providing backhaul services, and wireline carriers that are building wireless extensions to their fiber-optic networks. This reallocation of spectrum to new and hopefully more valuable employments is an automatic function of exclusive rights, even through the disruption of bankruptcy. Indeed, trial and error is a socially useful discovery process when incentives guide investors to place the best bets, generating "creative destruction" that iterates on new efficiencies and produces technological disruptions of its own.

A new family of fixed wireless technologies – commonly known as WiMax – emerged in parallel. The original WiMax standard (IEEE 802.16) was developed to operate in licensed bands between 10 and 66 GHz.¹⁷⁷ Recent versions of the standard support both licensed and unlicensed operations between 2-11 GHz,¹⁷⁸ including licensed bands at 2.5 GHz and 3.5 GHz, and the unlicensed 5.8 GHz band that Wi-Fi uses.¹⁷⁹

The new investment, however, is dominated by operators that will use licensed spectrum – equipment manufacturers and service providers have both concluded that this is where the most promising opportunities lie. Clearwire has aggregated licenses in the 2.5 GHz band pursuant to a series of FCC rulings expanding licensee rights to allow two-way, cellularized, broadband services.¹⁸⁰ By 2009, it was offering wireless broadband service in at least 56 markets, including Anchorage, Seattle, Jacksonville, Waco, Reno, and Rochester, New York,¹⁸¹ and deploying 4G networks in Atlanta, Baltimore Las Vegas, and Portland, Oregon. With ambitious plans for national rollout,¹⁸² It

¹⁷³ *Id.* at 25 (June 2004) (noting that prices for CPE are still high, but "[t]he consensus from our interviews is that prices will be halved over the next two years, reaching a \$100 price point within five years."); *id.* at 26 (The current generation of wireless broadband equipment is "greatly improved over equipment from the 1990s.").

¹⁷⁴ See, e.g., First Avenue Networks Press Release, *First Avenue Networks Closes Acquisition of Teligent Assets* (Jan. 18, 2005); M. Dano, *Nextel Adds to MMDS Spectrum*, RCR WIRELESS NEWS (Nov. 10, 2003.); in 2006, First Avenue was acquired by FiberTower, First Avenue Networks Press Release (May 15, 2006); http://www.fibertower.com/corp/downloads/investors/FT_FAN_Release.pdf.

¹⁷⁵ See First Avenue Networks, *Solutions*, <http://www.firstavenet.com/solutions.htm>; IDT Press Release, *IDT Spectrum, Inc. Names Peter B. Atwal, President, Engineering and Operations* (Apr. 28, 2005) ("IDT Spectrum, Inc. is the recently formed subsidiary of IDT Corporation that operates and markets wireless spectrum products and solutions.").

¹⁷⁶ IDT Corp. Press Release, *IDT Corp. Announces the Acquisition of Winstar Communications, Inc.* (Dec. 20, 2001).

¹⁷⁷ IEEE 802.16 Backgrounder, ieee802.org/16/pub/backgrounder.html.

¹⁷⁸ IEEE 802.16 Backgrounder, ieee802.org/16/pub/backgrounder.html.

¹⁷⁹ See, *Understanding Wi-fi and WiMAX as Metro-Access Solutions*, Intel White Paper (2004) at 10, <http://www.intel.com/netcomm/technologies/wimax/304471.pdf> ("Intel, WiMax").

¹⁸⁰ For the long regulatory history of 2.5 GHz licenses, see Hazlett, *Spectrum Tragedies*.

¹⁸¹ Clearwire Corp., *Clearwire Markets*, http://media.corporate-ir.net/media_files/irol/21/214419/mediakit/Market_List_12309.pdf (last visited Aug. 19, 2009).

¹⁸² Clearwire Press Release, *Clearwire Reports Second Quarter 2009 Results* (Aug. 11, 2009);

served 511,000 subscribers by June 30, 2009,¹⁸³ at least thirty times any WISP relying on access to unlicensed airwaves.¹⁸⁴

Carriers that have used unlicensed spectrum have done so predominantly in rural areas.¹⁸⁵ Intel, often a strong advocate of unlicensed spectrum, has concluded that to function as a “carrier-grade technology” WiMax requires licensed spectrum.¹⁸⁶ “In general,” Intel concludes, “unlicensed bands can be subject to [service quality] issues because deployment is open to anyone.”¹⁸⁷ More important is the market reality that firms seeking to build substantial wireless networks requiring large amounts of risk capital overwhelmingly favor liberal licenses. Clearwire itself began, in 1999, as a WISP operating “in the unlicensed 2.4-GHz frequency, which was subject to interference.” It found that it could lease bandwidth from educational institutions with ITFS (Instructional Television Fixed Service) licenses, upgrading its service and allowing it to craft an ambitious service strategy.¹⁸⁸

In that pursuit it has attracted powerful economic support, registering over \$4 billion in capital infusions from Intel, Motorola, Bell Canada, Google, Sprint, Comcast, Time Warner, Bright House Networks, and thousands of equity investors buying the firm’s shares in its 2007 IPO.¹⁸⁹ The financial meltdown of 2008-09 adversely impacted share prices; about one-half of Clearwire’s strategic investment was written off in early 2009. This is entirely consistent with the social efficiencies created by such investment incentives. Only when firms suffer the adverse consequences of the spectrum risks they take will their incentives be fully aligned with the interests of consumers. When, conversely, Apple Computer lobbied the FCC for an Unlicensed PCS frequency allocation in the early 1990s, prompting the Commission to allocate 30 MHz for U-PCS that has gone essentially unused for over a decade, the loss was socialized. Apple internalized only the cost of its lobbying.¹⁹⁰

¹⁸³ Clearwire Press Release, *Clearwire Reports Second Quarter 2009 Results* (Aug. 11, 2009) (This number includes a small fraction of non-US subscribers – generating 13% of the company’s total revenue).

¹⁸⁴ “Top Ten” *Wireless Internet Service Providers 2007*, Broadband Wireless Exchange Magazine, http://www.bbwxchange.com/wireless_isp/ (visited Feb. 27, 2009) (In its last ranking of Top Wireless ISPs, Broadband Wireless Exchange Magazine listed SpeedNet the third largest WISP with 15,000 customers. The two higher ranking ISPs (one of which was Clearwire) both use licensed spectrum in the 2.5 GHz band; it was not specified whether SpeedNet used licensed, unlicensed, or both.); *see also* Kenyon Communications Holdings, Inc., Form 10-Q at 13 (SEC filed June 30, 2009).

¹⁸⁵ *See* Intel, *WiMax* at 6, <http://www.intel.com/netcomms/technologies/wimax/306013.pdf> (“[L]icense-exempt WiMAX solutions are focused on rural areas. . .”).

¹⁸⁶ The “big difference between Wi-Fi and WiMAX . . . is that we’re going to use licensed spectrum to deliver WiMAX.” Intel, *WiMAX: Wireless Broadband for the World – An Interview with Jim Johnson*, <http://www.intel.com/netcomms/columns/jimj105.htm> (quoting James A. Johnson, VP, Intel Communications Group and General Manager, Wireless Networking Group). *See also* McCormack, *et al.*, *Wireless Broadband* (“In our view, the use of licensed spectrum is necessary to guarantee a level of service and availability for the paying portable user. The use of unlicensed spectrum could lead to wide disparities in quality of service, bottlenecks, and security issues.”).

¹⁸⁷ Intel, *Understanding Wi-fi and WiMAX as Metro-Access Solutions*, White Paper at 3 (Oct. 2004).

¹⁸⁸ Clearwire, Funding Universe, <http://www.fundinguniverse.com/company-histories/Clearwire-Inc-Company-History.html> (visited Feb. 27, 2009).

¹⁸⁹ *Id.*

¹⁹⁰ Thomas W. Hazlett, *The Spectrum-Allocation Debate: An Analysis*, IEEE INTERNET COMPUTING (Sept./Oct. 2006).

The FCC's recent proceeding to allocate the 3.65 GHz band for WiMax and related technologies was initiated at the behest of wireless WISPs who "expressed a clear need for additional spectrum for broadband use . . . especially in rural areas."¹⁹¹ The FCC was persuaded, stating that allocating the band for unlicensed devices "would be the most beneficial approach." Still, rural WISPs were concerned that "intense use of spectrum by a variety of devices under a traditional unlicensed approach could result in mutual interference, thereby reducing the utility of this band."¹⁹² In 2005, the Commission ultimately adopted a regime that eschews assigning any spectrum "for the exclusive use of any licensee," and instead directs all licensees "to cooperate and avoid harmful interference to one another."¹⁹³

Everyone operating in these bands must "register... their fixed and base stations in a common database."¹⁹⁴ And any interference between these high-power transmitters "will be addressed by the process we adopt to register fixed and base stations."¹⁹⁵ Registration rules require base stations to "operate at locations and with technical parameters that will minimize the potential for interference between stations."¹⁹⁶

The better this works in the short term, the faster its fundamental shortcomings will become apparent. Many companies will certainly want to offer WiMax service, competing in the \$32 billion per year U.S. market for DSL and cable modem services.¹⁹⁷ Spectrum-sharing protocols in WiMax radios can provide for orderly, reasonable sharing of spectrum – under certain circumstances. But they don't limit how many radios are deployed to share it.

Just as power limits are an implicit exclusionary device, a registration policy is likewise an acknowledgement of the benefits of coordinating spectrum users and an implicit rejection of the ad hoc "commons" approach. The unlicensed space is in some sense licensed, but without the benefit of de facto (or de jure) spectrum ownership. Under this hybrid approach, there are no claimants to seek gains from efficient spectrum reallocation – for example, to clear the 3650 MHz band of the satellite operations that could impinge on the use of WiMax devices. In a liberal license regime, licensees could pay satellite operators to move to alternative bands, expanding opportunities for WiMax. Under the hybrid approach, it is regulators, not market forces, that ultimately set sharing rules.

¹⁹¹ *Wireless Operations in the 3650-3700 MHz Band*, Report and Order and Memorandum Opinion and Order, 20 FCC Rcd 6502, ¶ 13 (2005) ("3.65 GHz Order").

¹⁹² *Id.* ¶¶ 13-14.

¹⁹³ *Id.* App. A & ¶ 29. All licensees are required "to cooperate and avoid harmful interference to one another." *Id.* ¶ 29. All WiMAX radios must incorporate protocols to determine who gets priority when "when two or more devices attempt to simultaneously access the same channel." *Id.* ¶ 58. These same protocols will "establish[] rules by which each device is provided a reasonable opportunity to operate." *Id.* ¶ 16. By "control[ing] access to spectrum, terrestrial operations will avoid interference that could result from co-frequency operations." *Id.* ¶ 16.

¹⁹⁴ *Id.*

¹⁹⁵ *Id.*

¹⁹⁶ *Id.*

¹⁹⁷ Ray Le Maistre, *US Tops Broadband Revenues Chart*, LIGHTREADING.COM (Jan. 2, 2009) http://www.lightreading.com/document.asp?doc_id=169812 ("According to data compiled for the report, [Global Fixed and Mobile Broadband Outlook](#), the U.S. generated more than \$32 billion in broadband revenues in 2008.")

What advantage does such state control afford society? The reflex response – that it protects spectrum access on a no-fee basis – is strictly correct. But the outcome of this regime can render “free” access a high-cost failure. If the coordination supplied by exclusive rights owners results in networks and wireless applications that are superior from the viewpoint of consumers, then the relative social benefits of the non-exclusive rights are negative.

U.S. regulators – just as Coase deduced from basic economic theory -- fail to properly account for the opportunity costs of alternative allocations when zoning spectrum. The results are starkly on display in the 3650 MHz proceeding. What is called the 3.5 GHz band includes the 3650-3700 MHz frequencies, and is the most popular location for *licensed* WiMax networks internationally.¹⁹⁸ Indeed, the IEEE 802.16 (WiMax) technology protocol at 3.5 GHz has been written for exclusive rights holders. U.S. regulators chose to deviate from world markets, a decision strongly opposed by Intel and Alvarion, firms with substantial sales of wireless hardware using the 2.4 GHz and 5 GHz unlicensed bands. Yet, the companies jointly urged the FCC to license 3650 MHz spectrum in the top fifty U.S. markets – areas with the lion’s share of potential customers and those in which potential airwave conflicts are most intense.¹⁹⁹ They lost that battle,²⁰⁰ and the only large-scale WiMax developments observed in the U.S. market today are those in the licensed 2.5 GHz band.

IX. INTERFERENCE

Smart radios have overcome the problem of interference, commons advocates allege. Unlicensed wireless devices may not have legal protection against interference, but they do not need any. It is possible that licensing spectrum may occasionally be useful, just as “toll roads or paid carpool lanes” sometimes make sense “in some predictably congestion-prone roads.”²⁰¹ But mostly we’re dealing here with “city streets and sidewalks, dirt roads, or highways at nighttime.”²⁰² Smart radios are like ships traveling on an ocean of spectrum – not infinite in size, perhaps, but so vast that vessels can simply “be trusted to navigate around one another.”²⁰³

These conclusions are said to flow from the laws of physics. “[I]nterference is a consequence of system design, rather than an inherent property of the radio spectrum.”²⁰⁴ Interference isn’t “physical” but “inherently a legal construct.”²⁰⁵ “Interference is a metaphor that paints an old

¹⁹⁸ Sam Churchill, *Italy Opens 3.5 GHz for WiMax*, DAILY WIRELESS (Dec. 29, 2006); <http://www.dailywireless.org/2006/12/29/italy-opens-35-ghz-for-wimax/>

¹⁹⁹ Intel et al., *Petition for Reconsideration of Intel Corporation, Redline Communications, Inc., Alvarion, Inc.*, Federal Communications Commission ET Docket No. 04-151 (June 10, 2005).

²⁰⁰ Jerry Brito, *The Spectrum Commons in Theory and Practice*, 2007 Stan.Tech. L. R. 1 (2007).

²⁰¹ Benkler, *Some Economics of Wireless Communications* at 69.

²⁰² *Id.* See also *id.* at 32-33 (Property rights/pricing mechanisms are “useful only occasionally, at peak utilization moments”).

²⁰³ Werbach, *Radio Revolution* at 20.

²⁰⁴ Werbach, *Radio Revolution* at 14.

²⁰⁵ *Id.*

limitation of technology as a fact of nature.”²⁰⁶ “Spectrum is not scarce. We’re talking about radio waves. Radio waves run through one another.”²⁰⁷ “More than one service can occupy the ‘same’ spectrum, in the same place, at the same time.”²⁰⁸ “The electromagnetic waves do not actually bounce off each other or ‘fall’ to the ground before reaching the receiver’s antenna. ‘Interference’ describes the condition of a stupid lone receiver faced with multiple sources of radiation that it is trying to decode but, in its simplicity, cannot.”²⁰⁹ “Radio waves do not . . . cancel each other out.”²¹⁰

A. Noise and Interference

But, in fact, they do. Thomas Young’s double slit experiment, first conducted in 1801 and repeated in high-school physics classes to this day, establishes that electromagnetic waves interact, interfere, amplify, and obliterate each other like waves on the surface of a pond. Two clean signals superposed become one messy one; throw in more, and you end up with cacophony of pure noise. No amount of additional intelligence embedded in the receiver can reverse the process when interference transforms information into chaos.²¹¹

In fact, radios dispatch streams of energy from their antennas, and that energy propagates through the surroundings at the speed of light. These fluxes aren’t legal constructs²¹² but physical things. In a microwave oven, they heat your soup. When they strike a silicon-crystal solar cell, electromagnetic energy at a slightly higher frequency can generate electricity. Suitably synchronized, flukes like these become a maser or laser that can cut through steel. And these same energy fluxes – these half-wave half-packet streams of photons – interact, deflecting flows and destroying communications.

Thus, for example, microwave ovens cause “noticeable” interference with Bluetooth devices operating nearby.²¹³ Bluetooth devices interfere with each other.²¹⁴ Cell phone jammers are readily

²⁰⁶ David Reed, as quoted in David Weinberger, *The Myth of Interference: Internet Architect Explains How Bad Science Created the Broadcast Industry*, SALON (March 12, 2003), <http://dir.salon.com/story/tech/feature/2003/03/12/spectrum/index.html?x>.

²⁰⁷ Kevin Werbach, as quoted in Heath Row, *The Open Spectrum Revolution*, FASTCOMPANY (Feb. 8, 2008), <http://www.fastcompany.com/blog/heath-row/open-spectrum-revolution>.

²⁰⁸ Werbach, *Radio Revolution* at 3.

²⁰⁹ Benkler, *Some Economics of Wireless Communications* at 39.

²¹⁰ Werbach, *Radio Revolution* at 5.

²¹¹ The concession is made that interference among smart radios is a “realistic possibility... [when] “very large numbers of such devices operate in the same location.” Werbach, *Radio Revolution* at 17. That this obviates the claim that interference is a myth, or that it fully supports the economic analysis of spectrum scarcity is, however, lost.

²¹² Were radio signals “only” legal constructs, the argument over how best to assign property rights would not be decided, of course. Intangible property rights, including those created in contract law, tend to dominate ownership institutions in advanced economies. More generally, all property rights are legal constructs and govern not things but relations between people.

²¹³ T.W. Rondeau, M.F. D’Souza, and D.G. Sweeney, *Residential Microwave Oven Interference on Bluetooth Data Performance*, IEEE TRANSACTIONS ON CONSUMER ELECTRONICS at 856, 863 (Aug. 2004).

²¹⁴ J.E. Ballagh, T.W. Rondeau, D.G. Sweeney, *Bluetooth Frequency Hop Selection Kernel Impact on ‘Inter-Piconet’ Interference*, IEEE Transactions on Consumer Electronics (submitted for publication). See also J. Lipman, *The ‘Other’ Wireless Technology Is Alive and Kicking*, TECHONLINE (Oct. 14, 2003),

available (though illegal²¹⁵); it is equally easy to jam Wi-Fi nodes. The most common form of interference arises when a beam from a single transmitter interferes with itself. This can occur when part of a signal travels directly from the tower to the TV, and part travels indirectly, reflecting off (say) a nearby skyscraper. Two different electromagnetic signals cannot in fact coexist at exactly the same place and time.

All else equal, the noisier the electromagnetic environment the longer it takes to transmit information through it without distortion. This too is a fundamental law of physics²¹⁶ that engineering cannot repeal. To state the same law another way: to get through at all, a radio transmission has to be powerful enough to penetrate the ambient noise.

The “ambient noise” itself is highly variable. It is composed of all the radio transmitters – “intentional emitters,” in FCC jargon – and all the “incidental” and “unintentional” emitters, including virtually every device that runs on AC electric power. It is therefore impossible to know precisely how noisy things will be along any given pathway, at any given point in time; getting a signal through is a fundamentally chancy business.²¹⁷ You can improve the odds by raising the power of your own radio, or lowering the power of other radios transmitting on the same frequencies, or shutting down competing radios altogether. You can switch your own radio to a different band, which may be quieter. And you can transmit the same message more than once, or simultaneously on multiple bands.

But none of these strategies eliminates fundamental economic trade-offs. Quite the contrary – *every* strategy that boosts the chances of punching your own signal through the airwaves either adds to the expense of the communications conducted, lowers the odds for every other radio that’s trying to do the same, or both. It is suggested that by searching for unused gaps in the airwaves, “agile radios can in effect *manufacture* new spectrum.”²¹⁸ “In effect,” correct, but *in fact* radios transmit radio signals, and when they do that, they don’t produce spectrum, they consume it.

The much-heralded smartness of Wi-Fi radios provides a case in point. When two Wi-Fi radios use the same (limited) channels in close proximity, each device detects the presence of a competing transmitter and adjusts by transmitting more slowly and using more power to send each bit. As Hewlett-Packard describes it, Wi-Fi radios “fail gracefully in the presence of interference” –

http://www.techonline.com/community/ed_resource/feature_article/28419 (“[S]imilar to devices operating in the 900 MHz spectrum interfering with other like-frequency devices, Bluetooth is more prone to interference from other Bluetooth devices, cell phones, microwave ovens, and other equipment operating at 2.4 GHz.”); J. Miller, *Tips on Using WiFi in RV Parks*, RVers Online (Mar. 2005), <http://www.rversonline.org/RVWiFi.html> (“From 4:30 to 6:00 pm each night at every RV resort in the country the WiFi signal is impeded the most. This is due to the concentration of RVs in a relatively small area preparing dinner and using Microwave ovens. The same is true in apartment complexes.”).

²¹⁵ The manufacture, importation, sale, and operation of transmitters designed to jam or block signals is a violation of 47 U.S.C. §§ 301, 302(a), 333, and subject to severe penalties. “Fines for a first offense can range as high as \$11,000 for each violation or imprisonment for up to one year.” See FCC, *Cellular Services, Operations: Blocking & Jamming*, <http://wireless.fcc.gov/services/cellular/operations/blockingjamming.html>.

²¹⁶ See C.E. Shannon, *A Mathematical Theory of Communication*, 27 Bell System Tech. J. 379-423, 623-656, (July & Oct. 1948), available at <http://cm.bell-labs.com/cm/ms/what/shannonday/shannon1948.pdf>.

²¹⁷ Weiser & Hatfield, *Spectrum Commons*.

²¹⁸ Werbach, *Radio Revolution* at 19 (emphasis added).

the “result of increasing levels of interference is almost always confined to a slowing of the data rate as more packets need to be resent.”²¹⁹ Wi-Fi does not eliminate the interference problem, but degrades performance to accommodate it. This is more acceptable for certain types of data transmission where it doesn’t matter too much just how fast the traffic gets through, such as web browsing, while less acceptable for voice and other inter-active applications that require steady throughput.

These limitations are costly. Moreover, the coordination between users that may mitigate these costs is difficult to achieve. Wi-Fi radio users, particularly those who attempt outdoor deployments, are advised to seek out other Wi-Fi users and gain their cooperation, using different channels and placing facilities in complementary locations.²²⁰ Indeed, WISPs may find themselves in “broadcast wars,” where transmissions to occupy Wi-Fi channels, along with the use of higher power levels, are strategic tools used to lower rivals’ quality of service.²²¹ Degraded performance is only the tip of the iceberg; networks never deployed due to the costs of coordination in this space constitute the largest losses. The tragedy of the commons is generally the unobserved counterfactual.

B. Physics and Architecture

Radio waves are real things transmitted with real energy.²²² Potential conflicts depend on the separation, if any, between the band being used by the interfering transmitter, and the band that the unwitting receiver is trying to receive. It depends on the power of the rival transmitter, its proximity, and on directional antennas mounted (or not mounted) on the transmitter, the unwitting receiver, or both.

The interference problem is defined by the *aggregate* of all competing transmitters, which is to say, by the transmission frequencies, power, proximity, and antenna configurations of *all* intentional, incidental, and unintentional interfering transmitters in the band, and all the buildings, foliage, fog, meteor trails, and extraterrestrial radiation belts, that may reflect their signals (usually aggravating the problem) or attenuate them (usually mitigating it). A spectrum licensee with liberal property rights uniquely possesses the information, economic incentive, and financial ability to optimize the architecture to make the best possible use of such a complex, turbulent resource.

²¹⁹ Hewlett-Packard, *WiFi and Bluetooth – Interference Issues* at 1 (Jan. 2002), http://www.hp.com/rnd/library/pdf/WiFi_Bluetooth_coexistence.pdf.

²²⁰ Tim Pozar, *Regulations Affecting 802.11 Deployments, Version 1.5* (March 10, 2004) (“Pozar, *Regulations Affecting 802.11*”); http://www.lns.com/papers/part15/Regulations_Affecting_802_11.pdf.

²²¹ Christian Sandvig, *Return of the Broadcast War*, paper delivered to the Telecommunications Policy Research Conference (Sept. 2005) at 23; http://www.communication.illinois.edu/csandvig/research/Broadcast_War.pdf (quoting one WISP operator as saying, “The more channels I grab means the less competition”).

²²² Although the concepts are often used interchangeably, it is here important to distinguish between “spectrum,” which itself is not a thing, and the radio waves or signals that are transmitted through space. See Howard A. Shelanski and Peter W. Huber, *Administrative Creation of Property Rights to Radio Spectrum*, 41 JOURNAL OF LAW AND ECONOMICS 581 (Oct., 1998), at 584 (“There is no such thing as ‘spectrum’ out there, any more so than there was ‘ether,’ to be bottled by the Commission or anyone else. ‘Spectrum’ is composed entirely of the engineering characteristics of transmitters and receivers. Those characteristics are defined, in turn, by power, sensitivity, and modulation parameters in a fuzzy and permeable zone of space.”). Thus, when we talk about the scarcity of spectrum, this is shorthand for the conflicts resulting from the transmission of radio waves within defined frequency bands.

As Ronald Coase noted decades ago, the appropriate quest is not to eliminate interference between wireless users, which is overly protective, but to achieve just the proper amount.²²³ How much interference is tolerable can never be defined by the interfering transmitter – it must, self-evidently, be defined by the receiver. Firefighters groping their way through an inferno tolerate less interference than teenagers text-messaging at the mall. “Tolerable” itself is inevitably defined in statistical terms: how often will noise levels rise high enough to block a transmission, and what blocking probability is acceptable?

The argument that radio waves do not interfere, that spectrum is not scarce, implies that the only quality of service issue lies in the design of the individual receiver. A race for better radios then becomes the alternative to network coordination.²²⁴ When interference is explained as a problem of insufficient processing power in the radio receiver, individual users are portrayed as efficiently pursuing – with help from equipment vendors, who profit from selling better radios – the optimal level of reception (the reciprocal of interference).

This mischaracterizes the economic problem, which centers on how to entice all productive contributions where benefits exceed costs. Whatever the incentive of an individual to buy a radio that punches through the din, and the vendor to profit from selling that device, the resulting transactions will not take account of the costs transmissions impose on other users. This loads all the interference mitigation on the individual user’s radio and government rules (such as power limits), with decisions taken in isolation from the other source of the conflict. While mobile carriers, as spectrum owners, aggressively deploy systems that make radios quieter and spillovers smaller, users predictably pollute the airwaves by blasting signals at higher power than necessary so as to guarantee safe passage for their communications.²²⁵ In short, each user competes to claim control over airspace, insensitive to the costs imposed on others. This is standard tragedy of the commons,²²⁶ and there is considerable

²²³ See *infra*, at note ____.

²²⁴ Benkler, *Some Economics of Wireless Communications*; Werbach, *Radio Revolution* at 37.

²²⁵ Radio engineers who work with Wi-Fi commonly acknowledge costs of non-exclusivity. Using 5.8 GHz frequencies to bring broadband connections to a housing development in a low-income part of San Francisco, Tim Pozar notes that “Frequency coordination is a constant problem,” as new radios disrupt existing links and there is “no way to encourage or to enforce coordination.” Tim Pozar, *A Sample Wireless Broadband Deployment – City of San Francisco Housing Projects*, presentation to the Unleashing Unlicensed Conference, George Mason University Information Economy Project (April 4, 2008) at slide 26; <http://www.iep.gmu.edu/documents/GMU-Pozar-20080404.pdf>. See also, Pozar, *Regulations Affecting 802.11*. The basic description of unlicensed usage therein is useful: “As 802.11 [Wi-fi] is designed for short-range use, such as in offices and homes, it is limited to very low power. Ideally, a well-engineered path will have just the amount of power required to get from point ‘A’ to point ‘B’ with good reliability. Good engineering will limit the signal to only the area being served, which both reduces interference and provides a more efficient use of the spectrum. Using too much power would cover more area than is needed, and also has the potential to wreak havoc on other users of the band.” More generally, Jon Peha writes: “It has been shown that devices in unlicensed spectrum are likely to transmit for greater duration and at greater power than is necessary, as this will advance other design goals. This phenomenon must be addressed if spectrum is to be used efficiently. The alternative is to allocate excessive spectrum so that contention is rare.” Jon M. Peha, *Wireless Communications and Coexistence for Smart Environments*, IEEE PERSONAL COMMUNICATIONS (Oct. 2000).

²²⁶ See Jon M. Peha, *Emerging Technology and Spectrum Policy Reform*, International Telecommunications Union Workshop on Market Mechanisms for Spectrum Management (Geneva, Switzerland; Jan. 2007); http://www.itu.int/osg/spu/stn/spectrum/workshop_proceedings/Background_Papers_Final/Jon%20Peha%20ITU%20spec%20workshop.pdf, at 5 (footnote omitted). (“When releasing unlicensed spectrum, regulators must guard against two related sources of inefficiency. One is that unlicensed spectrum will attract applications that would operate more

concern among engineers concerning how to deter it in unlicensed bands.²²⁷ This inevitably involves some level of enhanced coordination, public or private.²²⁸

The contrast with liberal licensed bands could not be sharper. Private spectrum owners will internalize the cost of spillovers – emissions that conflict with rival wireless users -- and invest heavily to reduce them. Such entities have a readily available efficiency metric to guide this calculus: undertake only those interference-reducing outlays where expected benefits exceed expected costs.

To be rude and to chew up bandwidth on such networks is to pay extra. Pricing schedules steer subscribers towards reducing costly interference, charging higher rates (or, equivalently, limited bucket minutes) for peak time calls. But network efforts to conserve spectrum go much further. Dynamic power control features in cell-phones provides one example of how private networks seek to reduce emissions, making their exclusively controlled bandwidth quieter, expanding valuable opportunities. Courteous protocols, often put forth as a way to share unlicensed spectrum,²²⁹ are actually hardwired into mobile handsets accessing licensed spectrum. Thus, handsets are developed and programmed to be polite emitters, and manufacturers -- to sell to carriers, or be certified to access their spectrum in sales directly to end users -- continually press to increase performance at lower power levels, reducing demands on shared frequencies. As Charles Jackson writes, “handsets are part of the network,”²³⁰ and carriers are careful to protect their spectrum by promoting (and often subsidizing) radios that behave in friendly fashion.

C. Smart Radios, Dumb Crowds

As noted, interference is determined by the total electromagnetic din created by the sum total of all the radios trying to transmit in a band, together with other incidental and inadvertent sources of noise. In the total-din calculus, the number of radios is important, as is their power. But no one directly controls the total number of transmitters in an unlicensed band.

End users compound the problem when they hang on to obsolete transmitters long after more spectrum-efficient technologies have been developed. Countless radios that rank as “low-power” and

effectively and efficiently in licensed spectrum. The other is that engineers will design “greedy” devices, i.e. those that transmit with greater power, duration, or bandwidth than necessary, because they have little incentive to conserve spectrum that is shared. In the extreme, greedy devices can lead to a tragedy of the commons, where many devices are greedy, and all devices in the band experience inadequate performance as a result.”).

²²⁷ Hyun Jin Kim and Jon M. Peha, *Detecting Selfish Behavior in a Cooperative Commons*, IEEE DySpan (2008); http://www.ece.cmu.edu/~peha/detecting_selfish.pdf.

²²⁸ Ad hoc mesh networks that create “cooperation gain” in unlicensed bands are touted as mechanisms for expanding the capacity of radios using non-exclusive spectrum rights. But the costs of organizing such solutions are relatively high, which is why the model has yet to be embraced in any appreciable volume. Indeed, the need for network coordination is itself hampered by the lack of spectrum ownership. This is why Jon Peha recommends licensed spectrum to affect the ad hoc mesh solution: “[A] ‘spectrum commons’ could be created by a license-holder instead of the regulator. Rather than using unlicensed spectrum, a private entity might obtain a license, establish its own operating rules, and allow devices to operate in its spectrum. The latter approach is particularly appropriate for a cooperative system...” such as ad hoc meshes. Peha *Emerging Technology and Spectrum Reform* at 7.

²²⁹ Lawrence Lessig, *Code And Other Laws of Cyberspace* 184 (1999).

²³⁰ Charles L. Jackson, *Wireless Handsets Are Part of the Network*, ITS 2006 Biennial Conference (June 2006); www.its2006bupt.org.

“smart” today may still be transmitting with impunity in unlicensed bands ten years hence, occupying spectrum that could be used much more efficiently by much smarter, lower-power technology developed in the interim. Arguments for more unlicensed bandwidth assert that competition between technology suppliers will produce devices that effectively limit interference. This fails to engage the central problem posed by unlicensed wireless users whose economic interest is to keep operating their old radios no matter the spillovers they cause.

Exclusive airwave rights help address both problems. The licensee controls the total number of transmitters (base stations, handsets, M2M radios,²³¹ and so forth). It can (and does) hardwire cooperation into such devices, promoting spectrum-saving devices. It also orchestrates orderly transitions from old technology to new. The cellular networks of the early 1980s, for example, were analog by FCC mandate. After the FCC authorized digital upgrades, carriers effected a seamless transition, in part by giving their customers new, less polluting, subsidized phones.²³²

Wi-Fi standards, commons advocates claim, have dealt with the problem of “orphan” technology much better than broadcasters have managed to make the transition from analog to digital television.²³³ This evinces the confusion discussed earlier over the distinction between traditional licenses and liberal licenses. The TV market is plagued by coordination problems precisely because TV broadcasters do not own their spectrum, cannot transact to rearrange it, and cannot control the radio receivers using it. TV sets are, in other words, *unlicensed*. These receivers are made to government specifications, and the program content they access is supplied via traditional licenses.

In the cellular market, with its liberal licenses, networks control their airspace and manage the subscriber interface: the leaps in technology – from the flip phones of just five years ago to the iPhones and broadband datacards of today – are large and continuous. No one seems much concerned about the “digital cellular transition” or the “EV DO transition,” despite the fact that the economic consequences for actual consumers are far more profound, remembering that over 90% of TV viewing takes place via cable and satellite, unaffected by the digital TV transition – completed in 2009, and officially *twenty-two* years in the making.²³⁴

Perhaps the most popular metaphor for the view that smart radios obviate the utility of a controlled spectrum space is the cocktail party tale. The party venue may fill up, and the din of the crowd increases to a dull roar. But the human ear is adroit at focusing on just one conversation in the mix. Sometimes so adroit that one can eavesdrop on particularly juicy chatter being conducted

²³¹ Machine to machine wireless devices are a burgeoning part of the mobile network landscape. See Mayo & Wallsten, *The Role of Secondary Markets*.

²³² The providers had an economic incentive to retain existing customers. For the rules governing the transition, see *Year 2000 Biennial Regulatory Review – Amendment of Part 22 of the Commission’s Rules To Modify or Eliminate Outdated Rules Affecting the Cellular Radiotelephone Service and Other Commercial Mobile Radio Services*, Notice of Proposed Rulemaking, 16 FCC Rcd 11169, ¶¶ 18-20 (2001).

²³³ Werbach, *Radio Revolution* at 23-24.

²³⁴ The FCC’s Advanced Television proceeding actually launched in 1987. See Hazlett, *Transition to Yesterday*.

halfway across the room.²³⁵ The moral of the tale is that good receivers can beat a noisy roar. And science has today given us just the technologies to make those good receivers.

The cocktail party metaphor in fact popped up long ago in the classroom of Claude Shannon, author of Shannon’s Law and a towering figure in modern radio frequency engineering.²³⁶ His version inspired his M.I.T. student, Irwin Jacobs, to implement the insight. Jacobs, with fellow scientist Andrew Viterbi, developed the “spread spectrum” technology that unraveled so many garbled sounds into intelligible conversations, and then applied that technology to mass communications. The company they founded, Qualcomm, pioneered advanced wireless networks based not on unlicensed, but licensed, spectrum.²³⁷ Hence, even the iconic spectrum-sharing technological twist is nested in a globally successful application using exclusive spectrum rights which, among other things, allowed spread spectrum methods to work by limiting the number of conversations and the overall level of noise – necessary for successful communications even with the most advanced science.²³⁸

D. Physical Separation

When an antenna transmits equally in all directions, the power of the signal falls with the square of the distance. Obstacles – buildings, trees, and the air itself – cause additional attenuation. The earth’s curvature blocks signals from transmitters situated over the horizon. But here too, physical separation involves trade-offs and judgment calls based on the cost and quality of the transmitters and receivers. The ability to squeeze more radios within a given space is at the heart of advanced communications. “Father of the Cellphone” Martin Cooper estimates that it accounts for the lion’s share of a *one million-fold increase in spectrum capacity* every fifty years, a relationship now known as Cooper’s Law.²³⁹

With broadcasting, the FCC’s historical policy was wide physical spacing to accommodate cheap receivers.²⁴⁰ This approach devoted most channels to “taboo” fillers, guard bands left idle to

²³⁵ See *On the Same Wavelength*, THE ECONOMIST (Aug. 14, 2004) (“A well-attended cocktail party has a din of many voices speaking at once and on similar frequencies. But it is still possible for party-goers to have conversations and pick out individual voices—ie, sound waves—from the din, because our brains are equipped with powerful software for this task. There is no limitation in the spectrum of sound waves, only in the refinement of the human ear. The same can be true in the electromagnetic spectrum.”).

²³⁶ Dave Mock, *The Qualcomm Equation 70-72* (Amacom; 2005) (“Mock, *Qualcomm*”).

²³⁷ U.S. wireless carriers Sprint and Verizon use Qualcomm’s CDMA technology. More generally, all 3G technologies are built around CDMA algorithms.

²³⁸ “At the code-division party... more people are allowed to flood into any one space at the same time to discussions. At this party, though, each pair speaks in a different language.... Because you would be keying in on the nuances in your partner’s spoken language, all the other languages would just sound like gibberish in the background. Even though thousands of dialects were available for couples to speak, there was still a limit on how many could be spoken at the same time – basically the limit that resulted from the overall noise. If there were fifty couples, all talking different languages, it could get too noisy for anyone to hear. So at the CDMA party it was important to regulate how loudly everyone spoke, to make sure that the maximum number of couples could be heard.” Mock, *Qualcomm* at 71.

²³⁹ Martin Cooper, *Antennas Get Smart*, SCIENTIFIC AMERICAN (July 2003).

²⁴⁰ See, e.g., *Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band*, Notice of Inquiry, 17 FCC Rcd 25632, ¶¶ 9, 10 (2002) (“To prevent interference, the Commission’s rules require distance separations between co-channel and first-adjacent-channel TV stations. In addition, distance separations are required between UHF TV

absorb stray interference. As technology improved, the Commission – with long lags -- has required less spacing.²⁴¹ The stultification associated with rigid administrative controls is evident. In 1952, four national commercial TV networks existed – ABC, CBS, DuMont and NBC. This set defined the scope of America’s programming choice. By 1984, that number had sunk to three. The elimination of rules blocking cable and satellite TV competition then permitted the number of national and local broadcast networks to skyrocket.²⁴² But for a generation, regulation put a stranglehold on competitive progress.

The administrative approach to spectrum resulted in massive under-utilization of radio,²⁴³ television,²⁴⁴ and other allocated bands.²⁴⁵ What appeared to be a cheap way to assure high-quality reception, turned out to be anything but. The opportunity costs – what valuable wireless stuff could have used the taboo channels – have easily dominated any improvement in off-air viewing they provide.

With flexible-use licenses for mobile services, the Commission has abandoned “site licensing” for “geographic licensing.” The new approach delegates physical-spacing decisions to wireless operators. The core engineering concept behind “cellular” phone service is that the same frequencies can be reused again and again when the arrays of potentially conflicting transmitters are suitably deployed. Wireless carriers are in charge of making these architectural calls. They generally add new cells as they add new subscribers. Wireless carriers thus control the spacing of their customers.²⁴⁶ Neither the FCC nor the licensees can easily control the location of the peripatetic

stations up to 15 channels apart. . . . Because the new digital TV system is more spectrally efficient, fewer channels will be needed after the transition to accommodate all existing television stations.”); J. Walker, *Don’t Touch That Dial: Free Radio Berkeley Takes on the FCC and Official History*, REASON at 30 (Oct. 1995) (quoting Fred Crock, engineering supervisor at San Francisco radio station KQED: “[T]he broadcast allocations in this country are based on allowing the use of inexpensive receivers by the general public. What appears to be a hole in the FM broadcast band may be there to accommodate the shortcomings of inexpensive receiver design. It would be possible to put more stations onto the broadcast band, but that would require the use of more expensive, more sophisticated radios by the public.”) See also Media Access Project, *Digital Television and Spectrum Allocation*, <http://www.mediaaccess.org/programs/digitaltv/6069.htm> (“Because analog transmission signals can interfere with each other, TV stations have traditionally been separated in their positions on the dial. For example, a station that is assigned to channel 3 cannot be in the same geographic region as another channel 3, or even a channel 2 or 4. But digital transmission will suffer less interference, and will allow channels 2, 3, and 4 to exist in the same region. The spectrum allocated to TV broadcasting could be ‘packed’ into a smaller range of frequencies.”).

²⁴¹ See, e.g., 47 C.F.R. §§ 73.610(b), 73.623(d) (on average, the minimum separation distance for the same channel in neighboring regions is significantly less for DTV compared to typical analog signals).

²⁴² See, e.g., W. Kip Viscusi, Joseph E. Harrington, Jr., and John M. Vernon, *Economics of Regulation and Antitrust*, Fourth Edition (2005), 480-81.

²⁴³ Thomas W. Hazlett & Bruno Viani, *Legislators vs. Regulators: Who Killed Low Power FM Radio?* 7 BUSINESS & POLITICS (April 2005).

²⁴⁴ Thomas W. Hazlett, *The U.S. Digital TV Transition: Time to Toss the Negroponte Switch*, AEI-Brookings Joint Center for Regulatory Studies No. 01-15.

²⁴⁵ Thomas W. Hazlett, *Optimal Abolition of FCC Spectrum Allocation*, 22 J. ECON. PERSP. 103 (Winter 2008).

²⁴⁶ See 47 C.F.R. § 22.907 (“Licensees in the Cellular Radiotelephone Service must coordinate, with the appropriate parties, channel usage at each transmitter location within [75 miles] of any transmitter locations authorized to other licensees or proposed by tentative selectees or other applicants, except those with mutually exclusive applications.”); 47 C.F.R. § 24.134 (“A co-channel separation distance is not required for the base stations of the same licensee or when the affected parties have agreed to other co-channel separation distances.”).

transmitters in cell phones, PDAs, and netbooks, so carriers follow their customers, building out facilities, splitting cells to increase capacity, executing roaming agreements for seamless “out of market” service, and pricing calls to limit crowding.²⁴⁷

Recently, carriers have followed their customers all the way to their homes, offering to better extend the reach of their WANs. T-Mobile offers a device that routes in-home calls to broadband modems (connected to DSL or cable data networks) for VoIP connections using Wi-Fi links, with calls flipping over to mobile networks when the subscriber hops in her car and drives off.²⁴⁸ Alternatively, Verizon and Sprint supply subscribers with femtocells, miniature base stations that extend “four bars” to the individual subscriber’s home.²⁴⁹ These transceivers utilize the carrier’s licensed frequencies within the home, but then route outgoing traffic via (fixed) broadband links.²⁵⁰

Advanced wireless technologies are alleged to end the role of geographical separation in network planning to an end. Radios in close proximity are now easily coordinated by smart technologies that use simple etiquettes to coordinate emissions. Mesh networks use Wi-Fi radios as links in a chain over which they hop across the Internet, creating capacity with the additional user. Instead of limiting capacity, the more the merrier: extra radios will mean more coverage, and more total wireless capacity, too.²⁵¹ Where scarcity and conflicts once reigned, abundance now flowers.²⁵²

But wireless meshes, which have been available for over a quarter century,²⁵³ are no free radio spectrum lunch. Costs of coordinating the mesh are substantial. So high, relative to the alternatives, that *ad hoc* meshes are virtually non-existent. Some agencies, including the U.S. military, do use mesh networks, but these are engineered top-down, not spontaneously, and the network providers that create such systems could purchase spectrum inputs just as mobile carriers do. Indeed, mesh

²⁴⁷ There is no irony in the fact that most customer minutes are “free,” in the sense of being off-peak, on-net, or within the allotted “bucket.” So long as network “members” support the jointly shared facilities (including spectrum) with monthly subscription fees, the carrier enthusiastically extends access rights (which, of course, is why subscribers join). Metering peak minutes that run past the bucket limits congestion.

²⁴⁸ Andrew Berg, *T-Mobile Intros Wi-Fi Plan for Enterprise*, WIRELESS WEEK (May 7, 2009); <http://www.wirelessweek.com/News-T-Mobile-Wi-Fi-Plan-Enterprise-050709.aspx>

²⁴⁹ Derek Kerton, *Pre-Brief Of The Upcoming CTIA Conference*, TECHDIRT (Mar. 31, 2009), <http://www.techdirt.com/articles/20090330/2030174313.shtml>.

²⁵⁰ Glenn Fleishman, *Verizon Getting on Femtocell Bandwagon with Sprint, AT&T*, ARS TECHNICA (Jan. 19, 2009); <http://arstechnica.com/telecom/news/2009/01/verizon-getting-on-femtocell-bandwagon-with-sprint-att.ars>.

²⁵¹ “[A]dding users with the right kind of equipment to an open wireless network can add capacity, not only demand.” *Benkler, Some Economics of Wireless Communications* at 45.

²⁵² “[E]very new device uses some of the network’s capacity but also adds capacity back. Because a device in a mesh no longer needs to send information all the way to its ultimate destination (such as a cell tower), it can use less power. That allows the network to add more devices without any noticeable increase in interference.” Greg Staple & Kevin Werbach, *The End of Spectrum Scarcity*, IEEE Spectrum (March 2004); <http://www.spectrum.ieee.org/mar04/3811>.

²⁵³ See, e.g., D. J. Baker & J. Wieselthier, *A Distributed Algorithm for Scheduling the Activation of Links in a Self-organizing, Mobile, Radio network*, in Proc. Int. Conf. Commun. (Philadelphia, PA,; 1982); N.F. Maxemchuk, *Regular Mesh Topologies in Local and Metropolitan Area Networks*, 64 AT&T TECH. J 1659 (1985); Tim B. Lee, *Multi-Hop Matters: The State of Wireless Mesh Networking*, ARS TECHNICA (Dec. 1, 2009), <http://arstechnica.com/tech-policy/news/2009/12/mesh-networks-come-of-age.ars/2>; Kristin Masters, *Mesh Networks*, POWERSOURCE ONLINE (Mar. 2010), <http://www.powersourceonline.com/magazine/2010/03/mesh-networks..>

networks are built using licensed spectrum.²⁵⁴ The promise of meshes as disruptive innovations was that they would eliminate the network coordination function altogether.²⁵⁵ That promise has not been realized.²⁵⁶ ArrayComm, a wireless technology firm pioneering the development of “smart antennas,” offers a general explanation:

The final and most confused argument against concerns about spectrum availability rests on the belief that “technology” will solve the problem by enabling through cognitive radios and other concepts the peaceful cohabitation of spectrum by formerly interfering applications. While there are large tracts of allocated but currently underutilized spectrum in the mobile-device sweet spot, especially for public safety and military applications, and while it is true in principle that continuing advances in signal processing technologies will *eventually* make the collaborating-radios vision feasible, the predominant view is that the long timeline for its realization does not make this argument relevant for current business planning purposes. In the meantime, the industry must maintain its focus on more efficient policies for licensed spectrum use...²⁵⁷

Tellingly, what has been deployed are network-centric meshes, where a carrier distributes devices across an area, hard-wires them to coordinate their use, and then links them to a broadband connection (over privately owned spectrum) to the Internet. This mimics the structural model of the cellular operator.

One difference, of course, is found in performance. Whereas mesh networks are designed for limited applications and have great difficulty handling mobile communications, cellular networks provide ubiquitous mobile coverage and scale to handle billions of minutes of use. The market test has been run. Were wireless meshes to render spectrum scarcity moot, the unlicensed bands would have displaced the cellular bands and the \$150 billion per year mobile industry would have been displaced by mesh carriers using “free” airwaves.

E. Technology and Innovation

When it liberally licenses spectrum, the FCC largely deregulates the hardware. When it un-licenses spectrum, the FCC necessarily regulates the hardware.

²⁵⁴ The 4.9 MHz band, allocated for licensed use by public safety organizations, hosts significant mesh deployments. *Interference and Metro-Scale Wi-Fi Mesh Networks*, Farpoint Group Technical Note at 4 (Jan. 2008); http://www.ict-partner.net/en/US/solutions/collateral/ns340/ns394/ns348/ns736/net_implementation_white_paper0900aecd805eb886.pdf.

²⁵⁵ Benkler, *Some Economics of Wireless*.

²⁵⁶ “[T]he performance of the [mesh] networks is dismal; experience shows that the throughput is limited, and unfairness and throughput degradations of multihop communication impose severe limitations. Moreover, from an economical perspective, subscription rates to city-wide meshes, such as in San Francisco, are dismal.” R. P. Karrer, A. Pescapé, and T. Huehn, *Challenges in Second-Generation Wireless Mesh Networks*, 2008 EURASIP J WIRELESS COMM. & NETWORKING (Aug. 2008) (footnotes omitted); <http://www.hindawi.com/journals/wcn/2008/274790.html>.

²⁵⁷ ArrayComm, *Wireless Isn't Broadband Without Us*, White Paper (2004); <http://www.arraycomm.com/docs/ArrayCommonMBWAecons.pdf>.

In the CMRS bands, where spectrum is licensed for flexible use, the licensee has wide discretion to decide what mix of low-power and high-power radios to deploy, selecting a mix to maximize profits. When spectrum is unlicensed, the regulator must – and does – regulate radio hardware power and standards.²⁵⁸ “Low-power,” “smart,” and “non-interfering threshold” aren’t technical terms, but regulatory constructs.

Thus, however smart they may be, all “intentional radiators” are regulated under Part 15, Subpart C, of the FCC rules, the first section of which establishes an “equipment authorization requirement.” This Subpart goes on to regulate antennas, power amplifiers, and bands of operation, and then sets out detailed “radiated emission” limits, band by band.²⁵⁹ The radios used in licensed bands require FCC approval, too. But Part 15 regulation of devices that operate in unlicensed bands is much more intrusive because it strictly regulates power, one of the two most important technical characteristics (alongside operating frequency) of every radio.

There is no law of engineering that says everyone will always be better served by low-power, short-range radios. By transmitting from 23,000 miles in space to cover half the continent, direct broadcast satellites deliver competitive digital television signals to over one hundred million households, including those in rural communities that have no prospect of getting comparable video service from unlicensed wireless devices any time soon. Mobile carriers built out their networks efficiently by starting with fewer, larger, higher-power cell sites; more cell sites and lower power radios followed in step with growth in subscribers and minutes of use. Here too, the economical roll-out of service in rural areas has often depended on using taller masts and higher-power transmitters to provide large service footprints across thinly populated areas. Where people are sparse, simpler, cheaper radios that “waste” spectrum are more efficient, because there’s spectrum to spare.²⁶⁰

These are exactly the tradeoffs that liberal license holders routinely discover and efficiently exploit. The FCC’s settled policy is now to give licensees “flexibility to determine the types of services and the technologies and technical implementation designs used to provide those services.”²⁶¹ Technology choices have thus emerged as a key dimension of competition among service providers.

Because about half of all transmissions originate in the hands of end users, wireless carriers have also invested heavily to get high-performance, feature-rich, spectrum-efficient wireless devices into their customers’ hands.²⁶² Carriers paid about three-quarters of the approximately \$13 billion spent on mobile phones in the U.S. in 2003.²⁶³ Such subsidies reflect carriers’ propertied interest in

²⁵⁸ This is true for every other developed country, as well. The “open access” free for all that is sometimes advanced as a regulatory alternative is simply utopian. The only country reported not to regulate unlicensed radio devices is Haiti, but little use is made of the policy. Jon M. Peha, *Lessons from Haiti’s Internet Development*, 42 COMMUNICATIONS OF THE ACM 67 (June 1999).

²⁵⁹ See 47 C.F.R. § 15.201

²⁶⁰ Ellen P. Goodman, *Spectrum Rights in the Telecosm to Come*, 41 SAN DIEGO L REV 269, 308-309 (Winter 2004).

²⁶¹ Federal Communications Commission, *Establishment of an Interference Temperature Metric to Quantify and Manage Interference and to Expand Available Unlicensed Operation in Certain Fixed, Mobile and Satellite Frequency Bands*, Notice of Inquiry and Notice of Proposed Rulemaking ¶ 6, ET Docket No. 03-237 (Rel. Nov. 28, 2003).

²⁶² Jackson, *Handsets Are Part of the Network*.

²⁶³ M. Dano, *Phone Subsidies Alive and Well*, RCR WIRELESS (Jan. 5, 2004) at 1.

their spectrum. Newer phones embed more advanced technologies, reducing spectrum spillovers (interference) and offering greater functionality for users. Both are of value to the network over and above the gains delivered to the individual adopter. Hence, handset subsidies are higher for newer models, and have been particularly important in spreading 3G technology.²⁶⁴ Subsidies are more aggressively supplied by smaller networks, underscoring the competitive role of such vertical promotions.²⁶⁵

Unlicensed bands accommodate non-exclusive use rights, but require highly exclusionary public policies. The technologies authorized in unlicensed bands effectively prohibit most wireless options, on the expectation that they would cause harmful interference. When the FCC un-licenses spectrum, carriers and consumers must choose Intel's Centrino chips over Qualcomm's CDMA chips and Wi-Fi access points over data networks provided by GSM UMTS/HSDPA, CDMA 1xEV-DV, or WiMAX optimized for licensed radio spectrum.²⁶⁶

The fact that the approved low-power technology choices sometimes result in widespread adoption is evidence that not all social value is eliminated by the allocation policy. It does not, however, prove that the resulting wireless activity is the optimum outcome. A government-managed band does not contain the requisite feedback mechanisms to reveal and then adjust to the most efficient spectrum sharing arrangements. It is always possible that an alternative set of rules would generate greater gains. But whereas owners of licensed spectrum have profit incentives and the financial ability (i.e., access to capital markets) to arrange positive-sum transactions to make such transitions as present themselves as good candidates for superior results, spectrum regulators do not.

Some unlicensed bands appear have performed well, like the 900 MHz and 2.4 GHz bands, while others, like U-PCS and the 3650 MHz band, appear to constitute allocation failures. But regulators have no reliable way to optimize any particular band because the relevant counter-factual obviously cannot be observed beforehand. More basically, even after the fact – when the FCC observes “tremendous success” or some other categorically salubrious outcome – it has not made the relevant social welfare evaluation: was the FCC's allocation, and the associated rules (including adoption of the unlicensed access model and the restrictions on radio usage attendant to that approach) the most efficient way to use this particular bandwidth? Could markets have supplied more creative, lower-cost ways to accommodate the services obtained, while stimulating additional wireless services of value to consumers? That the FCC does not have the institutional ability to make such judgments with the reliability of alternative institutions, notably profit-maximizing capital owners in competitive markets, is obvious on numerous levels. Perhaps most striking is that the FCC does not even, as a pro forma matter, deem it necessary to *ask the question*.

²⁶⁴ Ville Saarikoski, *The Odyssey of the Mobile Internet* (2006); http://www.tieke.fi/mp/db/file_library/x/IMG/20156/file/Saarikoskivaitoskirja.pdf; Marko Repo, *Regulation of Wireless Stakeholders* (2006); http://www.netlab.tkk.fi/opetus/s383042/2006/papers_pdf/B2.pdf.

²⁶⁵ Pedro Pita Barros, *Handset Subsidies – An Empirical Investigation*, ANACOM (Regulatory Authority of Portugal) (Nov. 22, 2008); <http://www.anacom.pt/render.jsp?contentId=415606>.

²⁶⁶ This set of technologies appears to include WiMax, by many accounts the most advanced technology thus far emerging from the “Wi-Fi” family. *Wi-Fi? How About Way Far?; WiMax Delivers High-Speed Wireless Internet Service as Far as 35 Miles Away*, Hartford Courant at D3 (Mar. 25, 2004).

The types of evidence needed to make such evaluations are market data generally unavailable to public sector regulators, government employees who do not generate information as to profitable opportunities for spectrum re-use but, rather, maximize utility under the political constraints governing their agency. Whereas entrepreneurs scour the marketplace looking for assets that are undervalued, searching for the financial means to divert such resources to more productive employments, the bureaucratic goal is to placate an existing governing equilibrium.

It is likewise unknowable within an administrative allocation system whether a given unlicensed block – even where it is certifiably creating more benefit than cost in aggregate – is of the right size. Perhaps the 2.4 GHz ISM band would optimally be half, or twice, its present scope. Without ownership, there are no transactions; without transactions no market values. This leaves regulators guessing about where to draw lines. Whereas New York City understands what the cost of an acre is, and can judge whether it is worth purchasing more land to add to Central Park (or subtract by a sale), the value of a license-free bandwidth allocation is a matter of mere conjecture.

Suppose that a firm like Apple, instead of arguing for the government to allocate more bandwidth to license-exempt use, were to buy liberal licenses and then provide a “spectrum commons” on its own.²⁶⁷ It could then set frequency sharing rules, including technology formats and power limits, becoming a private FCC. In fact, this is the vertical structure of the mobile carrier space that already exists, the twist being a business model that rides by contract on the carrier’s network infrastructure and yet “opens” the licensed airwaves to radio devices and applications provided by hundreds of third party providers.

Under this approach, competitive market forces regulate the performance of Apple in providing the “commons.” Just as carriers are rewarded for providing customers with superior user experiences, the “unlicensed” space would become profitable to the degree that sharing rules were properly balanced, generating value-added via useful applications. Not only is such a model already well established, if not ubiquitous, in the licensing of intellectual property rights,²⁶⁸ it mirrors the system in place for mobile carriers. There, device makers contract to gain access to carriers’ networks and spectrum assets, passing the rights to customers who “play” their radios right out of the box. Mobile handsets, including those like TracFone (a virtual mobile operator that enables wireless phone calls using access rights purchased in wholesale markets) or Kindle (a book reader, sold by Amazon, that downloads content via Amazon’s contract with Sprint) embed seamless spectrum access rights for end users.

The advantages of such an approach over administrative allocation are manifest. But such an outcome is displaced by mandated allocations to unlicensed allocations. Hence, public policy drives Apple to request that the government place spectrum resources at risk, and then relies on its lobbyists to steer those rules in the direction sought by the firm. Whatever Apple has gained from unlicensed allocation, it obliterates transparency, undermines productive efficiencies, and blocks information-rich feedback loops. And, it should be noted, that Apple has emerged as a powerhouse in the wireless

²⁶⁷ This option has been suggested by many analysts, including professional staff at the FCC. See Kwerel & Williams, *Big Bang* at 31.

²⁶⁸ This analogy is nicely developed in Dorothy Robyin & William J. Baumol, [Toward an Evolutionary Regime for Spectrum Governance: Licensing or Unrestricted Entry?](#) (Brookings, 2006).

sector by abandoning its quest for unlicensed allocations in favor of contracts with carriers owning exclusive spectrum rights.²⁶⁹

X. POLICY

Administrative allocation of radio spectrum has historically been plagued by overly conservative policies that unduly limited competition and blocked technological innovation. But as broadcasting was eclipsed by mobile telephony, a subtle shift in policy took hold that in hindsight amounted to a policy revolution. In the modern marketplace, liberal spectrum licenses host extremely complex economic structures, allowing millions of customers to buy wireless services using advanced technologies, while facing a continually increasing number of access options and applications. This regime generates intense sharing of spectrum by rival networks and by mass-market subscribers to voice and data services. In delegating choices to competitive firms, de facto spectrum ownership rationalizes spectrum use.

The suggestion that exclusive rights to radio spectrum are made obsolete by advancing technology has the basic economic coordination problem backwards. The advanced wireless devices are today superior, in their ability to send and receive data, to previous generations. But they cannot be fruitfully deployed without some form of social control over the airwaves they access. The alternative to competitive ownership is the imposition of behavioral constraints by regulators. Power limits and technology restrictions are inevitably applied to license-exempt spectrum to limit conflicts. Smart radios do not portend the “end of scarcity” but constitute yet another ascending pathway on the mountain wireless entrepreneurs have been climbing since Marconi triggered the race for wireless innovations in 1895.

That seminal technological breakthrough triggered a chain of events that created spectrum scarcity. Contrary to the view that advanced devices solve such mundane matters of economic organization and obviate the value of exclusive spectrum rights, each new and improved radio actually triggers more demand for airwave access, *increasing* potential spectrum conflicts. Intensifying calls for more unlicensed spectrum in more desirable bands reflects just this scarcity, with rival claims made in the political marketplace. The pro-consumer policy unleashing the social value of wireless would shift such competitive bidding from the political marketplace to the economic realm.

This approach carries great promise and little risk. There is nothing that “spectrum inventories” held by government can achieve. The most reliable way to destroy valuable spectrum, in fact, is not to use it. The second most reliable way is to distribute a massive number of tiny, overlapping rights that cannot be usefully re-aggregated; the Humpty Dumpty approach that can

²⁶⁹ Apple’s lobbying for U-PCS in the 1990s was driven by a strategy to secure wireless access for its early PDA, Newton. That the Newton flopped may or may not be associated with the limitations of the regulatory process generally, or the U-PCS allocation specifically. That the iPhone’s success following its 2007 launch is associated with liberal licenses and the wide area networks they enable is, however, crystal clear. No other spectrum regime could provide the level of social organization necessary to accommodate the access services embedded in the iPhone.

easily result from unlicensed allocations.²⁷⁰ By allocating liberal licenses to competitors, however, market forces will divert spectrum resources to where demands are highest. If regulators in the future ascertain that important demands are going, in fact, unmet, it will be free to acquire frequencies for the task and to know the market price of doing so.

The 700 MHz licenses auctioned in March 2008 raised \$19 billion for the U.S. Treasury. Those bids reflect future anticipated profits (now transferred to the government) available to firms that control the resource rights conveyed. Nothing prevented bidders from purchasing such bandwidth and deploying it as a “spectrum commons”; indeed, that approach would seem an attractive alternative to spending the many billions of dollars on network infrastructure required in executing the mobile carriers’ network-centric model – were customers willing to pay for the services therein offered.

Marketplace rejection of the “commons” model does not constitute market failure, but a competitive equilibrium. It reveals that there are superior choices, given the available technologies and the associated consumer demands, for using valuable radio frequencies. That is the rationality supplied by liberal spectrum licenses.

²⁷⁰ On tragedy of the anti-commons generally, see Michael Heller, *The Gridlock Economy* (2008). On such tragedy with respect to unlicensed use of TV band “white spaces,” see Thomas W. Hazlett, *Tragedy T.V.: Rights Fragmentation and the Junk Band Problem*, GMU Law & Economics Research Paper No. 10-3 (Sept. 29, 2009).