LIKE DECK CHAIRS ON THE TITANIC: WHY SPECTRUM REALLOCATION WON'T AVERT THE COMING DATA CRUNCH BUT TECHNOLOGY MIGHT KEEP THE WIRELESS INDUSTRY AFLOAT

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ABSTRACT

Skyrocketing mobile data demands caused by increasing adoption of smartphones, tablet computers, and broadband-equipped laptops will soon swamp the capacity of our nation's wireless networks, a fact that promises to stagnate a $1 trillion slice of the nation's economy. Among scholars and policymakers studying this looming "spectrum crisis," consensus is developing that regulators must swiftly reclaim spectrum licensed to other industries and reallocate those rights to wireless providers. In this interdisciplinary piece, we explain in succinct terms why this consensus is wrong. With data demands increasing at an exponential rate, spectrum reallocation plans that promise only linear growth are destined to fail. What regulators should focus on, instead, are policies that encourage the sluggish incumbents presently dominating the wireless industry to roll out new networking technologies (like tiered network architectures, cognitive radio, and multicell MIMO) that together may allow exponential increases in spectral efficiency.

INTRODUCTION

Americans have a seemingly insatiable appetite for wireless bandwidth. Global mobile data traffic has grown at an annual rate exceeding 140 percent each year since 2008, and it is predicted to increase another 26-fold by 2015.[1] Spurred by increasing adoption of smartphones and tablet

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1. CISCO VISUAL NETWORKING INDEX: GLOBAL MOBILE DATA TRAFFIC FORECAST UPDATE,

computers, growth in the U.S. has outpaced worldwide averages, with domestic wireless providers like AT&T reporting a 30-fold increase in traffic between 3Q 2009 and 3Q 2010 alone.[2] For the foreseeable future, it seems, mobile data demands will continue their exponential growth as users increasingly access multimedia, especially long-form HD video, and other data-intensive applications via mobile devices.[3]

Unfortunately, the capacity of the nation's wireless networks is not infinite. According to wireless providers, within spectrum bands allocated for commercial broadband use, increased competition for scarce bandwidth among mobile users will eventually lead to service bottlenecks that degrade network performance or worse.[4] With more and more

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2010–2015, at 5 tbl. 3 (2011), *available at* http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.pdf [hereinafter CISCO VISUAL NETWORKING INDEX]; *see also* CODA RESEARCH CONSULTANCY, US MOBILE BROADBAND: BEHAVIOR, CONTENT AND FORECASTS, 2009–2015 (2009) [hereinafter CODA RESEARCH] (predicting roughly 35-fold growth between 2009 and 2014); YANKEE GROUP, SPECTRUM-RICH PLAYERS ARE IN THE DRIVER'S SEAT FOR MOBILE BROADBAND ECONOMICS (2009) (predicting roughly 24-fold growth between 2009 and 2014); FCC, OMNIBUS BROADBAND INITIATIVE (OBI), MOBILE BROADBAND: THE BENEFITS OF ADDITIONAL SPECTRUM, OBI TECHNICAL PAPER NO. 6, at 5 (2010), *available at* http://transition.fcc.gov/Daily_Releases/Daily_Business/2010/db1021/DOC-302324A1.pdf [hereinafter OBI TECHNICAL PAPER NO. 6] (concluding that "mobile data demand is expected to grow between 25 and 50 times current levels within 5 years"); Randall Stephenson, Chairman, CEO, & Pres., AT&T, Presentation to Investors, slide 8 (Mar. 2011), http://www.att.com/Common/about_us/pdf/INV_PRES_3-2111_FINAL.pdf (predicting more modest, but still significant, growth of 8 to 10-fold between 2011 and 2015).

2. *See* CISCO VISUAL NETWORKING INDEX, *supra* note 1, at 3 tbl. 1; Kris Rinne, Sr. Vice Pres. of Architecture & Planning, AT&T, Remarks at the FCC Spectrum Workshop 11–12 (Sept. 17, 2009), *available at* http://www.broadband.gov/docs/ws_25_spectrum.pdf ("AT&T, over the last 3 years, has seen a 5,000 percent increase in our wireless data usage . . . ."); *see also* NAT'L SCI. FOUND., FINAL REPORT ON THE WORKSHOP ON ENHANCING ACCESS TO THE RADIO SPECTRUM 1 (2010), *available at* http://www.nsf.gov/mps/ast/nsf_ears_workshop_2010_final_report.pdf [hereinafter ENHANCING ACCESS TO THE RADIO SPECTRUM] ("Since the release of the latest generation of smart phones, . . . data traffic on some mobile networks has increased by over 6000%."); Press Release, International Data Corp., Worldwide Smartphone Market Expected to Grow 55% in 2011 and Approach Shipments of One Billion in 2015, According to IDC (June 9, 2011), *available at* http://www.idc.com/getdoc.jsp?containerId=prUS22871611 (documenting exponential growth in smartphone sales).

3. In 2010, video accounted for almost half of all mobile data traffic, a percentage that is projected to grow in the future. CISCO VISUAL NETWORKING INDEX, *supra* note 1, at 1; CODA RESEARCH, *supra* note 1, at 4 ("Video traffic . . . will form nearly two thirds (63%) of mobile broadband traffic by 2015."). Moreover, the popularity of social networking has contributed to an explosion in the number of users accessing broadband video games. David Kushner, *Facebook vs. Google: Game On*, IEEE SPECTRUM, June 2011, http://spectrum.ieee.org/consumer-electronics/gaming/facebook-vs-google-game-on/0 (noting that the worldwide gamer population skyrocketed from 200 million in 2001 to 1 billion in 2011).

4. *See, e.g.*, Holman W. Jenkins, Jr., *AT&T's Big Bet on Spectrum Folly: The Merger Between AT&T and T-Mobile is a Vote of Impatience with Washington's Proposed Fix for the Mobile Spectrum Crisis*, WALL ST. J., Mar. 23, 2011, http://online.wsj.com/article/SB10001424052748703858404576214583761791412.html (noting that "AT&T['s] . . . network in New York is sagging from all its iPhone

wireless users clamoring for more and more bandwidth each year, wireless providers warn that the wireless industry will soon lack the spectrum resources sufficient to satisfy users' demands, a looming "spectrum crunch"[5] that many promise will stagnate an industry that grossed almost $160 billion in 2010.[6]

To date, scholars studying the root causes of spectrum overcrowding have focused exclusively on the efficiency of FCC regulations dividing ownership of the airwaves.[7] Scholarly consensus suggests that the upcoming crunch is predominantly, if not purely, the result of the FCC's failure to place spectrum in the hands of society's highest value users. Accordingly, calls for the government to transfer spectrum licenses from presumed low value users—namely, over-the-air television broadcasters and the government itself—to wireless providers have completely dominated policy debates. For years, virtually every scholarly article analyzing spectrum policy has called for the FCC to strip TV broadcasters of some or all of their spectrum allocation[8] and for the government to open

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users" and quoting FCC Chief Julius Genachowski: "The spectrum crunch is real. If we don't do something about it we'll face lousy service and sky-high consumer prices.").

5. *See, e.g.*, Julius Genachowski, Chairman, FCC, Mobile Broadband: A 21st Century Plan for U.S. Competitiveness, Innovation and Job Creation, Remarks at the New Am. Found. (Feb. 24, 2010), *available at* http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-296490A1.pdf (using the terms "spectrum crunch" and "spectrum crisis"); Mitchell Lazarus, *The Great Radio Spectrum Famine*, IEEE SPECTRUM, Oct. 2010, http://spectrum.ieee.org/telecom/wireless/the-great-radio-spectrum-famine (using the term "spectrum famine").

6. *See Wireless Quick Facts: Mid-Year Figures*, CTIA-THE WIRELESS ASSOCIATION, http://www.ctia.org/media/industry_info/index.cfm/AID/10323 (last visited Jan. 28, 2012); ENHANCING ACCESS TO THE RADIO SPECTRUM, *supra* note 2, at 1 ("[E]stimates of the domestic economic impact of wireless technology approach[] $1 trillion annually . . . .").

7. *See* 47 C.F.R. § 2.106 (2010) (setting forth in tabular format all radio frequency allocations).

8. *See, e.g.*, Thomas M. Lenard et al., *Increasing Spectrum for Broadband: What are the Options?*, 1030 PLI/Pat 611 (2010); Karen R. Sprung, Note, *Broadcast v. Broadband? A Survey of the Reallocation of Broadcast Spectrum for Wireless Broadband*, 19 MEDIA L. & POL'Y 238 (2010); FCC, OMNIBUS BROADBAND INITIATIVE (OBI), SPECTRUM ANALYSIS: OPTIONS FOR BROADCAST SPECTRUM, OBI TECHNICAL PAPER NO. 3 (2010), *available at* http://download.broadband.gov/plan/fcc-omnibus-broadband-initiative-(obi)-technical-paper-spectrum-analysis-options-for-broadband-spectrum.pdf; Stuart M. Benjamin, *Roasting the Pig to Burn Down the House: A Modest Proposal*, 7 J. TELECOMM. & HIGH TECH. L. 95 (2009) [hereinafter Benjamin, *Roasting the Pig*]; Comment of Thomas W. Hazlett, *Unleashing the DTV Band: A Proposal for an Overlay Auction* (Dec. 18, 2009) (in response to *Data Sought on Public Uses of Spectrum*, GN Docket Nos. 09-47, 09-51 & 09-137, NBP Public Notice #26, 24 FCC Rcd. 14275) [hereinafter *Unleashing the DTV Band*]; COLEMAN BAZELON, THE BRATTLE GROUP, THE NEED FOR ADDITIONAL SPECTRUM FOR WIRELESS BROADBAND: THE ECONOMIC BENEFITS AND COSTS OF REALLOCATIONS (2009); Adam Thierer & Barbara Esbin, *An Offer They Can't Refuse: Spectrum Reallocation That Can Benefit Consumers, Broadcasters and the Mobile Broadband Sector*, 5 PROGRESS SNAPSHOT, no. 13, Nov. 2009; Stuart M. Benjamin, *Evaluating the Federal Communication Commission's National Television Ownership Cap: What's Bad for Broadcasting is Good for the Country*, 46 WM. & MARY L. REV. 439 (2004); *see also* Kathryn A. Watson, Note, *White Open Spaces: Unlicensed Access to Unused Television Spectrum Will*

some of its own reserves for public use,[9] which the government recently pledged to do.[10] Consensus, it would seem, has been established among economists, communications law scholars, lobbyists, and governmental regulators that spectrum reallocation can solve the problems created by ever increasing demand for bandwidth-intensive wireless services in the U.S.

In this Commentary, we explain why this consensus is wrong. Put simply, spectrum reallocation plans offer far too little, far too late. Problems stemming from *exponential* growth in mobile data needs[11] cannot be resolved by purely cellular solutions that scale *linearly*. Spectrum reallocation, therefore, is at best a temporary quick fix, not a long-term solution. If reallocation advocates get their wish, spectrum licensed for wireless broadband will increase by less than 200 percent.[12] Stacked against predictions of a 26-fold increase in mobile traffic in the next five years, a 3-fold expansion of available spectrum is exposed for what it is: woefully inadequate. Thus, while scholarship calling for spectrum reallocation is not per se unfounded,[13] this issue is almost certainly moot if current data trends continue or accelerate. At this time,

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Provide an Unprecedented Level of Interconnectivity, 2010 U. ILL. J.L. TECH. & POL'Y 181 (2010); Thomas W. Hazlett, *Tragedy T.V.: Rights Fragmentation and the Junk Band Problem* (George Mason Law & Economics Research Paper No. 10-03, 2010), *available at* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1533499.

9. *See, e.g.*, Lenard et al., *supra* note 8; Dale N. Hatfield, *The Challenge of Increasing Broadband Capacity*, 63 FED. COMM. L.J. 43, 56 (2010); Phillipa Marks & Brian Williamson, *Spectrum Allocation, Spectrum Commons and Public Goods: The Role of the Market*, COMM. & STRATEGIES, no. 67, Sept. 2007, at 65 ("Currently spectrum is not allocated to the most valuable uses, particularly the large amount of spectrum held for government use . . . ."); *see also* Benjamin Lennett & Sascha D. Meinrath, *Seven Key Options for Spectrum Allocation and Assignment*, 14 J. INTERNET L., no. 3, Sept. 2010 (proposing various other actions not related to reallocation).

10. In March 2010, the FCC recommended that 500 MHz of public and private spectrum should be reallocated for broadband use over the next decade. FCC, OMNIBUS BROADBAND INITIATIVE (OBI), CONNECTING AMERICA: THE NATIONAL BROADBAND PLAN 10, 75–76, 84–88, GN Docket No. 09-51 (2010) [hereinafter NATIONAL BROADBAND PLAN].

11. *See supra* note 1; *see also* Christine M. Crowe & Mark D. Schneider, *Major Wireless Policy Developments September 2009–September 2010*, 1030 PLI/Pat 183, 187 (2010); Charles M. Davidson & Michael J. Santorelli, *Seizing the Mobile Moment: Spectrum Allocation Policy for the Wireless Broadband Century*, 19 COMMLAW CONSPECTUS 1, 51–53 (2010); Hatfield, *supra* note 9, at 60.

12. *See infra* Part II.

13. Though a discussion of the costs and benefits of reallocation is beyond the scope of this Commentary, two of us have argued elsewhere that recent proposals to reallocate broadcast television spectrum for wireless cellular use are generally technically unsound. Many such proposals are based on International Telecommunications Union spectrum needs models that are highly sensitive. *See* Comment of James Krogmeier & David Love, *Technical Review: The Ongoing Need for Over-the-Air Broadcasting*, at 18–24 (Dec. 22, 2009), filed as Attachment A to Joint Comments of the Association for Maximum Service Television, Inc. & the National Association of Broadcasters (in response to *Data Sought on Public Uses of Spectrum*, GN Docket Nos. 09-47, 09-51 & 09-137, NBP Public Notice #26, 24 FCC Rcd. 14275).

proposals to reallocate spectrum among wireless providers, TV broadcasters, and government users—well-meaning as they might be—serve only as distractions that divert attention from other, potentially viable solutions.

In our view, now is the time for spectrum reallocation proposals to take a backseat to policy initiatives that encourage the rapid deployment of emerging network technologies that promise exponential growth in network capacity.[14] Rather than a "spectrum" crunch caused by inefficient resource management at the FCC, the wireless industry is first and foremost facing a "data" crunch caused by its own unwillingness to adopt new technologies capable of matching the high throughput mobile users require.[15] Instead of waging lengthy battles against current spectrum holders which so far have led to minimal gain, scholars and government regulators should hasten efforts to bring from theory to practice emerging technologies that promise drastic improvements in wireless data throughput and cross-technology solutions that bypass crowded spectrum altogether.[16] Until policy efforts are redirected toward fostering the rapid development of cutting edge network technology and such technologies are well on their way to widespread adoption, proposals to reallocate spectrum look an awful lot like well-intentioned plans to rearrange the deck chairs on a sinking ship.

I. THE SPECTRUM REALLOCATION DEBATE

Pointing to annual reports on the meteoric rise of cellular traffic, scholars have argued for the better part of a decade that the FCC should permit wireless broadband providers to takeover spectrum allocated to

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14. *See* Martin Cooper, *Personal Communications and Spectrum Policy for the 21st Century*, 31 TELECOMMUNICATIONS POLICY 566, 567–68 (2007) (observing that, thanks to continual innovation in networking technology, the "practical capacity of the radio spectrum" has doubled roughly every 30 months over the past 110 years).

15. *Cf.* UZOMA ONYEIJE, ONYEIJE CONSULTING LLC, SOLVING THE CAPACITY CRUNCH: OPTIONS FOR ENHANCING DATA CAPACITY ON WIRELESS NETWORKS (2011), *available at* http://www.nab.org/documents/newsRoom/pdfs/042511_Solving_the_Capacity_Crunch.pdf ("At some point in this policy debate, the word 'capacity' began to be used nearly synonymously with the word 'spectrum.' The conflation of these terms has led to a disproportionate emphasis on spectrum reallocation as a solution to capacity constraints although it is merely one method of achieving that result.").

16. Krogmeier & Love, *supra* note 13, at 18–24; *see also* Hatfield, *supra* note 9, at 61–62 (mentioning "microcells, picocells, and femtocells, as well as 'smart antennas' and outdoor Distributed Antenna Systems").

incumbents like television broadcasters and government users.[17] According to these scholars, the FCC has performed poorly as a steward of the nation's spectrum resources by failing miserably to place spectrum in the hands of society's highest value users. In this oft-repeated scholarly narrative, many non-cellular spectrum holders are portrayed as entrenched oligopolists. For example, television broadcasters are said to have successfully lobbied over the years to keep much of the same bandwidth they have controlled since the 1950s[18]—a "Mother Lode of underutilized radio spectrum" that may be "worth over $100 billion in license value and at least ten times that amount in Consumer Surplus"[19]—even though they have lost considerable market share over the years to cable and satellite TV providers.[20]

Accordingly, scholars have repeatedly called upon the government to take back spectrum from some existing holders, reallocate that spectrum for wireless broadband, and distribute licenses to wireless providers via auction.[21] Advocates of spectrum reallocation won a victory of sorts in

17. Calls for the FCC to transition spectrum licenses from television broadcasters to wireless providers date back as early as 2001. *See* Thomas W. Hazlett, *The Wireless Craze, the Unlimited Bandwidth Myth, the Spectrum Auction Faux Pas, and the Punchline to Ronald Coase's "Big Joke": An Essay on Airwave Allocation Policy*, 14 HARV. J.L. & TECH. 335 (2001); Stuart M. Benjamin, *The Logic of Scarcity: Idle Spectrum as a First Amendment Violation*, 52 DUKE L.J. 1 (2002). *See also* Jeffrey Silva, *TV Spectrum Could Convert to Wireless*, RADIO COMM. REP., July 8, 1996, http://www.rcrwireless.com/article/19960708/sub/tv-spectrum-could-convert-to-wireless/ (discussing a nascent FCC plan at the time to "reallocate TV channels 60 to 69 and make the spectrum available through competitive bidding for next-generation voice, data and video wireless services").

18. *See, e.g.*, *Unleashing the DTV Band*, *supra* note 8, at 5 fig. 1 (showing that over-the-air television broadcasters still utilize 294 MHz of the 486 MHz they were allotted in 1952).

19. *Id.* at 3–4. *See generally* Thomas W. Hazlett & Roberto E. Muñoz, *A Welfare Analysis of Spectrum Allocation Policies*, 40 RAND J. ECON. 424 (2009).

20. *See, e.g.*, David Goldman, *One in eight to cut cable and satellite TV in 2010*, CNNMONEY (Apr. 30, 2010, 10:08 AM), http://money.cnn.com/2010/04/30/technology/dropping_cable_tv/ (noting that "just over 90% of U.S. households subscribe to some form of pay TV" though this number may have dropped considerably in the last few years). Worse still, FCC regulations currently prohibit TV broadcasters from transferring their rights to other users. Each TV station *must* utilize all 6 MHz of its allotted channel; it cannot sublicense its spectrum in whole or in part for another use like wireless broadband service. *See Unleashing the DTV Band*, *supra* note 8, at 8. Legislative attempts to permit spectrum sharing remain ongoing, *see* Reforming Airwaves by Developing Incentives and Opportunistic Sharing (RADIOS) Act, S. 455, 112th Cong. § 5(c) (2011) (implementing a pilot program "to advance and promote spectrum sharing and reuse activities"); Public Safety Spectrum and Wireless Innovation Act, S. 28, 112th Cong. § 204 (2011) (establishing FCC authority to hold "incentive auctions" disseminating spectrum relinquished by current licensees), but similar legislation has failed repeatedly in the past, *see, e.g.*, S. 649, 111th Cong. (2009); S. 3756, 111th Cong. (2010). Aspects of these bills were also incorporated in the Obama Administration's recently announced American Jobs Act. The American Jobs Act §§ 272–99, *available at* http://www.whitehouse.gov/jobs act#jobs-text.

21. *See, e.g.*, Benjamin, *Roasting the Pig*, *supra* note 8, at 96 (calling for the FCC "to reclaim spectrum devoted to lower valued uses from the existing licensees, to allocate it to higher valued uses,

March 2010 when the FCC unveiled a National Broadband Plan with the stated goal of transitioning 500 MHz of public and private spectrum to the wireless broadband pool over the next decade.[22] Advocates were unable, however, to convince regulators to divest TV broadcasters of the 294 MHz of spectrum currently allocated to the remaining forty-nine television broadcast channels.[23]

If the National Broadband Plan was supposed to end debate about spectrum redistribution, it has failed to do so. Since plans were announced last year, calls for reclamation of broadcast spectrum have grown more frequent and urgent.[24] For now, it seems, public discussion of spectrum policy is firmly anchored to ongoing debate about the relative value of broadcast television.

II. VIABLE SOLUTIONS MUST SCALE EXPONENTIALLY

With scholars and policymakers single-mindedly focused for years on spectrum reallocation, it seems that few stopped along the way to consider whether reallocation could actually quench the nation's thirst for high throughput data service. While an infusion of spectrum may have seemed like a viable solution to keep the wireless industry afloat in the early- to mid-2000s when the vast majority of wireless traffic was generated by basic-feature cell phones, even a cursory review of current data reveals that spectrum reallocation alone is not a viable solution for an industry now dominated by smartphones, tablet computers, and mobile-broadband-equipped laptops, each of which consume 24, 122, and 515 times as much bandwidth as a cell phone, respectively.[25]

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and then redistribute (ideally, via auction) spectrum rights to a new set of licensees").

22. NATIONAL BROADBAND PLAN, *supra* note 10, at 75 (recommending the reallocation of 500 MHz of new spectrum over the next decade, of which 300 MHz should be allocated within 5 years); Memorandum for the Heads of Executive Departments and Agencies, Unleashing the Wireless Broadband Revolution (June 28, 2010), *available at* http://www.whitehouse.gov/the-press-office/presidential-memorandum-unleashing-wireless-broadband-revolution (directing the Secretary of Commerce and NTIA to collaborate with the FCC to make 500 MHz available over the next 10 years).

23. Television broadcasters controlled 402 MHz—i.e., 67 channels—until 2009, when the switch to digital broadcasting accompanied an 18-channel reduction. *See Unleashing the DTV Band*, *supra* note 8, at 5.

24. Media attention, for example, has increased markedly. *See, e.g.*, Jenkins, Jr., *supra* note 4.

25. *See* CISCO VISUAL NETWORKING INDEX, *supra* note 1, at 7 fig. 4; *see also* Implementation of Section 6002(b) of the Omnibus Budget Reconciliation Act of 1993, 14th Report, 25 FCC Rcd. 11407, 11417 (2010) ("[T]raditional handset users generate, on average, 25 MB of traffic each month, BlackBerry users generate 54 MB, iPhone users generate 275 MB, other smartphone users generate 150 MB, and laptop 'aircard' users generate 1.4 gigabytes (GB).").

The absence of this fact from policy debates is surprising given how easy it is to see why reallocation is bound to fail.[26] Consider a simple thought experiment. Suppose advocates for reallocation get their wish and FCC regulators reclaim all 294 MHz currently licensed to television broadcasters and make it immediately available to wireless providers.[27] Additionally, in a fit of civil-minded generosity, the government agrees to increase its National Broadband Plan goal from 500 to 660 MHz and makes that spectrum available immediately, rather than slowly over the next decade.

Combined with the 547 MHz already available for mobile broadband use,[28] wireless providers now have access to some 1.5 GHz. In other words, even in a rather fanciful best-case scenario, spectrum reallocation offers at most an immediate 3-fold increase in available spectrum. Keeping in mind that traffic increases have averaged over 2.5-fold *per year* for three years running and are projected to increase as much as 26-fold by 2015, it is easy to see why even aggressive reallocation is like putting a Band-Aid on a bullet hole. Put simply, solutions must scale. As long as demand for wireless bandwidth continues to increase at an exponential rate, any discrete influx of spectrum to existing cellular systems and architectures, even one almost 800 MHz in size, will soon be dwarfed by the ever-rising tide of mobile traffic.

III. TECHNOLOGY SOLUTIONS TO THE REAL PROBLEM

What the data crunch calls for, then, are solutions that promise exponentially scalable increases in the efficiency of existing spectrum resources. Fortunately, several slowly emerging communications technologies promise just such a solution, if they can swiftly be put into practice.

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26. This is by no means the first time the FCC's ability to gather and analyze data has been called into question. *See generally* Rob Frieden, *Case Studies in Abandoned Empiricism and the Lack of Peer Review at the Federal Communications Commission*, 8 J. TELECOMM. & HIGH TECH. L. 277 (2010).

27. Immediate availability, of course, is unattainable. Past experience shows that it takes years for reallocated spectrum to make its way to new licensees. *See, e.g.*, OBI TECHNICAL PAPER NO. 6, *supra* note 1, at 15–16 (2010) (noting that spectrum made available six years ago "is just now coming online"); Blair Levin, *You Can't Coach Height: A Winning Spectrum Strategy*, BLOGBAND: THE OFFICIAL BLOG OF THE NAT'L BROADBAND PLAN (Oct. 29, 2009), http://blog.broadband.gov/?entryId=10624 (noting that "it takes an average of 6 to 13 years to clear spectrum").

28. *See, e.g.*, OBI TECHNICAL PAPER NO. 6, *supra* note 1, at 15. "Old stock" cellular and PCS bands comprise 170 MHz of this amount; the remaining 377 MHz consists of "flexible use" bands, including the AWS, 2.5 GHz, and 700 MHz bands, that are not widely used outside major metropolitan areas. *Id.*

A. Spectral Efficiency and Cross-Technology Solutions

Several technologies under development promise to drastically increase the capacity of our airwaves. So-called "cognitive radio" is one such example.[29] This technology utilizes "self-aware" radios, which can detect changes in the propagation environment, interference conditions, user demands, and the like, and adapt accordingly to achieve optimum performance.[30] Fully developed cognitive radio technology may well permit multiple networks to co-exist at the same spectrum band with little or no interference[31]—a technical accomplishment that alone would exceed the benefits of even the most extreme spectrum reallocation plans.

Other technology promises even more impressive results. Rapid deployment of emerging "tiered network" technology, which employs densely packed low-power cells in coordination with or in place of existing cell towers,[32] might also single-handedly solve the wireless industry's data woes. With this kind of "picocell" or "femtocell" technology, many more cells (and thus many more users) in the same geographic area can use the same frequency band at the same time.[33] Other examples include technologies that would permit cell towers to coordinate with one another in "multicell" or "network" multiple input multiple output (MIMO) systems,[34] and improved techniques that would for the

29. *See generally* Joseph Mitola III & Gerald Q. Maguire, Jr., *Cognitive Radio: Making Software Radios More Personal*, 6 IEEE PERSONAL COMM., no. 4, Aug. 1999, at 13; Simon Haykin, *Cognitive Radio: Brain-Empowered Wireless Communications*, 23 IEEE J. ON SELECTED AREAS IN COMM. 201 (2005).

30. *See* Haykin, *supra* note 29.

31. *Id.*

32. *See generally* Vikram Chandrasekhar et al., *Femtocell Networks: A Survey*, 46 IEEE COMM. MAG., no. 9, Sept. 2008.

33. *Id.*; *see also* Shu-Ping Yeh et al., *Capacity and Coverage Enhancement in Heterogeneous Networks*, 18 IEEE WIRELESS COMM., no. 3, June 2011, at 32. Reducing cell size also has the added benefit of decreasing the distance between the user and the base station, which itself also dramatically increases network throughput. *See, e.g.*, THEODORE S. RAPPAPORT, WIRELESS COMMUNICATIONS: PRINCIPLES AND PRACTICE 60 (2d ed. 2002). Historically, virtually all increases in wireless throughput have come from incremental improvements in our ability to reuse spectrum, not from periodic infusions of additional spectrum. *See* Cooper, *supra* note 14, at 570.

34. *See generally* David Gesbert et al., *Multi-Cell MIMO Cooperative Networks: A New Look at Interference*, 28 IEEE J. ON SELECTED AREAS IN COMM. 1380 (2010); Sivarama Venkatesan et al., *A WiMAX-Based Implementation of Network MIMO for Indoor Wireless Systems*, EURASIP J. ON ADVANCES IN SIGNAL PROCESSING, July 2009. MIMO systems are so named because they employ multiple antennas at both ends of the communication link. Far simpler MIMO systems are now in use in 4G cellular technology. *See* JEFFREY G. ANDREWS ET AL., FUNDAMENTALS OF WIMAX: UNDERSTANDING BROADBAND WIRELESS NETWORKING ch. 5.5 (2007); HARRI HOLMA & ANTTI TOSKALA, LTE FOR UMTS: EVOLUTION FOR LTE-ADVANCED 80–81 (2d ed. 2011); David Astely et al., *LTE: The Evolution of Mobile Broadband*, 47 IEEE COMM. MAG., no. 4, Apr. 2009, at 44, 48.

first time allow robust wireless communication at extremely high frequencies currently deemed "unusable" for mobile broadband.[35]

In addition to technologies that permit high-efficiency use of existing spectrum, other systems under development would help reduce wireless congestion by quickly steering mobile broadband traffic off the airwaves entirely and onto other infrastructure better suited to accommodating data-intensive applications.[36] Wireless devices could, for example, come equipped with multiple radios that would permit "cross-platform" or "cross-technology" communication—i.e., data transmission via the most efficient communication link available at any given time.[37] Such technology would allow a mobile device user to communicate via the cellular network with one radio when on the go and when at home via her much faster fiber, cable, or DSL link using a separate WiFi-enabled radio on the same device.[38]

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35. Though many spectrum reallocation advocates have branded frequencies above 3 GHz unsuitable for mobile broadband, *see* Comments of CTIA – The Wireless Assoc., at 13 (Apr. 22, 2011) (in response to *Spectrum Task Force Requests Information on Frequency Bands Identified by NTIA as Potential Broadband Spectrum*, ET Docket No. 10-123, Public Notice, 26 FCC Rcd. 3486 (2011)) ("Spectrum above 3 GHz is useful for wireless services but not mobile broadband at this time."), *available at* http://ecfsdocs.fcc.gov/filings/2011/04/22/6016378170.html, emerging technology will allow high-frequency bands to play a valuable role in mobile broadband networks. In addition to bands located only slightly above 3 GHz, there has been much recent interest in millimeter wave systems (particularly those that use the unlicensed 60 GHz band) and terahertz systems. *See generally* Peter Smulders, *Exploiting the 60 GHz Band for Local Wireless Multimedia Access: Prospects and Future Directions*, 40 IEEE COMM. MAG., no. 1, Jan. 2002; Robert C. Daniels et al., *60 GHz Wireless: Up Close and Personal*, 11 IEEE MICROWAVE MAG., no. 7, Dec. 2010; Radoslaw Piesiewicz et al., *Short-Range Ultra-Broadband Terahertz Communications: Concepts and Perspectives*, 49 IEEE ANTENNAS & PROPAGATION MAG., no. 6, Dec. 2007; Ho-Jin Song et al., *Terahertz Wireless Communication Link at 300 GHz*, PROC. IEEE TOPICAL MEETING ON MICROWAVE PHOTONICS, Oct. 2010, at 42. Though high frequency systems have experienced problems with signal power in the past, new antenna and RF technology is quickly making this point surmountable. *See* Daniels et al., *supra*, at 2–3. For example, because signals have smaller wavelengths at higher frequencies, large arrays of small antennas can be built into a device of reasonable size. *See* Chinh H. Doan et al., *Design Considerations for 60 GHz CMOS Radios*, 42 IEEE COMM. MAG., no. 12, Dec. 2004, at 132. In fact, high frequency systems seem to be the perfect technology for backhaul networks (using highly directional beams and short-range communication). *See* Nan Guo et al., *60-GHz Millimeter-Wave Radio: Principle, Technology, and New Results*, EURASIP J. WIRELESS COMM. & NETWORKING, Sept. 2006.

36. *See* Krogmeier & Love, *supra* note 13, at 18–24 (noting that some data-intensive applications currently processed over mobile broadband networks could be accommodated by other high rate communications technologies such as fiber, cable, DSL, WiFi, and broadcast television, and furthermore that existing estimates of future spectrum needs fail to consider this fact).

37. *See generally* Shu-Ping Yeh et al., *supra* note 33, at 32; Chandrasekhar et al., *supra* note 32.

38. *See generally* Kyunghan Lee et al., *Mobile Data Offloading: How Much Can WiFi Deliver?*, PROC. OF ACM CONEXT, Nov.–Dec. 2010; Yiannis Yiakoumis et al., *Slicing Home Networks*, PROC. ACM SIGCOMM WORKSHOP ON HOME NETWORKS, Aug. 2011.

B. Encouraging Adoption

In principle, these technologies together may offer exponential increases in spectrum utilization that can rival the exponential growth of mobile data needs. "Cooper's Law"—named after Martin Cooper, the inventor of the first mobile phone[39]—predicts that advances in networking technology double spectral efficiency roughly every thirty months.[40] Unlike the more familiar "Moore's Law" from the computing industry which has accurately predicted the exponential growth of *actual* computing power for decades,[41] Cooper's Law predicts exponential increases only in the *practical* capacity of wireless networks using "the best technique available at any given time."[42] Why the discrepancy? Despite ever-growing demand for wireless services, established players in the wireless industry have been notoriously reluctant to embrace new cellular technology, a fact that has created a growing backlog of improved networking standards waiting for industry adoption.

While scholars have been quick to label television broadcasters as rent-seeking oligopolists, few have noted that the industry on the other side of this debate is dominated by only four behemoths,[43] two of which just attempted to merge last year.[44] Historically, these wireless giants have been agonizingly slow to adopt new standards. Rather than accelerate

39. *See, e.g.*, Tania Teixeira, *Meet Marty Cooper—the Inventor of the Mobile Phone*, BBC NEWS (Apr. 23, 2010), http://news.bbc.co.uk/2/hi/programmes/ click_online/8639590.stm.

40. Cooper, *supra* note 14, at 567–68. To be clear, not all networking technologies described above are alone capable of accommodating exponential growth. It is the combined effect of new technologies that has historically scaled exponentially.

41. *See* Gordon E. Moore, *Cramming More Components Onto Integrated Circuits*, ELECTRONICS, Apr. 19, 1965, at 114, 115 (predicting that computing power will double approximately every two years).

42. Cooper, *supra* note 14, at 567 (noting that his observations are based on the "practical" capacity of available spectrum).

43. Collectively, AT&T Wireless, Verizon Wireless, Sprint, and T-Mobile control about 82% of the mobile broadband market. *See, e.g.*, Brian Osbourne, *Should we agree with Sprint's CEO that AT&T will be too big?*, GEEK.COM (Mar. 25, 2011, 10:00 AM), http://www.geek.com/articles/mobile/should-we-agree-with-sprints-ceo-that-att-will-be-too-big-20110325/.

44. In March 2011, AT&T announced plans to acquire T-Mobile, a move that if consummated would have placed 80% of the cell phone market in the hands of AT&T and Verizon. *See* Cecilia Kang, *Senate panel chairman Kohl: AT&T, T-Mobile merger should be blocked*, POST TECH (July 20, 2011, 2:15 PM), http://www.washingtonpost.com/blogs/post-tech/post/atandt-t-mobile-merger- would-be-a-setback-democratic-lawmakers-tell-fcc-justice-dept/2011/07/20/gIQAy0gyPI_blog.html. In August 2011, the Department of Justice filed suit to block AT&T's proposed merger with T-Mobile. United States v. AT&T, Inc., No. 1:11-cv-01560 (D.D.C. filed Aug. 31, 2011). In light of ongoing resistance from government regulators, AT&T called-off the deal in December 2011. *See, e.g.*, Michael J. De La Merced, *AT&T Ends $39 Billion Bid for T-Mobile*, NY TIMES (Dec. 19, 2011), *available at* http://dealbook.nytimes.com/2011/12/19/att-withdraws-39-bid-for-t-mobile/.

innovation, they have largely maintained the status quo for years by amassing large spectrum reserves to accommodate new users and growing data demands without rolling out new technology.[45]

In addition to stifling innovation, this practice—sometimes referred to as "spectrum hoarding"—is especially pernicious because it acts as a formidable barrier to entry for new wireless competitors.[46] Every spectrum band held by industry incumbents is one less band available to new market players, a fact that is particularly troubling because, as in so many other industries, advances in mobile networking technology are predominantly championed by small firms.[47] Then-upstart Qualcomm was the first to introduce code division multiple access (CDMA) equipment in the early

45. *See Saturated Mobile Networks*, THE ECONOMIST, Feb. 11, 2010, *available at* http://www.economist.com/node/15498399 ("The cheapest way to increase capacity is to add more spectrum or to move a network to a lower frequency, which allows radio waves to penetrate walls more easily. So operators tend to lobby governments for more and better spectrum before investing in expensive kit."); Letter from Gordon H. Smith, Pres. & CEO, Nat'l Assoc. of Broadcasters, to Jay Rockefeller, U.S. Senator (Feb. 28, 2011), *available at* http://www.nab.org/documents/newsroom/pdfs/022811_Smith_spectrum_ltr.pdf (noting that many companies are "warehousing 'surplus spectrum' that, if deployed, presumably could help alleviate the alleged 'spectrum crisis'"); *see also* Caroline Gabriel, *NextWave warns of possible return to bankruptcy*, RETHINK WIRELESS (July 18, 2011), http://www.rethink-wireless.com/2011/07/18/nextwave-warns-possible-return-bankruptcy.htm (documenting the troubled history of notorious spectrum speculator NextWave Wireless).

46. *See* ONYEIJE, *supra* note 15, at 8 ("'[O]wnership' of spectrum is concomitant with exclusivity. When one acquires exclusive rights to spectrum, that spectrum is not available to others that might compete."); Susan P. Crawford, *The Radio and the Internet*, 23 BERKELEY TECH. L.J. 933, 974–75 (2008) ("Incumbents . . . will be willing to pay 'whatever it takes' to win the auction, because their top priority is blocking new entrants rather than paying the market price for spectrum."); Gregory Rose, *Spectrum Auction Breakdown: How Incumbents Manipulate FCC Auction Rules To Block Broadband Competition* (New Am. Found., Working Paper No. 18, 2007), *available at* http://www.newamerica.net/files/WorkingPaper18_FCCAuctionRules_Rose_FINAL.pdf (documenting collusion among incumbents against new entrants in spectrum auctions).

47. *See* Mark A. Lemley, *If AT&T Marries T-Mobile, All of Us Will Lose*, SACRAMENTO BEE, Aug. 9, 2011, *available at* http://www.sacbee.com/2011/08/09/v-wireless/3825030/if-att-marries-t-mobile-all-of.html (attributing recent, "tremendous innovation" in wireless technology to "outsiders like Apple and Google and fringe competitors like T-Mobile, not Verizon or AT&T"). The pharmaceutical and biotechnology industries are two other examples. *See* John M. Golden, *Biotechnology, Technology Policy, and Patentability: Natural Products and Invention in the American System*, 50 EMORY L.J. 101, 167 (2001); Yusing Ko, Note, *An Economic Analysis of Biotechnology Patent Protection*, 102 YALE L.J. 777, 800 (1992) ("[T]raditional pharmaceutical companies, despite their superior innovative resources, lag far behind the small start-up companies in contributing to biotechnological innovations."). Indeed, some commentators have argued that large dominant firms by their very nature are ill-suited to innovate. *See* RICHARD R. NELSON & SIDNEY G. WINTER, AN EVOLUTIONARY THEORY OF ECONOMIC CHANGE 279 (1982) (noting that a large firm's "hierarchical structure and culture may be inimical to innovation, or at least inimical to radical innovation"). On the innovative advantages small firms have over their large counterparts, see generally ZOLTAN J. ACS & DAVID B. AUDRETSCH, INNOVATION AND SMALL FIRMS (1990); RAY OAKEY ET AL., THE MANAGEMENT OF INNOVATION IN HIGH-TECHNOLOGY SMALL FIRMS (1988).

1990s,[48] IOSpan built the first commercial system using MIMO technology in 2001,[49] and most recently it was tiny Clearwire—not AT&T or Verizon—that began rolling out the nation's first 4G mobile network.[50] With wireless companies' spectrum reserves finally beginning to run dry, now is the time to reduce wireless providers' dependence on the availability of new spectrum, not to briefly extend the status quo with an influx of new spectrum, taken this time not at the expense of new entrants but from licensees in another industry entirely.

Thus, we believe policymakers would better serve the public by facilitating the rapid adoption of emerging technologies in the wireless industry, rather than endlessly debating spectrum reallocation. If, as scholars and policymakers seem to agree in principle, regulation of the airwaves should above all else seek to place spectrum in the hands of society's highest value users, spectrum policy should strive to place wireless broadband licenses in the hands of the most efficient wireless providers before simply importing spectrum from other supposedly less-efficient industries.

Though it is not our purpose in this brief Commentary to articulate a comprehensive policy framework to effectuate this change, a few reforms to the FCC's procedure for spectrum licensing could go a long way toward closing the technology gap between systems in use and standards waiting for widespread adoption.[51] For one, the FCC could condition spectrum license renewals on licensees' achievement of periodically increasing

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48. *See generally* Eric Nee & Christine Y. Chen, *Qualcomm Hits the Big Time Pushing a little-known digital cellular technology from surf's-up San Diego, this $4-billion-a-year hotshot wants to be The Next Intel*, FORTUNE MAG., May 15, 2000, *available at* http://money.cnn.com/magazines/fortune/fortune_archive/2000/05/15/279766/index.htm; *History*, QUALCOMM.COM, http://www.qualcomm.com/who-we-are/history/story (last visited Jan. 28, 2012).

49. *See generally* Arogyaswami J. Paulraj et al., *An Overview of MIMO Communications—A Key to Gigbait Wireless*, 92 PROC. OF THE IEEE 198 (2004); Hemanth Sampath et al., *A Fourth-Generation MIMO-OFDM Broadband Wireless System: Design, Performance, and Field Trial Results*, 40 IEEE COMM. MAG., no. 9, Sept. 2002.

50. *See The Clearwire Story*, CLEARWIRE.COM, http://www.clearwire.com/company/our-company (last visited Jan. 28, 2012). Sprint acquired a majority stake in Clearwire in late 2008 when the company merged with Xohm, Sprint's wireless broadband division. *See* Christopher Price, *Sprint Completes Clearwire Merger, Clear Will Replace XOHM*, PHONENEWS.COM (Dec. 1, 2008), http://www.phonenews.com/sprint-completes-clearwire-clear-will-replace-xohm-5650/.

51. Certain aspects of legislation currently pending in the Senate represent a promising step in the right direction, *see* S. 911 § 224 (2011) (funding the expansion of NIST and NSF "programs to support and promote innovation in the United States through transformative telecommunications research" including "cognitive radio technologies" and "low-power communications electronics"); Reforming Airwaves by Developing Incentives and Opportunistic Sharing (RADIOS) Act, S. 455, 112th Cong. § 7 (2011) (allocating funding, especially through the NSF, for spectral efficiency research), though these proposals as a whole remain firmly anchored to the reallocation debate and do not go nearly far enough in their support for network innovation.

efficiency benchmarks.[52] Similarly, the FCC could favor the most efficient wireless providers in the allocation of newly available spectrum, perhaps by resurrecting a simple, efficiency-focused version of the short-lived "pioneer's preference rule" implemented in 1991 to "extend[] preferential treatment in the FCC's licensing processes to parties that demonstrated their responsibility for developing new spectrum-using communications services and technologies."[53]

Whatever the precise mechanisms on the table, policy debates about how best to encourage the efficient use of presently allocated spectrum will be far more fruitful than ongoing debate about how to make discrete changes to existing licenses. Once efficiency gains are on track, debate can continue on the social and commercial value of existing government bands and broadcast television. Until that time, however, each passing day of continued debate makes reallocation a less viable solution and encourages the wireless industry to wait for yet another influx of spectrum to kick their problems down the road.

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52. *See* Marguerite Reardon, *Rethinking the Wireless Spectrum Crisis*, SIGNAL STRENGTH (May 25, 2010, 4:00 AM), http://news.cnet.com/8301-30686_3-20005831-266.html ("If I get granted an exclusive license, and the FCC grants me broad protection, my incentive is to make the cheapest, dumbest equipment possible, ... But if the FCC demands more efficient use of the spectrum, then license holders have the incentive to use more intelligent devices that use the spectrum more efficiently." (quoting Kevin Werbach)).

53. *See* Pioneer's Preference Program, FCC, http://transition.fcc.gov/oet/faqs/pioneerfaqs.html (last visited Jan. 28, 2012). As implemented in the early 1990s, the pioneer's preference rule proved unmanageable, largely because government regulators were unable to accurately select ex ante which technologies would become successful. *See* John F. Duffy, *The FCC and the Patent System: Progressive Ideals, Jacksonian Realism, and the Technology of Regulation*, 71 U. COLO. L. REV. 1071, 1140–43 (2000). It was ultimately scrapped in part over budgetary concerns. *See* Qualcomm, Inc. v. FCC, 181 F.3d 1370, 1380–81 (D.C. Cir. 1999) ("When Congress in 1994 set the date for withdrawal of the FCC's authority to grant new pioneer's preferences, its focus was on increasing federal revenues . . . ."). We do not recommend the wholesale revival of this program. We simply recommend that the FCC ensure that some spectrum remains available to accommodate small companies developing next-generation networking technologies and, moreover, that when such technologies have proven themselves highly-efficient (something that should be relatively easy to verify ex post) their owners have occasional opportunities to reclaim spectrum from incumbents using old technology. Spectrum licenses should function more as a revolving door letting innovators in and pushing laggards out, and less as a locked door keeping laggards safely inside and shutting innovators out in the cold. *See* ENHANCING ACCESS TO THE RADIO SPECTRUM, *supra* note 2, at 3 ("Spectrum management must be flexible to accommodate changing usage models and opportunities created by advances in technology."); Konstantinos K. Stylianou, *An Innovation-Centric Approach of Telecommunications Infrastructure Regulation*, 16 VA. J.L. & TECH. 221, 223 (2011) ("[B]ecause network innovation seems to be drawing significant benefits from an enlarged pool of actors, even if they are less efficient than a single big actor, . . . regulators wishing to prioritize innovation may be required to intervene in favor of facilitating entry . . . ."). *But see* T. Randolph Beard et al., *A Policy Framework for Spectrum Allocation in Mobile Communications*, 63 FED. COMM. L.J. 639, 644–45 (2011) (arguing that consolidation in the wireless industry "is merely the industry adjusting towards a sustainable structure" as existing firms seek "sufficient spectrum to run scalable networks").

CONCLUSION

At a minimum, we hope this Commentary serves as a call for communication and network technology experts to have a seat at the table in spectrum policy debates. There is far too little interaction between policymakers, who are predominantly drawn from the disciplines of economics and law, and wireless communications experts, who are predominantly engineers. The capacity of our nation's wireless networks depends on two variables: the distribution of spectrum resources (i.e., the width in Hertz of each licensee's allocated frequency band) and the spectral efficiency of cellular architectures currently in use (i.e., the number of bits-per-second transmitted per Hertz).[54] All too often, it seems, policymakers focus almost exclusively on the former, and communication and networking engineers on the latter, without regard for the work of one another.[55] Perhaps because of this disconnect, current policy seems hopelessly fixated on proposals that are destined to fail. If mobile data needs continue their exponential growth, any solution that employs current cellular network architectures cannot succeed, no matter how much spectrum regulators pump into the wireless industry. Against the rising tide of data, only technology stands a chance.

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54. Spectral efficiency, in turn, is also a factor of two variables: geographic reuse (i.e., the number of times that a specific frequency band can be reused in a given area without interference) and data transmission algorithm efficiency (i.e., the number of bits-per-second passing through each band repetition). *See, e.g.*, DAVID TSE ET AL., FUNDAMENTALS OF WIRELESS COMMUNICATION 7 (2005).

55. It is not surprising, of course, that lawyers, economists, and engineers tend to view spectrum policy through the lens of their respective specialties. As the old saying goes: "It is tempting, if the only tool you have is a hammer, to treat everything as if it were a nail." ABRAHAM H. MASLOW, THE PSYCHOLOGY OF SCIENCE: A RECONNAISSANCE 15 (1966).