COGNITIVE RADIO: MOVING TOWARD A WORKABLE FRAMEWORK FOR COMMERCIAL LEASING OF PUBLIC SAFETY SPECTRUM

TRAVIS E. LITMAN*

INTRODUCTION

In 1910, just fifteen years after the first successful use of radio technology by Guglielmo Marconi, the United States Senate contemplated legislation to address its widespread adoption and use.[1] At that time, recognition of the imperative of public safety overrode much of the discussion surrounding the use of radio, just as it does today. This awareness was compounded by the sinking of the Titanic in 1912, which further highlighted the importance of radio communication in public safety operations. Then, as now, radio promised dramatic change to the face of an uncertain technological environment.

Cognitive radio may be roughly defined as "a radio that can change its transmitter parameters based on interaction with the environment in which it operates."[2] The technology is currently employed in wireless

* Travis E. Litman is a J.D. candidate at the University of Colorado (2006) and Programs & Finance Director of the Silicon Flatirons Telecommunications Program.

1. S. REP. NO. 61-659, at 1 (1910).

2. Facilitating Opportunities for Flexible, Efficient, and Reliable Spectrum Use Employing Cognitive Radio Technologies; Authorization and Use of Software Defined Radio,

local area network services (LANS) and mobile wireless service networks.[3] Advancements in this area offer opportunities to open spectrum in "space, time and frequency dimensions that until now have been unavailable."[4] Because of an ability to interact with their environment, cognitive radio technologies promise a more efficient and comprehensive use of the spectrum with reduced risk of interference. Indeed, even the Federal Communications Commission (FCC or Commission) has recognized that a radical paradigm shift in spectrum management may come as a result of this technology.[5]

The FCC must, however, articulate clear principles and rules for cognitive radio, particularly in the public safety setting. A clear regulatory framework will, among other things, foster secondary markets for spectrum licenses, which are crucial to the broad deployment of cognitive radio technologies. To date, the pursuit of such a framework has been undermined by a contradictory regulatory path. In its Secondary Markets Order, the FCC clarified its policies surrounding types of dynamic spectrum leasing arrangements that would be permitted as result of smart or opportunistic use technologies like cognitive radio.[6] The Commission declined, however, to "permit public safety licensees to enter into spectrum leasing arrangements for commercial or other non-public safety operations."[7] Yet meanwhile, in the Notice of Proposed Rulemaking on Cognitive Radio (Cognitive Radio NPRM), the FCC continued to solicit proposals for what technologies would best work in the implementation of an interruptible public safety spectrum regime.[8]

Although models for commercial leasing of public safety spectrum have not received full treatment in the FCC's subsequent steps towards secondary markets generally,[9] the issue will likely return to the forefront. Indeed, in its Cognitive Radio NPRM, the FCC treated interruptible leasing of public safety spectrum as a foregone conclusion and solicited comments on the ways to best implement it.[10] As the potential leasing of

Notice of Proposed Rulemaking and Order, 18 FCC Rcd. 26,859, 26,863 (2003) [hereinafter Cognitive Radio].

3. *Id.* at 26,860; *See also* Facilitating Opportunities for Flexible, Efficient, and Reliable Spectrum Use Employing Cognitive Radio Technologies; Authorization and Use of Software Defined Radio, *Report and Order*, 20 FCC Rcd. 5486, 5487 (2005)[hereinafter Cognitive Radio Order].

4. Cognitive Radio at 26,860.

5. Cognitive Radio Order, *supra* note 3, at 3. (In the same breath, the FCC also indicated that at this juncture, 'it need not' address the implications of such a shift).

6. Promoting Efficient Use of Spectrum Through Elimination of Barriers to the Development of Secondary Markets, *Second Report and Order*, 19 FCC Rcd. 17,503, 17,506 (2004) [hereinafter Secondary Markets Second Report and Order].

7. *Id.* at 17,529.

8. *See* Cognitive Radio, *supra* note 2.

9. Secondary Markets Second Report and Order , *supra* note 6, at 17,529.

10. *See* Cognitive Radio, *supra* note 2; It should be noted that the FCC retrenched from

public safety bands remains in a state of speculative legal flux, it is important for the FCC to set out criteria by which the implementation of such a system should proceed. The Cognitive Radio Order's recent treatment of the technology demonstrates both the pitfalls of shortsighted management and the facilitating effects of forward-looking regulatory treatment. All the same, the FCC's avowal of an "evolutionary" approach to management of cognitive radio technology should be grounded in a basic framework by which regulation will facilitate development.[11] Thus, the FCC should (1) beware of adopting any technical model that stifles future innovation; (2) pursue regulatory strategies that prohibit incumbent users (i.e., public safety entities) from profiting at the expense of the integrity of their systems; and (3) seek a regulatory model that is technically proven to protect the ability of public safety agencies to respond. Although these criteria might be in tension at times, it is vital that the FCC adopt a solid analytical framework for cognitive radio applications.

This paper argues that the FCC should adopt such criteria and continue its proactive stance in support of the development and implementation of cognitive radio capacities that offer new opportunities in an already-crowded spectrum environment. Section II offers a brief background of cognitive radio. Section III then illustrates how the failure to develop a suitable definition of cognitive radio results in a confused dialogue over its challenges. Sections IV-V outline the capabilities and promise of cognitive radio in the public safety spectrum. Section VI outlines the regulatory history of cognitive radio to date. Finally, Section VII illustrates the nexus of economic and technical factors that will demand heightened FCC scrutiny in its consideration of future applications of spectrum leasing in cognitive radio.

I. BACKGROUND

A. History of Regulation of the Electromagnetic Spectrum

Spectrum may be broadly understood as a series of electromagnetic frequencies between three kilohertz and three hundred gigahertz that can be used for the transmission of information over the radio waves. On June 2, 1896, Guglielmo Marconi submitted the specifications for the world's first wireless patent using this spectrum.[12] Over the next decade,

its advocacy or suggestion of technical mechanisms by which interruptible leasing could be effected in its subsequent Report and Order. Cognitive Radio Order, *supra* note 3, at 5515.

11. Cognitive Radio Order, *supra* note 3, at 5493.

12. *See* Marconi Calling, *Marconi's Life* (Jan. 18, 2005), *at* http://www.marconicalling.com/introsting.htm.

radio technology proliferated and found science, business, and safety applications.[13] Governments worldwide soon recognized the need for understanding and regulating this new technology, which led to the Berlin Radiotelegraphic Convention of 1906. The conference created a record that stated in part "[w]ireless telegraph stations are bound to give absolute priority to calls of distress from ships, to similarly answer such calls, and to take such action with regard thereto as may be required."[14] Although the United States did not adopt the language of the Convention, it has a longstanding tradition of yielding "priority to government messages by ordinary telegraph lines. . .since July 24, 1866."[15]

In turn, the early 1910s were a seminal period for the recognition and emergence of government control over the radio spectrum in the United States. At that time, the Secretary of the Navy described the radio "ether" as existing in a state of "chaos" to the detriment of both public business and the Navy.[16] As the Secretary stated in a letter to the Senate Committee on Commerce, "[c]alls of distress from vessels in peril on the sea go unheeded or are drowned out in the etheric bedlam produced by numerous stations all trying to communicate at once. . . . It is not putting the case too strongly to state that the situation is intolerable, and it is continually growing worse."[17] The installation of radio equipment on ships was one of the first applications of radio technology. Radio offered several benefits at sea, including military advantage and the promotion of safety of life and property through enhanced responsiveness and communication. Unfortunately, these innovations were undermined by significant problems of interference.[18]

The sinking of the Titanic awakened popular consciousness to the advantages of government-managed spectrum. After the loss of the Titanic, some navy analysts suggested that the chaos of the radio spectrum did not allow a nearby ship to heed the Titanic's distress calls.[19] As a result, on August 13, 1912, Congress enacted the first legislation to create a regime of control of the radio spectrum.[20]

The first regulation of the radio spectrum, the Radio Act of 1912, established the principle that a federal license was required to use the

13. *Id.*
14. S. REP. NO. 61-659, at 1 (1910).
15. *Id.* at 2.
16. *Id.*
17. *Id.* at 4.
18. *Id.*
19. LAWRENCE LESSIG, THE FUTURE OF IDEAS: THE FATE OF THE COMMONS IN A CONNECTED WORLD 73 (2002).
20. Ronald Coase, *The Federal Communications Commission*, 2 J.L. & ECON. 1, 2 (1959); *See* Radio Act of 1912, Pub. L. No. 62-264, 37 Stat. 302.

spectrum.[21] In its final consideration of the flagship bill, the Senate voiced concern about the legislation's possible unintended hampering of technological progress. As the Senate Report stated, "the claim has been made that any precise regulation of radio communication, in view of the undeveloped stage of the art, will necessarily retard the progress of science and diminish the usefulness to mankind of the invention."[22] Although radio communication represented a remarkable step forward for safety, innovation, and commerce, policymakers were wary of potential problems with its regulation.

Nevertheless, Congress has since passed several bills that regulate spectrum. The Radio Act of 1927 established the Federal Radio Commission, which was charged with the classification of radio stations and regulation of spectrum bandwidth through licensing procedures.[23] In 1934, the FCC replaced the Federal Radio Commission and was given the mandate of regulating telephone, telegraph, and radio services. Since 1934, the FCC system of spectrum allocation through licensure has remained largely unchanged with few exceptions.[24]

The apportionment of spectrum-use licenses by the FCC was ostensibly designed to reduce the potential for harmful interference.[25] Indeed, this command-and-control regulatory posture adopted by the FCC survives to this day.[26] Under this regulatory model, the allocation of spectrum bands and accompanying technical and service rules are the primary factors in the development and structure of the industry.[27] At the FCC, spectrum policy has developed on a band-by-band basis, usually in response to requests for particular allocations or assignments.[28] The command-and-control structure has drawn widespread criticism

21. SPECTRUM POLICY TASKFORCE REPORT, ET Dkt. No. 02-135, *Report* 1, at 7 (Nov. 15, 2002), available at http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-228542A1.pdf [hereinafter SPECTRUM POLICY TASK FORCE REPORT].

22. S. REP. NO. 62-698, at 7 (1912).

23. SPECTRUM POLICY TASK FORCE REPORT, *supra* note 21, at 7.

24. In 1983, Congress did add section 7(a) to the Act, which sets as the policy of the United States to "encourage the provision of new technologies and services to the public." *Id.* at 7. Then, in 1993, the FCC implemented an auction system for spectrum whereby the participants would bid on a non-transferable license (though not property right) to operate in a given swath. Joshua Marsh, *Secondary Markets in Non-Federal Public Safety Spectrum*, at 3 (Working Paper, 2004), *at* http://web.si.umich.edu/tprc/papers/2004/384/tprc.pdf.

25. Comments of Pulse Link, to the *Notice of Proposed Rulemaking and Order* in Facilitating Opportunities for Flexible, Efficient, and Reliable Spectrum Use Employing Cognitive Radio Technologies, ET Dkt. No. 03-108, at 2-3 (May 17, 2004), *available at* http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6516185644 [Hereinafter Pulse Link].

26. Philip J. Weiser & Dale N. Hatfield, *Policing the Spectrum Commons*, 74 FORDHAM L. REV 101, 104 (forthcoming 2005), *available at* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=704741.

27. *Id.*

28. SPECTRUM POLICY TASKFORCE REPORT, *supra* note 21, at 8.

since the 1950s, particularly in comparison to property rights and commons models.[29]

The late 1990s witnessed some legislative movement responding to critics of command-and-control spectrum policy. For instance, Congress expanded the Commission's authority to provide flexibility of use in spectrum management as well as the authority to use auctions to distribute spectrum licenses.[30] In response to the heightened demand for spectrum-based devices and services, the FCC also created the Spectrum Policy Task Force and considered progressive proposals like the secondary markets in spectrum licensing discussed in greater detail in the next section.[31]

The demand for spectrum space and the number of spectrum devices has increased exponentially, especially with mobile and portable spectrum-based applications.[32] As the FCC's Spectrum Policy Task Force (SPTF) stated, the "increased demand is propelled by a host of factors: the economy has moved towards the communications-intensive service sector, the workforce is increasingly mobile, and consumers have been quick to embrace the convenience and increased efficiency of the multitude of wireless devices available today."[33] The FCC is increasingly confronted with a regulatory conundrum: improving flexible efficiency in the access and usage of the finite spectrum while maintaining reliability in its use.[34] The SPTF identified software-defined radios and opportunistic technologies as one means to achieve these competing goals.[35] Thus, nearly a century later, with the advent of cognitive radio technology, identical sets of policy concerns to those that accompanied the first uses of radio have arisen.

B. Secondary Markets and Interruptible Leasing

For the last century, "dumb" receivers have been the established norm in radio.[36] Administrative regulation and technology were limited by the finite nature of the electromagnetic spectrum through which radio receivers picked up their signals. Today, however, cognitive radio devices

29. *Id.* at 4-5; *see also* Coase, *supra* note 20, at 6.

30. Weiser & Hatfield, *supra* note 26, at 8; *See also*, 47 U.S.C. § 336 (2005).

31. The Spectrum Policy Task Force unequivocally states that the time for reform is now as "[i]ncreasing demand for spectrum-based services are straining long-standing, and outmoded spectrum policies. The overarching goal of effective spectrum policy is to maximize the potential public benefits to be derived through spectrum-based services and devices." SPECTRUM POLICY TASK FORCE REPORT, *supra* note 21, at 11-12.

32. *Id.*

33. *Id.* at 12.

34. Cognitive Radio, *supra* note 2, at 26,860.

35. SPECTRUM POLICY TASKFORCE REPORT, *supra* note 21, at 13-4.

36. PHIL WEISER & JONATHAN NUECHETERLEIN, DIGITAL CROSSWORDS: AMERICAN TELECOMMUNICATIONS POLICY IN THE INFORMATION AGE 235 (2005).

offer the ability to adapt and respond to their spectral environments. In so doing, cognitive radio will reorient the limits of allocable spectrum space and offer an invitation into a new era of radio and spectrum usage.

Secondary markets in spectrum develop through leasing arrangements whereby a party licensed by the FCC to use the spectrum leases the space to a third party. The concept of secondary markets in spectrum has received particular attention recently.[37] This is due in part to the increase in the number of spectrum license applications as well as the overall demand for spectrum space.[38] Moreover, in pursuit of secondary market solutions, the Commission has emphasized an "evolution toward greater reliance on the marketplace to expand the scope of available wireless services and devices," thereby "leading to more efficient and dynamic use of the important spectrum resource to the ultimate benefit of consumers."[39]

Secondary market leasing arrangements facilitate more efficient use of public safety spectrum though real-time spectrum exchanges such as interruptible leasing. Traditional spectrum leases occur where the original licensee transfers the right to use the spectrum to the lessee, thereby enjoying only minimal access to the spectrum while the lease is in effect.[40] Interruptible leasing, by contrast, enables the licensee to interrupt the lessee's use of the spectrum and return the spectrum to the licensee in a time of need. In public safety applications, a licensee may only require access to spectrum at infrequent intervals and for limited time periods. If the licensee can guarantee that its needs will be met during its critical use periods, it may pursue a leasing strategy for the non-critical times to realize potential revenue opportunities. Thus, cognitive radio technologies might serve the public interest in facilitating the active use of spectrum that might otherwise lie dormant. At the same time, in public safety spectrum bands, interruptible leasing is an acutely sensitive proposal because of the need for instant reversionary access to the spectrum.

The FCC has identified at least four ways in which cognitive radio may promote access while maintaining efficiency and reliability.[41] First, a licensee may utilize cognitive radio to improve efficiency. A coordinated system of cognitive radios would allow for more productive use of the airwaves.[42] Second, as discussed above, cognitive radio allows

37. *See, e.g.*, SPECTRUM POLICY TASK FORCE, *supra* note 21, at 1.

38. *See id.*

39. Promoting Efficient Use of Spectrum Through Elimination of Barriers to the Development of Secondary Markets, *Report and Order and Further Notice of Proposed Rulemaking*, 18 FCC Rcd. 20,604, 20,607 (2003) [hereinafter Secondary Markets Order].

40. Cognitive Radio, *supra* note 2, at 26,878.

41. *Id.* at 26,861.

42. *Id.*

for the development of secondary markets in spectrum use.[43] Third, it can facilitate automated frequency coordination.[44] Finally, it can allow for the use of non-voluntary third-party access to spectrum.[45] This paper explores only the second use in a very specific context – interruptible leasing of spectrum rights in public safety bands. Before moving into this analysis, however, it is useful to define the term 'cognitive radio,' and what it indicates about the state of the technology generally.

II. DEFINITION

The policy and implementation struggles with cognitive radio parallel the difficulties in developing a consensus as to what constitutes cognitive radio from the outset. As one commentator remarked, the FCC itself raised confusion in its use of terminology in the Cognitive Radio NPRM.[46] Although the FCC stated that a cognitive radio is not necessarily a software-defined radio (SDR), it later implied that an SDR was, in fact, a subset of cognitive radio.[47] The FCC has since clarified its definition of a software-defined radio, further evincing the difficulties plaguing this rapidly evolving area of technology.[48]

A software-defined radio is a radio with a microchip whose programming may be altered to perform on different frequencies and in different formats.[49] The Institute of Electrical and Electronics Engineers (IEEE-USA) argues that a cognitive radio does not have to be an SDR.[50] Instead, they insist that it is possible to implement cognitive radio features, like the ability to detect and avoid other users, using conventional technologies.[51] Indeed, a cognitive radio "distinguishes

43. *Id.*

44. *Id.*

45. *Id.*

46. Comments of Nat'l Pub. Safety Telecomm. Council, to the *Notice of Proposed Rulemaking and Order* in Facilitating Opportunities for Flexible, Efficient, and Reliable Spectrum Use Employing Cognitive Radio Technologies, ET Dkt. No. 03-108, at 7 (May 3, 2004), *available at* http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6516183126 [hereinafter NPSTC].

47. *See id.*; *see also* Cognitive Radio, *supra* note 2, at 26,863, 26,864, n 16.

48. *See* Cognitive Radio Order, *supra* note 3, at 5,499-507.

49. Comments of Motorola, to the *Notice of Proposed Rulemaking and Order* in Facilitating Opportunities for Flexible, Efficient, and Reliable Spectrum Use Employing Cognitive Radio Technologies, ET Dkt. No. 03-108, at 2-3 (May 3, 2004), *available at* http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6516183093 [hereinafter Motorola].

50. Comments of IEEE-USA, to the *Notice of Proposed Rulemaking and Order* in Facilitating Opportunities for Flexible, Efficient, and Reliable Spectrum Use Employing Cognitive Radio Technologies, ET Dkt. No. 03-108, at 3 (May 3, 2004), *available at* http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6516183217 [hereinafter IEEE-USA].

51. *Id.*

itself from an SDR by altering its transmitter parameters based on observation of and interaction with the environment in which it operates."[52] Motorola offers perhaps the best single definition of a cognitive radio: a radio that changes its transmitters based upon observation and interaction with its environment.[53] Although both SDRs and cognitive radio can be altered after their original manufacture, only cognitive radios communicate and adapt directly to their environment.[54]

An alternate definition proffered by the New York State Office for Technology asserts that "[c]ognitive [r]adio *is* a subset of [s]oftware [d]efined [r]adio (SDR) technologies."[55] Cognitive radio is a dynamic technology in that it can alter the basic operating rules and parameters that otherwise guide SDRs. As the Office for Technology points out, "[i]t has not been shown how a [cognitive radio] can perform the learning function without the use of software."[56] In other words, cognitive radio is dependent on software at a basic level in order to analyze its environment, but can go further than traditional software defined radios by modifying its parameters of operation.[57]

Regardless of whether one conceives of cognitive radio as a subset of SDR or not, the confusion and debate surrounding its very nature is illustrative of the novelty of cognitive radio as an innovation. All can agree that the Commission should not treat cognitive radio as little more than a modified SDR, but rather, it should be regulated as a distinct entity. Indeed, if cognitive radio and software-defined radio are equated, then they will be subject to the same regulatory regimes in terms of product certification and regulation. Lurking behind the confusion regarding cognitive radio lies the risk of unintended consequences in the form of regressive regulation when no definition can be agreed on. Further, as the New York Office for Technology fears, the "additional regulation of SDR could negatively impact innovation, development, and deployment of a very important communication technology."[58] In turn, the gains to be derived from cognitive radio have yet to be fully exploited - let alone conceived; as such, the Commission should be aware of the

52. *Id.*

53. Motorola, *supra* note 49, at 2.

54. *Id.*

55. Comments of the Statewide Wireless Network New York State Office for Tech., to the *Notice of Proposed Rulemaking and Order* in Facilitating Opportunities for Flexible, Efficient, and Reliable Spectrum Use Employing Cognitive Radio Technologies, ET Dkt. No. 03-108, at 5 (May 3, 2004), *available at* http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6516183263 [Hereinafter Wireless NY State Office] (Emphasis added).

56. *Id.* at 6.

57. *Id.*

58. *Id.*

potential impact of its regulation.

Most recently, the Commission itself has redefined "software defined radio" to include: "devices where a software change could change not only the operating parameters of frequency range, modulation type or maximum output power, but also the circumstances under which a transmitter operates in accordance with Commission rules."[59] In essence, the Commission has opted for a broader definition that is more inclusive of cognitive radios. The Commission acted to enhance the purview of its powers in order to mandate certain security features on new devices.

As the Commission has stated, "[a]s a matter of policy, the Commission wanted additional assurances that manufacturers of software-based equipment would take steps to prevent abuses, so it adopted a requirement that a device that is certified as a software defined radio must incorporate a means to ensure that only software that is part of an approved hardware/software combination can be loaded into a radio."[60] Here the importance of a settled definition again becomes clear – it enables manufacturers to know what certification protocols are necessary, and to ensure that devices which use spectrum have uniformly robust security. The FCC has redefined SDR in order to "help ensure that certain radios incorporating software cannot be easily modified on an unauthorized basis and cause harmful interference or otherwise violate our rules."[61] The FCC should be lauded for the reconsideration of its definition, but at the same time, the debate over the very definition of an SDR is emblematic of regulating the new technology as a whole. Nonetheless, a functional understanding of cognitive radios illustrates its vast potential in the public safety setting, as the next section explores.

III. COGNITIVE RADIO CAPABILITIES

A cognitive radio works by detecting other electromagnetic signals and responding accordingly. Unlike normal receivers, cognitive radio has two principle options if a signal is being broadcast in the band of spectrum it is analyzing. First, it may practice "avoidance" by moving to another band. Second, it may practice "coexistence" through changing the transmitter parameters (like modulation) to coexist with other users.[62] Cognitive radio technologies have already been deployed in Commercial Mobile Radio Services (CMRS) and in trunked radio public safety

59. Cognitive Radio Order, *supra* note 3, at 5499.

60. *Id.* at 5500.

61. *Id.* at 5502.

62. Motorola, *supra* note 49, at 2; Modulation is defined as "to vary the amplitude, frequency, or phase of (a carrier wave or light wave) for the transmission of intelligence (as by radio)." MERRIAM-WEBSTER ONLINE DICTIONARY (Feb. 5, 2005), *available at* http://www.m-w.com/cgi-bin/dictionary?book=Dictionary&va=modulating.

systems.[63] At this point, one of the primary technological obstacles to progress in cognitive radio technologies is the phenomenon known as "false positives," or indications that the spectrum is in use when, in fact, it is not.[64] Nevertheless, such difficulties are being researched and have not yet proved to be prohibitive in the development and deployment of cognitive radio.

In the Cognitive Radio Order, the FCC isolated several characteristics that distinguish cognitive radios from dumb receivers.[65] First, cognitive radios demonstrate frequency agility – the ability to change frequency to optimize use.[66] Second, cognitive radios may employ Dynamic Frequency Selection (DFS), where the signals of transmitters nearby are taken into account.[67] Further, cognitive radios may exhibit Transmit Power Control (TPC), where the radio can constrain its emissions power depending upon its environs.[68] Finally, cognitive radios may feature locational awareness vis à vis other transmitters and be able to negotiate use based upon terms agreed upon by a licensee and third party.[69]

As the FCC stated, "[c]ognitive radio technologies have the potential to provide a number of benefits that would result in increased access to spectrum and also make new and improved communication services available to the public."[70] Using these tools, cognitive radio can exploit the use of "white spaces" in the spectrum.[71] Cognitive radio may be deployed in any number of architectures and can be used by both licensed and unlicensed users of spectrum.[72] Cognitive radio technology also promises to further the "interoperability between or among communications systems in which frequency bands and/or transmission formats differ."[73] It can thereby 'bridge' two different systems by receiving signals at one frequency and format and retransmitting them in another. The FCC also has indicated that cognitive radio technologies could have applications that improve rural access to spectrum-based

63. Motorola, *supra* note 49, at 6; In trunked systems, frequency is controlled automatically by control-channel signaling and the assigned to users based upon availability and priority. Wireless NY State Office, *supra* note 55, at 7.

64. Interview with Dale Hatfield, Adjunct Professor, University of Colorado in Boulder, Colo. (Feb. 3, 2005).

65. Cognitive Radio Order, *supra* note 3, at 5489-90.

66. *Id.*

67. *Id.*

68. *Id.*

69. *Id.*

70. Cognitive Radio, *supra* note 2, at 26,866.

71. "White spaces" are known as spaces in the spectrum that are not in use at a given time or location. *Id.*

72. Indeed, cognitive radios can be used in network-centric, distributed, ad hoc and mesh architectures. *Id.* at 26,867.

73. *Id.* at 26,866.

services.[74] Finally, and most significantly, cognitive radio can allow for negotiation between users of spectrum, resulting in increased efficiency.[75]

One of the most promising possibilities presented by cognitive radio is the ability to identify unused spectrum which may be made available for leased use and then to allow for its reversion to the original licensee at designated times or in certain scenarios.[76] Interruptible spectrum leasing would allow a licensee to retain the right to "'interrupt' or preempt a lessee's use temporarily in order to satisfy their particular operational requirements for immediate access, reliability, or security."[77] In the public safety context, where events are time critical, the interruptible spectrum leasing model is the logical choice for secondary markets in spectrum because of its capability for instant interruption and reversion. As the FCC noted in the Cognitive Radio NPRM, "public safety licensees. . . are likely to demand robust technical mechanisms to ensure interruptible spectrum leasing."[78] The FCC went on to conclude that "[c]ognitive radio technology can provide the technical mechanisms to ensure the leased spectrum is instantly and reliably available for public safety use during emergencies [and can] serve a critical role in making leased use of public safety spectrum possible."[79] As such, in its mission to provide more flexibility in its command and control of the spectrum, the FCC sought input on cognitive radio through its rulemaking processes.[80]

Finally, although many leases are likely to be negotiated on a long-term basis, the capability of cognitive radio to negotiate leases in real-time merits further exploration.[81] As the FCC noted, "the negotiation of spectrum leasing opportunities would most likely require information about spectrum availability, e.g., which channels, scope of authorized service area, and the characteristics of spectrum available, e.g., modulation power limits."[82] In other words, not only is there the potential to lease raw spectrum in real-time (from moment to moment),

74. *Id.* at 26,867.

75. Cognitive Radio Order, *supra* note 3, at 5489-90.

76. Cognitive Radio, *supra* note 2, at 26,880.

77. *Id.* at 26,878.

78. *Id.*

79. Cognitive Radio, *supra* note 2, at 26,879. In its comments in response to the NPRM, the Industrial Telecommunications Association, Inc. was dubious of the FCC claims, instead advocating further testing. *See* Comments of the Indus. Telecomm. Ass'n, Inc., to the *Notice of Proposed Rulemaking and Order*, in Facilitating Opportunities for Flexible, Efficient, and Reliable Spectrum Use Employing Cognitive Radio Technologies, ET Dkt. No. 03-108 (May 8, 2004), *available at* http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6516182865 [hereinafter ITA].

80. *See generally* Cognitive Radio, *supra* note 2; SPECTRUM POLICY TASKFORCE REPORT, *supra* note 21.

81. *See* Cognitive Radio Order, *supra* note 3, at 5489-90.

82. Cognitive Radio, *supra* note 2, at 26,881.

but in order to do so, information must be rapidly conveyed and analyzed, including the expected duration and variable costs. Although the promise of real-time leasing has remained largely unfulfilled, the discussion of the technical barriers and ramifications will likely mirror that of cognitive radio in relation to interruptible leasing generally. The real-time and interruptible leasing that are now possible or on the immediate horizon through cognitive radio technologies may yield economic efficiencies when employed in the management and use of public safety spectrum, as illustrated by the following section.

IV. PUBLIC SAFETY SPECTRUM

Part 90 of the FCC's rules defines public safety services. Specifically, public safety services are services:

> (A) the sole or principle purpose of which is to protect the safety of life, health or property;
> (B) that are provided –
> (i) by State or local government entities; or
> (ii) by nongovernmental organizations that are authorized by a government entity whose primary mission is the provision of such services; and
> (C) that are not made commercially available to the public by the provider.[83]

Public safety services operate on bands of spectrum licensed under FCC rules for non-federal radio communications of state and local governmental entities.[84] The communications that are used in these bands are "time-critical, but episodic in nature."[85] In other words, these communications may not be consistent, but arise on an as-needed basis, such as in the event of a disaster. Thus, instant communication is required because lives may hang in the balance. The communications may include "communications among members of a firefighting team, directions to an ambulance crew, and coordination among different police and fire agencies responding to a regional crisis."[86]

Traditionally, public safety entities have used dedicated systems to handle their individual communication needs.[87] Public safety

83. 47 C.F.R. § 90.523 (2005); *see also*, 47 U.S.C. § 337(f)(1) (2005).
84. Cognitive Radio, *supra* note 2, at 26,878.
85. Secondary Markets Order, *supra* note 39, at 20,709.
86. *Id.*
87. Comments of Ericsson Inc., to the *Notice of Proposed Rulemaking and Order* in Facilitating Opportunities for Flexible, Efficient, and Reliable Spectrum Use Employing Cognitive Radio Technologies, ET Dkt. No. 03-108 at 8 (May 3, 2004), *available at*

communications may be conventional or trunked and operate using analog or digital modulation.[88] Trunked operations usually operate on multiple channels and may employ Frequency Division Multiple Access (FDMA) or Time Division Multiple Access (TDMA).[89] In so doing, communications between mobile-to-base station and base station-to-mobile are kept on distinct frequency channels. In contrast, in conventional systems, access is available on a first-come, first served basis. Conventional operations may use a repeater station or rely on direct communications and can operate on one or two frequency channels for communications.[90]

Regardless of the technology employed, some have argued that the amount of spectrum currently available to public safety services is not enough to meet their needs.[91] Conversely, others argue that public safety spectrum often lies fallow or is used only intermittently and should be exploited by secondary leasing strategies.[92] These contending ideas may both be correct depending on the market, though cognitive radio technologies can theoretically be used in either scheme. Public safety operations currently wanting for spectrum will be able to employ cognitive radio to make better and more efficient use of the spectrum they have; cognitive radio also will aid licensees in allowing third parties access to their under-utilized public safety spectrum.

V. REGULATORY HISTROY OF COGNITIVE RADIO

On March 21, 2000, the FCC released a Notice of Inquiry regarding software-defined radios, which sought input from industry on the current state of the technology and how the Commission might adjust its rules so as to facilitate its deployment.[93] Then, on September 14, 2001, the FCC released its First Report and Order on Software Defined Radios in which it released a new set of rules governing SDRs.[94] Following this, on December 30, 2003, the FCC terminated the

http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6516183063 [hereinafter Ericsson].

88. Wireless NY State Office, *supra* note 55, at 7.

89. *Id.*

90. *Id.*

91. NPSTC, *supra* note 46, at 4.

92. Comments of St. Clair County, to the *Notice of Proposed Rulemaking and Order* in Facilitating Opportunities for Flexible, Efficient, and Reliable Spectrum Use Employing Cognitive Radio Technologies, ET Dkt. No. 03-108 at 3 (July 23, 2004), *available at* http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6516285240. [hereinafter St. Clair County].

93. Inquiry Regarding Software Defined Radios, *Notice of Inquiry*, 15 FCC Rcd. 5,930 (2000).

94. Authorization and Use of Software Defined Radios, *First Report and Order*, 16 FCC Rcd. 17,373 (2001).

Authorization and Use of Software Defined Radios in favor of a Notice of Proposed Rule Making surrounding cognitive radio.[95] Concurrent with the termination order, the FCC released its Notice of Proposed Rule Making and Order, which sought comment on the opportunities to facilitate spectrum usage through cognitive radio technologies. Specifically, within the NPRM, the FCC sought comment on the technical controls and reversion models that would make interruptible public safety leasing a reality.[96]

In his accompanying statement to the NPRM, then Chairman Powell focused on the upside of cognitive radio features, including the promise of interoperability amongst public safety authorities, and in particular, first responders.[97] Meanwhile, in a separate statement, Commissioner Copps was reluctant to move forward with interruptible leasing until it has been proven "safe."[98] Finally, Commissioner Adelstein suggested that cognitive radio would provide an important role in "spectrum facilitation" through which regulatory, technical, and economic barriers would be eliminated from spectrum usage.[99]

At the time of the release of the Cognitive Radio NRPM, the FCC gave no indication whether interruptible public safety leasing would be of limited, commercial or other character, and in fact, made no affirmative decision whether interruptible public safety leasing would become a reality at all. Yet, at the same time, the NPRM sought comment on the feasibility of various access reversion models – namely, a beacon-system. In turn, the FCC received an array of responses from both the public and private sector through 103 filed comments.[100]

Meanwhile, the broader issue of developing secondary markets for spectrum was concurrently being addressed elsewhere. On November 27, 2000, the Commission issued a NPRM regarding secondary markets,

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95. Cognitive Radio, *supra* note 2, at 26,859.

96. *Id.* at 26, 779-80.

97. Separate Statement of Chairman Michael K. Powell, *Notice of Proposed Rulemaking and Order*, in Facilitating Opportunities for Flexible, Efficient, and Reliable Spectrum Use Employing Cognitive Radio Technologies, ET Dkt. No. 03-108 18 FCC Rcd. 26,859, 26,908 (2004).

98. Commissioner Copps was particularly concerned about the potential that public safety entities would compromise their systems by leasing out their 'core' spectrum in order to make up for other budgetary shortfalls. Separate Statement of Commissioner Michael C. Copps, *Notice of Proposed Rulemaking and Order*, in Facilitating Opportunities for Flexible, Efficient, and Reliable Spectrum Use Employing Cognitive Radio Technologies, ET Dkt. No. 03-108 18 FCC Rcd. 26,859, 26,909 (2004). [hereinafter Copps Statement]

99. Separate Statement of Chairman Jonathan S. Adelstein, *Notice of Proposed Rulemaking and Order*, in Facilitating Opportunities for Flexible, Efficient, and Reliable Spectrum Use Employing Cognitive Radio Technologies, ET Dkt. No. 03-108 18 FCC Rcd. 26,859, 26,911 (2004).

100. *See* ECFS Comment Search, Federal Communications Commission, *at* http://gullfoss2.fcc.gov/cgi-bin/websql/prod/ecfs/comsrch_v2.hts.

in order to "to remove unnecessary regulatory barriers to the development of more robust secondary markets in radio spectrum usage rights."[101] The Commission chose to specifically exclude public safety bands from consideration at the time because of the critical nature of those services.[102] In the October 6, 2003 Report and Order, however, the Commission followed the Spectrum Policy Taskforce's recommendation and solicited comment on the possibility for interruptible leasing mechanisms in the public safety bands.[103] As the Commission stated, "[n]ew technologies. . .may allow both ultra-reliable near-instant access by public safety licensees and use by other licensees at times of low public safety demand."[104] Finally, on September 2, 2004, the Commission elected to allow public safety entities to cross-lease their spectrum so long as the lease is dedicated to the support of public safety operations.[105] In the same breath, the Commission also decided to "decline *at this time* to permit public safety licensees to enter into spectrum leasing arrangements for commercial or other non-public safety operations."[106]

On March 10, 2005, the Commission released its Report and Order surrounding its cognitive radio proceeding.[107] In the Report and Order, the Commission offered a new definition of software defined radio, adjusted its thinking on the technical controls necessary in an interruptible spectrum leasing regime, yet did not take specific action with regard to the public safety spectrum. As a result, the Commission has left an open question as to how such markets will develop and be regulated.[108]

VI. INTERRUPTIBLE SPECTURM LEASING

As a result of the differing needs and mechanisms necessary for operation between differing frequency bands, it is not feasible to broadly define criteria for applications of cognitive radio.[109] In fact, "[c]ognitive radio technologies, while promising to maximize spectral efficiency in the future, are only in their infantile stages of development."[110]

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101. Promoting Efficient Use of Spectrum Through Elimination of Barriers to the Development of Secondary Markets, *Notice of Proposed Rulemaking*, 15 FCC Rcd. 24,203, 24,204 (2000).

102. *Id.* at 24,208.

103. Secondary Markets Order, *supra* note 39, at 20,709.

104. *Id.* at 20,709.

105. Secondary Markets Second Report and Order, *supra* note 6, at 17,529.

106. *Id.* (emphasis added)

107. Cognitive Radio Order, *supra* note 3.

108. *Id.*

109. Motorola, *supra* note 49, at 6.

110. ITA, *supra* note 79, at 4.

Nevertheless, as discussed in the previous section, the FCC has identified the capability of cognitive radio technologies to allow for the facilitation of a secondary market in leasing rights and has taken initial exploratory action.

In the Second Report and Order on Secondary Markets, the FCC moved forward in the leasing of public safety spectrum. Specifically, with regard to the public safety bands allocated under the Part 90 rules, the FCC decided to permit public safety licensees to lease their spectrum rights to other public safety entities to provide communications for operations support.[111] At the same time, commentators concluded that cognitive radio technology is "here to stay" and "will undoubtedly increase exponentially in the coming months and years."[112] Thus, one can reasonably expect that, as the technologies improve, further consideration of the interruptible leasing of spectrum rights will ensue.

The Cognitive Radio NPRM was a move in this direction. Therein, the FCC sought comment as to the technological means of implementing interruptible spectrum leasing in the public safety bands. Furthermore, in the Second Report and Order on Secondary Markets, the Commission stated, "[a]s our next step in this area, we intend to consider the technical issues raised in that proceeding, which appear to be important groundwork in addressing broader public safety spectrum leasing."[113]

The deliberations on the Cognitive Radio NPRM were guided by the intention to "allow a full realization of the potential of these technologies under [the FCC's] regulatory models for spectrum based use."[114] Nevertheless, the Commission has "failed to propose an overarching vision for a future spectrum policy and how the proposals in the NPRM fit."[115] In terms of the public safety analysis, industry and public safety entities have proffered a variety of different models by which cognitive radio and interruptible spectrum leasing may be implemented. Outside of continuing to explore the possibility of spectrum leasing, the FCC did little to clarify the prospect of such leasing arrangements. Nevertheless, it is vital for the Commission to adopt a set of criteria whereby the proposals and actions may be

111. Secondary Markets Second Report and Order, *supra* note 6, at 17,529. (emphasis added).

112. NPSTC, *supra* note 46, at 6.

113. Secondary Markets Second Report and Order, *supra* note 6, at 17,531. (emphasis added).

114. Cognitive Radio, *supra* note 2, at 26,861.

115. Comments of "The Technology Companies," to the *Notice of Proposed Rulemaking and Order* in Facilitating Opportunities for Flexible, Efficient, and Reliable Spectrum Use Employing Cognitive Radio Technologies, ET Dkt. No. 03-108 at 2 (June 1, 2004), *available at* http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6516208162.

measured so as to avoid either stifling innovation or facilitating the potential for abuse in spectrum leasing. In moving forward, the Commission must analyze interruptible spectrum leasing in the public safety sector through a prism encompassing the economic and technical values that it purports to uphold.

A. Economic Considerations

Interruptible spectrum leasing offers both promising avenues for the financial health of public safety agencies as well as potential pitfalls to the sanctity of emergency services. As such, the FCC or a similar regulatory body should oversee any potential regime of spectrum leasing to ensure that (1) the public and commercial buyers are not exploited by rent-seeking of public safety agencies and (2) the sale of rights is not in derogation of the needs of public safety operations.

In the First Report and Order on Secondary Markets, the Commission inquired as to whether interruptible public safety spectrum leasing would further the public interest.[116] Specifically, it highlighted the potential for public safety entities to exploit the full use of their spectrum and to gain compensation for leasing of their unused spectrum.[117] In raising the possibility of revenue generation, the Commission avoided specifying how the monies could be used, but did suggest that equipment upgrades would be one logical expenditure.[118] Public safety spectrum users usually employ different funding mechanisms, are more budget constrained, and have longer equipment replacement cycles than commercial entities.[119] In the Cognitive Radio NPRM , the Commission again stated that interruptible spectrum leasing was likely to yield an array of public interest benefits, including "more efficient use of public safety spectrum, providing an avenue of multiple public safety entities to use the same spectrum, and providing financial resources to public safety licensees."[120] The Commission noted an opportunity to reduce transaction costs within interruptible lease arrangements if action is taken to standardize equipment designs, particularly with regard to reversion mechanisms.[121] Fundamentally, as the Commission has recognized, financial opportunities and motives will determine the viability of the adoption and course of interruptible public safety leasing.

Several commentators have echoed the FCC's preliminary

116. Secondary Markets Order, *supra* note 39, at 20,710.
117. *Id.*
118. *Id.*at 20,710, n 481.
119. SPECTRUM POLICY TASKFORCE REPORT, *supra* note 21, at 43.
120. Cognitive Radio, *supra* note 2, at 26,879.
121. *Id.* at 26,880.

conclusion that interruptible leasing may lead to a significant revenue source. Spectrum can be leased through either a flat rate per-subscriber charge or a per-second use charge.[122] One municipality, St. Clair County, IL, has stated that the cash-generation aspect of the leasing arrangements is absolutely vital to incentivize its participation in such a regime.[123] St. Clair County imagines a world in which the unused channels of its trunked safety systems could easily be leased to a taxi service on an as-needed basis through prices defined by a broker system.[124] Although its system is subject to periods of peak activity, the County estimates that ninety percent of the time it operates at only thirty-five percent capacity.[125] Likewise, the Association of Public Safety Communication Officials International, Inc. (APCO) recognizes that spectrum leasing authority could be an asset used for financial gain.[126] The rents received from spectrum leasing may even lead some state entities to acquire more channel capacity than they need.[127] As such, secondary markets in interruptible spectrum leasing "will be a major contributor to ensuring efficient usage of spectrum through permitting market forces to govern how portions of the radio spectrum are used."[128] Therefore, the public safety agencies will have a means to fund the cost of conversion to an interruptible spectrum leasing regime and have a potential source of revenue to apply to their operations and expansion.

Despite the benefits that may be afforded to public safety agencies as a result of interruptible leasing, it is not a panacea. The costs associated with the transition to a regime conducive to interruptible leasing may be prohibitive. In order to allow spectrum leasing for any non-public safety entity, statutory barriers must be removed, an effort requiring considerable lobbying expenses. For instance, in the 700 MHz band, eligibility for spectrum is limited by the Communications Act to non-commercial services for which "the sole or principal purpose is to

122. St. Clair County, *supra* note 92, at 5.

123. *Id.*

124. *Id.*

125. *Id.* at 4.

126. Comments of Ass'n of Public-Safety Communications-Officials Int'l, Inc., to the *Notice of Proposed Rulemaking and Order* in Facilitating Opportunities for Flexible, Efficient, and Reliable Spectrum Use Employing Cognitive Radio Technologies, ET Dkt. No. 03-108, at 2-3 (May 3, 2004), *available at* http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6516183023. [hereinafter APCO Cog Rad].

127. Wireless NY State Office, *supra* note 55, at 13.

128. Comments of Vanu Inc., to the *Notice of Proposed Rulemaking and Order* in Facilitating Opportunities for Flexible, Efficient, and Reliable Spectrum Use Employing Cognitive Radio Technologies, ET Dkt. No. 03-108, at 1 (May 3, 2004), *available at* http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6516183203. [hereinafter Vanu].

protect the safety of life, health and property."[129] At the state and local levels, other statutory limitations may further limit the practicability of spectrum leases.[130] Moreover, state and local agencies may otherwise lack the legal authority to effectuate a spectrum lease.[131] All of these costs of removing or revising regulatory and legal constraints must be accounted for in evaluating the benefits of leasing public safety spectrum.

The initial costs to move to a spectrum leasing model may be prohibitive in light of an uncertainty of return. Significant one-time costs associated with moving toward secondary markets in the public safety sector include research and development for access and reversion mechanisms.[132] One of the main assumptions underlying the feasibility of secondary markets in the public safety spectrum is that the spectrum is "characterized by high peak-to-average use ratios and low average use."[133] However, the degree to which the public safety spectrum is underutilized will vary depending on the agency, the type of system (trunked or conventional), and whether it is urban or rural.[134] Ironically, in urban areas where a market for spectrum leases is most practicable, there will be no channels available to lease, whereas in rural areas, the opposite may be the case.[135] Demand for emergency services is much greater in urban centers than in rural areas. Indeed, as APCO states, "the presumed market for interruptible spectrum leasing will be greatest in urban areas, where non-interruptible commercial spectrum is unavailable."[136]

Another challenge is that a market for spectrum that could be rendered unavailable for indeterminate amounts of time (for instance, during major disaster like a wildfire or terrorist incident) remains a dubious proposition.[137] Like a public safety agency, during a large-scale emergency, a commercial lessee's need for spectrum may see a concurrent spike as their customer demand for channels is likely to grow instead of diminish.[138] Unfortunately, "the economic value of spectrum subject to such pre-emption would be very low, and unlikely to justify the substantial investment in cognitive radio technologies" that could make

129. 47 U.S.C. § 337(a)(1) (2005); 47 U.S.C. § 337(f)(1)(a) (2005).

130. Comments of Ass'n of Public-Safety Communications-Officials Int'l, Inc., to the Further *Notice of Proposed Rulemaking* in Promoting Efficient Use of Spectrum Through Elimination of Barriers to the Development of Secondary Markets, WT Dkt. No. 00-230, at 3 (Dec. 5, 2003), *available at* http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6515292189. [hereinafter APCO 2ND Markets].

131. Wireless NY State Office, *supra* note 55, at 13.

132. Vanu, *supra* note 128, at 1-2; *see also* APCO Cog Rad, *supra* note 126, at 3.

133. *See generally* Cognitive Radio, *supra* note 2; APCO Cog Rad, *supra* note 126, at 3.

134. APCO Cog Rad, *supra* note 126, at 2.

135. *Id.*

136. *Id.* at 4.

137. NPSTC, *supra* note 46, at 14.

138. *Id.*

implementation possible in the first place.[139] Others have also predicted the transaction costs inherent in any variable system like an interruptible leasing regime to be high.[140] Finally, potential lessees of public safety spectrum may be deterred by the risk of liability for injuries that may arise by a failure to revert the spectrum immediately.[141]

The FCC also should be wary of perverse incentives that may accompany interruptible leasing of public safety spectrum should such markets prove to be lucrative. First, public safety agencies would have a financial incentive to acquire more spectrum or greater channel capacity assets than are needed.[142] This would not only deprive other public safety licensees of needed spectrum, but also would undermine the public interest. As APCO has stated, this could "distort and potentially corrupt spectrum management, worsening the already serious spectrum shortages that exist in many areas."[143]

Further, the authority to lease spectrum by state and local government entities may confuse their mission in serving the health and safety of the public at large. The leasing funds received may not be subject to legal constraint, and hence, may be likely to go into general revenue coffers in order to cover overall budget shortfalls.[144] The costs of spectrum use would be immediately quantifiable and comparable, perhaps leading to lower quality public safety services in favor of seeking a profit. There is also concern that a public safety entity may become a 'front' for a commercial entity that operates under the auspices of a public safety use.[145] Similar problems have occurred in the ITFS and MMDS frequency bands, serving as a warning for applications of interruptible leasing in the public safety arena.[146] Should the FCC authorize public safety spectrum leasing for profit, it must be vigilant in the face of both the over-acquisition of spectrum licenses as well as the potential for abuse in the interruptible leasing systems.

Some commentators have urged a market-based model for handling the public safety spectrum. Ericsson proposed that the public safety agencies abandon the idea of interruptible leasing in favor of using the public mobile networks on a cost basis.[147] Even John Muleta, former chief of the FCC Wireless Bureau, suggested that a reevaluation of the paradigm of self-provisioning government agencies may be

139. APCO 2ND Markets, *supra* note 130, at 4.
140. Ericcson, *supra* note 87, at 8.
141. *Id.*
142. Wireless NY State Office, *supra* note 55, at 13.
143. APCO Cog Rad , *supra* 126, at 3.
144. APCO 2ND Markets, *supra* note 130, at 4, n 6.
145. *Id.*
146. *Id.* at 5.
147. Ericcson, *supra* note 87, at 8-9.

appropriate.[148] For Ericsson and others, the commercial networks are the logical vehicle to carry the public safety transmission because "they offer nationwide and improved in-building coverage, position location, encryption, priority access, group communications, and complete functionality for voice, messaging, data and imaging."[149] Further, the commercial networks would not be subject to the high transaction, research, and development costs associated with a spectrum regime driven by cognitive radio. Finally, Ericsson has posited that the commercial networks already offer flexibility for the integration and information sharing within the databases that the public safety agencies utilize.[150]

Although the market-based model effectively highlights some of the flaws of an interruptible spectrum leasing system, it is not the best solution. Certainly, the potential transaction costs associated with the establishment of a new proprietary network will be enormous and the efficiency of commercial networks merits consideration. However, the idea of public safety agencies as beholden to commercial interests for their spectrum needs is a dubious proposition at best. Even if the charges for spectrum use were kept at 'cost,' it is unclear how that 'cost' would be negotiated. Commercial interests may be tempted to overextend their spectrum commitments and subject the public to price-gouging or inferior or intermittent service. Indeed, Commissioner Copps stated his concern over the "lure of big dollar figures from commercial companies" that might lead to "states and municipalities living in difficult budget environments to lease out not only extra spectrum, but core spectrum."[151]

In an area where timing is often mission critical, it is both logical and necessary to keep the public safety systems proprietary and not subject to the technical constraints and market forces inherent in the commercial sector. In short, the risk of market failure is unacceptable in situations where public safety agencies need access to their spectrum bands.[152] Finally, if public safety agencies were forced to compete in the market at large (in spectrum auctions), they would have to ask Congress for funding. If the congressional allocation is inadequate, there could be a "catastrophic failure of public safety duties nationwide."[153]

As a result, the Commission should proceed cautiously and outline

148. *Id.* at 9 *citing* John Muleta, Chief, Wireless Telecommunications Bureau, Federal Communications Commission, Presentation to National Academy of Science, Computer and Telecommunications Board (Feb. 12, 2004).

149. Ericsson, *supra* note 87, at 9.

150. *Id.* at 8.

151. Copps Statement, *supra* note 98, at 26,909.

152. Joshua Marsh, *supra* note 24 at 8.

153. *Id.*

specific steps to avert any possibility for inappropriate spectrum management on the part of public safety entities or the government agencies that oversee them. The Commission should consider several possible actions to accomplish such a monitoring function. The FCC may conduct frequent comprehensive studies of the use of spectrum and/or may provide a forum for dispute settlement by parties aggrieved by the system. The FCC might wish to oversee the entire system to guard against 'fronts' for spectrum and the exploitation of monies for undue gain. Finally, the statutory scheme currently in place around public safety bands may serve as an express block to the implementation of cognitive radio in spectrum leasing. A calculus of whether outlay of funds to reconfigure the dominant legal and technological regimes can be recouped will be necessary. If the barriers to entry can be minimized and the operation of interruptible leasing proves economical, the move toward such a regime should be advanced with appropriate vigilance.

B. Technical Considerations

Aside from the economic and legal pitfalls discussed above, there are also a number of technical impediments that need to be considered in addressing cognitive radio technology and interruptible public safety leasing. One objective of the Cognitive Radio NPRM was to identify an access and reversion mechanism that would be acceptable.[154] The Commission has subsequently backed away from endorsing any specific technical model for interruptible leasing in the Cognitive Radio Report and Order.[155] Instead, the Commission rightly chose to isolate a number of guiding principles in the technical consideration of future spectrum leasing applications. The Commission's one step forward and two steps back approach illustrates the difficulties attendant any regulation of prospective technology. As such, the Commission needs to be guarded in its consideration of such technologies so that (1) it does not inadvertently stifle their development and (2) it does not endorse an inferior or infeasible technology.

In the FCC's 5-Year Strategic Plan, it identified a number of overriding objectives in relation to public safety.[156] One objective is that the Commission's policies shall facilitate rapid restoration of the United States communications infrastructure and facilities "after disruption by any cause."[157] In the Plan, the Commission noted the imperative to act "swiftly and responsibly" in relation to matters of public safety and the

154. Cognitive Radio, *supra* note 2, at 26,879.

155. Cognitive Radio Order, *supra* note 3, at 5516.

156. *See* FCC, Strategic Plan 2006-11 (rel. July 5, 2005), *available at* http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-261434A1.doc.

157. *Id.* at 15.

need to "coordinate with *private industry* to develop policies that will further the vision, goals, and objectives of public safety."[158]

The foremost concern in moving forward in spectrum leasing should be the reliability of reversion systems so as to avoid a breach of the public confidence or loss of life.[159] And again, secondary questions of how the government will adopt the best standard without stifling innovation also needs to be considered. Finally, current fears of after-market alteration of cognitive radio devices need to be addressed prior to the adoption of the interruptible leasing model.[160]

Without technology that would allow reliable and near-instant access to leased spectrum, interruptible leasing would fail outright. The Cognitive Radio NPRM states that in applications of public safety spectrum leasing, "access to, as well as reliable and secure use of, spectrum are critical and the public interest may require strong technical assurances."[161]Thus, the FCC expressed interest in identifying a technical method of accessing and reclaiming spectrum for the purpose of standardizing all leasing equipment in order to lower transaction costs to interruptible leasing.[162] Fundamentally, "[c]ognitive radio technologies can be used both to identify spectrum that is available for leased use and to ensure that it reverts to the licensee under the prescribed conditions."[163] As a result of these considerations, the FCC initially favored a "beacon" model of access/reversion. It is important to note the FCC's initial preference for the beacon model as it set the initial dialogue for how the system would be implemented, even without guiding principles. However, by putting the cart before the horse in this manner, the FCC acted prematurely.

In any case, the FCC has since disavowed its support of the beacon method and likewise criticized the 'hand-shaking' method. Instead, the FCC espoused general principles by which technical controls can be judged instead of specific mechanisms of such control. Here, then, the attendant dangers of the FCC's favoring or forcing technology are

158. *Id.* at 16 (emphasis added).

159. The Commission itself has isolated five guiding principles in this light: "1. The licensee must have positive control as to when the lessee can access the spectrum; 2. The licensee must have positive control to terminate the use of spectrum by the lessee so it can revert back to the licensee's use; 3. Reversion must occur immediately upon action by the licensee unless that licensee has made specific provisions for a slower reversion time; 4. The equipment used by the licensee must perform access and reversion functions with an extremely high degree of reliability; 5. The equipment used by the licensee and the lessee must incorporate security features to prevent inadvertent misuse of, and thwart malicious use of, the licensee's spectrum." Cognitive Radio Order, *supra* note 3, at 5515-16, ¶ 86.

160. After market alterations may include any non-factory adjustments made to a cognitive radio that would alter or change its performance characteristics.

161. Cognitive Radio, *supra* note 2, at 26,879.

162. *Id.*

163. *Id.* at 26,880.

manifest – the perverse outcomes associated with the adoption of an inferior control can inhibit innovation. As seen in the analysis of the beacon model below, there are many challenges associated with cognitive radio with regard to adequate functionality in the public safety context. However, these challenges are not unique to public safety. Instead, they demonstrate the broader uncertainties facing this nascent technology. As a result, the lessons to be learned by the FCC's latent adoption of underlying principles in assessing such technologies are instructive. Indeed, the FCC should adopt overarching principles as related to interruptible spectrum leasing in sum total, particularly as it moves from the speculative realm toward reality.

According to the analysis in the Cognitive Radio NPRM , a beacon-based access/reversion system offers the most robust security and reliability to allow for interruptible spectrum leasing.[164] Under a beacon system, the lessee will receive a continuous control signal from the licensee during times when the lessee is permitted to transmit on the frequency. As the FCC noted,

> The lessee may not commence transmissions if the beacon signal is not received, and if the beacon signal is present but then stops while the lessee is transmitting, transmission must cease within a specified time interval. The beacon could be an RF signal sent by the licensee on a designated control frequency, or it may be a signal received over a physical connection such as fiber, copper or coaxial cable.[165]

A public safety licensee would have control of the beacon and demand the reversion of its spectrum as needed. This may be analogized to a light-switch: during times when the lights are off another user may be in the room, but when the lights come on, that user must cease its activities immediately and leave the room. The beacon is self-reinforcing, for if there is a weak-signal or any question as to whether the signal has been triggered, the activity must cease (the light will be turned on). With the release of the NPRM, the FCC postulated that the beacon system promised not only to be the most reliable, but also the most cost-effective to implement.[166]

Also in the Cognitive Radio NPRM, the FCC offered a framework for the security of the beacon system dependent on time signatures and encryption.[167] Given the proliferation of smart and cognitive radio technologies, it is foreseeable that someone might seek an unauthorized

164. *Id.*
165. *Id.*
166. *Id.,* at 26,881.
167. *Id.* at 26,881-82.

use of the spectrum or attempt to cause chaos through spoofing the beacon signal.[168] Spoofing occurs where an unauthorized party originates a rogue beacon signal.[169] To combat spoofing, the beacon might include the time of day and an electronic signature for proper authentication.[170] To further avert the possibility of unauthorized use, "the beacon would contain information on the channel(s) available to prevent unauthorized use of channels by lessees."[171]This electronic signature would be encrypted to further enhance the security profile.[172]

The potential for spoofing or making deleterious after-market modifications to cognitive radios is a daunting one. Some worry that interference from signals emanating from illegal devices may be impossible to track.[173] Others have argued that cognitive and smart radio technologies may make public safety operations susceptible to large-scale virus-like attacks as have occurred on the Internet.[174] The Commission has invited feedback on peer enforcement mechanisms to deal with such problems, and its authentication signature is one step in the right direction. [175] However, before the widespread deployment of cognitive radio technology in the public safety setting, more will need to be done to ensure the sanctity of transmission and security of the overall system.

Unfortunately, the beacon system is not without other flaws. First, as the FCC notes, this "mechanism is fallible. . . because the licensee's signal may not be heard by the lessee under unfavorable propagation conditions."[176] Second, the beacon system assumes that the public safety user would broadcast its presence, which is often neither desired nor operationally acceptable.[177] Battery limitations on some public safety systems would be overwhelmed by the responsibilities of a beacon system, thus making it "simply an impossibility" according to the National Public Safety Telecommunications Council (NPSTC).[178]

Within a beacon system, a quality of performance requirement would demand that a 250 millisecond period be the controlling

168. Webopedia defines spoofing as "to fool" or, in some contexts (like networking and cognitive radio), spoofing "involves trickery that makes a message appear as if it came from an authorized IP address." Webopedia, *What is spoof?*, *at* http://www.webopedia.com/TERM/s/
spoof.html (last visited Sept. 30, 2005).

169. *Id; See also*Cognitive Radio, *supra* note 2, at 26,881-82

170. Cognitive Radio, *supra* note 2, at 26,881-82

171. *Id.* at 26,881.

172. *Id.*

173. ITA, *supra* note 79, at 5.

174. *See* Cognitive Radio, *supra* note 2, at 26,870.

175. *Id.*

176. Cognitive Radio, *supra* note 2, at 26,880.

177. NPSTC, *supra* note 46, at 15.

178. *Id.*

variable.[179] The 250 ms period is derived from the current performance of both small and large public safety networks, including multi-channel analog and digital trunking systems.[180] According to the NPSTC, in the 250 ms period, "the secondary market user would have to detect the presence of a public safety user and relinquish the spectrum while still allowing sufficient time for the public safety user to complete a number of network and device set-up functions."[181] As a result, the reversion time would be expected to be less than 250 ms. Although not an impossibility, such a reversion time would cause high transaction and monitoring costs and would require a concurrent high speed beacon signal that would be subject to numerous radio frequency propagation limits.[182] The Commission has suggested that given the non-linear growth rate of service demands in response to an emergency, instantaneous reversion may be unnecessary.[183] In other words, even in an emergency, a public safety agency may not need to utilize its full spectrum allowance. However, as the NPSTC also points out, attempting to differentiate a critical versus non-critical emergency response is ridiculous in light of the ease with which a crisis situation may arise.[184]

Furthermore, the Industrial Telecommunications Association (ITA) highlighted an important illustration of the need for secure wireless systems, including those currently employed by many public safety agencies and potential beacon systems. According to the ITA, crane operators in shipping ports use private wireless systems to coordinate with workers on the dock and the ships. As the ITA concluded, a delay of even a second can have disastrous consequences in such applications.[185] Likewise in a setting where police, fire, or other emergency crews rely on instantaneous communication, it is vital that spectral pathways be clear to assure the safety of life and service.

The sanctity of human life and property may be compromised in the public safety setting where an alert is delayed to due a slow resource release. In non-continuous use situations like interruptible leasing, predictions regarding initiation and reversion of the principle user's activity will be futile. In both TDMA and traditional systems, the time between assignments and access may vary.[186] As Motorola has indicated, "[t]he consequences of non-voluntary third parties lingering on a

179. *Id.*
180. *Id.* at 14.
181. *Id.*
182. *Id.* at 15.
183. Cognitive Radio, *supra* note 2, at 26,883.
184. NPSTC, *supra* note 46, at 15.
185. ITA, *supra* note 79, at 4-5 n 7.
186. Motorola, *supra* note 49, at 12.

resource when the primary user needs it could be significant and should not be casually dismissed."[187] Many observers thus remain 'skeptical' when dealing with the mission critical functions of public safety radio.[188] The uncertainty of implementing a frequency sensing element in cognitive radio is thus exacerbated in the public safety bands and has led some to conclude that "the Commission should not undermine the reliability of mission critical communications in current or additional future frequency bands used for public safety."[189]

Others, no less skeptical, have argued for a rigorous testing regimen before the deployment of a beacon or like technology.[190] The FCC responded to these and similar criticisms by discontinuing its support for the beacon model, stating that "[u]ltimately, a licensee must itself be satisfied that the technical mechanism being implemented under a lease does in fact provide it with the ability in real time to reclaim use of its spectrum when necessary."[191] Although the FCC has articulated some criteria by which success of reversionary mechanisms may be judged, it has left the definition of such criteria to the discretion of the lessee.[192] In the public safety spectrum, however, the FCC will need to address more specifically the type of mechanism, the criteria by which it will be implemented, and a rigorous testing regimen (either through the non-public safety commercial market or under artificial conditions). Testing would need to occur in non-public safety environments that would approximate the timeliness of the reversion and offer confidence to public safety agencies, interested parties, and the public at large.

Alternative access/reversion mechanisms also merit mention. Overt permission mechanisms might be employed at greater expense, but with greater reliability than beacon-like systems.[193] In one type of overt system, "handshaking," a lessee would be required to "request and receive explicit permission to use spectrum before each transmission."[194] However, this approach would be hampered by the pure number of interactions required, and may necessitate allocation of a separate 'control frequency.'[195] Although overt permission models might yield the greatest reliability, thus far, these models have been deemed unacceptable because of their high transaction costs, as well as their attendant need for further allocation of scarce spectrum space.

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187. *Id.*
188. APCO Cog Rad, *supra* note 126, at 4.
189. Motorola, *supra* note 49, at 10.
190. *See, e.g.*, APCO Cog Rad, *supra* note 126, at 4.
191. Cognitive Radio Order, *supra* note 3, at 5516.
192. *Id.* at 5515-16; *see supra* text accompanying note 155.
193. Cognitive Radio, *supra* note 2, at 26,880.
194. *Id.*
195. *Id.*

Above all, the potential for interruptible spectrum leasing should not be cast aside lightly for a fear of access or reversion failures. The acute environmental sensory abilities of cognitive radio are likely to overcome any access/reversion and spoofing obstacles in time. The criteria by which viability in reversion will be judged will be determinative and vital in facilitating a successful transition. Certainly, the FCC should not prematurely push the technology at the expense of the public interest and the needs of first responders.

By the same token, it is important that the technology is not unduly delayed or overburdened by regulation that would inhibit its development. The FCC should continue its recently enunciated policy to avoid "inadvertently…[becoming] a barrier to the development and deployment of these technologies."[196] As such, the FCC has correctly moved back from its endorsement of the beacon model and outlined a specific set of criteria by which interruptible leasing technologies will have to be judged in the future.[197] In the public safety context, however, the Commission must be ready to closely scrutinize any technical control before allowing interruptible leasing to become a reality.

CONCLUSION

The sinking of the Titanic has come to be understood as a defining moment in United States history. The loss of the ship served as a catalyst for the development of a unified spectrum policy to promote rescue operations. Likewise, on September 11, 2001, the United States suffered a tragedy that was a turning point in modern history. There is evidence that firefighters responding inside of the World Trade Center were not able to communicate effectively and did not receive or heed the call to evacuate just prior to its collapse.[198] The failing of September 11 was "chiefly found in the response by the New York City Fire and Police Departments, which was [sic] hampered by inadequate command, unreliable communications equipment and an overwhelmed dispatching system."[199]

At the Pentagon, the lack of interoperability between radio systems caused confusion and delay. The non-federal responders at the Pentagon included responders from Maryland Fire & Rescue, Virginia Fire & Rescue, Virginia State Police, Virginia Department of Transportation, as well as the numerous federal responders, including the FBI and the

196. Cognitive Radio Order, *supra* note 3, at 5487.

197. *Id.* at 5514-16.

198. *See* The National Commission on Terrorist Attacks, THE 9/11 COMMISSION REPORT, 287-88, 290, 307, 318 (2004)

199. Eric Lipton, *Study Suggests Design Flaws Didn't Doom Towers*, N.Y. TIMES, Oct. 20, 2004, at A1.

United States Park Police.[200] All of these responders operated "across the entire span of the 138-174 MHz band."[201] Cognitive radio technologies can facilitate greater interoperability within the public safety bands and allow for greater coordination on the part of first responders. As Chairman Powell has stated, "smart radios could… translate signals between two different radio systems" and accordingly, "[t]his ability may enable more interoperability between public safety first responders – so that, in an emergency, firefighters from one jurisdiction could more effectively communicate with firefighters in another jurisdiction."[202] Cognitive radio technologies offer much hope for the public interest, not only in the form of interoperability, but also in promoting efficient use of the spectrum.

According to the Spectrum Policy Task Force, the "overarching goal of effective spectrum policy is to maximize the potential public benefits to be derived through spectrum-based services and devices."[203] FCC Commissioner Jonathan Adelstein stated that "cognitive radios can potentially play a key role in shaping our spectrum use in the future [and]. . . [c]ognitive radios may also provide licensees with innovative ways to use their current spectrum more efficiently, and to lease their spectrum more easily on the secondary market."[204] One of the most exciting and provocative areas in the application of secondary markets for spectrum is in the public safety realm. The advent of cognitive radio has, for the first time, allowed consideration of the leasing of spectrum on an interruptible basis. Cognitive radio will allow the identification of fallow bands that may be exploited for non-public safety use and the return thereof when needed. Currently, only public safety agencies are allowed to lease one another's spectrum, though the future is likely to bring commercial leasing to the forefront.

Although the public interest may be served by the opportunities for new revenue sources for public safety and a greater use of the radio spectrum, the adoption of interruptible public safety leasing merits pause. First, though the theory behind the interruptible leasing is sound, it is unclear what, if any, market there will be for such spectrum and if it will be self-sustaining. Equally as important, if interruptible spectrum leasing is widely adopted and deployed, criteria or safeguards need to be identified to prevent the potential for economic exploitation, technical failure, and social misunderstanding. In so doing, the nexus of

200. Cognitive Radio, *supra* note 2, at 26,887, n. 86.

201. *Id.*

202. Cognitive Radio, *supra* note 2, at 26,908; Separate Statement of Chairman Michael K. Powell, *supra* note 97, at 26,908.

203. SPECTRUM POLICY TASK FORCE REPORT, *supra* note 21, at 11-12.

204. Cognitive Radio, *supra* note 2; Separate Statement of Chairman Jonathan S. Adelstein, *supra* note 99, at 26,911.

unintended consequences, stifling of innovation, failure of mission critical systems, and the possibility of government responsiveness to the undue influence of commercial parties interested in leasing public safety spectrum may be avoided.

The FCC should venture forth and articulate guiding principles for leasing of the public safety spectrum. Embodied in these principles should be the notion that only legitimate commercial markets will be permissible. This would preclude the possibility that a public safety entity would unduly rent-seek at the expense of its intended beneficiaries. Secondly, since the public is the intended beneficiary of this system, all such leases should be able to demonstrate an end toward the public interest. Third, the market should be free to develop only to the extent that it can demonstrate a robust security profile. Finally, leasing of public safety spectrum should not be considered without a proven, reliable, and cost-effective reversion mechanism.