

MANDATED SPECTRUM SHARING: A RETURN TO “COMMAND AND CONTROL”

Gerald R. Faulhaber*

David J. Farber†

INTRODUCTION

In Faulhaber and Farber (2009) we concluded that all segments of the U.S. wireless industry have exhibited very substantial innovation and investment, that innovation at the edges is highly dependent upon innovation and investment at the network core, that firms are driven to innovate and invest in order to win in the competitive marketplace, and that consumer welfare is maximized by customer-centric policies that promote business model experimentation and allow customers to choose which marketplace offerings best meet their needs. We cautioned, however, that soaring demand for traditional and new wireless services threatens to exhaust the capacity of existing spectrum licensed for commercial mobile uses and that job one for the FCC must therefore be to identify, allocate and auction much more licensed spectrum. All recognize that this will take time and that U.S. service providers have their work cut out for them in the meantime to find ways to squeeze the most out of each slice of existing licensed spectrum and to continue to meet the many competing demands for that bandwidth with high quality services.

In its recent Comments filed with the Federal Communications Commission in the Fostering Innovation and Investment in the Wireless Communications Market docket, Google (2009) recommended that the Commission adopt an Interference Temperature Model for mandating spectrum sharing of licensed spectrum, including CMRS (Commercial Mobile Radio Service) spectrum, with unlicensed users. Although the Commission has terminated its proceeding on this model, Google recommends it be re-opened in the light of new research in order to encourage innovation, in the inaptly named “No Harm, No Foul” section of its comments.

* Professor Emeritus, Business and Public Policy Dept., Wharton School and Penn Law School, University of Pennsylvania, and former Chief Economist, Federal Communications Commission

† Distinguished Career Professor of Computer Science and Public Policy, Carnegie Mellon University, and former Chief Technologist, Federal Communications Commission.

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To preview our results, we find:

1. While there is a very urgent need for more licensed spectrum to be made available for wireless voice and broadband, there is much spectrum already available for unlicensed use; there appears to be little reason to encroach on scarce licensed bands when potential innovators have plenty of spectrum available now in the unlicensed bands.
2. Technologies such as cognitive radio which would be using mandated sharing are very much in their infancy, especially in applications sharing intensely used licensed spectrum. It's a great theory, but presents many problems, and much experimental work needs to be done to prove in the concept. We enthusiastically support more research, but this technology is far from ready for prime time; there is no need to consider it at this time.
3. Should cognitive radio, low power or any other unlicensed technologies be commercially proven at some point in the future to be able to share licensed spectrum without impacting the primary licensed uses, we believe the Commission (and Google) is asking the wrong question: why do we assume that mandating spectrum sharing under FCC rules is even necessary? *If sharing really imposes little or no cost on licensees, then why is it necessary to mandate it?* The market would certainly permit voluntary exchange between unlicensed users (more likely, their agents) and licensees in which access can be sold and the resulting market structure, complemented by market-based dispute resolution, would be far more efficient than a mandatory solution contrived by regulatory authorities.

We conclude that viable spectrum sharing of licensed spectrum by unlicensed users is a long way off; if and when it occurs, market-based sharing is far preferable to command-and-control mandated sharing. As has been proven so often in this market, the competitive wireless market, driven by the needs of buyers and sellers, will lead to better, faster and more efficient solutions than will the heavy hand of government regulation.

SPECTRUM, SPECTRUM EVERYWHERE AND NOT A DROP TO DRINK

All parties to the spectrum debate now acknowledge both that the FCC's move away from old-style command and control regulation of licensed spectrum and towards a liberal licensing regime that puts spectrum to its highest value uses has generated very substantial customer benefits, but that this is only a first step. There is an urgent need for allocation of much more spectrum to mobile wireless through liberal licenses.

Today, CMRS providers are at imminent risk of exhausting their stock of licensed spectrum in the very near term unless the FCC acts quickly. CTIA (2009a) documents the coming shortage; Rysavy (2008) tells much the same story. An earlier ITU study (2006) comes to the same conclusions. In Faulhaber and Farber (2009), we come to the

same conclusion, based on overwhelming evidence. In the face of this impending crisis, the FCC's response to the need for licensed spectrum has been minimal, consisting of the 700 Mhz auction in 2008, which spectrum has only recently become available. Yet the FCC has been rather generous in assigning spectrum for unlicensed uses; it appears that well over 500 Mhz has been designated by the FCC for unlicensed use. There is no record to support that, beyond the busy WiFi bands, any of this spectrum has actually been put to beneficial use.

It is surprising, therefore, that Google is arguing that innovators need unlicensed access to licensed spectrum, especially the most intensely used spectrum on the planet: the CMRS bands. Wireless voice and broadband are precisely the applications that cry out for more spectrum, and yet Google suggests that the FCC needs to encroach on licensed spectrum in order to provide unlicensed users with more spectrum. Yet spectrum actually devoted to unlicensed use abounds, thanks to the FCC's largesse. If there is a problem for innovators who need access to unlicensed spectrum, it is certainly not because unlicensed spectrum is scarce. In fact, the U-PCS band (1910-1930 Mhz) has been available since 1996 and remains virtually unused, as is much of the U-NII band, as noted in Faulhaber and Farber (2009). Why the need to encroach on valuable licensed spectrum? Perhaps Google has a point to make with this request; it certainly can't be based on need.

Even assuming there could be a need for more unlicensed access to spectrum by innovators, are the technologies that could use spectrum underlays (in licensed spectrum) for unlicensed use really ready for deployment? In fact, cognitive radio¹ (along with mesh networks and other enabling technologies) is very far from commercial deployment. Google references an excellent research paper by Clancy (2009) which may well be state of the art and proposes further research that we wholeheartedly support. But as any good researcher, Clancy recognizes that "it has been shown that measuring interference temperature² is a tricky task" and "Mobility will offer a more challenging analysis environment". He notes that the determination of the parameters required to manage the interference temperature "can be difficult, and for a general interference environment, this must be done numerically" and yields multiple solutions so that further compute-intensive analysis is required "on the fly." Further, these solutions to ensure non-interference may depend upon certain assumptions concerning the RF environment that may change in practice.

Unfortunately, there are more problems. According to a recent ITU (2009) report

"When primary and secondary cognitive radio systems coexist...[and CMRS systems are themselves cognitive]...an adaptation by a cognitive radio (or network or system) alters the operating environment which changes the observations of other cognitive radios (or networks or systems) thereby

influencing their adaptations. This can easily spawn an infinite sequence of adaptations that never converge or can yield an unstable network...”

The upshot of this research is that actually running a minimally-interfering cognitive radio system is very much a work in progress, and that significant work remains to be done before any consideration of deploying these technologies in even the simplest of licensed RF environments (such as radar bands) should occur.³

We are enthusiastic in supporting further research in cognitive radios, and indeed in all radio research. But we strongly believe that no technology should be served before its time, and for cognitive radios, that time is very much in the future.⁴ While we agree that the FCC should track this technology, this is the time for experimentation, not deployment.

WHO SAYS SHARING MUST BE MANDATED?

The section on mandated sharing of licensed spectrum in Google’s comments is named “No Harm, No Foul”, suggesting that if an underlay use such as cognitive radio causes no harm (interference) then such a use ought to be permitted. The promise of cognitive radio is exactly that: the possibility of opportunistic use that would in no way interfere with the use of the spectrum by the licensee. But in fact this early vision has now been modified; proponents propose that cognitive radio may seek to use the noise floor, or interference temperature, to transmit its signals at low power. The language has now changed from “no interference” to “no harmful interference” (whatever “harmful” may mean). For example, Google speaks of creating a balance of interests between spectrum licensees and unlicensed users, admitting that *some* interference may occur.

Accordingly, the title “No Harm, No Foul” is inapt; it should read “Some Harm, Some Foul”.

But the assumption of this entire debate is that the FCC must mandate sharing to compel licensees to accept some increase in, and loss of control of the noise floor to make room for unlicensed users. And it is this assumption that is deeply flawed; there is simply no rationale whatsoever for the FCC to mandate sharing at all. In fact, *if sharing involves no harm to licensees, then any licensee would be happy to share its spectrum (without interference) for a fair market price.* If there really is no harm, then any price (above zero) is profitable for the licensee, and in a competitive market (which Faulhaber and Farber (2009) among others demonstrate) the price of permitting sharing would be rather low.

Even better, even if sharing involved some interference, then licensees are likely to share but at a higher price (reflecting the capacity lost to sharing), provided the increased interference were to be predictable. Further, the terms and conditions of this sharing would evolve within a competitive market, reflecting the needs of both

licensees and unlicensed users, without the mistakes and delays of bureaucratic regulatory actions. It is surprising that although the FCC has generally moved away from command-and-control regime for allocating spectrum, it now signals a willingness to consider a command-and-control regime for encroaching on licensed spectrum in contravention of the licensees understanding of what they bought at the time of auction.⁵ When the authors served at the FCC in 2000-01, we were of the view that the FCC had moved beyond the command-and-control mentality; we are chagrined at this unfortunate regression.

And it is a regression that threatens particularly substantial harm in the face of the current spectrum crisis. Spectrum licensed for commercial mobile use is already highly congested and any remaining “spare” capacity is or soon will be needed to meet soaring demand in the years before large blocks of additional spectrum will be available even if the FCC acts with all deliberate speed to begin that process (as it should). With no “spare” to share, the “foul” associated with a “some harm, some foul” interference temperature approach could be very large indeed. Sprint (2009, p. 19) notes for example that “even a small increase in noise of 1-2 dB would trigger a 33% reduction in data rates for some users”. Many others⁶ have documented the enormous costs of counteracting seemingly minor increases in the noise floor; for example Qualcomm (2009, p. 40) states that “a 1 dB increase in noise temperature in a licensed band would cause each CDMA-based cell to suffer a 10-15% decrease in coverage area”. Whichever way it’s measured, tweaking the noise floor has disastrous effects.

Ironically, Google states very clearly in its comments that it believes in market solutions: “Optimally, the Federal government should have in place a highly flexible, marketplace-driven spectrum regime...”⁷ and later they advocate “a more open and market-driven spectrum access policy,”⁸ in contrast to the heavy-handed bureaucratic command-and-control model. We couldn’t agree more, and commend Google on urging reliance on the market, as befits their entrepreneurial heritage. Unfortunately, elsewhere in its comments, Google inconsistently appears to favor mandated sharing. We hope they join us in urging the FCC to abandon mandated sharing and embrace market-based sharing.

We commend Google on the concern they show for innovators in the wireless space; we also are fans of innovation (who isn’t?) and believe innovation of all types should be encouraged. We would hope that in a market-based sharing regime, Google’s concern for innovation would extend to Google becoming a major network sharing manager, purchasing sharing rights with carriers in the competitive wireless sharing market, and providing this service free to innovators on an unlicensed basis. Thus far, Google’s concern for innovators only extends to advising the FCC to ask others to bear the cost of sharing. Google’s concern would be more credible if they were willing to bear the cost of spectrum sharing, should it ever come to pass.

Three (Bogus) Reasons Why Markets Won't Work

Advocates of mandated sharing will claim that a market solution will not work, and demand government command-and-control, if for no other reason than to gain free access to other people's assets. Can their claims be supported?

1. *There will be thousands of unlicensed devices; is each device owner expected to bargain with each licensee?*

Of course not; there are several solutions to this; we note that most cognitive radio systems rely on a "third-party network manager" that would monitor transmissions and assign frequencies.⁹ Each device owner would be registered with the network manager. This manager could be proactively used to minimize transactions costs.

- a. Licensees could post prices; device owners would be offered the price and could be billed through the network manager.¹⁰
 - b. The network manager could negotiate access prices with the licensee, which would apply to all devices under its control. Possible network managers are:
 - i. Licensees themselves
 - ii. Device manufacturers, such as Motorola, Samsung, Nokia,...
 - iii. Interested parties such as Google, Microsoft or other firms with a demonstrated interest in unlicensed devices.
2. *Licensees would never agree to permit sharing by potential unlicensed competitors.*

But this practice is standard in the CMRS industry today; all large licensees host Mobile Virtual Network Operators (MVNOs) who do not possess licenses and own no facilities.¹¹ They arrange with facilities-based carriers to host their traffic for which the MVNO¹² distributes the service, manages the handset sales and customer service. CMRS carriers provide this service at a market-based price. Since the CMRS market is highly competitive (see Faulhaber and Farber (2009), Katz (2009) and Willig (2009)) the market in spectrum sharing will be equally competitive; should a carrier decide not to offer sharing on reasonable terms, its competitors will surely be happy to pick up the business. Spectrum sharing on a market basis is the norm in this industry. To contend that this norm would suddenly change in the face of (properly administered) unlicensed users flies in the face of all the market evidence.

3. *But innovators have limited budgets and may not be able to afford to pay posted prices*
We are all on limited budgets and innovators are no different than other businesspersons. If indeed there is “no harm” and sharing is effectively free to licensees, then the competitive market price will be low and should not be a burden. If sharing does create interference, thereby reducing carriers’ capacity to transmit voice and data over the spectrum they paid for, then the price will be higher to reflect the opportunity cost of the licensees’ lost capacity, which is exactly what ought to happen. If this is still felt to be a burden on innovators, then perhaps the government should subsidize innovators with direct payments. It seems both unfair and inefficient to force carriers to subsidize the FCC’s more favored interest group. If the FCC really favors unlicensed users, then let the government find the money to subsidize them someplace other than the pockets of the carriers.¹³

Three Real Reasons Why Markets Could Fall Short...If the FCC Gets It Wrong

Of course, well-functioning markets must be supported by a state-supported rule-based environment which protects against trespass and is conducive to transactions and contracts and efficient dispute resolution. But unwise and unnecessary state intervention can also make things go very wrong. What should the FCC do, or conversely, what are the market-destroying actions the FCC may fall prey to? In the case of market-based spectrum sharing arrangements, the answer is simple: stay out of the way and let market-based contracts and contract law determine appropriate responses to unanticipated interference. However, we note that there must also be effective mechanisms to deal with unlawful interference from interlopers who have not contracted with the licensee. Here, the FCC’s track record (as discussed below) confirms a failure to respond with timely and effective enforcement even when harmful interference is prohibited and provides a cautionary tale of the disastrous consequences of a mandated sharing regime that would necessarily place even more reliance on FCC enforcement.¹⁴

1. *Who fixes the problem if there is more interference than contracted?*
It is one thing to say there will be “no harm” or even to say there will be “little harm”, but it is entirely another thing to be for a carrier to be managing its own spectrum in the field and be faced with unanticipated excess unlicensed demand, failures of the third party network manager, or other interference-creating condition. Who get to turn off the unlicensed devices, and how fast can they turn them off? Contracts and any government regulations should parallel a simple application of property law: if a shopkeeper finds a person in its store (and potentially a paying customer) who is disruptive, the shopkeeper may eject them from the store immediately. It is the shopkeeper who makes the call between ejecting a customer who may eventually buy something or not ending

the disruption and bothering other customers who otherwise might leave the store. Likewise, it should be the carrier's call to eject one or even a class of unlicensed customers if the carrier detects excessive interference.

- a. There is thus the need for the carrier to be able to turn off unlicensed devices in real time. This could happen at the third-party network manager level or at the device level. In either case, the hardware protocols in the devices or network manager must be able to accept a shutdown command, without negotiation. Carriers, of course, would find it in their own interest to maintain complete system records of the perceived interference, in case their shutdown is later disputed. The network manager could then begin negotiations to turn the system back on; carrier and network manager documentation of the problem would be most useful at this point. But the licensee must have control of its own licensed spectrum.
- b. In a market solution, the carrier could impose conditions on devices/network managers it was willing to do business with, and insist on devices/network managers that could be shut down on a signal from the carrier. *Competition* can ensure that carriers are unable to impose unnecessary conditions that network managers/unlicensed users would find unduly onerous, as a competitor would be happy to offer less stringent conditions and take the business.¹⁵
The recommendation for the FCC is simple: don't get in the way of such market transactions, or attempt to dictate the transaction terms. The competitive market will ensure that reasonable terms will evolve.

Be very clear: there will be interest groups that will benefit if the FCC mandates sharing, as they will get other people's assets for free. There will be interest groups that would prefer that *they* manage the carriers' networks rather than the carriers, as this would enhance the value to them of sharing others' assets. As usual, expect interest groups to lobby hard for the government to let them use other people's assets; it is up to the FCC to make the tough choice in the face of political pressure and let the market decide.

2. *What if hackers/jailbreakers tweak their devices to break the rules for their own benefit at the cost of interfering with others?*

Will people bend or break the rules if (i) it is to their benefit to do so, and (ii) it is technically feasible to do it without punishment? Of course they will. In the last decade, we have seen firms attempt to protect their business models using Digital Rights Management and various hardware and software protection schemes, and virtually all of them are circumvented by ingenious hackers. Most

recently, customers dissatisfied with Apple's exclusive distribution arrangement with AT&T for its popular iPhone "jailbreak" and unlock their iPhones so that they can be used on the networks of other carriers. What gets broken, of course, is the Apple-AT&T business model, upon which this most innovative wireless phone ever was based. More to the point, virtually any protection system can be hacked, and if it is in the interest of some to do so with little prospect of penalty, be assured that they will do so. *This is also true if the hack can negatively impact not only the firm but also other customers.* In the 1970s, it was easy to buy a power boosted CB radio that could substantially increase the range of the purchaser's radio but at the same time interfere with other nearby CB radio customers as well as nearby TV broadcast reception (see Faulhaber (2005), pp. 130-131). Illegal overpowered cordless phones were on sale several years ago that not only interfered with other cordless phones but also with airport/airplane communications (see Faulhaber, *op. cit.*). And hacked cognitive radios could be much worse; as opportunistic users, when they cause interference in one or more bands, they would be almost impossible to trace and identify (Faulhaber (2008) refers to this as "hit and run radio", p.1122).

Could this break the market? If hackers/jailbreakers represent a relatively small fraction of customers, then the market survives. For example, the market for automobiles is quite active even though auto theft is fairly widespread. The market for homes is active even though home break-ins and invasions occur with depressing regularity. The market for iPhones is robust even though jailbreaking them seems to be a popular topic on the Internet among techies. But widespread hacking and piracy can bring an industry to its knees, even destroying it. It is generally agreed that the Hong Kong movie industry was driven out of business by wholesale piracy of DVDs originating in Asia (Taipei Times (2005)).

It would appear that carriers and network managers have a common purpose, in that hackers who modify their devices to override sharing rules and/or increase power will surely cause interference for both licensed customers and unlicensed customers. If carriers and third-party network managers aggressively pursue such miscreants through the courts, the problem can probably be controlled sufficiently to protect the integrity of the market. If not, the carriers are likely to shut down spectrum sharing altogether.

Recommendation to the FCC: facilitate tracking and pursuing illegal users, working cooperatively with spectrum licensees (and their sharing partners).

3. *How will disputes be resolved and rules enforced?*

It is past and current practice that interference disputes and challenges to the rules are heard and resolved by the FCC. As the FCC makes clear in the NOI, it

is questioning whether some alternative dispute resolution mechanism would be fairer and more efficient.

The FCC is correct in raising this issue. Even when it is in a rush, such as the Nextel 800 Mhz case, the dispute took over one-and-a-half years to resolve (Faulhaber (2005), pp. 136-137). But a recent case is more telling as to the actual speed of dispute resolution at the FCC.

- a. In 2002 and 2004, Digital Antenna was granted type certification (AT&T (2009), Appendix C) for its Bi-Directional Antenna (BDA, or “booster”), a device that substantially increases the power levels of a cellular telephone. These devices are only permitted to be used by carrier personnel under controlled circumstances and not by customers of the carrier (unless specifically authorized by the carrier/licensee). Nevertheless, from its product launch of PowerMax booster in 2005 to today, Digital Antenna and its distributors market the PowerMax to cellphone customers as “approved by the FCC to be used with all carriers in the USA and Canada.” (Digital Antenna (2008)).
- b. The product proved popular, particularly with boaters and RV owners, but to no one’s surprise, it generated interference among other cellular customers. On May 1, 2006, CTIA files a white paper with the FCC urging immediate action with respect to BDAs, and documents “that as a result of these unauthorized operations, wireless carriers, including all of the nationwide providers and many regional and smaller providers, are experiencing significant interference that often results in a portion of a carrier’s network going down, cutting off service to all of its customers in a given area.” (CTIA (2006)). CTIA further requests that customers be notified that these devices cannot be legally used with any cellular phone. The FCC takes no action.
- c. The FCC sends a Letter of Inquiry to Digital Antenna on November 5, 2007¹⁶ explicitly informing them that Digital’s BDA “is for use with a licensed PCS transmitter and cannot be marketed to the general public under our Rules and Regulations.” Digital Antenna continues its marketing practices.
- d. On November 2, 2007, CTIA files a petition for declaratory ruling (CTIA (2007)) that unauthorized use and sale is illegal. The FCC takes no action on this petition.

- e. On February 4, 2008, the FCC again sends a Letter of Inquiry¹⁷ to Digital Antenna (FCC (2007)) ordering the firm to cease and desist its sales to customers. Neither ceasing nor desisting ensues.
- f. March, 2008: Florida county officials advise the FCC Chairman that dangerous increases in BDA-related interference in South Florida “jeopardize[s] the safety of the public as well as the lives of first responders.” (AT&T (2009), Appendix D).
- g. March, 2008: nine members of the US House of Representatives write a letter to then-Chairman Kevin Martin requesting the FCC to “issue a declaratory ruling that... the unauthorized sale and use of boosters and repeaters [is] unlawful.” (AT&T (2009), Appendix B).
- h. May, 2008: the FCC issues a Notice of Apparent Liability for Forfeiture and Order (FCC (2008a) to Digital Antenna, noting their unresponsiveness and continued marketing of their devices; they are fined \$11,000.
- i. August-November, 2008: FCC Miami field office issues a number of letters to individual boat owners notifying them that their boosters are causing interference and ordering them to stop using them. But of course there are over 50,000 customers of Digital Antenna and it would be forbiddingly costly if the carriers or the FCC to track them all down (FCC (2008b, 2008c)
- j. April 30, 2009: AT&T (2009a) files a complaint requesting the FCC take enforcement action against Digital Antenna, including ordering the firm to “cease and desist”. The FCC has not disclosed what if any action it will take.
- k. April 30, 2009: AT&T (see AT&T (2009b)) files a court complaint against Digital Antenna, claiming Lanham Act violations for Digital Antenna’s false advertising that use of its devices is authorized. Digital moves to refer the matter to the FCC under the primary jurisdiction doctrine.

In the four years since these products were first sold to the public, the FCC’s enforcement of its own rules has been ineffectual to say the least.¹⁸ Digital Antenna *still* markets its boosters as “FCC and IC approved to amplify all North American cell carriers operating on 850 and 1900 MHz” (Digital Antenna (2009)) to this day. It is no wonder that Digital Antenna seeks to refer the matter to the FCC; based on this track record, Digital Antenna has likely concluded that the FCC will do nothing, while a court of law might actually enforce the law, which is clearly not in Digital Antenna’s interest.

Justice delayed is justice denied. If this is how the FCC conducts its enforcement business under rules designed strictly to limit opportunities for the operation of unlicensed devices in licensed spectrum, imagine the chaos that could ensue in a regime that not only encouraged but mandated forced sharing of licensed spectrum with countless cognitive radios and other unlicensed devices and left it to the FCC to sort out the inevitable crush of interference disputes.

Would any firm be willing to invest and innovate in a regime in which the firm's license rights are given away to sharers that break the rules and create interference without fear of punishment or correction? The question answers itself.

This is yet another reason why the FCC should reject calls for mandated sharing. Market-based sharing solves the enforcement problem much more efficiently than unwarranted regulation. If carriers have contracts with network managers and/or normal commercial relations with customers/device owners, then normal commercial dispute resolution mechanisms should come into play. If network managers believe that they have been disconnected erroneously, they can bring suit in court against the carrier, as would occur in any commercial dispute. Of course, alternative dispute resolution mechanisms may be employed, such as mediation or binding arbitration. The market would seek out and implement the most efficient dispute resolution mechanism. If device owners feel aggrieved at an action by a host carrier, entrepreneurial lawyers will be anxious to help launch a class action suit, again as would occur in any commercial dispute. Do we mean to suggest that courts of law are an efficient means of resolving disputes? Of course not; the question is, are they more efficient than the FCC? Given the record of the FCC, it is hard not to find in favor of the courts. Of course, if the FCC mandates sharing, the inefficiencies of FCC dispute resolution will come with the package; unfortunately, mandated sharing would most likely substantially increase such disputes, so inefficient FCC dispute resolution becomes much more burdensome.

Recommendation: remove the FCC from interference dispute resolution in shared networks eschewing mandated sharing and embracing market-based sharing with normal commercial transactions and contracts, enforceable through the courts.

There is a simple home truth here: regulatory mandates, requirements, and limitations on suppliers make both investment and innovation more costly. As a result, mandates will lead to less of both investment and innovation. This is not an argument against regulation; it is simply an argument that before regulators impose mandates and constraints they must demonstrate that the benefits of these mandates outweigh the considerable costs, and that this demonstration must be based on hard evidence, not mere hand waving. The burden of proof rests with those advocating the mandates, and

thus far such proof regarding shared spectrum has not been forthcoming, partisan assertions notwithstanding.

We note that this simple home truth also applies to another recommendation in Google's Comments (2009): adoption of mandated network neutrality. As we noted previously (Faulhaber and Farber (2009)), *competitive forces will drive the market to whatever "network neutrality" that customers actually value without the need for a government mandate*. Attempts by regulators to preempt customers' choices and impose a bureaucratic network neutrality mandate can only lead to inefficient outcomes that increase costs, reduce incentives to invest and innovate, and reduce customer choice.

CONCLUSIONS

There are two clear and simple conclusions:

- Technologies such as cognitive radio that are potential users of shared spectrum are very far from actual deployment; there is no need to act precipitously to establish rules for technologies whose eventual implementations may be very different from today's views.
- Abandon *mandated* spectrum sharing as a relict of the bad old "command-and-control" FCC; enable competitive market-based sharing (which the market has already demonstrated is the most likely outcome) by adopting the recommendations of this paper.

The answer is so clear and obvious that it is, in retrospect, amazing that mandating spectrum sharing with a new and untried technology is even being considered. What could we have been thinking?

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-- Endnotes --

¹ A description for the lay person of cognitive radio and the problems that must be solved before deployment are in Faulhaber (2008).

² Interference temperature is identical to noise temperature, a measure of signal degradation in any electronic communication channel due to thermal and other additive forms of noise. This signal degradation noise can interfere with the intended signal (from the licensee) and has a random component (Gaussian noise); as the noise temperature decreases (due to random fluctuations) transmitters temporarily have increased capacity to send their signal; when the noise temperature increases (again due to random fluctuations) capacity is reduced and the signal is impaired. When the *mean* temperature increases, signal capacity is permanently reduced.

³ A telling anecdote: Faulhaber assigned his MBAs at the Wharton School an article (from The Economist (2002) to teach the new radio technologies such as mesh networks, ultra-wideband, and ad-hoc (cognitive) radios, all of which were described in the article as just around the corner. Eventually, my students noted that the date of this article was 2002 and the inventions had still not arrived. Along with my students, we are still waiting.

⁴ Some forms of cognitive radio spectrum sharing are currently being used in military applications, in a strictly controlled environment where interference is either controlled or even desirable.

⁵ When CMRS firms bought their licenses at auction, there was no hint that the FCC would snatch back paid-for capacity in order to share with unlicensed users. Is the FCC considering refunding a portion of the bids of the winners as recompense for this taking? Or will it simply claim that since it is the government, it can do anything it likes?

⁶ In addition to Sprint Nextel and Qualcomm, Verizon (2009, pp. 137-8)), Motorola (2009, p. 14), CTIA (2009b, pp. 79-81) and Ericsson (2009, pp. 17-20) show how small changes in the noise floor will have large negative impacts on licensees' ability to use their own spectrum efficiently.

⁷ Google (2009), p. 2

⁸ *Id*, p. 9

⁹ Some researchers (Clancy (2009)) have discussed having a network of devices act as intercommunicating sensors, with each device acting as its own manager. For several reasons discussed below, this regime leads to a variety of interference problems.

¹⁰ This approach is exactly analogous to shopping in a supermarket and paying with a credit card. The supermarket owner posts prices, the customer chooses what and how much they would like, and a third party (the credit card-issuing bank) arranges payment. No one could possibly claim that food distribution to customers is overburdened with transaction costs.

¹¹ For a description of the MVNO market worldwide, see Wikipedia (2009)

¹² For a list of MVNOs in the US, see Radio Raiders (2008).

¹³ To be perfectly clear, we believe such a subsidy scheme to be wildly bad public policy. There are many expenses that innovators face; they have to buy computers, office space (if only their garage), Internet access, office supplies, etc. Should the government be in the business of subsidizing (or forcing the innovators' suppliers to subsidize) any of these expenses, simply to make innovation in the *unlicensed* space easier? On the face of it, this is a nonsensical policy prescription. But this is precisely what mandated sharing is.

¹⁴ In previous work (Faulhaber (2005)), it is argued that establishing a property rights regime in spectrum (which both authors support) would change the locus of dispute resolution from the FCC to the courts which would be an efficiency-enhancing change.

¹⁵ In fact, even in imperfectly competitive markets, providers still have an incentive to offer sharing if they may earn profits from doing so. But since the wireless market is competitive, this insight is supernumerary for this paper.

¹⁶ This Letter of Inquiry is referenced in the FCC's Notice of Apparent Liability (2008a) but is unavailable in public FCC records.

¹⁷ This Letter of Inquiry is also referenced in FCC (2008a), p. 2.

¹⁸ There is no public record to indicate that Digital Antenna ever paid the paltry fine of \$11,000, or indeed what follow up was made by the FCC.