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# ADVANCED WIRELESS TECHNOLOGIES AND PUBLIC POLICY

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Joint research of the authors includes: THOMAS W. HAZLETT & MATTHEW L. SPITZER, *PUBLIC POLICY TOWARD CABLE TELEVISION: THE ECONOMICS OF RATE CONTROLS* (1997); Thomas W. Hazlett & Matthew L. Spitzer, *Digital Television and the Quid Pro Quo*, 2 BUS. & POL. 115 (2000). Alison Sexton provided valuable research assistance. The authors, while retaining all liability for errors or omissions, also wish to thank Coleman Bazelon, Josh Gordon, Robert Hahn, and Chuck Jackson for valuable comments.

## ABSTRACT

*The traditional U.S. spectrum allocation system has long been criticized—even by regulators—as overly rigid. To unleash innovative wireless technologies, the Federal Communications Commission (“FCC”) has gradually loosened government restrictions on airwave use. But the path to liberalization leads in alternative directions. One policy reform paradigm, championed by leading economists such as Ronald Coase, allows markets to allocate exclusively assigned spectrum use rights. A rival approach, advanced by advocates of an “open spectrum” such as Lawrence Lessig, favors allocating greater bandwidth for unlicensed use. In such bands, there is free entry by wireless users, provided they use regulator-approved devices that comply with protocols (including power limits) established by the government.*

*The FCC’s November 2002 Spectrum Policy Task Force Report called for greater reliance on both the exclusive and unlicensed models. Yet, considered in historical context, the FCC’s analysis veered decidedly toward more intense use of “spectrum commons,” abandoning previous agency goals to expand licensed allocations. Citing the “tremendous success” of unlicensed use of cordless phones and Wi-Fi access points, regulators have since argued that advanced wireless technologies create a new policy imperative. Because modern radios use sophisticated techniques for sorting out competing signals, “block allocations” are outdated.*

*The FCC sees the “spectrum commons” regulatory paradigm as suited to the new opportunities in wireless. In the wake of the spectrum report, it allocated additional 5 GHz bands for unlicensed use, and pursued several regulatory initiatives to dramatically expand bandwidth available for unlicensed devices. In contrast, new allocations for exclusively assigned, flexible-use spectrum rights (analogized as “property rights”) have stalled.*

*The FCC states that advanced wireless technologies yield valuable new opportunities to share radio spectrum on an unlicensed basis. Yet, the same advances increase opportunities for using exclusively assigned bands, where market data reveal that the most intense and complex frequency sharing actually occurs. Exclusive rights allow coordination of frequency use by competitive network operators; consumers generally find this a superior form of organization than that provided through regulated*

*protocols, and overwhelmingly value marginal allocations of exclusively assigned rights more highly.*

*This Article examines tradeoffs in allocating spectrum for exclusive rights versus unlicensed use, focusing on an ongoing FCC rulemaking to create an “interference temperature.” This policy would permit unlicensed users to share bandwidth, including frequencies “exclusively” allocated to licensees, according to FCC rules. Our aim is to demonstrate that standard economic principles illuminate the path to proconsumer rules.*

## I. RADIO SPECTRUM REGIMES

Dueling paradigms present new options and challenges for spectrum regulators. The FCC, mistakenly believing that when it chooses a “property rights” system it automatically loses the benefits of an “open spectrum” system, is failing the challenge. The FCC’s choices threaten both to destroy hundreds of billions of dollars in consumer welfare and to hamper innovation in broadband wireless in the United States.

Advocates of “property rights” argue that the most effective way to create social value is to assign exclusive bandwidth rights with liberal regulatory constraints.<sup>1</sup> This view dates to papers written in the 1950s by University of Chicago law student Leo Herzel<sup>2</sup> and Nobel Laureate Ronald H. Coase,<sup>3</sup> and is today subscribed to by a wide cross-section of law and economics scholars.<sup>4</sup> The most compelling example of such a regime in the

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1. “Property rights” exist under any regime, so describing any single approach this way can be misleading. The same is true when the standard terms “command and control” and “spectrum commons” are invoked asymmetrically. We attempt to minimize confusion in our usage, while relying on the stylized terminology used elsewhere.

2. Leo Herzel, *My 1951 Color Television Article*, 41 J.L. & ECON. 523 (1998); Leo Herzel, *Rejoinder*, 20 U. CHI. L. REV. 106 (1952). See also R.H. Coase, *Law and Economics at Chicago*, 36 J.L. & ECON. 239, 249 (1993) (discussing the influence of Herzel’s property-rights argument on Coase’s own analysis); Comment, “*Public Interest*” and the Market in *Color Television Regulation*, 18 U. CHI. L. REV. 802 (1951).

3. R.H. Coase, *The Federal Communications Commission*, 2 J.L. & ECON. 1 (1959).

4. See generally Comments of 37 Concerned Economists, *In re Promoting Efficient Use of Spectrum Through Elimination of Barriers to the Dev. of Secondary Mkts.*, No. 00-230 (FCC Feb. 7, 2001), available at [http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native\\_or\\_pdf=pdf&id\\_document=6512460886](http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6512460886) [hereinafter Comments of 37 Concerned Economists]; Stuart Minor Benjamin, *Spectrum Abundance and the Choice Between Private and Public Control*, 78 N.Y.U. L. REV. 2007 (2003); Thomas W. Hazlett, *The Wireless Craze, the Unlimited Bandwidth Myth, the Spectrum Auction Faux Pas, and the Punchline to Ronald Coase’s “Big Joke”*: An Essay on Airwave Allocation Policy, 14 HARV J.L. & TECH. 335 (2001); Gerald R. Faulhaber & David J. Farber, *Spectrum Management: Property Rights, Markets, and the Commons* (AEI-Brookings Joint Ctr. for Regulatory Studies, Working Paper No. 02-12, 2002), available at <http://100x100network.org/papers/faulhaber-brookings2002.pdf>.

United States is found in the commercial mobile radio services (“CMRS”) market, where four national networks deliver wireless telephone service to over 200 million subscribers.<sup>5</sup> With competitive licensees having wide latitude to choose the technologies deployed and the services offered, market forces largely determine how spectrum is utilized in these bands.<sup>6</sup>

An alternative policy approach has emerged with the use of “open spectrum,” also known as a “spectrum commons.”<sup>7</sup> Under this regime, the right to use a given frequency is *not* exclusively assigned. Rather, bands may be accessed by all who transmit with equipment that meets government specifications. In certifying radios, regulators impose limits on the power used to emit signals and restrict technology choices, addressing potential conflicts by governing how spectrum is utilized. Frequencies regulated in this fashion are called “unlicensed” or “license-exempt” bands and host such devices as cordless telephones, which now outsell the corded variety,<sup>8</sup> and Wi-Fi access points, a popular method for distributing

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5. Six national mobile phone networks were reduced to four after two mergers, announced in 2004, were recently consummated. The four surviving carriers are Cingular, Verizon, Sprint, and T-Mobile. The two mergers combined Cingular with AT&T Wireless, and Sprint with Nextel. See Ken Belson, *Regulators Back Sprint's Deal to Buy Nextel for \$35 Billion*, N.Y. TIMES, Aug. 4, 2005, at C11; Ken Belson, *With F.C.C. Consent, Cingular Buys AT&T Wireless*, N.Y. TIMES, Oct. 27, 2004, at C4. As of April 1, 2006, there were 205,894,256 wireless subscribers in the United States. CTIA—The Wireless Association, <http://www.ctia.org> (last visited Apr. 1, 2006).

6. The U.S. regime does not offer complete flexibility in the use of CMRS licenses, nor are licensees in other markets generally allowed to transition into CMRS services. In addition, most spectrum use rights are not allocated to licenses, blocking any private party from access. Hence, this property-rights framework is limited both in the extent of the liberalization and in its scope (that is, allocated spectrum). See Evan Kwerel & John Williams, *A Proposal for a Rapid Transition to Market Allocation of Spectrum* 4–8 (FCC, Office of Plans & Policy, Working Paper No. 38, 2002), available at [http://hraunfoss.fcc.gov/edocs\\_public/attachmatch/DOC-228552A1.pdf](http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-228552A1.pdf). For an international perspective that includes a discussion of regimes with more far-reaching liberalization, see Thomas W. Hazlett, *Property Rights and Wireless License Values* (AEI-Brookings Joint Ctr. for Regulatory Studies, Working Paper No. 04-08, 2004), available at <http://www.aei-brookings.org/admin/authorpdfs/page.php?id=771>.

7. For arguments supporting a policy regime favoring “spectrum commons,” see LAWRENCE LESSIG, *THE FUTURE OF IDEAS: THE FATE OF THE COMMONS IN A CONNECTED WORLD* 73–84 (2001); Yochai Benkler, *Overcoming Agoraphobia: Building the Commons of the Digitally Networked Environment*, 11 HARV. J.L. & TECH. 287 (1998) [hereinafter Benkler, *Agoraphobia*]; Yochai Benkler, *Some Economics of Wireless Communications*, 16 HARV. J.L. & TECH. 25 (2002); Stuart Buck, *Replacing Spectrum Auctions with a Spectrum Commons*, 2002 STAN. TECH. L. REV. 2; Kevin Werbach, *Supercommons: Toward a Unified Theory of Wireless Communication*, 82 TEX. L. REV. 863 (2004).

8. Since 1997, more cordless telephones have been sold for use with fixed-line networks than the corded variety. Stephen Moore & Julian L. Simon, *The Greatest Century That Ever Was: 25 Miraculous Trends of the Past 100 Years*, POL’Y ANALYSIS 21, Dec. 1999, at 1, 21.

broadband Internet connections via “hotspots” or enterprise-wide local area networks.<sup>9</sup>

The rival approaches compete directly when government agencies allocate frequencies. Coordination between spectrum users is valuable because conflicts can destroy significant opportunities. Radio emissions that provide useful services to one consumer can raise costs, or lower benefits, for others. We will presume, for purposes of analysis in this Article, that maximizing the total social value of spectrum access is the goal of policy.<sup>10</sup>

Advocates for the policy alternatives may agree on one issue: standard methods used to regulate radio spectrum undermine consumer welfare.<sup>11</sup> Historically, the “block allocation system”<sup>12</sup> has directed regulators to determine what services, if any, may be provided, what technologies may be used, and what business models may be deployed. For broadcast television in the United States, for instance, the FCC imposed rules between 1939 and 1953 that allocated eighty-one channels for over-the-air service in the VHF (very high frequency) and UHF (ultrahigh frequency) bands.<sup>13</sup> Each station license was allotted 6 MHz of bandwidth, and the transmission format was fixed by the National Television Standards Committee, which devised its technology over a half-century ago.<sup>14</sup> Video programs were provided on an advertiser-supported basis; nonvideo services and subscription fees were ruled out. The rules have proven rigid

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9. For a mobile communications industry perspective on Wi-Fi hotspots generally, see Jeffrey K. Belk, *Adventures in the Public Hotspot Wi-Fi World 7–10* (May 2003) (unpublished manuscript), available at [http://www.qualcomm.com/enterprise/pdf/Adventures\\_in\\_the\\_Wi-Fi\\_Public\\_Hotspot\\_J\\_Belk.pdf](http://www.qualcomm.com/enterprise/pdf/Adventures_in_the_Wi-Fi_Public_Hotspot_J_Belk.pdf).

10. In an analogous context, many claim that a “consumer welfare standard” properly governs antitrust enforcement. See, e.g., ROBERT H. BORK, *THE ANTITRUST PARADOX* 81–89 (1978).

11. “There is general agreement that the traditional command-and-control regulation of radio spectrum by the FCC (and NTIA) has failed. There is no general agreement on which regime should succeed it.” Gerald R. Faulhaber, *The Question of Spectrum: Technology, Management, and Regime Change 1* (AEI-Brookings Joint Ctr. for Regulatory Studies, Working Paper No. 05-15, 2005), available at <http://www.aei-brookings.org/admin/authorpdfs/page.php?id=1176>.

12. For discussions of the block allocation system, see PETER HUBER, *LAW AND DISORDER IN CYBERSPACE* 63–76 (1997); John O. Robinson, *Spectrum Management Policy in the United States: An Historical Account* 44–52 (FCC, Office of Plans & Policy, Working Paper No. 15, 1985), available at [http://www.fcc.gov/Bureaus/OPP/working\\_papers/oppwp15.pdf](http://www.fcc.gov/Bureaus/OPP/working_papers/oppwp15.pdf); NAT’L TELECOMMS. & INFO. ADMIN., *U.S. SPECTRUM MANAGEMENT POLICY: AGENDA FOR THE FUTURE* (1991), <http://www.ntia.doc.gov/osmhome/91specagen/1991.html>.

13. Thomas W. Hazlett, *The U.S. Digital TV Transition: Time to Toss the Negroponte Switch 2* (AEI-Brookings Joint Ctr. for Regulatory Studies, Working Paper 01-15, 2001), available at <http://www.aei-brookings.org/admin/authorpdfs/page.php?id=179>.

14. See *id.* at 4 n.11.

and restrictive, preventing new technologies from accessing the valuable airspace set aside for broadcast television generations ago.

This regulatory barrier to innovation is perhaps best seen in the market for residential broadband service. Today, more than thirty-five million U.S. households and small businesses enjoy high-speed Internet access.<sup>15</sup> Cable modem services offered by cable television operators and digital subscriber line (“DSL”) subscriptions via local telephone carriers dominate this market. An array of economists,<sup>16</sup> study groups,<sup>17</sup> and policymakers<sup>18</sup> have pointed out that a wireless third path in the broadband race could provide economic stimulus and expand consumer choices. Moreover, the path could easily emerge were television frequencies made available for this purpose. But this efficient spectrum migration has been blocked, and the deterrence of wireless broadband thwarts economic development. One recent study estimated that, were household broadband to become deployed as widely as residential telephone service (that is, subscribed to by about ninety-four percent of homes), consumer gains would total about \$300 billion.<sup>19</sup>

The FCC is finding it difficult to kick the “command and control” habit, even as it steps away from block allocations. In its 2002 *Spectrum Policy Task Force Report* (“SPTFR”),<sup>20</sup> and in a series of decisions made in its wake, the FCC sought to address how advanced wireless technologies can be unleashed. As reported, “Chairman Powell saw the purpose of this Task Force as the establishment of ‘new ways to support innovation and

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15. As of year-end 2004, there were 35.3 million high-speed lines serving residential and small-business subscribers. Press Release, FCC, Federal Communications Commission Releases Data on High-speed Services for Internet Access (July 7, 2005), available at [http://www.fcc.gov/Bureaus/Common\\_Carrier/Reports/FCC-State\\_Link/IAD/hspd0705.pdf](http://www.fcc.gov/Bureaus/Common_Carrier/Reports/FCC-State_Link/IAD/hspd0705.pdf).

16. See, e.g., THOMAS W. HAZLETT ET AL., U.S. CHAMBER OF COMMERCE, SENDING THE RIGHT SIGNALS: PROMOTING COMPETITION THROUGH TELECOMMUNICATIONS REFORM 67–71 (2004), available at <http://www.uschamber.com/portal/teleconsensus/041006telecommstudy.htm>; Gerald R. Faulhaber, *Policy-induced Competition: The Telecommunications Experiments*, 15 INFO. ECON. & POL’Y 73, 94–97 (2003).

17. NAT’L ACAD. OF SCIS., BROADBAND: BRINGING HOME THE BITS 139–48 (2002).

18. OFFICE OF SENATOR JOSEPH I. LIEBERMAN, BROADBAND: A 21ST CENTURY TECHNOLOGY AND PRODUCTIVITY STRATEGY 42 (2002), available at [http://lieberman.senate.gov/documents/whitepapers/Broadband\\_Lieberman\\_5\\_28\\_02.pdf](http://lieberman.senate.gov/documents/whitepapers/Broadband_Lieberman_5_28_02.pdf); SPECTRUM POLICY TASK FORCE, FCC, REPORT 11–17 (2002), available at [http://hraunfoss.fcc.gov/edocs\\_public/attachmatch/DOC-228542A1.pdf](http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-228542A1.pdf) [hereinafter SPTFR].

19. ROBERT W. CRANDALL & CHARLES L. JACKSON, THE \$500 BILLION OPPORTUNITY: THE POTENTIAL ECONOMIC BENEFIT OF WIDESPREAD DIFFUSION OF BROADBAND INTERNET ACCESS 20–21 (2001), available at [http://www.sbc.com/public\\_affairs/broadband\\_policy/BrookingsStudy.pdf](http://www.sbc.com/public_affairs/broadband_policy/BrookingsStudy.pdf).

20. SPTFR, *supra* note 18.

the efficient, flexible-use of spectrum.”<sup>21</sup> The report issued a critique of “command and control” regulatory practices, and called for deregulation.

Yet, in mapping out its policy, the SPTFR signaled a clear agency preference for increasing unlicensed, as opposed to licensed, allocations. This preference is made evident by the report’s retreat from previous goals set by regulators to allocate additional spectrum for flexible-use by licensees. In 1999, an FCC Policy Statement proposed to make an additional 200 MHz available for flexible-use licenses allocated to prime spectrum, and spelled out the precise bands where such allocations could be achieved.<sup>22</sup> These proposed allocations, which were not implemented in the intervening years, were absent in the 2002 SPTFR. Instead, the SPTFR reversed course by calling on the FCC to identify just 100 MHz of spectrum to allocate for flexible, licensed use over five years.<sup>23</sup> This heightened conservatism contrasts sharply with the suggestion in an FCC Working Paper, released the same day as the SPTFR, proposing the immediate release of some 438 MHz of prime spectrum below 3 GHz for flexible-use licenses.<sup>24</sup>

The shift in FCC policy was quickly evidenced in a series of policy initiatives. While flexible-use licensed allocations have stalled since the 1993 rulemaking (which made 120 MHz available for licensed personal communications services), the FCC followed the SPTFR with several proposals to make new frequencies available for unlicensed use.<sup>25</sup>

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21. Peter Jarich, *Unlicensed Wireless and the FCC’s Spectrum Policy Task Force*, BROADBAND WIRELESS ONLINE, Nov.–Dec. 2002, [http://www.shorecliffcommunications.com/magazine/print\\_article.asp?vol=31&story=305](http://www.shorecliffcommunications.com/magazine/print_article.asp?vol=31&story=305).

22. Policy Statement, *In re Principles for Reallocation of Spectrum to Encourage the Dev. of Telecomms. Techs. for the New Millennium*, 14 F.C.C.R. 19,868, 19,869–70 (1999). *See also infra* Part I, tbl.1.

23. SPTFR, *supra* note 18, at 51.

24. Kwerel & Williams, *supra* note 6, at 33.

25. These proposals include the following:

(1) *Unlicensed Use of the TV Band*. *See* Notice of Inquiry, *In re Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band*, 17 F.C.C.R. 25,632 (2002). This initiative sought to allow unlicensed devices to access TV band white space not used for broadcasting. It effectively displaced a rival approach advanced by Senate Commerce Committee Chair Larry Pressler (R-S.D.) in 1996, wherein exclusively assigned rights would be issued in overlays allowing new licensees to reallocate bandwidth. *See* Spectrum Reform Discussion Draft, 142 CONG. REC. S4928-01 (1996).

(2) *255 MHz of Additional Unlicensed Spectrum*. In November 2003, the Commission nearly doubled the 325 MHz of spectrum in the 5 GHz band used for unlicensed devices. *See* Report & Order, *In re Revision of Parts 2 & 15 of the Commission’s Rules to Permit Unlicensed Nat’l Info. Infrastructure (U-NII) Devices in the 5 GHz Band*, 18 F.C.C.R. 24,484 (2003).

(3) *Interference Temperature*. Rules proposed in November 2003 would permit unlicensed devices to share the spectrum allocated to licensed users, slotting low-power applications “underneath”

TABLE 1. New licensed allocations proposed in the 1999 *FCC Spectrum Report* with status as of November 2002

<i>Service</i>	<i>Band</i>	<i>MHz proposed</i>	<i>MHz allocated</i>	<i>MHz in use</i>
GWCS	4.9 GHz	25	0	0
AMFCS	1.7 GHz 2.1 GHz	90	0	0
LMCS	1.4 GHz	10	0	0
TV Reallocation	700 MHz	48	18	0 <sup>26</sup>
Fixed and Mobile Services	1.6 GHz 2.4 GHz	10	0	0
TOTAL		183	18	0

The FCC's tilt toward administrative fiat is unmistakable. Each of these rulemakings aims to provide additional spectrum space for the operation of unlicensed devices.<sup>27</sup> The FCC's argument for favoring license-exempt spectrum is that advanced wireless technologies dictate a new approach to spectrum management. Innovative wireless systems are today far more nimble than in previous generations, meaning that

higher-power uses. *See* Notice of Inquiry & Notice of Proposed Rulemaking, *In re* Establishment of an Interference Temperature Metric to Quantify & Manage Interference & to Expand Available Unlicensed Operation in Certain Fixed, Mobile & Satellite Frequency Bands, 18 F.C.C.R. 25,309 (2003) [hereinafter INTEM Notice].

(4) *Cognitive Radio*. *See* Notice of Proposed Rulemaking & Order, *In re* Facilitating Opportunities for Flexible, Efficient, & Reliable Spectrum Use Employing Cognitive Radio Techs., No. 03-108, 2003 WL 23022050 (FCC Dec. 30, 2003). This is a proceeding that began in December 2003 and "grew out of the Spectrum Policy Task Force and that explores the many benefits of smart radio technology and its real-time processing capabilities." Statement of Chairman Michael K. Powell, FCC Opens Proceeding on Smart Radios, No. 03-108, 2003 WL 2295679, at \*2 (FCC Dec. 17, 2003). The proceeding generally considers how to expand unlicensed applications. *Id.*

(5) *3650–3700 MHz*. An April 2004 proposal, adopted in March 2005, provides 50 MHz for nonexclusive access rights. *See* Notice of Proposed Rule Making, *In re* Unlicensed Operation in the Band 3650–3700 MHz, 19 F.C.C.R. 7545 (2004). Exclusive rights were rejected on the grounds they would interfere with unlicensed applications. *See* Press Release, FCC, FCC Opens Access to New Spectrum for Wireless Broadband in the 3650 MHz Band (Mar. 10, 2005), available at [http://hraunfoss.fcc.gov/edocs\\_public/attachmatch/DOC-257309A1.pdf](http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-257309A1.pdf).

26. In September 2002, the FCC auctioned licenses allocating 18 MHz of the 700 MHz TV band spectrum, but these licenses are encumbered by existing analog television broadcasters.

27. The Cognitive Radio proceeding, for example, explores the use of smart radios in both licensed and unlicensed spectrum. Press Release, FCC, FCC Opens Proceeding on Smart Radios (Dec. 17, 2003), available at [http://hraunfoss.fcc.gov/edocs\\_public/attachmatch/DOC-242312A1.pdf](http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-242312A1.pdf).

communications that in the past would have created unacceptable interference can today peacefully coexist. Receivers and transmitters are more sophisticated in sending and deciphering messages, and in delineating those messages intended for recipients while ignoring radio clutter.

It is true that exponentially more users can now productively use a given frequency space. U.S. regulators claim these spectrum sharing innovations raise demand for additional unlicensed allocations. Former FCC Chairman Michael Powell states that unlicensed devices can

dramatically increase the availability and quality of wireless Internet connections—the equivalent of doubling the number of lanes on a congested highway. . . . Such technologies could create the same explosion in new business and growth that we have seen in the case of Wi-Fi and Bluetooth. For instance, it could help bring high-speed Internet services to rural communities . . . .<sup>28</sup>

The popularity of short-range devices accessing license-exempt spectrum provides the rationale for increasing unlicensed spectrum access.<sup>29</sup>

But none of this justifies the FCC's tilt toward unlicensed spectrum. The same technical advances that increase value in unlicensed applications also offer potential social value when used in *exclusively assigned* frequencies. The availability of increasingly powerful wireless communications raises the social cost of regulatory barriers that block innovation and entry, but does not offer a priori evidence as to which way regulators should travel when leaving block allocation.

To maximize social value, government spectrum allocations are properly evaluated on the appropriate margin, with alternative wireless opportunities considered. Let us say that unlicensed devices accessing a given frequency space currently produce social benefits. Each new unlicensed spectrum allocation now considered hinges on how much additional benefit is likely to result. Let us call this additional social benefit  $A$ , and assume that  $A > 0$ .

But this condition, while necessary for efficiency, is insufficient to support the allocation of additional unlicensed spectrum. Before we can decide how to allocate additional spectrum, we must estimate what economic value would be generated under different rules.<sup>30</sup> In particular,

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28. Statement of Chairman Michael K. Powell, Notice of Proposed Rule Making, *In re* Unlicensed Operation in the TV Broadcast Bands, 19 F.C.C.R. 10,018, 10,052 (2004).

29. Wi-Fi signals travel up to about three hundred feet, Bluetooth about one-tenth as far.

30. This process requires information that is not available to regulators, resulting in various outcomes, including agency paralysis. In his 1985 FCC working paper, John Robinson writes,

we must consider allocating additional spectrum according to the dueling paradigm—the “property rights” approach—wherein flexible-use rights are assigned exclusively. What matters is the size of *A*—new benefits from additional unlicensed spectrum—contrasted with the expected value of a property regime—let us call that *B*. Importantly, the magnitude of *B* will encompass many, if not all, of the spectrum use options permitted for unlicensed users because the flexible-use regime allows licensees to innovate across business models and market structures. If the kinds of “open access” rules characteristic of unlicensed bands are efficient, then exclusive spectrum rights holders will have strong incentives to adopt them.<sup>31</sup>

This is a basic analytical point, and it offers a powerful critique of current spectrum policy. Rather than evaluate the tradeoffs inherent in alternative allocations, regulators offer categorical assessments that justify political conclusions. Past “successes” in cordless phones or Wi-Fi equipment are offered as rationales for additional unlicensed spectrum. No analysis is undertaken to discern how one past “success” can differ from others, how those results translate into future benefits (that is, *A*), or what opportunity costs will be incurred (that is, *B*). The magnitude of *B* is a function of the social gain that would obtain were the bandwidth in question used under the best alternative (that is, other than unlicensed) rules. This is an unobserved counterfactual, as is the projected value of *A*. The expected costs of errors in administratively imposed decisions at this crucial spectrum planning phase should be included in the cost-benefit analysis, particularly because such regulation has historically been expensive for consumers.<sup>32</sup>

This Article explores the FCC’s regulatory efforts to induce innovation by spectrum sharing under rules designed to expand a “spectrum commons.” Our basic point is that regulatory action to set aside more spectrum for unlicensed use deserves systematic analysis of costs and benefits, an analysis that appears nowhere in current FCC rulemaking. To

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The Commission in its function of spectrum allocation . . . requires information by which to establish the level of need for a radio service and also technical information to determine the best spectrum location for the service and the amount of spectrum required. This information is not available in complete and objective form. The end result of the process . . . is not only imperfect and inefficient allocation of the spectrum, but also long delay in its use.

Robinson, *supra* note 12, at 52.

31. Indeed, if private rights holders fail to adopt efficient market structures, such rights could be acquired by nonprofit institutions, including public agencies, to remedy this outcome.

32. This is generically true of government resource allocation, and provided the original motivation for Coase’s suggestion that economic planning be transferred to “the price system.”

illustrate in some detail, we focus our analysis on an important, ongoing FCC proceeding to craft rules allowing unlicensed users to share the use of bands assigned to licensed users, a mechanism called an “interference temperature.”

This Article is organized in the following manner. In Part II, we explain the FCC’s proposal for an interference temperature. Part III more generally summarizes FCC spectrum allocation policy, and the regulatory choice between licensed and unlicensed bands. Part IV charts the introduction of advanced wireless services under a liberal regime of exclusively-assigned spectrum access rights. Part V then evaluates the costs of increasing traffic (or the “noise floor”) in licensed bands as proposed in the Interference Temperature Notice. Using conservative assumptions, a single national mobile operator would incur additional outlays (both capital and operating costs) of an estimated \$1 billion annually to maintain coverage and capacity. These costs dominate expected gains from a new underlay allocation for unlicensed use. In Part VI, we show how the FCC’s interference temperature proposal extends the very uneconomic decisionmaking the Coase Theorem was framed to critique. In Part VII we offer a conclusion.

## II. INTERFERENCE TEMPERATURE<sup>33</sup>

The FCC is considering implementation of an interference temperature (“INTEM”).<sup>34</sup> This would allow new unlicensed devices to share spectrum “underlay rights” in licensed bands, a recommendation offered in the FCC’s *Spectrum Policy Task Force Report*.<sup>35</sup> An underlay is where a low-power application is given permission to share the bandwidth allocated to existing users on the premise that it can peacefully coexist with those operating at higher power.<sup>36</sup> Given that frequency space can generally be used more intensely as radios become increasingly adept at distinguishing signals, much of the bandwidth now set aside for existing

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33. A previous version of this analysis is found in Comments of Thomas W. Hazlett & Matthew L. Spitzer at 5–16, *In re Establishment of an Interference Temperature Metric to Quantify & Manage Interference & to Expand Available Unlicensed Operation in Certain Fixed, Mobile & Satellite Frequency Bands*, No. 03-237 (FCC Apr. 5, 2000), available at [http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native\\_or\\_pdf=pdf&id\\_document=6516086620](http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6516086620).

34. See INTEM Notice, *supra* note 25, at 25,309–11.

35. SPTFR, *supra* note 18, at 36, 40, 53.

36. Hazlett, *supra* note 4, at 509, 550. See also Faulhaber & Farber, *supra* note 4, at 19 (referring to underlay rights as “easements”).

services appears to be relatively underutilized “white space.”<sup>37</sup> Additional wireless services could be provided, theoretically, by authorizing underlays.

In Figure 1, adopted from the INTEM Notice, the radio space used by a licensee is graphically represented. The signal is strongest at the transmitter and declines in strength as it travels. At some distance from the transmitter, it fades such that it is indistinguishable from various other emissions, which are characterized as the “noise floor.” This electronic clutter is generated by various sources: nature (for example, lightning or the warm earth itself), noncommunications equipment emitting incidental radiation (for example, neon lights or a personal computer), spurious emissions, and out-of-region wireless communications traffic.<sup>38</sup>

Signals transmitted from an antenna are intended to reach receivers.<sup>39</sup> When signal strength is only as strong as the noise floor, distinguishing the intended signal from other emissions is difficult. Traditionally, most wireless systems have been engineered such that coverage ends where signal strength equals that of the underlying noise floor. This is marked on Figure 1 as “Service Range at Original Noise Floor.”

The FCC observes, however, that licensed radio services also seek to avoid signal degradation caused by interfering emissions above the degradation caused by standard background noise.<sup>40</sup> These often emanate from communications traffic, both in-band and out-of-band, causing spikes above the noise floor at certain times, places, and frequencies.<sup>41</sup> Because they occur only intermittently, they do not eliminate reception of low-power signals much, or even most, of the time.<sup>42</sup> But because they can seriously degrade quality of service, systems may be engineered to avoid this interference by relying solely on higher power levels.<sup>43</sup> This contracts geographical coverage, as shown in Figure 1 at the point marked “Minimum Service Range with Interference Cap.”

The essential proposition is that there exists a well-defined space between the noise floor and the licensed signal floor, the minimum power used by the licensee in order to avoid intermittent noise jutting up above

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37. “White spaces” are frequencies interspersed between those actively used for transmissions. The frequencies so designated may change over time.

38. INTEM Notice, *supra* note 25, at 25,319.

39. The antenna can be installed almost anywhere, from a major tower to a chip in a handset.

40. *See* INTEM Notice, *supra* note 25, at 25,312.

41. *Id.* at 25,313.

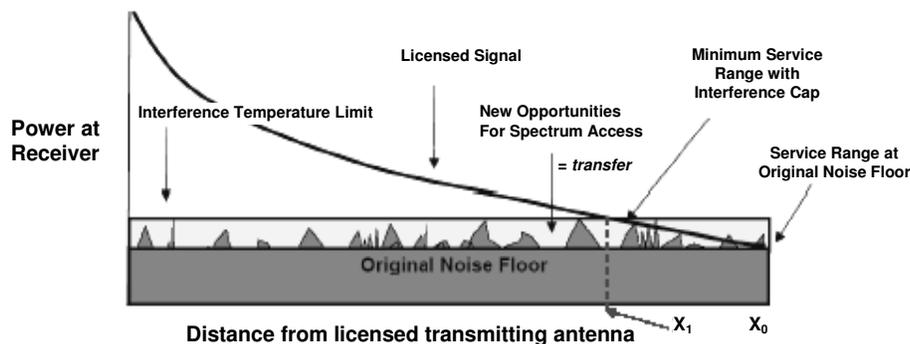
42. *See id.*

43. *Id.* at 25,313–14.

the noise floor.<sup>44</sup> This space, defined in a given band in a given geographical market by the power of the signal at the receiver, is an area we label “Transfer.” The Transfer space carves out bandwidth from the licensed spectrum allocation, and reallocates it for use by unlicensed devices under FCC rules.

Unlicensed users are seen to be given valuable new opportunities. But the FCC believes the reallocation also benefits the licensed operator. First, the licensee is not seen to be productively utilizing the Transfer space, avoiding it in order to escape intermittent interference.<sup>45</sup> The FCC dubs this area “New Opportunities for Spectrum Access,” on the grounds that it is not utilized by the incumbent licensee and, therefore, the opportunity cost of reallocation is zero.<sup>46</sup> Second, the licensed operator is said to gain security.<sup>47</sup> By defining the Transfer space as bounded by the upper limit of the noise floor, the FCC sets an interference temperature. This boundary replaces the status quo, under which a rising level of encroachment may occur over time. Bandwidth available to the licensee is protected by an INTEM, reducing risk to infrastructure investments made by the licensee.

FIGURE 1. The FCC’s basic proposal<sup>48</sup>



Seen this way, imposition of an interference temperature produces mutually beneficial results. Licensed users gain protection from increases in the noise floor: “This would assure that the licensed operation would not experience any further degradation or loss of service from new

44. *Id.* at 25,314–15.

45. *Id.*

46. *Id.* at 25,315 fig.1.

47. *Id.* at 25,311.

48. *Id.* at 25,315 fig.1.

interference, and thereby provide incumbents greater certainty . . . This could aid designers in balancing the numerous technical and economic tradeoffs involved in radio system planning.”<sup>49</sup> While, on the other hand, new uses create value:

This approach could also be beneficial for users of unlicensed devices. In areas where the interference temperature would not have been exceeded, opportunities would exist for additional operation by “underlay” transmitters equipped to monitor the interference temperature and to control their operations so that they do not contribute to a condition where the interference temperature cap would be exceeded. Thus spectrum access for unlicensed users and devices would be increased.<sup>50</sup>

#### A. PUBLIC POLICY ANALYSIS

FCC policy analyst Michael Marcus lays the theoretical foundation for the interference temperature proceeding, characterizing the proposed spectrum reform as driven by changing technology options.<sup>51</sup> Improved wireless technologies create new demands for spectrum access, while simultaneously creating much wider opportunities for sharing bandwidth. Marcus concludes that there is actually a reduction in spectrum scarcity if new policy approaches like the interference temperature are implemented, due to the science now available:

Today’s spectrum managers are faced with a dilemma of growing spectrum demand coupled with low average utilization in large public sector blocks in urban area[s]. With traditional technology this dilemma was inevitable as public sector users need blocks of dedicated spectrum sized for peak demand. New technology can open new policy options for the spectrum manager here. We may no longer have to choose between “guns and butter” but may be able to have the spectrum use associated with both at the same time through improve[d] policies and technologies.<sup>52</sup>

While it is true that powerful new wireless technologies are being created, and that the creation of more valuable communications systems makes regulatory barriers ever more costly, the new options do not eliminate choices. Better ways to utilize spectrum *increase* the opportunity

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49. *Id.* at 25,315.

50. *Id.*

51. M.J. Marcus, *Interruptible Spectrum: A Policy Prospectus* (May 6, 2003) (unpublished manuscript, on file with author).

52. *Id.* at 15.

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cost of deploying a particular technology to the exclusion of another. These costs do not disappear when government imposes mandates such as selecting maximum power levels, permissible technical standards, or sharing protocols. These costs produce the intense interest the FCC takes in defining how advanced wireless technologies work, how spectrum sharing is accommodated, and how frequencies can be monitored. The FCC seeks to make rules that will help some networks, applications, or business models. But others, less viable under the rules adopted, are implicitly or explicitly rejected.

By focusing solely on technology questions—how agile radios, smart antennas, software-defined radios, and other “opportunistic devices” can share spectrum allocated to existing licensees—the FCC skips the essential policy consideration: *how spectrum sharing rules should be developed*. These rules can be imposed by government regulation, the choice implicitly made in the INTEM proceeding, or by private firms constrained by market competition. This alternative mechanism merits consideration because private firms constantly weigh and balance alternative uses of spectrum. For this reason, the alternative mechanism has been repeatedly endorsed by economists as an efficient structure for organizing airwave use.<sup>53</sup>

In contrast, the FCC’s singular focus on unlicensed devices excludes consideration of the opportunity associated with licensees’ authority over the Transfer space. A spectrum ownership approach permits competitive market forces to allocate access to white space, using profit incentives to create, promote, and monitor spectrum usage. Three aspects of this policy alternative are important to consider.

First, existing rights held by licensees are truncated, preventing possible efficiencies. This can be remedied by expanding rights such that licensees have full flexibility to use allocated frequencies subject only to the constraint that they be liable for costly interference inflicted on other lawful users.

Second, not all white space is inefficient. Rather, there is an optimal level of frequency use that balances the gains from additional traffic against the costs generated by emissions, which include damage from conflicts with other users. These tend to be internalized by band managers when spectrum rights are exclusively assigned.

Third, even within a monopoly market structure, profit incentives drive licensees to rationalize the use of white space. Yet, the benefits of

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53. See *supra* note 4.

competitive markets are higher, and these can be achieved by policies steering spectrum allocations toward competitive outcomes.<sup>54</sup>

Arguments favoring one or the other of these policy options—inserting unlicensed users into licensed spaces, or expanding the complement of rights held by licensees—center on incentives and transaction costs: which option will allow economic agents to coordinate airwave use so as to make the most productive use of wireless technologies? We demonstrate below that the existing evidence strongly suggests the latter course maximizes social value. Yet, before this debate can conclude, it must first commence. The INTEM proposal must be contrasted with alternative rights structures.

FIGURE 2. Overlays on unlicensed spectrum

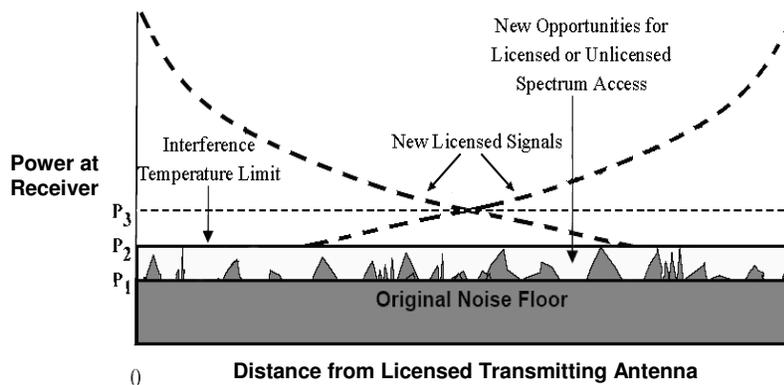


Figure 2 helps to illustrate the relevant policy options by shifting the focus to an unlicensed band. Given power limits imposed by regulation, considerable high-powered white space is left idle in unlicensed bands. Suppose that this bandwidth could be utilized by fixing an interference temperature at about the maximum power level allowed, and licensing new operators to construct high-power transmitters at Points 0 and 1. The licensed entrants would utilize the entire band with power (at receivers) exceeding  $P_3$ . It can be argued that the insertion of high-powered users would impose costs on low-powered users in the band, but this is entirely

54. This is the situation with mobile phone markets in the United States, which have been governed by “spectrum caps” (limiting consolidation of carriers) and are now regulated by general antitrust rules.

symmetric with the externalities associated with the unlicensed underlays proposed in the INTEM Notice, as we show below.

The policy represented in Figure 2 is symmetric to that in Figure 1; we propose neither. Our purpose is to illustrate that the FCC's approach to promoting advanced wireless technologies is analytically skewed. Allowing white space to be utilized by either licensed or unlicensed users may promote innovative services. Yet the relevant policy determination remains a choice between the competing paradigms: unlicensed underlays and exclusively assigned, flexible-use overlays.

The INTEM Notice offers a technical analysis to answer an economic question. A spectrum analyzer graphic does not reliably separate "used" from "idle" bandwidth. Thus, the spectrum analyzer graphic cannot determine whether underlays (or overlays, as just discussed) in white space impose costs on incumbent users. Yet, the INTEM Notice rulemaking leaps directly from Figure 1's mapping of band emissions to a policy conclusion about the opportunity to insert unlicensed underlays to create "new opportunities for spectrum access."

What matters to spectrum users are the net benefits of one alternative relative to another. If, for instance, the area identified as Transfer in Figure 1 benefits unlicensed users by \$100, but eliminates voice and data services for licensed spectrum users worth \$10,000, then the FCC's spectrum usage diagram—which portrays the area as vacant white space—is both irrelevant and misleading. Spectrum that hosts little activity, as physically measured by spectrum analyzers, may nonetheless serve valuable purposes as buffer space (limiting conflicts) or capacity backup (inventory).<sup>55</sup> Moreover, engineering experts familiar with system operations may consider it dead wrong. That is because what looks "quiet" or "noisy" depends critically on network architecture and can change dramatically over time. As applied to CDMA networks,<sup>56</sup> for instance, the Transfer space is highly productive.<sup>57</sup>

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55. Within the regulatory system, it is quite common for traditional licensees to argue against competitive entry by overvaluing "idle" spectrum. The classic example of this is the TV band, where vast allocated bandwidth hosts relatively few channels. This overconservatism is a predictable outcome of the incentives yielded by the administrative allocation process. Hazlett, *supra* note 4, at 384–92. When frequency space is controlled by private parties, the opportunity cost of wasted space is internalized, yielding incentives for optimal airwave usage. The key point here is that this optimum is not the maximum. Society should not aim to have the highest level of emissions on each frequency at all times.

56. CDMA stands for Code Division Multiple Access, a family of wireless spread spectrum technologies used to provide wireless voice and data service. What Is CDMA?, <http://www.webopedia.com/TERM/C/CDMA.html> (last visited Apr. 1, 2006). Nationwide CDMA networks are operated in the United States by Verizon and Sprint-Nextel.

The FCC's approach contains another basic flaw. Even if some technical experts concluded that the Transfer area was not utilized by licensees, the public policy argument for *reassigning those rights to unlicensed underlays* would not be addressed. That argument requires evidence that the economic benefits created by a shift in rights will yield benefits in excess of their costs.<sup>58</sup> Consider first the case in which the licensed service is liberally regulated, meaning that the licensee has unrestricted freedom to use the allocated spectrum subject to their noninterference with other users. In this case, the licensee is well positioned to consider the competitive benefits of efficiently utilizing the opportunity afforded by the Transfer space. The incumbent's refusal to implement low-power underlays is evidence that there may be no net benefit from doing so.

Next, consider the situation in which the licensee's rights are truncated, and certain valuable uses of white space are therefore not provided. In this instance, it is clear that extending exclusively assigned rights—that is, liberalization of the licensee's property rights—provides a potential remedy. Liberalizing the licensee's property rights is an alternative to transferring the rights to others. Hence, there is no prima facie case for unlicensed underlays to promote advanced wireless technologies. The argument requires a compelling case that market failure exists when property rights are extended to private spectrum owners and that social value is improved by regulatory imposition of sharing rules under an unlicensed regime.<sup>59</sup> This crucial analysis is not addressed, let alone completed, in the FCC's INTEM Notice.

## B. ECONOMIC ANALYSIS

Unlicensed underlays may inflict large economic costs. To show this, we focus on the CMRS, the licenses governing cellular telephone

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57. See Declaration of Dr. Charles L. Jackson Regarding Limits to the Interference Temperature Concept at 8–11, *In re* Establishment of an Interference Temperature Metric to Quantify & Manage Interference & to Expand Available Unlicensed Operation in Certain Fixed, Mobile & Satellite Frequency Bands, No. 03-237 (FCC Apr. 5, 2004), available at [http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native\\_or\\_pdf=pdf&id\\_document=6516086642](http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6516086642) [hereinafter Jackson 2004]; Comments of Lucent Techs., Inc., *In re* Comm'n Seeks Public Comment on Spectrum Policy Task Force Report, No. 02-135 (FCC Jan. 7, 2003), available at [http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native\\_or\\_pdf=pdf&id\\_document=6513404862](http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6513404862).

58. The general analysis of how to efficiently assign rights is presented in Harold Demsetz, *When Does the Rule of Liability Matter?*, 1 J. LEGAL STUD. 13 (1972).

59. That burden includes compelling evidence that the proposed transfer improves the status quo *and* is superior to alternative reforms. This engages the issue of expanding flexibility of exclusively-assigned rights, discussed *infra* in Part III.A.

competitors. CMRS licenses, having liberal regulatory constraints, are most analogous to spectrum property rights.<sup>60</sup> These licenses also yield the largest consumer surplus in the wireless sector—in excess of \$150 billion annually.<sup>61</sup> This makes the CMRS market of great practical and analytical significance.

The first source of INTEM damage derives from a reduction in coverage. In Figure 1, signal range is reduced from  $X_0$  to  $X_1$ . Radio engineering expert Charles Jackson projects about a seventeen percent capacity reduction in the hypothetical situation presented by the FCC.<sup>62</sup> This follows from the standard tradeoff between noise temperature and communications volume, formally given by Shannon's Law.<sup>63</sup> For a 30 MHz band (analogous to broadband personal communications services ("PCS") licenses) capacity losses are substantial. Table 2 shows percentage capacity losses at varying power and noise levels.<sup>64</sup> Dr. Jackson notes that "[a] noise temperature of 300 K [where K is the basic unit of electromagnetic noise] is approximately the lower limit on PCS system noise and is set by nature."<sup>65</sup> Capacity reductions are measured relative to this base level in bits per second. Losses vary with power; levels in the table are similar to those in PCS networks.

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60. Other licenses allocated spectrum in much higher frequencies—such as LMDS (local multipoint distribution service) licenses in the 28 GHz band—also have relatively liberal rules. Of course, the radio spectrum involved is much less valuable, given its propagation characteristics and the current state of technology.

61. ROGER ENTNER & DAVID LEWIN, THE IMPACT OF THE U.S. WIRELESS TELECOM INDUSTRY ON THE U.S. ECONOMY 3 (2005), [http://www.independ.co.uk/panda/docs/final\\_ovum\\_independ\\_report\\_for\\_ctia\\_on\\_the\\_us\\_economy.pdf](http://www.independ.co.uk/panda/docs/final_ovum_independ_report_for_ctia_on_the_us_economy.pdf).

62. "That is, the remedy for interference blocking service in 3% of the original service region is to declare defeat and give up on an additional 17% of the service region." Jackson 2004, *supra* note 57, at 6.

63. Shannon's law defines the theoretical limit of rate at which information (error-free bits) can be transmitted given limited bandwidth and the presence of noise. Definition: Shannon's Law, [http://www.its.bldrdoc.gov/fs-1037/dir-033/\\_4816.htm](http://www.its.bldrdoc.gov/fs-1037/dir-033/_4816.htm) (last visited Apr. 1, 2006).

64. Later, we will attempt to translate such losses into economic costs.

65. Jackson 2004, *supra* note 57, at 23.

TABLE 2. Loss of Shannon capacity of a 30 MHz channel as a function of noise temperature (loss relative to capacity at 300 K)

		Received Power (dBm)				
		-110	-100	-90	-80	-70
Noise Temperature (K)	300	0%	0%	0%	0%	0%
	600	49%	43%	27%	15%	10%
	900	66%	60%	41%	24%	16%
	1200	74%	69%	50%	31%	21%

Annual revenues for wireless telephone service (voice and data) in the United States totaled about \$88 billion in 2003.<sup>66</sup> To the extent that unlicensed underlays increase noise levels, the quality and quantity of telephone services would be reduced and economic costs would be incurred.<sup>67</sup> Take the lowest levels of capacity loss occurring for received power levels of -70 dBm. If an INTEM produced an increase in noise in the cellular/PCS bands of 300 K to 600 K—a change well within the realm of increases contemplated by the analysis in the INTEM Notice and in the SPTFR—capacity reductions would be substantial.

Wireless carriers would react by considering various means to offset capacity losses. Gaining access to greater bandwidth would be one potential option,<sup>68</sup> another would be to construct additional cells and base stations. Upgrading technology would be yet a third approach. The net gains associated with each option are complex. They depend on the revenues extracted from consumers, enterprises, advertisers, and application suppliers; the costs of equipment manufacturers; the compatibility of rival users; and the profitability of alternative business models. Importantly, if the licensed operator controls the Transfer space, additional options become available, and the operator optimizes over a broader range of inputs (that is, the spectrum capacity denoted by the Transfer space).

In lieu of competitive wireless markets grappling with these myriad tradeoffs, a policy to insert unlicensed users into licensed bands imposes a

66. See *infra* Part III, tbl.5.

67. Even if actual usage of underlays turns out to be light, they will be costly if licensed systems are engineered to use higher power levels.

68. This depends on a spectrum allocation policy that makes such additional bandwidth available to carriers.

regulatory determination of the optimal mix of applications. Such a policy is far from a no-lose proposition; a forced transfer sacrifices the opportunity for cellular operators to determine use of the Transfer space. Hence, the white space reallocated from licensees to unlicensed users improves social welfare only if gains to recipients exceed losses incurred by CMRS networks and their customers.

Wireless phone operators make valuable use of bandwidth that the interference temperature analysis identifies as empty white space. CDMA systems use spread spectrum techniques to increase the flow of communications, meaning that overlapping signals are sent over relatively wide bands.<sup>69</sup> Coding allows targeted receivers to decipher the content intended for them.<sup>70</sup> This is the paradigmatic advanced wireless technology. Yochai Benkler writes, “The core assumption underlying both licensing and privatization [of spectrum] is an anachronism.”<sup>71</sup> He continues, “The technological shift derives from various techniques—such as spread spectrum and code division multiple access, time division multiple access, frequency hopping, and packet switching—for allowing multiple users to communicate at the same time using the same frequency range.”<sup>72</sup>

Yet CDMA networks are deployed using exclusive spectrum rights. As shown in Table 3, these networks serve over 285 million mobile subscribers worldwide, up from approximately zero in 1996. By any measure, this constitutes a most successful spread spectrum application. Moreover, the leading mobile phone technology,<sup>73</sup> Time Division Multiple Access (“TDMA”), used by over 1.3 billion subscribers,<sup>74</sup> is another of the advanced systems touted as paradigm-shifting.<sup>75</sup> It, too, is deployed by wireless networks granted exclusively assigned spectrum use rights.

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69. GEORGE GILDER, *TELECOM: HOW INFINITE BANDWIDTH WILL REVOLUTIONIZE OUR WORLD* 85–92 (2000).

70. *Id.*

71. Benkler, *Agoraphobia*, *supra* note 7, at 322.

72. *Id.* at 324.

73. TDMA is the basic technology in the GSM (global system for mobile communications) standard, a standard assisted by regulatory endorsement (and mandates) throughout Europe. See Neil Gandal, David Salant & Leonard Waverman, *Standards in Wireless Telephone Networks*, 27 *TELECOMM. POL’Y* 325, 327–28 (2003).

74. The Global Mobile Suppliers Association website listed 1,761,637,189 worldwide subscribers to GSM networks as of 3:19 p.m. (Eastern Standard Time) on March 13, 2006. GSA—The Global Mobile Suppliers Association, <http://www.gsacom.com> (last visited Apr. 1, 2006).

75. See Benkler, *Agoraphobia*, *supra* note 7, at 324. In the United States, Sprint-Nextel and Verizon deploy the CDMA standard; Cingular and T-Mobile use GSM/TDMA. Upgrades to 3G (third generation) networks providing high-speed data (in addition to voice) service, bring convergence as GSM-3G relies on CDMA technology.

TABLE 3. Global CDMA subscribers<sup>76</sup>

<i>Sept. of:</i>	<i>Asian-Pacific</i>	<i>North America</i>	<i>Caribbean &amp; Latin America</i>	<i>Europe, Middle East, &amp; Africa</i>	<i>Total</i>
1997	3,350,000	900,000			4,250,000
1998	11,200,000	4,500,000	285,000	5000	15,990,000
1999	24,824,000	12,913,000	3,033,000	370,000	41,140,000
2000	33,510,000	26,500,000	10,130,000	862,000	71,002,000
2001	40,200,000	43,404,000	18,205,000	1,375,000	103,184,000
2002	48,700,000	58,400,000	25,500,000	2,300,000	134,900,000
2003	69,300,000	71,400,000	30,400,000	2,950,000	174,050,000
2004	96,200,000	88,000,000	39,000,000	3,570,000	226,770,000
2005	124,900,000	102,600,000	53,400,000	4,800,000	285,700,000

Digital phone systems create valuable spectrum sharing in licensed frequencies. A CDMA chip dynamically adjusts its emitted power hundreds of times per second,<sup>77</sup> using just the minimum needed to maintain a connection. In general, an exclusive spectrum rights holder attempts to exploit every usable part of the allocated spectrum space, including the area Figure 1 characterizes as beneath the noise floor.<sup>78</sup>

76. CDG: Worldwide: 3Q 2005 CDMA Subscribers Statistics, [http://www.cdg.org/worldwide/archives/cdma\\_world\\_subscriber\\_0905.asp](http://www.cdg.org/worldwide/archives/cdma_world_subscriber_0905.asp) (last visited Apr. 1, 2006).

77. "CDMA handsets adjust their power output 800 times per second in response to signals from nearby base-stations." *Spread Betting*, *ECONOMIST*, June 19, 2003, at Technology Quarterly.

78. What makes the CDMA uplink channel unique is that the per-data bit transmit power of each mobile unit is constantly and precisely controlled so that the signals arriving at the serving base station are at about the same level. What's more, the mobile transmit power is always controlled so that the received signal is just sufficient to allow reception without any frame errors. You might think that in a heavily loaded channel the combined signals from many mobiles would be well above the noise floor, and thus a modest change in the thermal noise level would have no effect. This is not the case, however. In fact, in a properly operating uplink CDMA channel, the noise floor precisely defines the required receive signal even at maximum channel loading. This can be demonstrated on a heavily loaded CDMA channel by momentarily and artificially increasing the noise figure of base station receivers. Increase noise figure by 3 decibels ("dB") (the functional equivalent of a 3 dB noise floor rise) and the average transmit power of each served mobile will immediately increase by a similar amount. Elliott Drucker,

In addition to extending battery life, dynamic power adjustments reduce airwave congestion, saving spectrum capacity for other users. This is a standard example of spillovers being internalized: carriers invest in technology to utilize “underlays” (the Transfer in Figure 1) because they profit from the increased capacity—additional wireless phone calls, fewer dropped or blocked calls—that reduction in airwave pollution yields. Alternatively, TDMA systems attempt to recover utilizable white space by alternating traffic flows in small temporal increments.<sup>79</sup> Hence, identifying the Transfer space as unused is misleading, as is the presumption that the availability of advanced wireless technologies makes an interference temperature advantageous. Exclusively assigned spectrum rights are a proven mechanism for extracting value via advanced wireless technologies, an alternative to government sharing protocols.

Four aspects of the economics are crucial. First, exclusively assigned, flexible-use spectrum rights create powerful incentives for licensees to invest in bandwidth conservation. Network operators internalize gains from sharing spectrum more efficiently, realizing access fees (for example, subscription and per-minute charges) while simultaneously absorbing costs. Each margin on which spectrum capacity can be increased is rationally evaluated. Innovations expected to produce consumer benefits exceeding their costs are adopted; projects flunking the efficiency test are rejected.

Second, this cost-benefit calculus extends broadly. Investments in basic research and development, selection of standards, adoption of applications, network architecture, technology upgrades, and coverage extensions are efficiently undertaken. Competition pushes economic gains to consumers. When an opportunity to reduce power without sacrificing quality becomes available, the network operator vested with spectrum control weighs the cost of deploying the innovation against the value of the gains created, including increased battery life and additional communications traffic.

Third, identifying low-power areas available for increased utilization is an economic, not a technical, exercise. To reallocate such areas from licensed to unlicensed use may impose substantial costs on consumers. This may be true even where spectrum space appears underutilized.

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*Time to Take “Noise Temperature” at FCC*, WIRELESS WK., Mar. 22, 2004, available at <http://www.wirelessweek.com/article/CA404854.html?text=drucker>.

79. “TDMA works by dividing a radio frequency into time slots and then allocating slots to multiple calls.” What Is TDMA?, <http://www.webopedia.com/TERM/T/TDMA.html> (last visited Apr. 1, 2006).

Finally, reallocating white spaces identified by regulators undercuts private networks' incentives to invest in measures to increase spectrum efficiencies. By denying the band licensee the opportunity to expand productive use of spaces made quieter by the use of spillover-mitigation techniques, efficiency incentives are dulled and social gains are sacrificed.

There is perhaps no more widely accepted principle of economic regulation than the standard of "technological neutrality."<sup>80</sup> When government departs from neutrality, it engages in industrial policy that supplants market competition with its rich sources of information gleaned from decentralized decisionmaking, profit incentives, feedback loops, and continuous testing for efficiencies. Administratively determined structures have not fared well in comparison to competitive markets, as learned in countless real-world experiments, not the least of which involves wireless communications markets.<sup>81</sup> The FCC has noted that the development of wireless telephone networks demonstrates the superiority of market competition in assembling resources, including radio spectrum, to produce valuable services to the public.<sup>82</sup>

That logic is abandoned in the INTEM Notice. Using technical criteria to identify what it perceives to be underutilized radio space, the FCC suggests a reallocation from licensed to unlicensed use. This imposes a government plan to select "winners" (government-approved unlicensed devices) and "losers" (devices and networks created with licensed spectrum). The most serious losses will be inflicted on those who deploy the most advanced techniques for utilizing the low-power frequency space (such as CDMA systems) that will be reassigned for other uses.

Proponents of unlicensed spectrum allocations concede that certain technologies are hurt when underlays are created. As a group of advocates for additional unlicensed allocations recently told the FCC in a proceeding involving the multichannel multipoint distribution service ("MMDS") band, "To be fair, ITFS/MDS [instructional television fixed service/multipoint distribution service] licensees are correct that to the extent they

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80. For instance, "[r]egulatory policies must promote technological neutrality, competition, investment, and innovation to ensure that broadband service providers have sufficient incentive to develop and offer such products and services." FCC Strategic Goals: Broadband, <http://www.fcc.gov/broadband> (last visited Apr. 1, 2006).

81. Hazlett, *supra* note 4, at 373-402.

82. See First Report, *In re* Implementation of Section 6002(b) of the Omnibus Budget Reconciliation Act of 1993, Annual Report & Analysis of Competitive Mkt. Conditions with Respect to Commercial Mobile Servs., 10 F.C.C.R. 8844, 8845-46 (1995).

use their spectrum in very low-power situations, a low-power unlicensed underlay creates a more serious interference problem.”<sup>83</sup>

The INTEM Notice fundamentally alters the economics of alternative technologies and business models; the FCC chooses those it prefers. By imposing tight power limits for individual users, and by providing for unlimited access for approved devices, it favors some wireless services and business models over others. FCC rules, not consumers in the marketplace, determine that Intel’s Centrino Wi-Fi chips are preferred over Qualcomm’s CDMA chips, and that the local area networks provided by Wi-Fi access points are socially more useful than a wide-area data network provided by a HSPDA,<sup>84</sup> CDMA EV-DO,<sup>85</sup> Flarion OFDM,<sup>86</sup> IPWireless TD-CDMA,<sup>87</sup> or other systems optimized for use with exclusive spectrum rights.<sup>88</sup>

Licenses ought to be made more flexible, allowing licensees to assign control over spectrum use to third parties without FCC notification or transfer approval. This extension of the secondary market rules<sup>89</sup> would enable a licensee to delegate spectrum control to device owners, and to

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83. Reply Comments of the New Am. Found. et al. at 15, *In re* Amendment of Parts 1, 21, 73, 74 & 101 of the Commission’s Rules to Facilitate the Provision of Fixed & Mobile Broadband Access, Educ. & Other Advanced Servs. in the 2150–2162 & 2500–2690 MHz Bands, No. 03-66 (FCC Oct. 23, 2003), available at [http://gulfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native\\_or\\_pdf=pdf&id\\_document=6515287068](http://gulfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6515287068).

84. HSPDA (high-speed downlink packet access) technology upgrades GSM networks to permit wireless broadband service at speeds of 400–700 kbps. Cingular is engaged in a nationwide HSPDA build-out, scheduled for completion by year-end 2006. Jamie Bsales, *Catch the Next Wave in Wireless*, SMALL BUS. COMPUTING, Mar. 9, 2006, <http://www.smallbusinesscomputing.com/news/article.php/3590276>.

85. EV-DO (evolution-data optimized) technology overlays a 1X CDMA network to provide wireless access with peaks of up to 2.4 mbps. Speeds enjoyed by individual users typically range from 400 to 700 kbps; the technology is currently deployed nationwide by Verizon Wireless. *Id.* A competing EV-DO network is being constructed by Sprint-Nextel. Mike Roberts, *WiMAX Arrives but Faces Squeeze from Mobile and Fixed Broadband*, INFORMA TELECOMS & MEDIA, Jan. 4, 2006, <http://www.informatm.com/itmcontent/icom/s/sectors/networks-infrastructure/20017327865.html;jsessionid=8A1AB5FB5FA186CD67DCD598A229ED73>.

86. For an explanation of Flarion’s OFDM (orthogonal frequency division multiplexing) technology, see Joni Morse, *Flarion Touts Flash-OFDM Speeds*, RCR WIRELESS NEWS, Jan. 2, 2006, at 7.

87. For an explanation of IPWireless’s TD-CDMA (time division-CDMA) technology, see Timothy Sanders, *Bullish on the Band: Vendors Sound Off on Broadband Wireless for 2.5 GHz Spectrum*, BROADBAND WIRELESS ONLINE, Sept.–Oct. 2003, <http://www.shorecliffcommunications.com/magazine/volume.asp?Vol=40&story=372>.

88. This set of technologies includes WiMAX, by many accounts the most advanced technology thus far emerging from the Wi-Fi family. See Martha McKay, *Wi-Fi? How About Way Far?*, HARTFORD COURANT, Mar. 25, 2004, at D3. See *infra* note 147 and accompanying text.

89. See Report & Order & Further Notice of Proposed Rulemaking, *In re* Promoting Efficient Use of Spectrum Through Elimination of Barriers to the Dev. of Secondary Mkts., 18 F.C.C.R. 20,604, 20,626–31, 20,726 app.B (2003) [hereinafter *Secondary Markets 2003*].

negotiate the price of access with device makers. Private firms, organizations, universities, user groups, or industrial consortia would then be able to establish their own rules for spectrum use. Firms that argue for unlicensed spectrum to be allocated by the FCC—such as Intel,<sup>90</sup> Microsoft,<sup>91</sup> Apple,<sup>92</sup> and Cisco<sup>93</sup>—could bid for licenses conveying rights to establish the form of organization they advocate. This would enable a competitive solution rather than one imposed through government mandate.<sup>94</sup>

Without marketplace feedback, how is government to judge the merit of a low-power unlicensed solution versus any one of a number of high-power licensed solutions? The answer to this question is illuminated by contrasting the underlay options favored in the INTEM Notice with rival technologies emerging in exclusively assigned, flexible-use spectrum. For instance, in Australia, where liberal spectrum policies have permitted investors to create “4G” (fourth generation) wireless networks, this assessment was recently offered:

Personal Broadband Australia’s iBurst network is a connectivity cure-all for everyone from road warriors to home users. The former will appreciate the ability to connect from almost anywhere without hunting down Wi-Fi hotspots or facing outlandish GRPS data rates. But iBurst isn’t just for the mobile set: the service brings broadband within reach of homes not serviced by ADSL and cable. . . .

. . . iBurst makes clever use of portions of the 3G mobile phone spectrum to provide users with always-on Net access with a reach and data rate that puts Wi-Fi to shame . . . .<sup>95</sup>

90. See Peter Pitsch, *The Future of Radio Spectrum Policy*, TECHNOLOGY@INTEL MAG., Feb.–Mar. 2004, at 1, available at <http://www.intel.com/technology/magazine/standards/st02041.pdf>.

91. See Comments of Microsoft Corp. at 2–3, *In re* Revision of Parts 2 & 15 of the Commission’s Rules to Permit Unlicensed Nat’l Info. Infrastructure (U-NII) Devices in the 5 GHz Band, 18 F.C.C.R. 24,484, No. 03-122 (FCC Sept. 3, 2003), available at [http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native\\_or\\_pdf=pdf&id\\_document=6514784111](http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6514784111).

92. See Comments of Wireless Info. Networks Forum, *In re* Wireless Info. Networks Forum Petition for Rulemaking to Allocate the 5.1–5.35 GHz Band & Adopt Serv. Rules for a Shared Unlicensed Personal Radio Network, No. RM-8653 (FCC July 10, 1995), available at <http://www.warpspeed.com/winf.html>.

93. See High-tech Policy Guide—Government Affairs—Cisco Systems, [http://www.cisco.com/web/about/gov/networks/wireless\\_spectrum\\_management.html](http://www.cisco.com/web/about/gov/networks/wireless_spectrum_management.html) (last visited Apr. 1, 2006).

94. Stuart Benjamin notes that particular protocols or standards imposed via unlicensed rules themselves bias technology outcomes. Benjamin, *supra* note 4, at 2046–47.

95. Dan Warne, *Personal Broadband Australia iBurst*, APCMAG.COM, Nov. 17, 2003, <http://www.apcmag.com/apc/v3.nsf/0/EABDFD174F749AF4CA256DE0007CD3AD>.

Although the Sydney rollout has reportedly met with enthusiastic response and coverage has been extended to the Gold Coast, Brisbane, and Melbourne markets,<sup>96</sup> it remains to be seen if this approach will ultimately prove the best use of radio spectrum. What is clear is that technologies optimized via network-coordinated spectrum use may meet user needs more efficiently than government-set technology constraints and power limits, and that spectrum owners will respond to economic incentives in selecting the most efficient solutions. Spectrum allocations imposed by regulators, on the other hand, face no such market test. Technological neutrality is violated, and government planners largely select winners and losers.

### III. FCC SPECTRUM REGULATION OPTIONS

The FCC characterizes its spectrum allocation choices as (1) licensed exclusive use, (2) unlicensed commons, or (3) command and control.

These are taken to comprise three rival regulatory modes,<sup>97</sup> but the taxonomy is unfortunate for several reasons. First, licensed spectrum use has traditionally been highly regulated via command and control. Second, “exclusive use” is not an apt characterization for liberally defined wireless licenses, which host intense sharing of allocated spectrum. Third, unlicensed use is everywhere regulated, with the regulation applied to devices rather than users. Hence, command and control is decidedly part of unlicensed allocations. Without spectrum owners to coordinate usage, unlicensed bands rely on alternative control mechanisms to mitigate conflicts—most notably, power limits and technical standards imposed by regulators. Fourth, in mandating such usage rules on unlicensed devices, radio spectrum does not constitute a “commons,” which connotes ownership by a group of responsible economic agents, but rather constitutes de facto state property.

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96. See Rebecca Buckman, *Unbound Down Under*, WALL ST. J., Feb. 17, 2005, at B1; *Optus Leans on iBurst*, UNSTRUNG, May 20, 2005, [http://www.unstrung.com/document.asp?doc\\_id=74233&site=unstrung](http://www.unstrung.com/document.asp?doc_id=74233&site=unstrung).

97. See SPTFR, *supra* note 18, at 5.

TABLE 4. Regulatory modes for spectrum use

	Agency "Command & Control" Decisionmaking		Private Decisionmaking	
	Hardware	Spectrum Use	Hardware	Spectrum Use
Unlicensed	X			X
Traditional Licenses	X	X		
EAFUS			X	X

"A consensus is forming that the current process of allocating radio spectrum by administrative decision-making is in serious need of reform."<sup>98</sup> The observed failure of central planning is half the story. The other half is the observed success of more liberal rules for licensed and unlicensed bands. Steps to reduce regulatory limits imposed on unlicensed devices date back to the mid-1980s. Whereas each radio previously had to be approved by the FCC, a new rule permitted classes of equipment to gain certification. This moved regulation from case-by-case approvals to general standards.<sup>99</sup> The unlicensed regime encompasses several bands, all of which restrict communications to low-power devices most easily deployed

98. Kwerel & Williams, *supra* note 6, at 1.

99. Wi-Fi would certainly not exist without a decision taken in 1985 by the FCC, America's telecoms regulator, to open several bands of wireless spectrum, allowing them to be used without the need for a government license. This was an unheard-of move at the time; other than the ham-radio channels, there was very little unlicensed spectrum. But the FCC, prompted by a visionary engineer on its staff, Michael Marcus, took three chunks of spectrum from the industrial, scientific, and medical bands and opened them up to communications entrepreneurs.

These so-called "garbage bands," at 900 MHz, 2.4 GHz, and 5.8 GHz, were already allocated to equipment that used radio-frequency energy for purposes other than communications—microwave ovens, for example, which use radio waves to heat food. The FCC made them available for communications purposes, as well, on the condition that any devices using these bands would have to steer around interference from other equipment. They would do so using "spread spectrum" technology, originally developed for military use, which spreads a radio signal out over a wide range of frequencies, in contrast to the usual approach of transmitting on a single, well-defined frequency. This makes the signal both difficult to intercept and less susceptible to interference. See *A Brief History of Wi-Fi*, *ECONOMIST*, June 12, 2004, at Technology Quarterly [hereinafter *Brief History*]. See also Kenneth R. Carter, Ahmed Lahjouji & Neal McNeil, *Unlicensed and Unshackled: A Joint OSP-OET White Paper on Unlicensed Devices and Their Regulatory Issues* 7–8 (FCC, Office of Strategic Planning & Policy Analysis, Working Paper No. 39, 2003), available at [http://hraunfoss.fcc.gov/edocs\\_public/attachmatch/DOC-234741A1.pdf](http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-234741A1.pdf).

for short-range services, such as remote controls, cordless phones, and home or enterprise Wi-Fi systems.<sup>100</sup>

An important deregulation has also occurred with respect to exclusively assigned rights. To avoid the confusion of “exclusive use” terminology, we employ the phrase “exclusively assigned, flexible-use spectrum” (“EAFUS”). This regulatory approach is best observed in the U.S. market by the regime governing the approximately 189 MHz allocated to CMRS licenses. This relatively parsimonious allocation may be compared to the much broader allocations to heavily regulated licenses, including those for the TV band<sup>101</sup> or MMDS.<sup>102</sup> Despite its limited scope, EAFUS bandwidth provides an important marketplace experiment in liberalization, much as the existence of the intrastate airline market demonstrated the effects of price competition before the demise of the Civil Aeronautics Board.<sup>103</sup> Table 4 offers a simple matrix outlining the differences in the alternative approaches to spectrum rights. Table 5 summarizes the important unlicensed and EAFUS allocations, including data on sales for services, equipment, and network infrastructure.

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100. Some devices are also allowed to radiate across bands, for example, those using ultrawide band technology. See Carter et al., *supra* note 99, at 4.

101. For an in-depth discussion and analysis of the regulation of TV band licenses, see Hazlett, *supra* note 13.

102. “The 2.5 GHz [MMDS] band has labored for years under the heavy hand of command-and-control regulation. The regime has not served the American people or the Commission’s licensees particularly well. Our rules have, at times, been complex and stifling, and have shifted in their objectives . . .” Statement of Chairman Michael K. Powell, *In re* Amendment of Parts 1, 21, 73, 74 & 101 of the Commission’s Rules to Facilitate the Provision of Fixed & Mobile Broadband Access, Educ. & Other Advanced Servs. in the 2150–2162 & 2500–2690 MHz Bands, 18 F.C.C.R. 6722, 6858 (2003). See also Thomas W. Hazlett, *Spectrum Tragedies*, 22 YALE J. ON REG. 242 (2005).

103. See Michael E. Levine, Note, *Is Regulation Necessary? California Air Transportation and National Regulatory Policy*, 74 YALE L.J. 1416, 1430–43 (1965).

TABLE 5. Flexible-use licensed and unlicensed bands (estimated monetary values for 2003)

Band	MHz	Type	Services <sup>104</sup>	Revenue (bil.)
				(1) Service (2) Equipment (3) Net Capex
1.9 GHz, 2.4 GHz	30	UNL	PCS voice, data local area networks	(1) 0 <sup>105</sup> (2) \$0.04 <sup>106</sup> (3) \$0.02 <sup>107</sup>
900 MHz,	26	UNL	Remotes, listening devices, cordless	(1) \$0.088 <sup>108</sup>

104. BENNETT Z. KOB, WIRELESS SPECTRUM FINDER (2001); Comments of IEEE 802 at 7, *In re* Revision of Parts 2 & 15 of the Commission's Rules to Permit Unlicensed Nat'l Info. Infrastructure (U-NII) Devices in the 5 GHz Band, No. 03-122 (FCC Sept. 3, 2003), available at [http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native\\_or\\_pdf=pdf&id\\_document=6514784167](http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6514784167); News Release, Juniper Research Ltd., Commercial Hotspot Providers Chase Elusive Wi-Fi End-users (July 17, 2003), available at <http://www.pnewswire.co.uk/cgi/news/release?id=105463>.

105. Service revenues for the 1.9 GHz unlicensed PCS allocation are approximately zero. In the 1910–1920 MHz band, comprising half the U-PCS allocation, not a single device had been approved for use by the FCC as of September 2004. See Sixth Report & Order, Third Memorandum Opinion & Order, & Fifth Memorandum Opinion & Order, *In re* Amendment of Part 2 of the Commission's Rules to Allocate Spectrum Below 3 GHz for Mobile & Fixed Servs. to Support the Introduction of New Advanced Wireless Servs., Including Third Generation Wireless Sys., 19 F.C.C.R. 20,720, 20,727 (2004) [hereinafter Sixth Report]. In the 1920–1930 MHz band, wireless private branch exchanges ("PBXs") are owned and operated by businesses. See *id.*

106. The wireless PBX systems operating in the U-PCS band enable only about 400,000 handsets. Comments of Motorola, Inc. at 20, *In re* Amendment of Part 2 of the Commission's Rules to Allocate Spectrum Below 3 GHz for Mobile & Fixed Servs. to Support the Introduction of New Advanced Wireless Servs., Including Third Generation Wireless Sys., No. 00-258 (FCC Oct. 22, 2001), available at [http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native\\_or\\_pdf=pdf&id\\_document=6512768898](http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6512768898) [hereinafter Comments of Motorola]. While revenue data are not available from this source, the units are analogous to cordless phones used in households. The mean price of such phones in 2001 was \$37.79. Carter et al., *supra* note 99, at 26. We adjust the unit price to \$100, reflecting the possibility that wireless telephones purchased by businesses incorporate additional functionality. This yields total equipment expenditure (over several years) of \$40 million. Without revenue on the PBX equipment used with these handsets, we assume expenditures equal to \$20 million, or one-half the estimated handset revenues.

107. See *supra* note 106.

108. Hotspots generated about \$16 million in revenues in the United States in 2003. Scott Thurm & David Pringle, *Chill Hits Wi-Fi "Hot Spots,"* WALL ST. J., Mar. 18, 2004, at B1. This excludes revenues generated by CMRS carriers offering hotspot service. In addition, wireless broadband access providers using unlicensed frequencies were estimated to have 150,000 subscribers at year-end 2003. YUANZHE (MICHAEL) CAI, PARKS ASSOCS., JUDO LESSONS FOR WIRELESS ISPS 1 (2004), available at [http://www.parksassociates.com/free\\_data/downloads/parks-judo\\_lessons\\_WISPs.pdf](http://www.parksassociates.com/free_data/downloads/parks-judo_lessons_WISPs.pdf). Assuming that each subscriber pays \$40 per month for service, or \$480 per year, implied annual service revenues are \$72 million. We attribute eighty percent of these revenues to 900 MHz/ 2.4 GHz bands, with twenty percent attributable to 5 GHz bands. Attributing all hotspot service revenues to the 900 MHz/ 2.4 GHz

2.4 GHz	83.5		phones, WLANs, Wi-Fi, microwave ovens, industrial/ scientific/ medical equipment, local positioning systems, school experiments	(2) \$3.81 <sup>109</sup> (3) \$0.264 <sup>110</sup>
5 GHz	555 MHz	UNL	Wi-Fi, HiperLAN, HiSWAN, IEEE 802.16 devices, cordless phones, amateur radio, field disturbance sensors, door openers, aviation radar	(1) \$0.014 <sup>111</sup> (2) \$0.197 <sup>112</sup> (3) \$0.017 <sup>113</sup>
800 MHz, 1.9 GHz	189 MHz	LIC	Mobile phones, data, various applications	(1) \$88 <sup>114</sup> (2) \$13 <sup>115</sup> (3) \$21 <sup>116</sup>

band results in an aggregate 2003 service revenue estimate of \$88 million. This leaves \$14 million (twenty percent of \$72 million) attributable to wireless broadband services using the 5 GHz bands.

109. Total Equipment revenues of \$4.01 billion are estimated by summing 2003 cordless phone revenues of \$2.44 billion, *see* Carter et al., *supra* note 99, at 27, and 802.11b/g equipment revenues of \$1.57 billion, *see* MORGAN STANLEY, WIRELESS INFRASTRUCTURE: WIRELESS WEIGH-IN—12/03, exhibit 8 (2003) [hereinafter WIRELESS WEIGH-IN]. This estimate is substantially above the \$2.01 billion 2003 North American sales estimate for all wireless local area (including Wi-Fi equipment in the 2.4 GHz and 5 GHz bands) given by Infonetics. Press Release, Infonetics Research, Enterprise Adoption and Hot Spots Drive Wireless LAN Market Growth: HW Market Hits \$481.9M in 1Q03 (May 21, 2003), *available at* <http://www.infonetics.com/resources/purple.shtml?nr.wlanms.1q03.052103.shtml>. About 12.5% of Wi-Fi equipment sales are to supply public access; this portion of equipment sales (\$0.196 billion) is included in network capital expenditures. Carter et al., *supra* note 99, at 33. In addition, we include expenditures for non-Wi-Fi wireless broadband systems. Alvarion reports, “In 2003, \$85 million was spent on unlicensed wireless broadband product in the United States.” *Wireless Wonderland: Unlicensed Wireless Broadband in North America*, FAST COMPANY NOW, Apr. 3, 2004, [http://blog.fastcompany.com/archives/2004/04/03/wireless\\_wonderland\\_unlicensed\\_wireless\\_broadband\\_in\\_north\\_america.html](http://blog.fastcompany.com/archives/2004/04/03/wireless_wonderland_unlicensed_wireless_broadband_in_north_america.html) [hereinafter *Wireless Wonderland*]. Apportioning eighty percent of these sales to 900 MHz/ 2.4 GHz (the remainder to 5 GHz) adds \$68 million to revenues in the lower bands, which total \$0.264 billion (\$0.196 billion + \$0.068 billion).

110. *See supra* note 109.

111. *See supra* note 108.

112. Equipment sales from 802.11a devices, which utilize 5 GHz frequencies for local area networking, equaled \$180 million in 2003. WIRELESS WEIGH-IN, *supra* note 109. To these local networking devices we add sales of broadband access providers, assumed to be twenty percent of the \$85 million spent (according to Alvarion) in 2003. Hence, estimated total sales equal \$0.197 billion. We note that the 80/20 assumption is intentionally made favorable to 5 GHz spending, as implied by the ratio between 802.11b/g equipment sales and 802.11a equipment sales. This implies that sales of devices using the 2.4 GHz band are about nine times (1.57/.18) that of comparable 5 GHz revenues.

113. Assuming twenty percent of \$85 million in unlicensed broadband equipment sales is attributable to gear using 5 GHz bands.

114. CTIA—THE WIRELESS ASS’N, SEMI-ANNUAL WIRELESS INDUSTRY SURVEY RESULTS: JUNE 1985–JUNE 2004, at 5 (2004), <http://files.ctia.org/pdf/CTIAMidyear2004Survey.pdf> [hereinafter CTIA SURVEY 2004].

115. Obtained by summing \$3.6 billion and \$10.2 billion spent by consumers and carriers, respectively, on mobile phones. Mike Dano, *Phone Subsidies Alive and Well*, RCR WIRELESS NEWS, Jan. 5, 2004, at 1.

116. *See supra* note 114.

## A. EXCLUSIVELY ASSIGNED, FLEXIBLE-USE SPECTRUM

The productivity of EAFUS has been so pronounced that the policy “solution, according to most economists, is to replace the current administrative allocation with a spectrum market.”<sup>117</sup> Reform has produced efficiencies by liberalizing the rights granted to licensees,<sup>118</sup> permitting profit-maximizing firms, constrained by competitive forces, to determine how spectrum is used. The EAFUS licensee both bears the expense and captures the gains from creating valuable services. This makes the licensee a zealous protector of radio space, an aggressive investor in infrastructure, and a risk-taking entrepreneur in search of new “killer apps.”

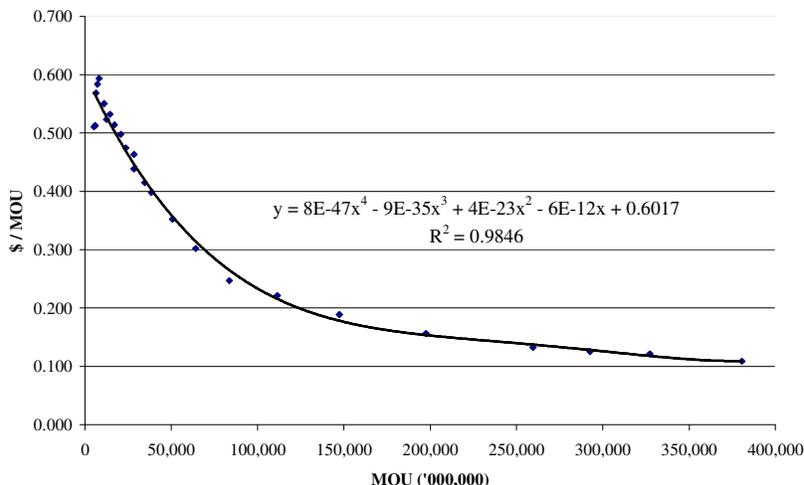
In the relatively limited EAFUS allocations in the United States, enormous social value has been created. A conservative valuation approach is suggested in Figure 3, which displays the historical pattern of price-quantity vectors for mobile phone service in the United States. Each point represents the total service revenues for a six month period (beginning in 1991 and going through 2003) divided by total minutes of use (“MOU”), plotted against total MOU. This results in price per minute on the vertical axis, and quantity in MOU on the horizontal.

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117. Kwerel & Williams, *supra* note 6, at 1. The success of the property-rights model in producing efficiencies relative to alternative regulatory models is discussed extensively in Hazlett, *supra* note 4.

118. Some countries have gone much further than the United States in deregulating exclusive assignments. See Hazlett, *supra* note 6, at 12–17.

FIGURE 3. Plot of six-month total service revenues per MOU against MOU<sup>119</sup>



This is not a standard demand curve representation. While quantity expands as price falls, a demand curve is defined at a point in time: the relationship between price and quantity demanded with all else constant. Here, much is changing as time elapses—six months between each point. Hence, this diagram is the historical pattern of price/quantity pairs, not demand.

This does, however, offer a lower bound for the demand curve.<sup>120</sup> It appears clear that demand for mobile phone usage has grown substantially over the period spanned by the data. Demand would logically increase as handsets improve in performance and functionality, as handset prices fall, and as the quality of service provided by wireless networks rises. All these factors drive consumers to purchase more wireless minutes at any given price, such that the current demand curve for mobile phone service is very likely to lie substantially to the right of the historical pattern seen in Figure 3.

119. MOU are obtained from CELLULAR TELECOMMS. & INTERNET ASS'N, SEMI-ANNUAL WIRELESS INDUSTRY SURVEY RESULTS: JUNE 1985–JUNE 2003 tbl.110 (2003) [hereinafter CTIA SURVEY 2003]. Total Service Revenues are obtained from *id.* tbls.28 & 29.

120. A demand curve maps the relationship between consumer purchases and product prices. When factors other than the price of the product change consumer behavior, the entire curve tends to shift.

Consumer Surplus (“CS”) is the difference between what consumers are willing to pay for a good or service and the market price they do, in fact, pay.<sup>121</sup> Graphically, this is the area between the Demand Curve and Market Price. Given our assumptions, it is possible to estimate a lower bound for CS by integrating the area beneath the price-quantity curve (which nicely fits the fourth-order equation shown in the diagram) and above a horizontal line drawn at 10.9 cents per MOU (the average revenue per minute in June 2003, the most recent period for which we have data). This magnitude equals 90.06% of June 2003 revenues. On an annualized basis, with 2003 revenues totaling \$88 billion, this implies that consumer surplus exceeds \$79 billion.<sup>122</sup>

In their FCC working paper, economist Evan Kwerel and engineer John Williams consider how additional competition and advanced wireless technologies could be accommodated in the relatively crowded, but relatively productive, frequencies below 3 GHz.<sup>123</sup> They offer two public policy insights directly relevant to the INTEM Notice. The first is that the type of spectrum access found in unlicensed bands does not require FCC allocations mandating unlicensed rules:

Future expansion of dedicated spectrum for unlicensed use could be obtained through negotiation between the manufactures [sic] of such devices and spectrum licensees. One possible arrangement would be for a licensee or group of licensees covering a particular band throughout the U.S. to charge manufacturers a fee for the right to produce and market devices to operate in that band. Such contracts could provide different grades of access for different fees, thus providing for a wider range of uses than are possible under the current rules. Competition between licensees would ensure that fees reflect the opportunity cost of the spectrum. Alternatively, manufacturers of low power devices might form a bidding consortium to acquire additional spectrum . . .<sup>124</sup>

The suggestion that “exclusive use” spectrum can efficiently serve multiple users, applications, or networks, is scalable. When regulated liberally, such that licensees have the right to broadly determine spectrum use within the allocated frequency space and to freely reassign such rights, the EAFUS model has proven adept at creating sharing opportunities, inventing and deploying compatible technologies, and maintaining and

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121. JACK HIRSHLEIFER, AMIHAI GLAZER & DAVID HIRSHLEIFER, PRICE THEORY AND APPLICATIONS 203–05 (7th ed. 2005).

122. This approach, by using average revenue per minute of use as a proxy for price, incorporates effects of multipart tariffs.

123. Kwerel & Williams, *supra* note 6.

124. *Id.* at 31.

upgrading wireless infrastructure to accommodate a broad range of diverse, valuable uses. Further liberalization would assist this process of discovery by encouraging creative destruction, the evolution of superior economic structures through competitive trial and error.

FCC rules have traditionally mandated that licensees control the spectrum uses permitted by their licenses.<sup>125</sup> While license transfers are routinely approved, transfers do not (cannot) change service rules.<sup>126</sup> Moreover, lags in license ownership changes eliminate whole classes of frequent transactions. Secondary Market rules were liberalized in 2003, reducing the process whereby pro forma transfers take place to twenty-one days.<sup>127</sup> Some transfers were permitted to be approved without delay in 2004.<sup>128</sup>

The FCC sees the more flexible rules for licensed spectrum as potentially enabling a spectrum park, or a “private commons.”<sup>129</sup> The concept mirrors arrangements that have emerged in licensed and unlicensed bands. In unlicensed bands, manufacturers sell wireless users radios that come ready to utilize the frequencies made available for unlicensed use on the terms and conditions set by FCC regulators. A park constructed with privately owned spectrum would substitute negotiated access terms covering power limits, technology standards, and access fees. Spectrum rights owners and equipment manufacturers would strike agreements taking the place of unlicensed device regulation.

This model is observable. CMRS licensees contract with equipment manufacturers to produce devices to use specific frequencies (which may differ from market to market). Devices are customized for networks, with technologies, functions, and quality-of-service differing across providers. Consumers purchase devices bundled with spectrum access. They share this bandwidth with millions of users, paying a combination of subscription fees and per-minute charges to access wireless networks. The carriers effectively purchase spectrum parks for their subscribers, securing licenses, building infrastructure, arranging for the production of compatible handsets, and maintaining quality of service by policing traffic congestion.

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125. See Second Report & Order, Order on Reconsideration, & Second Further Notice of Proposed Rulemaking, *In re Promoting Efficient Use of Spectrum Through Elimination of Barriers to the Dev. of Secondary Mkts.*, 19 F.C.C.R. 17,503, 17,507–08 (2004) [hereinafter *Secondary Markets 2004*].

126. Comments of 37 Concerned Economists, *supra* note 4.

127. *Secondary Markets 2003*, *supra* note 89, at 20,609.

128. *Secondary Markets 2004*, *supra* note 125, at 17,509.

129. *Id.* at 17,549.

Networks further increase the value of spectrum access by facilitating a wide range of complementary applications, such as paging, email, web access, text messaging, pictures, file transfer, video or audio clips, GPS or other locational services. Roaming agreements are also negotiated by carriers, giving consumers access to a much larger increment of radio spectrum than is allocated to the licenses of any one carrier.<sup>130</sup> Competition among carriers regulates each carrier's behavior in supplying consumers a suite of services which incorporates spectrum, network infrastructure, devices, and applications. Profits provide rewards for efficient performance and punishment for failure.

When spectrum rights are nonexclusive, coordination of rival users remains beneficial. Yet governance rules—mainly device regulation—leave incentive problems. “In shared bands, just providing technical and service flexibility would not create the correct incentives for economically efficient use of the spectrum, because licensees can not capture the benefits from deploying spectrum-conserving equipment.”<sup>131</sup>

Where no economic entity internalizes gains and losses from airwave use, inefficient outcomes are likely. Unlicensed bandwidth is allocated by government regulators who do not stand to gain from efficient outcomes or suffer loss from inefficient ones. They will, accordingly, make political judgments about how spectrum should be allocated under the “public interest” standard enacted in the Radio Act of 1927.<sup>132</sup> This is true both in the initial allocation stage and when new demands or technologies render existing nonexclusive uses obsolete.<sup>133</sup>

Without a responsible economic entity internalizing costs and benefits, there is no accurate way to measure value.<sup>134</sup> This leads Kwerel and

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130. Cingular, for instance, provides its customers with access to over one hundred domestic networks and to carriers in more than 165 countries via roaming agreements. Thomas W. Hazlett, *Mobile Roaming & Rate Regulation: An Economic Analysis 1* (Jan. 26, 2006) (unpublished manuscript, on file with the author).

131. Kwerel & Williams, *supra* note 6, at 5.

132. See Thomas W. Hazlett, *Physical Scarcity, Rent Seeking, and the First Amendment*, 97 COLUM. L. REV. 905, 913–30 (1997); Thomas W. Hazlett, *The Rationality of U.S. Regulation of the Broadcast Spectrum*, 33 J.L. & ECON. 133, 158–71 (1990).

133. See Kwerel & Williams, *supra* note 6, at 30 (noting “the political sensitivities associated with broadcast spectrum and maintenance of free over-the-air television” and declining to “propos[e] to include any of the core TV spectrum in initial band-restructuring auctions”).

134. The problem created when there is no market feedback establishing relative values for alternative uses of radio spectrum has long been seen, and has not been solved. Douglas Webbink, writing in 1977, began his analysis by noting, “Because the spectrum is a scarce non-priced resource whose ownership rights are not freely transferable, the use of the spectrum is inefficient.” Douglas W.

Williams to suggest that bands set aside for unlicensed use at least be procured by a bid tendered by the government in an open auction. They write, "If there is a continued desire as a matter of public policy to provide spectrum for such devices on a 'free' basis, the FCC itself might purchase the spectrum in the auction . . . . This would have the advantage of making the opportunity cost of such allocations more explicit."<sup>135</sup>

In sum: (1) licensed bands are widely used by advanced wireless devices; (2) agile technologies supplied under the subscriber model could be deployed on exclusively assigned spectrum without network coordination if (a) that form of organization were efficient, and (b) the business model were legal under FCC rules; (3) exclusivity yields incentives to optimally conserve bandwidth; and (4) eliminating exclusivity leaves policy makers without market prices for spectrum—data that reveal the value of alternatives.

## B. UNLICENSED SPECTRUM

In the 1980s, rules for unlicensed use were expanded to accommodate newer technologies and a broader class of services.<sup>136</sup> As a result, a great deal of new wireless activity has occurred in the bands primarily affected, 900 MHz and 2.4 GHz.<sup>137</sup> The policy implications, however, have generated considerable confusion. The argument that because unlicensed use has been "successful" we should allocate more spectrum for unlicensed use is an analytical error the FCC makes explicitly:

The Commission's rules for unlicensed transmitters have been a tremendous success. A wide variety of devices have been developed and introduced under these rules for consumer and business use, including cordless telephones, home security systems, electronic toys, anti-pilfering and inventory control systems and computer local area networks. Moreover, the past few years have witnessed the development of industry standards, such as IEEE 802.11b (Wi-Fi), Bluetooth, and Home RF that have greatly expanded the number and variety of devices that operate in the 2.4 GHz ISM band.<sup>138</sup> This has provided for the

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Webbink, *The Value of the Frequency Spectrum Allocated to Specific Uses*, 19 IEEE TRANSACTIONS ON ELECTROMAGNETIC COMPATIBILITY 343, 343 (1977).

135. Kwerel & Williams, *supra* note 6, at 31.

136. The key reforms were permission to use spread spectrum technologies in 1985, and the standardization of service categories for equipment seeking FCC approval under Part 15 rules in 1989. See Carter et al., *supra* note 99, at 7–8.

137. See *supra* Part III, tbl.5.

138. "These operating standards provide manufacturers with guidance for developing spread spectrum devices for the 2.4 GHz band. The IEEE 802.11b standard applies to direct sequence devices,

introduction of wireless headsets and computer connections for cellular and PCS phones, wireless computer peripherals such as printers and keyboards, and a host of new wireless Internet appliances that will use all of the spread spectrum bands. Because of this, a large number of new devices have been developed and placed into operation in the ISM bands.

The success of our unlicensed device rules for the ISM bands shows that there could be significant benefits to the economy, businesses and the general public in making additional spectrum available for unlicensed transmitters.<sup>139</sup>

There are at least two fundamental flaws in this logic.<sup>140</sup> First, the premise of “success” may be wrong. The FCC errs when it describes “tremendous success” without regard to the opportunity cost of spectrum. This approach assumes there are no alternative uses foreclosed by unlicensed allocations, which is untrue. As it relates to the 900 MHz and 2.4 GHz bands, it is certainly plausible that the alternative uses *likely to be allowed under FCC regulation* were not as valuable as the unlicensed services actually allowed. But if one were to compare the value of the unlicensed services to all of the potential alternative uses for the spectrum, the bandwidth allocated to unlicensed devices—or some increment therein—might appear wasteful.

Second, assuming that the unlicensed bands have been productive relative to any alternative use of the allocated spectrum, this does not imply that additional spectrum produces similar efficiencies. The tradeoff between alternatives is evaluated at the margin. While it is argued that 900 MHz and 2.4 GHz have been a “tremendous success” given the economic activity that has arisen there, more recent unlicensed allocations in 1.9 GHz (unlicensed PCS (“U-PCS”) in 1994), and 5 GHz (unlicensed national information infrastructure (“U-NII”) in 1997), and again in 5 GHz (2003), have generated much less activity.<sup>141</sup> Meanwhile, CMRS operators are producing extraordinary levels of valuable service, as determined by consumer purchases.<sup>142</sup> Thus, before one can endorse or reject the INTEM Notice’s suggested transfer of spectrum space from one regime (EAFUS)

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while the Bluetooth and Home RF standards apply to frequency hopping devices.” Notice of Inquiry, *In re* Additional Spectrum for Unlicensed Devices Below 900 MHz & in the 3 GHz Band, 17 F.C.C.R. 25,632, 25,634 n.15 (2002).

139. *Id.* at 25,634–35.

140. A third has already been alluded to, and is explained in greater detail in Thomas W. Hazlett, “*Barbed Wireless*” and the Vertical Structure of Property Rights (Nov. 3, 2005) (unpublished manuscript, on file with author).

141. *See supra* Part III, tbl.5.

142. *Id.*

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to another (unlicensed), the value of *relevant* alternatives must be appraised. The FCC, which provides only a categorical endorsement of the “tremendous success” of unlicensed applications, fails to compare incremental choices.

Before we supply the omitted analysis, we must explain why initial allocations for unlicensed use are likely much more valuable than subsequent allocations will be. Primary unlicensed bands (900 MHz and 2.4 GHz) have largely hosted short-range wireless applications not coordinated with the assistance of network service providers. Property rights in land, augmented by FCC regulation of equipment, substitute for market coordination mechanisms.

Remote controls, baby monitors, cordless phones, headsets, printer connections, fire alarms, and other devices requiring signals to travel within offices or households generate very localized demands for spectrum use. In such applications, highly restrictive power limits can be applied without destroying useful services, and they can often separate users such that traffic congestion is manageable.

In short-range applications users tend to internalize costs and benefits from interference mitigation; exclusive rights in real property substitute for exclusive rights in spectrum. Mike Chartier, Director of Regulatory Policy for the Corporate Technology Group at Intel, explains the situation in personal terms:

[M]y wife . . . discovered while using her lap-top in a room far away from the access point, that simultaneous use of our (expensive) 2.4 GHz phone would cause her internet connection to stop working. Accordingly we replaced the expensive 2.4 GHz phones with (cheaper) 900 MHz ones, problem solved.

However later wanting the caller ID feature on the 2.4 GHz phone she reconnected it in a different location, trading off a smaller amount of interference for the added feature.

This behavior is the epitome of an efficient Coasian firm—internalizing transactions costs and optimizing resources in a way neither regulation nor market transactions could achieve.<sup>143</sup>

Businesses commonly build and supervise use of wireless local area networks (“WLANs”) in the workplace. Information technology (“IT”) departments are used to build and maintain corporate Wi-Fi hotspots. This

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143. Mike Chartier, *Local Spectrum Sovereignty: An Inflection Point in Allocation*, in U.S. DEP’T OF COMMERCE, PROCEEDINGS OF THE INTERNATIONAL SYMPOSIUM ON ADVANCED RADIO TECHNOLOGIES 29, 33 (2004), available at <http://www.its.bldrdoc.gov/pub/ntia-rpt/04-409/04-409.pdf>.

function involves both investing in infrastructure (access points and backhaul, for instance) and engineering solutions that reduce conflicts. Competing wireless nodes are not permitted and access to the corporate WLAN is exclusive. Intel, for instance, restricts unauthorized use of unlicensed frequencies within its corporate office space.<sup>144</sup>

Universities perform the same function on college campuses, where the demand for WLAN access is particularly intense due to high demand for access to databases and communications services, and the mobility of college students who travel between classes and activities rather than occupying offices. To limit conflicts, universities protect “their” airspace by effectively privatizing the “commons.” Using their position as landlords, they attempt to assert local jurisdiction over unlicensed bands. The policy adopted by Carnegie-Mellon University is illustrative:

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.<sup>145</sup>

But short-range devices do not exhaust the demand for wireless. Consumers also want the efficiencies associated with larger scale networks. Here, the mechanisms that limit interuser conflicts in unlicensed radio spectrum work less well. Over wider areas, additional users are involved, potential conflicts exponentially increase, and transaction costs rise markedly. Coordination breaks down when, for example, the 100-foot Wi-Fi radius is replaced by a 3-mile PCS base station radius. No longer can a hotspot owner impose a scheme to ration radio access. And neither can a corporate IT department impose an integrated, low-cost solution. In fact, to induce investors to undertake the capital expenditures creating the wide-area PCS network, exclusive spectrum rights are highly useful. Wireless users here rely on ownership rules to efficiently coordinate spectrum access.

The assertion that we do not need such institutions to achieve efficient spectrum utilization starts by observing popular applications developing in some unlicensed bands, extrapolating that usage trend, and then citing the development of new technology as the justification for imposing unlicensed allocations more generally. The logic fails to understand where unlicensed

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144. “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.” *Id.* at 32–33.

145. *Id.* at 33 n.9.

use is relatively effective or ineffective, or to understand the constraints imposed by spectrum scarcity.

Consider the following analogy: in a downtown business district, one may observe that parking spaces, metered during the day, are free after the stores close. This switch is clearly associated with shifting demands, which change scarcity conditions. One form of rationing (price) is relatively important where conflicts are relatively intense, but becomes less so when demand drops. Whereas spectrum scarcity may not be so intense when using cordless phones or WLANs, this does not imply that conflicts are absent when wide-area networks (“WWANs”) are involved. This complexity rises still further when services are efficiently provided with substantial network infrastructure that is complementary to both end-user devices (handsets) and radio spectrum. Across large numbers of users and investors, coordination becomes considerably more important, and competitive markets prove adept at organizing resource use in these circumstances. Competitive spectrum markets, which largely require exclusive spectrum rights, are an essential component of this mix.

Should unlicensed services be allocated more radio spectrum? Conflicts in unlicensed bands are cited as detrimental by the providers of unlicensed services, and this congestion is used as the premise on which new bands should be allocated for unlicensed use. But the logic is suspect. Extending unlicensed bands where congestion is problematic expands the problem of conflicting use. This is happening as unlicensed WWANs attempt to provide “last-mile” services.<sup>146</sup> “Wi-Fi is often portrayed in the media as a last-mile wireless solution, which it is not,” writes John Yunker of Pyramid Research. “That’s where 802.16, or WiMAX, fits in.”<sup>147</sup> It is worth noting that promoters of WiMAX, such as Intel, seek to deploy WiMAX on licensed frequencies in high-demand areas, in order to overcome coordination problems with unlicensed spectrum.<sup>148</sup>

Pleas made to regulators by wireless Internet service providers (“WISPs”) attempting to provide broadband connectivity via unlicensed spectrum vividly illustrate the point. WISPs complain about congestion with each other, as well as with unlicensed devices used by potential

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146. “Last mile” voice and broadband services supply the end-user links that deliver traffic to telephone or data networks.

147. John Yunker, *Five Wi-Fi Myths*, PYRAMID INSIGHT (Pyramid Research, Taipei, Taiwan), at 2, <http://www.techinsight.com.tw/news/pyramid%20insight%201.pdf>.

148. “In congested urban areas, licensed services may be the best way to proceed in order to encourage deployment, ensure optimal quality of service, and manage interference.” Pitsch, *supra* note 90, at 4.

subscribers. Exclusively assigned, flexible-use spectrum offers the opportunity such operators are requesting,<sup>149</sup> although the FCC is urged to extend the benefits of licensed use while sparing established WISPs from bidding for licenses. One operator recently petitioned the FCC to impose a “WISP Homestead Policy,” under which property rights would be enjoyed by a few “unlicensed” WISPs:

I own and operate a WISP (Wireless Internet Service Provider) in rural Southern Illinois. I provide services over the network I have built there that exceed the quality and varied uses seen in any other broadband based networks. . . . This is not just coffee shop WiFi we are discussing . . . .

This type of highly engrained use of this technology in small towns and metro areas is not unique to Mt. Vernon, IL. These services are part of the infrastructure of our communities now on a worldwide scale. The aggressive adoption of these bands has come with little protections to WISPs and their high profile customers and is in danger of creating a disastrous implosion if nothing is done to remedy the impending interference hazards on the horizon. WISPs have no rights to the spectrum they use. . . .

. . . .

I want to suggest a policy to help solve these issues and provide unlicensed use of this band simultaneously. I propose a new policy called the “WISP Homestead Policy”. . . . Homestead status would be given to WISPs who register with the FCC and provide documentation proving active use . . . . There would be no enforcement of license rights unless a homestead operator proves they have a claim to spectrum and that they are receiving interference from other sources.

Part-15 devices that interfere with a homestead WISP operation that are not owned and operated by a homestead would be required to change channels or move their equipment to alleviate the interference. This would be the extent of the rights granted WISPs . . . .<sup>150</sup>

This view is echoed in numerous other FCC filings by those attempting to use unlicensed frequencies for last-mile broadband, including the following filing:

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149. Stuart Benjamin, presenting evidence that congestion incurs serious inefficiencies on unlicensed bands, proposes greater reliance on licensed bands. Benjamin, *supra* note 4, at 2020–24.

150. Comments of John Scrivner, Mt. Vernon Net, Inc., *In re* Amendment of Parts 1, 21, 73, 74 & 101 of the Commission’s Rules to Facilitate the Provision of Fixed & Mobile Broadband Access, Educ. & Other Advanced Servs. in the 2150–2162 & 2500–2690 MHz Bands, No. 03-66 (FCC Mar. 19, 2004), available at [http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native\\_or\\_pdf=pdf&id\\_document=6516083609](http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6516083609).

I would like to encourage the FCC to reallocate some spectrum for exclusive use of internet service providers or other deployers of outdoor fixed wireless broadband data networks.

....

... I would strongly discourage the FCC from allowing consumer products to use these frequencies, as they already have several different ISM bands to use (900 MHz, 2.4 GHz, etc.).<sup>151</sup>

### C. BENEFITS OF RIVAL ALLOCATIONS ON THE MARGIN

Spectrum allocation involves incremental choices. Where an unlicensed allocation comes at the expense of a licensed allocation—as in the INTEM Notice in which underlay rights are transferred from licensees—the issue is one of alternative benefit streams. What economic value would ensue given the licensee’s right to control use in the underlay, versus activities resulting under unlicensed rules?

The allocation of 900 MHz, 2.4 GHz, and 5.8 GHz unlicensed bands has been followed by these unlicensed spectrum allocations: (1) in 1993, 30 MHz was set aside for U-PCS in the 1.9 GHz band (1910–1930 MHz) and

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151. Comments of Jeff Phillips, Rural Ramp at 1–2, *In re* Amendment of Parts 1, 21, 73, 74 & 101 of the Commission’s Rules to Facilitate the Provision of Fixed & Mobile Broadband Access, Educ. & Other Advanced Servs. in the 2150–2162 & 2500–2690 MHz Bands, No. 03-66 (FCC Mar. 22, 2004), *available at* [http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native\\_or\\_pdf=pdf&id\\_document=6516083615](http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6516083615). For additional examples of similar FCC filings, see Comments of John Buwa, Michiana Wireless, *In re* Amendment of Parts 1, 21, 73, 74 & 101 of the Commission’s Rules to Facilitate the Provision of Fixed & Mobile Broadband Access, Educ. & Other Advanced Servs. in the 2150–2162 & 2500–2690 MHz Bands, No. 03-66 (FCC Mar. 22, 2004), *available at* [http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native\\_or\\_pdf=pdf&id\\_document=6516083636](http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6516083636); Comments of Tim Steele, *In re* Amendment of Parts 1, 21, 73, 74 & 101 of the Commission’s Rules to Facilitate the Provision of Fixed & Mobile Broadband Access, Educ. & Other Advanced Servs. in the 2150–2162 & 2500–2690 MHz Bands, No. 03-66 (FCC Mar. 22, 2004), *available at* [http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native\\_or\\_pdf=pdf&id\\_document=6516083705](http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6516083705); Comments of Accel Net, Inc., *In re* Amendment of Parts 1, 21, 73, 74 & 101 of the Commission’s Rules to Facilitate the Provision of Fixed & Mobile Broadband Access, Educ. & Other Advanced Servs. in the 2150–2162 & 2500–2690 MHz Bands, No. 03-66 (FCC Mar. 19, 2004), *available at* [http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native\\_or\\_pdf=pdf&id\\_document=6516083597](http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6516083597); Comments of Kevin Sullivan, *In re* Amendment of Parts 1, 21, 73, 74 & 101 of the Commission’s Rules to Facilitate the Provision of Fixed & Mobile Broadband Access, Educ. & Other Advanced Servs. in the 2150–2162 & 2500–2690 MHz Bands, No. 03-66 (FCC Mar. 19, 2004), *available at* [http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native\\_or\\_pdf=pdf&id\\_document=6516083570](http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6516083570); Comments of Reliable Internet Servs., *In re* Amendment of Parts 1, 21, 73, 74 & 101 of the Commission’s Rules to Facilitate the Provision of Fixed & Mobile Broadband Access, Educ. & Other Advanced Servs. in the 2150–2162 & 2500–2690 MHz Bands, No. 03-66 (FCC Mar. 19, 2004), *available at* [http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native\\_or\\_pdf=pdf&id\\_document=6516083522](http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6516083522).

2.4 MHz band (2390–2400 MHz);<sup>152</sup> (2) in 1997, 200 MHz of additional bandwidth was made available for unlicensed devices, including 802.11a Wi-Fi systems, in the 5 GHz band (5.15–5.35 GHz);<sup>153</sup> (3) in 2003, 255 MHz was approved by unlicensed devices in the 5 GHz band (5.470–5.725 GHz);<sup>154</sup> and (4) in 2005, 50 MHz was allocated to license-exempt devices in the 3650–3700 MHz band.<sup>155</sup>

Even industrial users of unlicensed bandwidth and firms manufacturing wireless equipment for use in license-exempt bands suggest that the additional allocations produce little value relative to alternative allocations for flexible-use licensed spectrum. This can be seen in the admission that many unlicensed users prefer to have access to additional licensed spectrum to meet their communications needs:

A whopping 38 percent of [the National Telecommunications Cooperative Association]’s members who responded to NTCA’s 2003 wireless survey indicated that they are utilizing unlicensed spectrum to provide wireless services. . . . While interference was not yet cited as a major problem among NTCA members completing the survey, many have indicated that they are seeing more and more interference from unlicensed devices. Therefore, they contend, unlicensed spectrum is not a reliable method of providing wireless service to rural America. . . . Despite the costs associated with licensed spectrum, NTCA members indicated that they would prefer more licensed spectrum to more unlicensed spectrum by a 71% to 29% margin.<sup>156</sup>

There is nothing ironic about the fact that unlicensed users, or consumers of services provided by networks operating on unlicensed spectrum, may be better served by additional EAFUS allocations. Alvarion, a leading manufacturer of wireless last-mile broadband equipment for WISPs using unlicensed spectrum, prefers allocating 190 MHz of spectrum to MMDS/ITFS at 2.5 GHz (to be used more flexibly by licensees) to reallocating the frequencies for unlicensed use: “‘There’s really not that much [MDS/ITFS spectrum],’ commented [equipment manufacturer

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152. *In re* Amendment of the Commission’s Rules to Establish New Pers. Commc’ns Servs., 9 F.C.C.R. 4957 para. 26 (1994).

153. *In re* Amendment of the Commission’s Rules to Provide for Operation of Unlicensed NII Devices in the 5 GHz Frequency Range, 12 F.C.C.R. 1576, 1589 (1997).

154. *TIA Applauds FCC’s Adoption of Unlicensed Spectrum Rules*, PULSE ONLINE, Dec. 2003, <http://pulse.tiaonline.org/article.cfm?id=1882>.

155. *See In re* Wireless Operations in the 3650–3700 MHz Band, 20 F.C.C.R. 6502 (2005).

156. Comments of the Nat’l Telecomms. Coop. Ass’n at 11–12, *In re* Facilitating the Provision of Spectrum-based Servs. to Rural Areas & Promoting Opportunities for Rural Tel. Cos. to Provide Spectrum-based Servs., No. 02-381 (FCC Dec. 29, 2003), available at [http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native\\_or\\_pdf=pdf&id\\_document=6515383228](http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6515383228) (internal footnote omitted).

Alvarion's chief evangelist Patrick] Leary. 'There's actually a lot more available in the unlicensed bands.'"<sup>157</sup> Alvarion has an interest in promoting new wireless investments in either licensed or unlicensed bands.<sup>158</sup>

Consider the marginal allocations for unlicensed use noted above. The 255 MHz allocation in the 5 GHz band made in 2003<sup>159</sup> and the allocation at 3650 MHz made in 2005 have not yet produced market results to evaluate. The 30 MHz of unlicensed PCS spectrum allocated in 1993 has had sufficient time to generate observable activity, as has the FCC's U-NII proceeding that allocated 200 additional MHz in the 5 GHz band.<sup>160</sup> Equipment has been sold for use in these bands, and sales revenues are available for the Wi-Fi (WLAN) technology deployed at 5 GHz, 802.11a.<sup>161</sup> We take these data to offer information on the economic activity generated via use of this unlicensed spectrum.

In Tables 5 and 6, sales data for equipment using the U-PCS and 5 GHz unlicensed allocations are displayed (service revenues are de minimis) for 2003. The U-PCS bands have hosted virtually no economic activity. The 5 GHz bands (including the 100 MHz of unlicensed bandwidth allocated prior to 1997) gave rise to about \$180 million in 802.11a equipment sales, the largest portion coming from user devices as opposed to network infrastructure.

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157. Daniel Sweeney, *A Second Chance for MMDS*, BROADBAND WIRELESS ONLINE, Sept.–Oct. 2003, <http://www.shorecliffcommunications.com/magazine/volume.asp?Vol=40&story=353>.

158. As Patrick Leary, Alvarion Chief Evangelist, notes, According to a Dell'Oro study from Q2 2002, Alvarion enjoys the largest market share of the entire wireless broadband marketplace, including the millimeter wavelengths. Our share in 3.5 GHz exceeds 50%, as does our 10.5 GHz share (which we captured in a single year). In unlicensed, Alvarion is the pioneer in PMP, and maintains the global #1 position is [sic] 2.4 GHz as well. Our systems also address more unlicensed bands than any other, as well as supporting multiple technologies. Alvarion's customers comprise the largest deployments of unlicensed broadband among many diverse customer types and in most countries in the world where unlicensed can be found.

License Exempt Spectrum, Questions for Nominees, [http://www.wcai.com/lea/lea\\_vote.htm](http://www.wcai.com/lea/lea_vote.htm) (last visited Apr. 3, 2006).

159. See *supra* note 154 and accompanying text.

160. See *supra* note 153 and accompanying text.

161. "[802.11a is] an extension to 802.11 that applies to wireless LANs and provides up to 54 Mbps in the 5 GHz band." What Is 802.11?, [http://www.webopedia.com/TERM/8/802\\_11.html](http://www.webopedia.com/TERM/8/802_11.html) (last visited Apr. 3, 2006).

TABLE 6. Total U.S. revenue for 802.11a devices<sup>162</sup>

2000	2001	2002	2003	2004	2005	2006
\$0.00	\$4.40	\$125.60	\$176.60	\$281.70	\$351.40	\$431.50

Alternatively, CMRS licensees have approximately 189 MHz of allocated bandwidth at 800 MHz, 900 MHz, and 1.9 GHz.<sup>163</sup> Current supply-side valuations for marginal CMRS bandwidth are available from the FCC. In a 2004 “swap” of radio spectrum with the wireless carrier Nextel (acquired in 2005 by Sprint-Nextel), the FCC determined that a CMRS license which allocated 10 MHz of nationwide spectrum in the 1.9 GHz band was worth \$4.8 billion.<sup>164</sup> This is an estimate of the producers’ surplus anticipated by service suppliers; total social value would be a substantial multiple of this. Greg Rosston shows that the ratio of consumers’ surplus to producers’ surplus in CMRS valuations is likely to be at least ten to one.<sup>165</sup> This lopsided distribution of demand- and supply-side benefits from the use of radio spectrum is supported by research on U.S. mobile phone markets by economist Jerry Hausman,<sup>166</sup> and by a study on the value of wireless services conducted by the spectrum regulatory agency for the United Kingdom.<sup>167</sup> Applying the ratio in the instant case implies a *marginal social value* of nationwide CMRS spectrum in excess of \$5 billion per MHz.

Annual equipment expenditure data (for 5 GHz unlicensed) cannot be directly compared to lump sum present values (for 2 GHz CMRS licensed). Various transformations could be employed to capitalize the annual data or annualize present values, but the magnitudes are not close enough to

162. Revenues are in millions and 2003 to 2006 revenues are estimates. Revenues obtained from WIRELESS WEIGH-IN, *supra* note 109, exhibit 8.

163. Recall that this bandwidth comprised the entire allotment of exclusively-assigned, flexible-use spectrum as of November 2002. *See supra* notes 101–03 and accompanying text.

164. Nextel traded licenses which allocated spectrum in the 700 MHz and 800 MHz bands to the FCC in exchange for licenses which allocated a contiguous 10 MHz in the 1.9 GHz band. The FCC valued the 10 MHz license at \$4.8 billion. *See* Ninth Report, *In re* Implementation of Section 6002(b) of the Omnibus Budget Reconciliation Act of 1993, Annual Report & Analysis of Competitive Mkt. Conditions with Respect to Commercial Mobile Servs., 19 F.C.C.R. 20,597, 20,635 (2004) [hereinafter 2004 FCC CMRS Report].

165. Gregory L. Rosston, *The Long and Winding Road: The FCC Paves the Path with Good Intentions* 23 (Stanford Inst. for Econ. Policy Research, Discussion Paper No. 01-08, 2001), available at <http://siepr.stanford.edu/papers/pdf/01-08.pdf>.

166. Jerry Hausman, *Mobile Telephone*, in 1 HANDBOOK OF TELECOMMUNICATIONS ECONOMICS 564 (Martin E. Cave, Sumit K. Majumdar & Ingo Vogelsang eds., 2002).

167. RADIOCOMMUNICATIONS AGENCY, THE ECONOMIC IMPACT OF RADIO, 2002 UPDATE (2002), available at [http://www.ofcom.org.uk/static/archive/ra/topics/economic/economicisreport\\_final.pdf](http://www.ofcom.org.uk/static/archive/ra/topics/economic/economicisreport_final.pdf).

warrant further inspection: billions for licensed versus millions for unlicensed. Consumers appear to value additional licensed frequencies (under CMRS rules) much more highly.

This is not surprising for several reasons. First, CMRS spectrum is tightly constrained given its extensive use. Carriers providing voice and data over integrated systems express intense demand for additional bandwidth.<sup>168</sup> Second, the most compelling applications of unlicensed use are highly localized. Given the control that an unlicensed user exerts in that user's immediate area, the 900 MHz and 2.4 GHz allocations offer abundant opportunities for short-range deployments.

Third, demands for additional bandwidth are primarily driven by wide-area applications, where exclusive spectrum rights are increasingly desirable. Thus, demand for additional CMRS spectrum is high; even in the face of hundreds of MHz of new unlicensed bands, carriers still seek to utilize exclusively assigned rights, and they are willing to spend billions of dollars to secure them.<sup>169</sup> The different characteristics of wide-area applications also drive strategic decisions to design WiMAX and "4G" wireless broadband technologies as licensed spectrum applications.<sup>170</sup>

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168. Cingular, Verizon, and Sprint-Nextel are each constructing nationwide broadband networks, upgrading existing systems. Access to radio spectrum has been instrumental in this migration to 3G and has provided impetus for merger. "In October, Cingular Wireless closed its acquisition of AT&T Wireless, creating the nation's largest wireless company with 47 million subscribers. Cingular said the acquisition gave it the additional radio spectrum necessary to deploy the high-speed network." Matt Richtel, *Cingular to Upgrade Data Network*, N.Y. TIMES, Dec. 1, 2004, at C9.

169. This is the implication of the FCC's Nextel 10 MHz license valuation of \$5 billion. This represents the government's best guess as to what a private bidder would offer to own such a license.

170. WiMAX technologies are being developed primarily for use with exclusively assigned spectrum rights. Jim Johnson, Vice President of the Intel Communications Group and General Manager of the Wireless Networking Group, explains,

Although the fundamental technology is the same, over time we can add levels of sophistication to WiMAX. Wi-Fi channels occupy a fixed width of the spectrum. But with WiMAX, we're going to enable the traffic lanes—or channels—to get smaller and narrower. This helps service providers seeking to offer wireless last-mile DSL or cable-type service because they can provide a narrower channel that uses less bandwidth and serve more users. You can take what used to be a fixed Wi-Fi lane and make a bunch more lanes and serve more people.

The other big difference between Wi-Fi and WiMAX—starting right away—is that we're going to use licensed spectrum to deliver WiMAX. To date, all Wi-Fi technology has been delivered in unlicensed spectrum. WiMAX will use one of the unlicensed frequencies, but we're also supporting two other frequencies that are licensed. What that means is that you can turn up the output power and broadcast longer distances. So where Wi-Fi is something that is measured in hundreds of feet, usually WiMAX will have a very good value proposition and bandwidth up to several miles.

WiMAX: Wireless Broadband for the World—An Interview with Jim Johnson, <http://www.intel.com/netcomms/columns/jimj105.htm> (last visited Apr. 3, 2006).

The INTEM Notice proposes that underlays be transferred from licensees, including CMRS operators, to unlicensed users.<sup>171</sup> This exchange is likely to create little incremental value, as seen in the modest use of recent unlicensed allocations. Alternatively, it will restrict spectrum access in CMRS bands where the incremental social value of bandwidth likely exceeds \$5 billion per MHz for nationwide spectrum.<sup>172</sup> The evidence in today's marketplace strongly suggests that applying the INTEM Notice proposal to the CMRS bands would destroy social value rather than create it.<sup>173</sup> As for inserting the underlays into other bands, an alternative option—extending license flexibility there—must first be considered.

#### IV. EFFICIENT SHARING OF LIBERAL LICENSE RIGHTS

The INTEM Notice claims that administrative allocation of spectrum has historically been successful: “In the past, this model generally served well to control interference and to facilitate effective use of the spectrum in environments in which the specific services and operating technology were stable and well defined.”<sup>174</sup> Changes in the laboratory and the marketplace are upsetting this happy state of affairs:

However, the dramatic increases in the overall demand for spectrum based services, rapid technical advances in radio systems, in particular the introduction of various advanced modulation technologies, the increased use of spectrum for mobile services, and the need for increased access to the limited supply of spectrum in recent years are straining the effectiveness of the Commission's longstanding spectrum policies in dealing with some allocations and applications.<sup>175</sup>

The FCC's first claim—that it has efficiently allocated spectrum historically—is both wrong and dangerous. In fact, the central planning methods used to allocate radio spectrum under the 1927 Radio Act (absorbed into the 1934 Communications Act) have consistently resulted in more harm to consumer welfare than would have resulted were more liberal rules in place.<sup>176</sup> While interference between users has been limited, the social costs of preventing conflict have been far too high. As a consequence, new technologies have been delayed or deferred, bandwidth

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171. INTEM Notice, *supra* note 25, at 25,315.

172. This assumes the FCC's valuation for supply-side benefits (\$500 million/MHz) and a ten-to-one ratio for consumer surplus to producer surplus.

173. This is the logical outcome if the social value of the spectrum rights transferred is greater under licensed than unlicensed rules.

174. INTEM Notice, *supra* note 25, at 25,311.

175. *Id.*

176. *See generally* Hazlett, *supra* note 4.

has been extremely underutilized, and net social gains of large magnitude have been sacrificed.<sup>177</sup>

The evidence supporting these conclusions is overwhelming. FCC spectrum allocation provided inefficient use of AM band airwaves in the 1920s and 1930s,<sup>178</sup> FM radio technology in the 1930s, 1940s, and 1950s,<sup>179</sup> the broadcast TV band from the 1940s until the present,<sup>180</sup> and cellular telephony in the 1950s, 1960s, 1970s, and 1980s.<sup>181</sup> In each instance, the FCC (or its predecessor, the Federal Radio Commission) allocated bandwidth such that consumers were given far less access to wireless services than less regulated markets would have offered. Long before the advent of advanced digital wireless systems, the FCC's spectrum allocation regime had failed, becoming a textbook example of anticonsumer regulation.<sup>182</sup>

The twin claims that the regulatory structure was well suited to a previous era, but must now change due to new circumstances, obscure precisely the problems in spectrum allocation that should be fixed. The

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177. See generally ITHIEL DE SOLA POOL, *TECHNOLOGIES OF FREEDOM* (1983); HUBER, *supra* note 12; HARVEY J. LEVIN, *THE INVISIBLE RESOURCE: USE AND REGULATION OF THE RADIO SPECTRUM* (1971); BRUCE M. OWEN & STEVEN S. WILDMAN, *VIDEO ECONOMICS* (1992); R.H. Coase, *Evaluation of Public Policy Relating to Radio and Television Broadcasting: Social and Economic Issues*, 41 *LAND ECON.* 161 (1965); Harvey J. Levin, *New Technology and the Old Regulation in Radio Spectrum Management*, 56 *AM. ECON. REV.* 339 (1966); Harvey J. Levin, *The Radio Spectrum Resource*, 11 *J.L. & ECON.* 433 (1968); Douglas W. Webbink, *Radio Licenses and Frequency Spectrum Use Property Rights*, 9 *COMM. & L.* 3 (1987); Reed E. Hundt & Gregory L. Rosston, *Spectrum Flexibility Will Promote Competition and the Public Interest*, *IEEE COMM. MAG.*, Dec. 1995, at 40; Douglas W. Webbink, *Frequency Spectrum Deregulation Alternatives* (FCC, Office of Plans & Policy, Working Paper No. 2, 1980), available at [http://www.fcc.gov/Bureaus/OPP/working\\_papers/oppwp2.pdf](http://www.fcc.gov/Bureaus/OPP/working_papers/oppwp2.pdf); Gregory L. Rosston & Jeffrey S. Steinberg, *Using Market-based Spectrum Policy to Promote the Public Interest* (Jan. 1997) (unpublished manuscript), [http://www.fcc.gov/Bureaus/Engineering\\_Technology/Informal/spectrum.txt](http://www.fcc.gov/Bureaus/Engineering_Technology/Informal/spectrum.txt).

178. See ROBERT W. MCCHESENEY, *TELECOMMUNICATIONS, MASS MEDIA, AND DEMOCRACY* 12–37 (1993). See also Thomas W. Hazlett, *The Rationality of U.S. Regulation of the Broadcast Spectrum*, 33 *J. LAW & ECON.* 133 (1990); Hazlett, *supra* note 4, at 406–07.

179. See LAWRENCE LESSING, *MAN OF HIGH FIDELITY: EDWIN HOWARD ARMSTRONG* 250–78 (1956); Stanley M. Besen, *AM Versus FM: The Battle of the Bands*, 1 *INDUS. & CORP. CHANGE* 375 (1992).

180. See HARVEY J. LEVIN, *FACT AND FANCY IN TELEVISION REGULATION passim* (1980); ROGER G. NOLL, MERTON J. PECK & JOHN J. MCGOWAN, *ECONOMIC ASPECTS OF TELEVISION REGULATION* 97–128 (1973); BRUCE M. OWEN, JACK H. BEEBE & WILLARD G. MANNING, JR., *TELEVISION ECONOMICS* 112–14, 137–38 (1974); Harvey J. Levin, *Federal Control of Entry in the Broadcast Industry*, 5 *J.L. & ECON.* 49 (1962); Hazlett, *supra* note 13.

181. See GEORGE CALHOUN, *DIGITAL CELLULAR RADIO* 29–140 (1988).

182. See THOMAS SOWELL, *KNOWLEDGE AND DECISIONS* 195–96 (1980) (citing regulation by the FCC, the Civil Aeronautics Board (“CAB”), and the Interstate Commerce Commission (“ICC”) as similar in consumer welfare effects; it should be noted that the CAB and the ICC have both since been abolished in procompetitive deregulatory reforms).

FCC has never had the institutional ability to allocate spectrum so as to provide the most valuable wireless services to society. Failing to acknowledge this today is dangerous because it obscures both the consequence of administrative allocation and the opportunity presented by new technology. The FCC seeks to impose—by *command*—its spectrum allocation choices on the marketplace.

#### A. THE ANALOG-TO-DIGITAL TRANSITION IN CMRS

How do spectrum markets create valuable new spectrum-sharing technologies? Consider the mass migration of cellular phone users from analog to digital. This episode began when cellular telephone licenses for the 306 largest U.S. markets, issued from 1983 to 1986, were mandated to use the analog AMPS (advanced mobile phone system) standard.<sup>183</sup> It was soon obvious that digital standards would prove superior,<sup>184</sup> and the FCC permitted cellular carriers to deploy these in 1988.<sup>185</sup>

Existing cellular systems—for which billions of dollars had been invested to build base stations and buy subscriber handsets—were already using the spectrum allocated, and the FCC chose not to allocate additional frequencies for the transition. Not only did cell phone networks have an economic interest in continuing to serve analog customers, but also FCC rules required that existing subscribers using legacy technology be able to receive service.<sup>186</sup> The networks had to make room for new digital technologies, while accommodating an embedded base of analog users, splitting frequency use in the existing bandwidth.<sup>187</sup> Substantial infrastructure investments were needed to replace or upgrade both base

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183. CALHOUN, *supra* note 181, at 67. See generally Thomas W. Hazlett & Robert J. Michaels, *The Cost of Rent-seeking: Evidence from Cellular Telephone License Lotteries*, 59 S. ECON. J. 425 (1993).

184. Many technical experts see the analog regulatory mandate as a costly error, or a “megamiscalculation.” CALHOUN, *supra* note 181, at 67.

185. See *In re* Amendment of Parts 2 & 22 of the Commission’s Rules to Permit Liberalization of Tech. & Auxiliary Serv. Offerings in Domestic Public Cellular Radio Telecomms. Serv., 3 F.C.C.R. 7033 (1988).

186. The mandate to continue analog service will be phased out, according to 2002 FCC rules, as of January 1, 2008. See Onstar—Helpful Info, [http://www.onstar.com/us\\_english/jsp/explore/onstar\\_basics/helpful\\_info.jsp?info-view=tech\\_equip](http://www.onstar.com/us_english/jsp/explore/onstar_basics/helpful_info.jsp?info-view=tech_equip) (last visited Apr. 3, 2006).

187. See Thomas Crawford, *A Steady Apple Cart: Smart Antennas Can Ease the Transition from Analog to Digital Service*, TELEPHONY ONLINE, Sept. 22, 1997, [http://telephonyonline.com/mag/telecom\\_steady\\_apple\\_cart/index.html](http://telephonyonline.com/mag/telecom_steady_apple_cart/index.html).

stations and handsets.<sup>188</sup> Such a transition could easily fail, foundering on the rocks of complexity and cost. Indeed, the transition from analog to digital television, initiated in 1987 by the FCC, has yet to produce any meaningful progress.<sup>189</sup>

In contrast, an exclusive rights structure in CMRS has succeeded. The wireless industry developed new digital standards, TDMA and CDMA, and hosted a marketplace-standards competition.<sup>190</sup> Investments made by U.S. wireless carriers—over \$156 billion in book value through June 2004<sup>191</sup>—drove development and deployment of competing technologies. Digital systems have helped expand capacity more than tenfold, and have simultaneously improved quality, reliability, and functionality.<sup>192</sup> They also deliver high-speed data services. From 1995–2004, digital usage in the United States went from about zero percent to over ninety percent of wireless phone service.<sup>193</sup> This was achieved without public policy intervention (beyond regulatory forbearance) or rent-seeking for winner-take-all regulatory mandates.

At least three crucial issues arise here. First, the expansion of technology choices spurred a vigorous, socially valuable competition among advanced wireless technologies. Second, this productive rivalry featured exclusive property-rights holders. Operators' abilities to control swaths of radio space gave them incentives to invest aggressively in systems that efficiently accounted for the opportunity costs of bandwidth. As digital systems make relatively intense use of frequency space, newly created capacity increases a carrier's profits.<sup>194</sup> EAFUS licenses allow

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188. See Bruce Felps, *BAM Fills Digital Gap in Southeast: Carrier Pushes to Upgrade System in North Carolina*, WIRELESS WK., June 21, 1999, available at <http://www.wirelessweek.com/index.asp?layout=articlePrint&articleID=CA3643>.

189. See Elisa Batista, *Crooked Path Ahead for Digital TV*, WIRED NEWS, Nov. 8, 2002, <http://wired.com/news/business/1,56244-0.html>.

190. See GILDER, *supra* note 69, at 87–94.

191. CTIA SURVEY 2004, *supra* note 114, at 2.

192. As reported by the Cellular Telecommunications and Internet Association database, total minutes of use for the six months ending December 1994, just as digital networks were entering the market (and existing cellular networks were being upgraded), equaled 14,489,550,591. Ten years later, when the digital transition was substantially complete, total minutes of use for the six months ending December 2004 equaled 585,174,443,040, or about forty times as much.

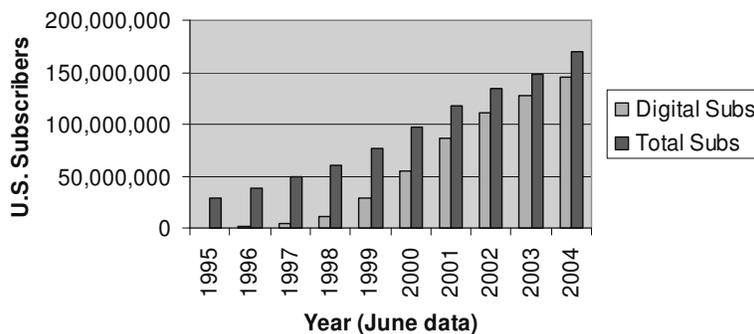
193. See *infra* Part IV.A, fig.4.

194. Importantly, carriers' profits may fall. As competition from advanced digital systems intensifies, retail prices are predicted to decline; depending on costs and demand elasticities, profit margins may decline, as well. A single carrier, however, adopts digital technology to increase the capacity of its allocated spectrum, increasing its profits compared to what they would be if it (alone) were using analog technology.

(indeed, force) operators to internalize investment returns earned from adopting advanced wireless technologies.

Third, private firms possessing exclusive spectrum rights adroitly coordinated conflicts among rival technologies accessing the same radio space. In addition to investing in technologies and infrastructure upgrades, wireless networks sought to ease the digital transition for analog customers, subsidizing handsets and promoting new digital services with attractive pricing and service plans. They also invested in the development and distribution of multimode phones, so that users could transition to digital technology and still not lose the coverage afforded by older (and larger) analog networks. When these investments proved popular with users, carriers prospered, capturing additional revenues.

FIGURE 4. The analog-to-digital cellular transition<sup>195</sup>



#### B. INVESTMENT INCENTIVES AND SPECTRUM SHARING

In EAFUS bands, licensees invest enormous sums to deploy advanced technologies.<sup>196</sup> They do so due to two advantages offered by the property rights regime. First, the governance rules imposed on unlicensed users, including power limits and technology standards, are absent. With exclusive rights, decisions about governance are delegated to rights holders, providing the network operator wider latitude to optimize spectrum use than networks accessing unlicensed bandwidth enjoy. Second, unlicensed bandwidth potentially allows large numbers of users to access spectrum now and in the future without the permission of network

195. CTIA SURVEY 2003, *supra* note 119.

196. *See supra* Part III, tbl.5.

investors. This constitutes a threat of appropriation for such investors, lowering expected returns for irreversible network infrastructure investments. Exclusive ownership of spectrum rights, alternatively, provides security for investors sinking capital complementary to the use of frequencies.

Consider the evolution of CDMA systems, such as those deployed in the United States by Verizon Wireless and Sprint-Nextel. Both carriers created nationwide data networks by upgrading their original infrastructures to 1xRTT technology,<sup>197</sup> allowing data speeds of up to 144 kbps, with 40–60 kbps typical throughput.<sup>198</sup> The next generation technology, EV-DO technology, is being deployed, and delivering typical throughput at broadband speeds of 400–700 kbps.<sup>199</sup> The initial upgrade to EV-DO was reported to cost Verizon \$1 billion in network infrastructure improvements.<sup>200</sup> In December 2004, Sprint announced that it was investing \$3 billion to upgrade its nationwide network to EV-DO.<sup>201</sup>

These investments constitute only a small fraction of the capital that wireless carriers with exclusively assigned spectrum rights have sunk into network infrastructure to provide advanced services. Carriers also subsidize telephone handsets for subscribers—about three fourths of the nearly \$14 billion spent on mobile phones in the United States in 2003 was spent by carriers.<sup>202</sup> Network operators undertake this strategy both to introduce new applications (newer model phones typically offer more features) and to conserve spectrum, as newer radios are more spectrally-efficient.

Similar capital investment is not observed using unlicensed radio spectrum. Networks using Wi-Fi hotspots to link customers to the Internet have been constructed, but are of extremely limited geographic scope in contrast to the national wireless networks built by mobile phone carriers.<sup>203</sup> Short-range Wi-Fi links—typically about one hundred feet for indoor uses—require backhaul connections (such as cable modems, DSL service,

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197. See Belk, *supra* note 9, at 5.

198. Cellco P'ship, Annual Report (Form 10-K), at 6 (Mar. 27, 2003).

199. Bsales, *supra* note 84; Roberts, *supra* note 85.

200. Dan O'Shea, *National EV-DO Plan Reflects Capex Renewal*, TELEPHONY ONLINE, Jan. 12, 2004, [http://telephonyonline.com/mag/telecom\\_national\\_evdo\\_plan/index.html](http://telephonyonline.com/mag/telecom_national_evdo_plan/index.html).

201. *Wireless Consolidates*, TIA'S TECHTRENDS (Telecomms. Indus. Ass'n, Wash., D.C.), Jan.–Feb. 2005, at 3, <http://www.tiaonline.org/business/research/mrf/documents/January2005.pdf>.

202. Dano, *supra* note 115, at 1.

203. The coverage of wireless phone networks is orders of magnitude larger than that provided by Wi-Fi access networks. "Sprint PCS today has equivalent wireless data coverage of about 500,000,000 [Wi-Fi] access points. . . . Wayport, Boingo and T-Mobile[, the three largest Wi-Fi networks,] combined have less than 5,000 Access Points deployed nationwide." Belk, *supra* note 9, at 26.

or T1 lines) to deliver traffic to the Internet. In other words, traffic carried via unlicensed airwaves is quickly delivered to privately owned conduits for delivery by long-distance networks. These networks rely heavily on private ownership of exclusive rights to “spectrum in a tube” (for wired connections).

In December 2002, Intel, along with AT&T, IBM, Apax, and 3i, announced the formation of Cometa.<sup>204</sup> The venture was to promote unlicensed spectrum applications by building 20,000 hotspots in the United States within two years.<sup>205</sup> Yet, the business collapsed when, in mid-2004, only two hundred hotspots had been launched. Despite deep-pocketed investors, Cometa’s owners were willing to sink only \$6 million into the enterprise before pulling the plug.<sup>206</sup> The power limits that make local applications possible via unlicensed spectrum simultaneously have the effect of making wide-area deployments relatively expensive.<sup>207</sup>

#### V. THE COST OF REASSIGNING UNDERLAY RIGHTS IN SPECTRUM ALLOCATED TO A CMRS LICENSE

The cost of inserting unlicensed underlays as proposed in the INTEM Notice can be estimated. We focus, again, on the impact on CMRS bands, where licensed operators have been awarded the flexibility to make productive use of low-power emissions and deploy networks that do so.

If unlicensed underlays were to be imposed on CMRS spectrum, an operator would either (1) lose capacity, (2) increase infrastructure investment to regain lost capacity, or (3) some combination of (1) and (2). Any of these outcomes reduces network profitability.

We utilize estimated reductions in network coverage and capacity associated with increasing noise levels that might be permitted under the INTEM Notice. These estimates are provided by V-Comm, a wireless engineering firm, and relate to a hypothetical CMRS licensee deploying a national network using CDMA technology.<sup>208</sup> We then translate the

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204. Thomas W. Hazlett, *Missing the Next (Radio) Wave*, BARRON’S, Aug. 2, 2004, at 31.

205. *Id.*

206. *Id.*

207. *Id.*

208. See Comments of V-Comm, L.L.C. at 52–61, *In re* the Commission’s Notice of Inquiry for the Establishment of an Interference Temperature Metric to Quantify and Manage Interference and to Expand Available Unlicensed Operation in Certain Fixed, Mobile & Satellite Frequency Bands, No. 03-237 (FCC Apr. 5, 2004), available at [http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native\\_or\\_pdf=pdf&id\\_document=6516086643](http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6516086643) [hereinafter V-Comm 2004]. Other systems may tolerate noise

technically derived capacity and coverage changes into estimates of economic loss. The exercise shows that increased noise levels in CMRS bands contemplated in the INTEM policy carry substantial economic consequences.

#### A. ESTIMATING CAPACITY LOSSES FROM INCREASED INTERFERENCE

We consider four scenarios, each corresponding to a distinct level of increased noise over the existing noise floor. Those four “noise increments” are 0.33 dB, 0.5 dB, 1 dB, and 3 dB.<sup>209</sup> To put these in perspective, a 0.33 dB increase in noise raises the noise floor less than ten percent, while a 3 dB increase approximately doubles the noise floor.

The effect of increased noise on a mobile phone system can be measured in at least three dimensions. First, the increase in interference can be represented as a reduction in geographic coverage area, holding call volumes per cell site constant. This impact depends on how spectrum is utilized; because the intensity of wireless use varies with population density, noise effects on capacity differ in rural, suburban, and urban areas. Second, increased interference can be represented as reduced capacity, holding the coverage area of the system constant. This measures the impact of the added noise if the carrier does nothing to respond to the interference and continues to serve its original contour. Third, the damage of the incremental interference can be quantified by the increase in the number of cell sites needed to maintain original coverage and capacity. We report estimates produced by the three approaches, for each of the four noise increments, in Table 7.

TABLE 7. CDMA network capacity losses from increased noise<sup>210</sup>

Case	Increase in Noise (dB)	Coverage Reduction			Capacity Reduction	Increase in Cell Sites
		Rural	Suburban	Urban		
1	0.33	5%	5%	4%	5%	5%
2	0.5	8%	7%	6%	8%	8%
3	1	15%	13%	12%	16%	18%
4	3	38%	35%	32%	61%	111%

differently. In addition, different firms or organizations could well produce a different set of estimates, even for the same technology.

209. A “dB” refers to “decibels,” a standard metric for comparing noise levels.

210. V-Comm 2004, *supra* note 208, at 56 tbl.2, 57 tbl.5.

B. THE ECONOMIC COSTS AND BENEFITS OF INCREASED  
INTERFERENCE

The next step in the analysis requires translating the reduced capacity of mobile networks into economic costs. We can do this in two different ways. First, the losses stemming from reduced usage of the current network can be valued in dollar terms. Second, we can calculate the monetary costs of recovering lost capacity.

Mobile phone operators continually invest capital and incur additional operating expenses to expand the capacity of their networks. Because network capacity is costly, mobile phone operators typically deploy capacity as needed. Consequently, there is a fairly tight relationship between a mobile phone system's capacity and its usage.

The connection between system capacity and system usage can break down if the network has minimum size constraints that require more capacity than is used. To be economically efficient, a cell can only be so large. In some cases, typically in rural areas where usage is sparse, a reduction in the carrying capacity of a cell will not impact users. The estimated capacity reductions displayed in Table 9 take these "lumpy" investment effects into account.

1. Capacity

One way to measure the economic costs of capacity reduction is to start with a demand function for mobile phone usage. Using the curve in Figure 3 to quantify the value of reduced capacity is a conservative approach because the actual current demand for mobile phone use is very likely to be above historical levels due to improvements in equipment pricing and network performance over time.

Reductions in usage lead to losses by carriers, measured as producers' surplus ("PS"), and consumers, measured as consumers' surplus ("CS"). Estimated revenue reduction equals the reduction in capacity times the price paid for that capacity, which we set equal to 10.9 cents per MOU (the price recorded in June 2003).<sup>211</sup> This reduction in revenues overstates the value of lost sales to carriers, because carriers may save some costs by not serving those minutes. We thus estimate lost PS by multiplying lost revenue by 0.313, reflecting (approximately) the mean operating cash flow

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211. See *supra* Part III.A, fig.3.

ratio of U.S. wireless carriers.<sup>212</sup> CS is the sum of benefits received by mobile phone customers over and above what they pay for service. It is calculated as the area between the Figure 3 price-quantity curve and 10.9 cents. Table 8 reports the reduction in both PS and CS for the four interference increments, estimates which apply to one hypothetical nationwide CDMA carrier.<sup>213</sup>

TABLE 8. Annual economic loss from reduction in capacity for nationwide CDMA carrier facing increased interference (\$ in billions)<sup>214</sup>

Case	Reduction in Capacity	Reduction in Revenues	Reduction in PS	Reduction in CS	Total Annual Welfare Loss
1	5%	\$0.573	\$0.179	\$0.002	\$0.181
2	8%	\$0.917	\$0.287	\$0.008	\$0.295
3	16%	\$1.833	\$0.574	\$0.066	\$0.640
4	61%	\$6.989	\$2.188	\$1.757	\$3.944

## 2. Remediation

We also estimate the economic costs of increased interference by measuring the incremental capital and operating costs a network operator incurs to maintain network performance. This analysis takes into account different usage patterns in rural, suburban, and urban markets, and assumes that the impact of interference on the system is measured in terms of

212. This is estimated using the average EBITDA to net revenues ratio for AT&T, Cingular, Nextel, Sprint PCS, and Verizon Wireless. Data are obtained from SMITH BARNEY, STILL STANDING—INITIATING COVERAGE OF THE TOWER INDUSTRY 180 fig.171 (2004). Merrill Lynch states a similar ratio of thirty-two percent. MERRILL LYNCH, GLOBAL WIRELESS MATRIX 2Q04, at 32 tbl.18 (2004), available at <http://www.comcom.govt.nz/IndustryRegulation/Telecommunications/Investigations/MobileTerminationRates/ContentFiles/Documents/Global%20Wireless%20Matrix%202Q04%20Sept%2004.pdf>.

213. A reduction in usage occurring from the INTEM supply shock would, *ceteris paribus*, be accompanied by an increase in prices. That increase would transfer revenue from consumers to producers for service units still purchased. That transfer does not represent a welfare loss to society and is unaccounted for here. Hence, the CS loss is estimated as the area below the curve shown in Figure 3 for the last (and least valued) five percent of 2003 utilization and above the original price of 10.9 cents per minute.

214. The analysis assumes that the representative carrier has thirteen percent of total U.S. revenue, an approximation of the average share of the six largest carriers in 2003. Reduction in PS is calculated as 31.3% of the reduction in revenues. Estimates exclude transfers from consumers to carriers resulting from higher retail prices.

coverage in rural areas, capacity in urban areas, and a mix of both in suburban markets.

TABLE 9. Increased capital and operating costs for nationwide CDMA carrier to maintain coverage with increased interference (\$ in billions)<sup>215</sup>

Case	Reduction in capacity	Increased capital expenditures	Increase annual capital amortization	Increased annual operating expenses	Increased cost per subscriber
1	5%	\$2.2	\$0.3	\$0.1	2%
2	8%	\$3.5	\$0.4	\$0.2	3%
3	16%	\$7.4	\$0.9	\$0.4	6%
4	61%	\$45.7	\$5.7	\$2.3	36%

Table 9 reports estimated increases in capital and operating costs for a national CDMA network operator to offset coverage and capacity losses from increased interference. The calculations assume (1) 37.5 million nationwide subscribers, (2) construction cost per cell site equal to \$2 million, (3) annual operating expenses per cell site equal to \$100,000, (4) capital life equal to eight years, and (5) straight-line depreciation with zero discount.<sup>216</sup>

The calculations offer a reasonable range of estimates for the impact on advanced wireless systems using licensed bandwidth. They suggest that (1) the low damage scenario for unlicensed underlays calculates a capacity loss of just five percent on a single CDMA network and annual welfare losses of \$181 million, and (2) the high damage scenario calculates a capacity loss of sixty-one percent, and annual losses of nearly \$4 billion.

Market evidence suggests that users of licensed spectrum have a high willingness to pay for access to incremental bandwidth. Wireless carriers purchasing CMRS licenses value 10 MHz of nationwide spectrum located in the 2 GHz band at approximately \$5 billion.<sup>217</sup> This reveals only PS, representing an estimate of the present discounted value of future profits accruing to the licensed network operator. CS represents social value above this level. Earlier, we noted that consumer gains are likely to exceed ten

215. V-Comm 2004, *supra* note 208, tbls.6 & 7.

216. These values mimic those of the Verizon Wireless network, deploying CDMA.

217. See *supra* note 164 and accompanying text.

times producer profits.<sup>218</sup> The implication is clear: additional bandwidth is very valuable to wireless licensees and their customers. This supports the conclusion that transferring bandwidth rights, as is proposed via the INTEM Notice, would impose large social welfare costs.

### 3. Benefits of Unlicensed Underlays

The benefits generated by the FCC's INTEM Notice could justify the costs imposed. We address this issue, again, in social welfare ("SW") terms, ranking public policies according to their success in generating  $SW = CS + PS$ .<sup>219</sup> This formula omits consideration of the distribution of benefits. Our analysis focuses on the margin, identifying likely gains from increased spectrum access from opportunities created by implementation of an interference temperature specifically applied to the CMRS bands.<sup>220</sup> The spectrum allocated to CMRS licenses, and potentially available for shared use with unlicensed devices, is summarized in Table 10.

TABLE 10. CMRS spectrum allocations

<i>License type</i>	<i>Bandwidth</i>	<i>Band</i>
Cellular	50 MHz	800 MHz
PCS	120 MHz	1.9 GHz
SMR <sup>221</sup>	19 MHz	700, 800, and 900 MHz

In 1985, the 900 MHz, 2.4 GHz, and 5.8 GHz unlicensed bands were opened to spread spectrum devices, and these bands have hosted

218. See *supra* note 165 and accompanying text.

219. The objective of maximizing consumer welfare is standard in many legal and economic analyses. See, e.g., RICHARD A. POSNER, *ECONOMIC ANALYSIS OF LAW* 3–12 (5th ed. 1998).

220. It is also crucial to identify the correct policy margin. Because exclusive rights assigned to private owners can be reconfigured by market transactions (as when a network sells airwave access by subscription, or contracts with equipment vendors to permit manufactured devices to access its bandwidth), alternative spectrum access structures are not uniquely identified with licensed versus unlicensed regimes. An inquiry into why a market allocation of exclusive rights is made in one form versus another further informs the policy choice, as does consideration of how efficiencies could be generated by rearranging rights in the market resulting under a given regime. The paradigmatic example is the construction of a public park, using government funds, under a private property regime for real estate. This creates a "commons," in the sense of government-mandated common access rights, but preserves rational allocational aspects (including revelation of opportunity costs) of private ownership. See generally Hazlett, *supra* note 140.

221. SMR was the situation before the FCC's announced "spectrum swap" with Nextel. See 2004 FCC CMRS Report, *supra* note 164, at 20,633–35.

considerable economic activity.<sup>222</sup> As seen in Table 5, U.S. consumers and businesses spent about \$4 billion on unlicensed services, equipment, and network infrastructure in 2003, most of which was attributable to cordless phones. Without attempting to quantify the social value of these purchases, we examine commensurate revenue data for more recent unlicensed allocations made by the FCC.

Since the 1985 reforms, the FCC has allocated three additional major blocks for unlicensed use.<sup>223</sup> While the results of the 255 MHz unlicensed allocation at 5 GHz are too recent to be captured in the annual data displayed in Table 5, the previous allocations at 1.9 GHz, 2.39 GHz, and 5.2 GHz are of interest. Economic activity, as proxied by revenues, is dramatically lower in these bands as compared to the previous unlicensed allocations at 900 MHz and 2.4 GHz, as shown in Table 11.<sup>224</sup>

TABLE 11. Economic activity across unlicensed allocations<sup>225</sup>

<i>Band</i>	<i>Bandwidth (MHz)</i>	<i>2003 Revenues (\$ bil)</i>	<i>Rev/bandwidth (\$bil/MHz)</i>	<i>Ratio of Marginal to Infra-marginal</i>	<i>Discount (Marginal from Infra-marginal)</i>
900/2.4 GHz (infra-marginal)	109.5	4.162	0.038	—	—
1.9 GHz, 2.39 GHz (as of 1993)	30	0.06	0.003	0.078	92%
5 GHz (most as of 1997)	325	0.228	0.00070	0.02	98%

These data suggest that there is relatively little economic activity associated with additional unlicensed spectrum. Before concluding that this

222. This deregulatory action was spearheaded by FCC engineer Michael Marcus. The reform was controversial, but Marcus is now labeled a “visionary.” See *Brief History*, *supra* note 99.

223. The rules that permitted unlicensed spread spectrum devices specifically affected the allocations at 902–928 MHz, 2400–2483.5 MHz, and 5.725–5.850 GHz. Carter et al., *supra* note 99, at 7. The 50 MHz allocated at 3650 MHz for unlicensed use is currently the subject of an FCC reconsideration.

224. We attribute all 5.8 GHz economic activity to the later 5 GHz allocations, given data availability. This biases such activity in favor of the new marginal unlicensed spectrum.

225. See *supra* Part III, tbl.5.

implies low demand for new unlicensed bandwidth, we consider other explanations. First, the recent unlicensed allocations may involve less desirable frequencies. Generally, wireless applications are less expensive when using lower frequencies, as radio signals tend to fade more rapidly in higher bands. The ease with which lower frequencies are received over wider areas, and through walls, often aids network design. The importance of frequency reuse, however, means that higher frequencies also have some advantages. The tradeoffs are summarized thus:

The value of radio spectrum depends strongly on the frequency range. The low frequencies (below 3 GHz) are considered the most valuable part. This is because the propagation characteristics of the low frequency radio waves enable wide-area coverage. Also the availability of RF components for low frequencies is better because of mature technologies. However, the frequencies below 1 GHz require larger physical size of antennas and other components. Therefore the best frequency band for small size portable wireless devices is in practise between 1 and 3 GHz. For very small cells frequencies up to 10 GHz can be used supporting high capacity but propagation through walls and behind the corners is getting poor as well as the RF technologies for high frequencies are more expensive. High frequencies are also suitable for unlicensed operation because the poor propagation is in this case an advantage, which reduce [sic] the need for cell and frequency planning.<sup>226</sup>

The spectrum allocated to unlicensed PCS services is highly valued for mobile phone service offered via EAFUS bandwidth. These frequencies lie below the 2.4 GHz unlicensed band popular for use by cordless phones and Wi-Fi devices. U-PCS spectrum, divided into three 10-MHz blocks, may constrain usage due to inadequate scope, but this would vividly contrast with the value attached to 10-MHz PCS licenses—recently estimated by the FCC to equal \$4.8 billion for nationwide coverage.<sup>227</sup> Moreover, were narrow bandwidth a distinct constraint, this would imply that the 300 MHz of unlicensed spectrum available at 5 GHz would be extremely hospitable for wireless services.

Second, limited investment in new unlicensed bands might be explained by overly restrictive FCC regulation. In particular, the U-PCS

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226. Timo Ali-Vehmas, *Scarcity of Licensed Spectrum for Mobile 2* (2004) (unpublished manuscript), available at [http://keskus.hut.fi/opetus/s38042/s04/Presentations/17112004\\_Ali-Vehmas/Ali-Vehmas\\_paper.pdf](http://keskus.hut.fi/opetus/s38042/s04/Presentations/17112004_Ali-Vehmas/Ali-Vehmas_paper.pdf). See also William Lehr, *Economic Case for Dedicated Unlicensed Spectrum Below 3 GHz* 14–17 (May 17, 2004) (unpublished manuscript), available at [http://itc.mit.edu/itel/docs/2004/wlehr\\_unlicensed\\_doc.pdf](http://itc.mit.edu/itel/docs/2004/wlehr_unlicensed_doc.pdf) (discussing “important differences in the usefulness of spectrum at different frequencies”).

227. 2004 FCC CMRS Report, *supra* note 164, at 20,635.

band is widely acknowledged to be a failed policy experiment,<sup>228</sup> with not a single data device having been approved for use by the FCC.<sup>229</sup> The FCC is reallocating 10 MHz of this band.<sup>230</sup> The remaining 20 MHz of U-PCS band is used sparingly in comparison to either licensed PCS or unlicensed 2.4 GHz bands.<sup>231</sup>

FCC governance rules, however, are not exogenous to unlicensed allocations, but rather, are necessary components. Regulatory constraints substitute for rules imposed by de facto spectrum owners. Mandates imposed, like the “listen before talk” protocol required for U-PCS devices,<sup>232</sup> are precisely the sort of rules that “opportunistic” wireless devices are designed to adopt. The argument that advances in wireless technology bolster the case for additional unlicensed allocations incorporates the logic that spectrum sharing can be efficiently achieved with just such rules.

Thus, low investment and utilization of the new unlicensed bands is not explained either by propagation characteristics or exogenous factors limiting use. Instead, we are forced to conclude that economic demand for unlicensed bandwidth, as contrasted with political advocacy within the regulatory system, appears low. This coheres with our earlier observation that unlicensed use tends to be best managed in localized applications.

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228. A coalition of unlicensed spectrum advocates recently told the FCC that “[t]he unlicensed PCS band did not succeed because of regulatory failure . . . .” Reply Comments of New Am. Found. et al. at 17, *In re* Additional Spectrum for Unlicensed Devices Below 900 MHz & in the 3 GHz Band, No. 02-380 (FCC May 16, 2004), available at [http://gulfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native\\_or\\_pdf=pdf&id\\_document=6514088951](http://gulfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6514088951). FCC policy analyst Kenneth Carter offers this assessment: “The future of unlicensed PCS is uncertain at best. . . . Given the lack luster performance of the service, the Commission has initiated several proceedings seeking to allocate the band to higher, better uses . . . .” Kenneth R. Carter, *Policy Lessons from Personal Communications Services: A Hohfeldian Analysis of Licensed vs. Unlicensed Spectrum Access* 17–18 (2004) (unpublished manuscript, on file with author).

229. “There are currently 27 original equipment authorizations for U-PCS devices authorized to operate under Part 15D; however, none of these are authorized to operate in the 1910–1920 MHz band.” *Id.* at 15.

230. The FCC is now attempting to reallocate at least 10 MHz of unlicensed PCS spectrum to licensed services due to lack of utilization. *See* Sixth Report, *supra* note 105.

231. There are only 400,000 users of devices in the U-PCS voice band. This compares to about 130 million cordless phones overall. *See* Comments of Motorola, *supra* note 106, at 20; Carter et al., *supra* note 99, at 22.

232. As Carter notes,

The FCC’s rules governing Unlicensed PSC [sic] devices are similar in most major respects to other Part 15 devices, such as their low power restrictions, requirement that they not cause harmful interference, and must accept all interference they receive. However, the FCC imposed several other service rules on the devices operating in the 1910–1930 band. Foremost are the rules requiring U-PCS devices to monitor the spectrum prior to transmitting. This was because the FCC believed that with these rules U-PCS systems can share with Broadband PCS without causing harmful interference to those systems.

Carter, *supra* note 228, at 15.

Where users are geographically separated via power limits, they are then able to utilize short-range applications without the assistance of network coordination. Multiple sources of radio emissions, from devices used within the home or office, can also be mitigated at relatively low cost. Additional services may be produced as users coordinate devices without having to deal with numerous other parties. In such a setting, wireless consumers effectively internalize the gains they create by switching channels, altering power levels, focusing emissions (say, pointing beams in lieu of omni-directional transmissions), or investing in equipment that coordinates better with other devices. In situations less susceptible to individual control, the incentive to pay for improved reception is present, but the incentive to improve the reception of others is not. The obvious example is the use of higher power, which improves one party's reception while producing spillovers reducing the opportunities enjoyed by others.

The advantages afforded by additional unlicensed bandwidth appear small, as is the opinion of some of those most bullish on the value of license-free services. For example, "Dewayne Hendricks, boss of Dandin Group, a wireless internet-access provider, does not care whether governments open up more spectrum because, 'all the spectrum we need is already in play.'"<sup>233</sup> This echoes the view of Alvarion, the leading seller of wireless broadband equipment used in unlicensed bands.<sup>234</sup>

And it reflects the marketplace experience of Korea, a country featuring more public Wi-Fi hotspots per capita than any other nation.<sup>235</sup> The extensive network of access points is funded by both fixed and wireless telecommunications providers, most notably Korea Telecom ("KT"). Only 2.4 GHz bandwidth is employed; 5 GHz frequencies are unused. Indeed, the Korean government has allocated only 100 MHz for license-exempt devices in the 5 GHz band, having yet to allocate the additional 455 MHz made available by the U.S. since 1997. Yet, Korean deployment of advanced wireless technologies is robust; KT alone reported 360,000 Wi-Fi customers at year-end 2003.<sup>236</sup> This suggests that the

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233. *On the Same Wavelength—Spectrum Policy*, ECONOMIST, Aug. 14, 2004, at Special Report.

234. *See supra* notes 157–58 and accompanying text.

235. Moon Ihlwan, *Half the World's Hot Spots*, BUSINESS WK., Apr. 28, 2003, at 53.

236. KT Corp., Annual Report (Form 20-F), at 23 (June 25, 2004). KT offers a monthly subscription to DSL customers for an incremental fee of \$11.50 a month. John Latta, *Broadband Wireless World 2003*, WAVE REP., Apr. 9, 2003, <http://www.wave-report.com/archives/2003/03180201.htm>. This entitles a subscriber to use KT's Nespot network of over 16,000 Wi-Fi hotspots. Kim Tae-gyu, *Korea's Wireless Internet Market Explodes*, KOREA TIMES, Nov. 5, 2004, available at <http://times.hankooki.com/lpage/tech/200411/kt2004110418252711800.htm>.

marginal unlicensed spectrum allocations are of little value in economically achieving more widespread use of Wi-Fi.

Conversely, the opportunity costs of additional EAFUS allocations are demonstrably large. This can be quantified by estimating the potential damage in transferring underlay rights from CMRS licensees in the INTEM Notice, as in the analysis above. The value of adding bandwidth in CMRS markets has also been estimated. In a model using quarterly mobile phone data from twenty-nine countries, Thomas Hazlett and Roberto Muñoz find that additional bandwidth has a large and statistically significant effect in reducing the price of mobile phone usage.<sup>237</sup> The model estimates, for example, that were the United States to expand its CMRS allocation from its current utilization of about 170 MHz to 230 MHz, per-minute prices would drop from about eleven cents to just over nine cents.<sup>238</sup> Assuming an estimated demand elasticity of approximately -2.0, this implies annual consumer gains of approximately \$24 billion.<sup>239</sup>

These results are consistent with other empirical measures. A recent study conducted by former FCC Chief Economist Simon Wilkie estimated that the consumer surplus that would be realized by utilizing an additional 30 MHz of nationwide PCS spectrum in the United States was between \$7.0 billion and \$16.6 billion per year.<sup>240</sup> The midpoint of this range, \$11.8 billion, is almost exactly one-half the estimated consumer surplus projected by Hazlett and Muñoz for a 60 MHz increment. In 2002, a United Kingdom regulatory authority estimated that annual consumer welfare associated with mobile phone spectrum totaled about £13 billion (equivalent to about \$23 billion in early 2006).<sup>241</sup> While not focused on the marginal value of bandwidth, the estimate is about twice the magnitude of social gains estimated for CMRS spectrum in the United States when scaled to reflect the size of the respective economies, corroborating the conservative estimation technique used in the above analysis.<sup>242</sup>

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237. See Thomas W. Hazlett & Robert E. Muñoz, *What Really Matters in Spectrum Allocation Design* (AEI-Brookings Joint Ctr. for Regulatory Studies, Working Paper No. 04-16, 2004), available at <http://www.aei-brookings.org/admin/authorpdfs/page.php?id=1025>.

238. *Id.* at 32.

239. *Id.*

240. Declaration of Simon Wilkie at 16–17, *In re Broadband PCS Spectrum Auction Scheduled for Jan. 12, 2005*, No. DA 04-1639 (FCC July 30, 2004). In addition, Wilkie estimates lost producer surplus for a loss of 30 MHz in PCS bandwidth at approximately \$538 million per year. See *id.* at 18–19.

241. RADIOCOMMUNICATIONS AGENCY, *supra* note 167, at 5.

242. Above we estimated 2003 consumer surplus to be at least approximately \$80 billion. See *supra* note 122 and accompanying text. United Kingdom GDP in 2005 is estimated to equal \$1.87 trillion, as against U.S. GDP of \$12.37 trillion. CIA—The World Fact Book—Rank Order—GDP,

Prices for PCS licenses in the United States have not diminished over the past decade. In March 1995 the auction of PCS A and B licenses concluded with winners paying about \$7.7 billion in total.<sup>243</sup> This translated into an average price per MHz per person (in the area of each license) of about \$0.52.<sup>244</sup> Above we presented data on current market valuations implying that PCS licenses today sell for approximately \$1.60 per MHz per person.<sup>245</sup> Hence, the incremental value of CMRS licenses appears robust.

Capital markets continue to fund the expansion of wireless networks using licensed spectrum. Currently, three national carriers—Cingular,<sup>246</sup> Sprint-Nextel,<sup>247</sup> and Verizon Wireless<sup>248</sup>—are engaged in billion-dollar network upgrades, enabling them to offer nationwide wireless broadband service. Overall, U.S. mobile carriers spend about \$20 billion annually in capital infrastructure.<sup>249</sup>

In contrast, investment in wide-area networks using newly available unlicensed bands is de minimis. Even with both the robust growth in unit sales of Wi-Fi equipment and 200 MHz of new unlicensed spectrum allocated in the 5 GHz band, specifically to encourage wireless broadband, total U.S. sales of wireless broadband equipment (base stations and customer premises equipment used by WISPs) equaled just \$85 million in 2003.<sup>250</sup> Whatever the “tremendous success” of Wi-Fi may be,<sup>251</sup> it has not extended to newly allocated unlicensed bandwidth or to wide-area broadband applications. Moving marginal spectrum from liberally regulated licensed spectrum to unlicensed allocations would then be likely to sacrifice highly valued uses in favor of opportunities with much less consumer value. This also implies that, rather than imposing underlays in

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<http://www.cia.gov/cia/publications/factbook/rankorder/2001rank.html> (last visited Apr. 3, 2006). The value of wireless phone service in the United Kingdom, scaled to U.S. levels, then equals about \$152 billion.

243. Peter Cramton, *The FCC Spectrum Auctions: An Early Assessment*, 6 J. ECON. & MGMT. STRATEGY 431, 453 (1997).

244. *Id.* at 479 tbl.8.

245. This uses the FCC's valuation of \$4.8 billion for a PCS license allocated 10 MHz of nationwide spectrum, and assumes a U.S. population equal to 300 million.

246. “Cingular did not say how much it would cost to upgrade its network. Industry executives said it could cost around \$1 billion, though that figure did not include other enhancements to the underlying network that may cost the company significantly more.” Richtel, *supra* note 168.

247. *Wireless Consolidates*, *supra* note 201, at 3.

248. Eric Hellweg, *Verizon's \$1B Upgrade*, CNN MONEY, Jan. 12, 2004, <http://money.cnn.com/2004/01/12/technology/techinvestor/hellweg/>.

249. *See supra* Part III, tbl.5.

250. *Wireless Wonderland*, *supra* note 109.

251. Notice of Inquiry, *In re* Additional Spectrum for Unlicensed Devices Below 900 MHz & in the 3 GHz Band, 17 F.C.C.R. 25,632, 25,634–35 (2002).

licensed bands featuring traditional regulation, regulators consider expanding exclusively assigned rights to achieve the relatively high social returns obtained with CMRS licenses.

## VI. SPECTRUM SHARING AND THE COASE THEOREM

The classic 1959 analysis of radio spectrum rights and the FCC offered by Ronald Coase<sup>252</sup> is directly relevant to the interference temperature, particularly when the famous extension of that analysis—the Coase Theorem<sup>253</sup>—is considered. In his article on the FCC, Coase considered the question of spectrum allocation and critiqued the view that government had to strictly regulate radio use in order to maintain order in the airwaves.

Coase made three basic showings. First, he established that property rights were the key institutional device in preventing dissipation of resource value. Such rights exclude certain activities (without permission of a resource owner), thereby limiting conflicts among rival users. Second, he demonstrated that awarding property rights is what the government effectively did in awarding wireless licenses. Despite being effective in averting certain common-pool tragedies, the traditional licensing regime burdened users with rigid rules that made it unlikely for interference reduction benefits to be obtained at the lowest cost. Finally, he made it clear that, were exclusive frequency ownership rights distributed via the price system, decentralized decisionmakers could transact to discover the efficient levels of spectrum use (and interference).

The seeds of the Coase Theorem are found in a discussion of how the optimal level of radio interference is discovered: “It is sometimes implied that the aim of regulation in the radio industry should be to minimize interference. But this would be wrong. The aim should be to maximize output.”<sup>254</sup> Conflicting uses in radio are not just inevitable, but *desirable*; an efficient outcome obtains when the value gained by one use is equal at the margin to the loss in value due to interference from that use. The practical issue is how to properly assess the tradeoffs.

The theoretical possibility of liberal, flexible-use spectrum rights (what we call “EAFUS”) played an important analytical role here. Coase made a normative argument for assigning EAFUS rights on the grounds

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252. Coase, *supra* note 3.

253. R.H. Coase, *The Problem of Social Cost*, 3 J.L. & ECON. 1 (1960).

254. Coase, *supra* note 3, at 27.

that information about efficient tradeoffs best comes when decentralized spectrum owners control resource use:

It is clear that, if signals are transmitted simultaneously on a given frequency by several people, the signals would interfere with each other and would make reception of the messages transmitted by any one person difficult, if not impossible. The use of a piece of land simultaneously for growing wheat and as a parking lot would produce similar results. . . . [T]he way this situation is avoided is to create property rights (rights, that is, to exclusive use) in land. The creation of similar rights in the use of frequencies would enable the problem to be solved in the same way in the radio industry.<sup>255</sup>

Coase embarks on a discussion of the importance of negotiations and contracts between rights holders who strive, out of self-interest, to produce efficient levels of interference. This analysis led to an epiphany, one that struck even free-market Chicago School economists as incorrect:<sup>256</sup>

The advantage of establishing exclusive rights to use a resource when that use does not harm others (apart from the fact that they are excluded from using it) is easily understood. However, the case appears to be different when it concerns an action which harms others directly. For example, a radio operator may use a frequency in such a way as to cause interference to those using adjacent frequencies.

. . . .

. . . [T]here is no analytical difference between the right to use a resource without direct harm to others and the right to conduct operations in such a way as to produce direct harm to others.<sup>257</sup>

Coase is not suggesting that all liability rules are equally efficient. In fact, the logic leads him to favor EAFUS and a rule protecting well-defined frequency spaces: “[B]y delimiting the rights of operators to transmit

255. *Id.* at 25–26.

256. In the late George Stigler’s account, Coase had “rather casually” criticized conventional microeconomics “in the course of a masterly analysis of the regulatory philosophy underlying the Federal Communications Commission’s work,” and that “Chicago economists could not understand how so fine an economist as Coase could make so obvious a mistake.” GEORGE J. STIGLER, MEMOIRS OF AN UNREGULATED ECONOMIST 75 (1988). Coase, then a professor at the University of Virginia, was invited to return to Chicago to explain his analysis further:

[W]hatever the assignment of legal rights of ownership, [Coase asserted,] the assignments would have no effect upon the way economic resources would be used! We strongly objected to this heresy. Milton Friedman did most of the talking, as usual. He also did much of the thinking, as usual. In the course of two hours of argument the vote went from twenty against and one for Coase to twenty-one for Coase. What an exhilarating event! I lamented afterward that we had not had the clairvoyance to tape it.

*Id.* at 76.

257. Coase, *supra* note 3, at 26.

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signals which interfere, or might potentially interfere, with those of others . . . it can be left to market transactions to bring an optimum utilization of rights.”<sup>258</sup> To achieve efficient transactions, where parties trade away less valuable opportunities in order to gain additional value, negotiators are needed. The standard approach in a market economy is to enable property owners, who can exclude some activities while favoring others. Competition among such actors creates the market forces that promote both maximization of welfare at a given point in time and economic growth over time.

The attempt to impose an interference temperature is a rejection of the Coase Theorem. With secure, expansive, and exclusive rights to use radio spectrum, property owners pursue profit incentives to establish optimal sharing arrangements. A firm with ownership of a band seeks to develop its use, coordinating alternative deployments so as to maximize returns. Under the pressure of rival spectrum, owners this dynamic process iterates on productive technologies, networks, and applications. The gains from more of one kind of use are weighed against opportunities to pursue other, potentially conflicting, uses.

The interference temperature substitutes for this process an administrative rulemaking that determines how interference should be increased, how it should be monitored, and how the rival parties should be afforded protection from the conflicting economic activities pursued by others. Given the extremely wide dispersal of rights to underlay users, market renegotiation will typically be impossible. Government regulators dictate resource allocation rules, excluding market mechanisms.

## VII. CONCLUSION

Traditional regulatory structures have created bottlenecks in wireless markets, blocking advanced technologies and leaving spectrum seriously misallocated. In limited instances, policymakers have moved to liberalize spectrum use. These progressive steps have occurred in both licensed and unlicensed bands, with social benefits resulting in both.

Recently, however, U.S. regulators have veered away from the property-rights path to liberalization. The rationale offered is one of technological determinism: emerging wireless systems dictate increased spectrum sharing on the “spectrum commons” model. The interference temperature concept is one of a number of FCC proposals that seeks to

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258. *Id.* at 27.

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promote advanced wireless technologies by enabling greater access to unlicensed radio spectrum. These initiatives are deemed to promote deployment of wide-area broadband networks and to accommodate the emergence of radios that are more agile in their use of radio frequencies.

The official position of many interested parties, and of the FCC, is that both licensed and unlicensed allocations are called for. Yet it has already been established that both kinds of allocation exist. The issue now is how to get additional bandwidth most productively utilized by the myriad wireless innovations that consumers would like to try. Since 120 MHz was allocated for PCS licenses in a proceeding which officially began in 1990, virtually no frequency space in the most valuable bands below 10 GHz have been allocated with exclusively assigned flexible-use rights. Meanwhile, in the 5 GHz band, an additional 200 MHz was designated for unlicensed use in 1997, with 255 MHz more opened to unlicensed devices in 2003. The FCC, ignoring a 1996 proposal by U.S. Senator Larry Pressler (then Chair of the Commerce Committee) to reallocate TV band spectrum using exclusively assigned overlay rights, issued a 2004 proposal to pursue the opposite tact: determining administratively how underlay rights can be issued to unlicensed users without creating “harmful interference” for television broadcasters.<sup>259</sup> And, in another clear expression of its policy preferences, the FCC has proposed transferring white spaces productively used by CMRS licensees to unlicensed device users under an interference temperature which is set, monitored, and adjusted by regulators.

The economic evidence points to two fundamental errors in this regime. First, within the existing allocation framework, consumer interests are poorly balanced. Additional allocations of exclusively assigned liberal rights would have an extremely high value to wireless users, whereas marginal gains from the additional unlicensed initiatives pursued by the FCC are likely to be far less significant. Indeed, the most easily identified deficiency in U.S. spectrum policy is a dearth of licensed spectrum for cellular and PCS competitors, a shortfall that deprives consumers—under

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259. See Statement of Chairman Michael K. Powell, FCC Proposes Rules to Facilitate Wireless Broadband Servs. Using Vacant TV Channels, No. 02-380, 2004 WL 1066335, at \*2 (FCC May 13, 2004). The regulatory issues in overlay and underlay rights are highly asymmetric. With an exclusively assigned overlay right, a de facto bandwidth owner is awarded the right to use unoccupied frequency space subject to protection of the transmissions of incumbent users. The new overlay owner and the incumbent licensees can then bargain to produce efficient outcomes. With unlicensed underlays awarded, negotiation between the new users and incumbent licensees is prohibitively expensive; with open entry into unlicensed uses, the rights are too widely dispersed to be assembled in a negotiation. Hence, government regulation is the necessary substitute, and this solution necessarily sacrifices the discovery process revealing efficient exchanges in radio space.

very modest assumptions—of tens of billions of dollars annually in lost benefits.

Second, the institutional framework under which reforms are considered continues to employ command and control at its core. While touting the advantages of deregulatory steps allowing licensed and unlicensed spectrum use to provide additional service to the public, the FCC continues to determine which new bands should be made available for use, and what model of governance will be available to each. This approach fails to incorporate the logic of the Coase Theorem—that decentralized markets can effectively substitute for administrative allocation where competitors are vested with resource ownership.

Improvements in wireless devices have not eliminated, and instead may have intensified, the demand for government-mandated power limits and other behavioral rules (for example, etiquettes and protocols) in unlicensed bands. These coordinating mechanisms are costly. They exclude innovative wireless alternatives, particularly networks optimized to offer wide-area applications via exclusive spectrum rights. Ongoing market experiments reveal that these networks attract robust investment, incorporate smart radio design, stimulate further technological advances, and drive competitors to expand deployments. The economic activity generated with exclusively assigned flexible-use spectrum rights produces social value that dominates alternative forms of organization.

The coordination provided by effective spectrum owners offers an alternative to coordination provided by government regulation of unlicensed devices. In some applications, power limits and technology mandates allow valuable applications to emerge. These tend to occur when users do not extensively share spectrum in complex ways, most often due to spatial separation of short-range uses, but also due to limited congestion in areas of sparse economic activity. Often, users can adjust to traffic congestion by adopting measures that better sort communications, but these solutions are not costless. Moreover, when users adjust to obtain better performance, they have incentives which are distinct from a spectrum owner who has a greater ability—through added property rights—to capture the gains created from reducing damage inflicted on others. Unlicensed users could capture these gains were negotiations simple and free-riders sparse. But the unlicensed regime awards common rights to a large class of potential spectrum users, and thus bargains—except in very localized applications, where real property ownership may function as a proxy for exclusive spectrum rights—are relatively difficult. Regulators, not markets, set parameters.

In the regulatory proposal to impose new unlicensed spectrum allocations examined here, the evidence is that the social costs of a mandated “spectrum commons” are highly likely to far outweigh benefits. This calculation is made possible by the specifics of the interference temperature proceeding, and the observation of existing wireless networks using flexible-use, exclusively assigned spectrum in the cellular phone market. Spectrum that is wasted under traditional regulation can be highly productive under a liberal private property regime. Market data strongly suggest that inserting new spectrum-sharing requirements by regulation would introduce relatively low-valued opportunities for unlicensed devices, and would impose relatively costly damage on the operators and customers of CMRS networks—ironically reducing the value that advanced wireless technologies deliver via more intense sharing of radio frequencies.

