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Innovation in the Wireless Ecosystem: A Customer-Centric Framework

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The Federal Communications Commission's Notice of Inquiry in GN 09-157 Fostering Innovation and Investment in the Wireless Communications Market is a significant event at an opportune moment. Wireless communication has already radically changed the way that not only Americans, but people the world over communicate with each other and access and share information. In this article, we review the wireless industry's past performance in three dimensions: (i) the rate of innovation, (ii) how competitive the industry is, and (iii) how competitive *wireless innovation* is. We do so by examining the record of three key layers in the industry's vertical chain: software applications, devices (handhelds), and the core wireless distribution networks. We find that all three markets exhibit very high rates of innovation, that the markets are competitive, and that this competition has driven innovation. As in previous work (Faulhaber, 2009a) we argue that, absent market failure, regulatory intervention is not appropriate. A *customer-centric* perspective should govern the FCC's actions in the wireless ecosystem: let customers decide what they want in this competitive market.

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Introduction

The Federal Communications Commission's Notice of Inquiry in GN 09-157 Fostering Innovation and Investment in the Wireless Communications Market is a significant event at an opportune moment. Wireless communication has already radically changed the way that not only Americans, but people the world over communicate with each other and access and share information, and there appears to be no end in sight for this fundamental shift in communication markets. Although the wireless communication phenomenon is global, the United States has played, and will continue to play, a major role in the shaping of this market. At the start of a new U.S. Administration and during a time of important changes at the FCC, it is most appropriate that this proceeding be launched.

The title of the proceeding has been chosen wisely. Innovation and Investment are two sides of the same coin; new ideas, new technologies, and new business methods cannot happen without investment, and neither investment nor innovation will happen without incentives for innovators and investors to perform their roles. The focus on market is also a wise choice; some might view wireless as a technology, or perhaps a social phenomenon, and of course it is all of these. But it is the market which brings all of this to fruition, and certainly, it is the market that determines what innovations and investments customers really want. Of course, this is not enough; key resources such as spectrum must be readily available in order for markets to play their role in eliciting innovation and investment.

Some analysts and pundits have suggested that the market for wireless communications is flawed, controlled by a few large firms that suppress new technologies and limit the market.[1] They call for FCC intervention to fix these flaws via regulation, and many of the issues raised by these analysts and pundits are raised in the NOI. But good policy requires that intervention in markets must be based on empirical evidence of market failures and the likelihood of a proposed remedy's efficacy in correcting that failure. Unless interventions are based on rigorous analysis of market failure and the efficacy of the remedy, the most likely outcome is increased cost, reduced customer choice, reduced incentives to invest, and reduced incentives to innovate.[2]

In earlier work, Faulhaber (2009a) argued that FCC policy must be *customer-centric*; ensuring that key decisions about products and services should be made by customers in the competitive marketplace, not regulators, legislators, pundits, self-styled advocates, lobbyists, or even academics. The job of the FCC is not to make decisions about "approved" business models, but rather, to ensure that customers are able to make such choices in markets which are competitive, innovative, and transparent. The customer must be at the center of decision-making; it is the job of the FCC to make that happen. We take the same perspective in this paper.

In this paper, we review the wireless industry's past performance in three dimensions: (i) the rate of innovation, (ii) how competitive the industry is, and (iii) how competitive *wireless innovation* is.

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[1] The most prominent is Tim Wu (2007) who noted a number of problems with openness (and lack thereof) in the wireless industry. We discuss and critique Wu's assertions in detail below.

[2] The economics literature on well-meaning regulations causing substantial harm is extensive. We note particularly Carlton and Perloff (2005) and Noll (1989).

We do so by examining the record of three key layers in the industry's vertical chain: software applications, devices (handhelds), and the core wireless distribution networks. We find it useful to compare and contrast the wireless ecosystem (including Internet access) with the personal computer/Internet ecosystem, both in terms of innovation and in terms of market structure.

To preview our results, we find that the three segments of the wireless marketplace (applications, devices, and core network) have exhibited very substantial innovation and investment since the market's inception. Perhaps more interesting, innovation in each segment is highly dependent upon innovation in the other segments. For example, new applications depend upon both advances in device hardware capabilities and advances in the spectral efficiency of the core network to provide the network capacity to serve those applications. Further, we find that the three segments of the industry are also highly competitive. There are many players in each segment, each of which aggressively seeks out customers through new technology and new business methods. The results of this competition are manifest: (i) firms are driven to innovate and invest in order to win in the competitive marketplace; (ii) new business models have emerged that give customers more choice; and (iii) firms have opened new areas, such as wireless broadband and laptop wireless, in order to expand their strategic options.

Having found that all three segments are highly competitive, we ask, where is the market failure? If none is there, then the principle of customer-centrism applies: let *customers* make the key decisions regarding which products, services, open vs. managed business models, net neutrality, etc. will survive in the marketplace. While there is no shortage of pundits, advocates, lobbyists, and academics advising the FCC that it, rather than customers, should be making these decisions, as well as advising the FCC what those decisions should be, a customer-centric FCC must leave these decisions to customers in a competitive marketplace. Should the FCC decide to preempt customers and make choices for them, it follows as night does from day that the result will be (i) less customer choice, and therefore reduced customer well-being; (ii) higher costs for producers and therefore customers; (iii) lower incentives to invest and innovate, harming customers, producers, and the American economy. In this case, economics and technology are on the same page: Economists advise intervention only in the case of demonstrated market failure, and then only if there is evidence that the intervention will do more good than harm. The technologist's advice is more pithy and down to earth: If it ain't broke, don't fix it!

We then consider potential problems raised in the NOI as possible targets for FCC intervention. The subsequent sections of the paper explore whether or not there are market failures in wireless communications, and, if so, what some appropriate interventions might be. We are mindful, and ask that the FCC be mindful, of the potential negative effects of well-meaning interventions that are unsupported by hard evidence.

We explicitly ask if there is a proactive role for the FCC in fostering innovation and find that, indeed, there is. The FCC can and must play a crucial role in making available much more licensed spectrum for use in wireless communications. Only if sufficient spectrum is made available will innovators and investors have the critical input they need to keep up the rate of innovation that the industry has so far exhibited.

Specifically, we address issues in the NOI regarding whether the FCC should

- mandate spectrum sharing of licensed spectrum, with the view of encouraging "non-interfering" uses such as cognitive radio;[3]
- adopt network infrastructure policies that foster the deployment of 4G and future technologies for wireless broadband, as well as explore alternatives to traditional network architectures, such as mesh networks.

Adopt alternative dispute resolution processes for resolving interference disputes; consider "openness" regulation, so that all applications can run on all compatible devices (we discuss the proposed network neutrality regulations of the FCC's recently released NPRM below); and

- consider how different business platforms and different business models affect innovation.

Lastly, we raise an issue not addressed in the NOI, transparency. In the body of the article, we make the consistent argument that competition in all segments of the industry has driven innovation and can continue to do so. But it will only do so if customers understand what they are buying and can make informed and intelligent purchase decisions. This requires all producers (application providers, device makers, and core network providers) to be transparent in their dealings with customers concerning all matters that are relevant to customers' purchase decisions. Part and parcel of a customer-centric policy must be ensuring the transparency of all wireless markets, a charge that government must take very seriously.

To preview our conclusions, we find all wireless segments to be demonstrably innovative, with competition driving this innovation. We find that there is no market failure which would necessitate market intervention by the FCC. Indeed, we strongly support a customer-centric policy: Put the customer at the center of decision-making. Let the customer, rather than regulators, legislators, pundits, advocates or academics, decide among open or managed business models and various network management options, as well as on the degree to which they demand network neutrality and interconnection. Firms that don't satisfy customers' needs will lose out to firms that do. The job of the FCC is to put the customer in the driver's seat. This leads us to make two specific policy recommendations to the FCC: (i) make more spectrum available for licensed use; and (ii) ensure that customers have the information they need to make informed decisions.

[3] In earlier work (2003), the authors suggested the use of "non-interfering easements" as a means of encouraging more efficient use of spectrum. In later work, Faulhaber (2005, 2008) raised doubts about how "non-interfering" such uses would be in practice.

Wireless Innovation — The Story Thus Far

Virtually anyone anywhere in the world is aware of the speed of innovation in wireless handsets over the past decade. New handsets of ever-increasing functionality appear weekly, in every country in the world.[4] But rapid innovation has also occurred throughout the vertical chain of the wireless industry — in applications, devices, and the core network. Although the innovation in handsets/devices (and applications) has been most obvious to customers, innovation in the core network has been just as rapid, if not as visible.

In this section, we review recent innovations in applications, devices, and the core network. The innovation record in the first two segments is unsurprising, but certainly worth studying. The innovation record in core networks should not be a surprise, as networks have become much more capable over the past five years. But while the innovation process is less obvious and more behind-the-scenes, it is still perhaps the most important *situ* of innovation, because network innovation enables all the innovation in the other segments. We discuss how innovation must necessarily be integrated across all three segments in this industry, which is in stark contrast to innovation in the PC/Internet ecosystem.

Innovation in Applications

Software applications for wireless phones have gone from essentially zero a few years ago to tens of thousands of applications today. Software vendors, device vendors, and carriers offer app stores, each offering hundreds or thousands of applications for download — some free, some for a fee. Table 1 in the Appendix is a list of application stores available online for downloading wireless apps. Virtually all major players in both the carrier and the device markets now have a very rich selection of applications from which customers may choose — a result consistent with a highly competitive market sporting a high rate of innovation.

What demonstrates the extremely rapid pace of innovation in the applications segment is the fact that the Apple's *affiliated app store* was established in July 2008; almost all of the rest of the affiliated stores have started up since then.[5]

The range of applications available is also worth a look, as nothing like this existed a decade ago. It demonstrates the extraordinary inventiveness of software developers. A few selected applications, from the useful to the social to the wacky, are displayed in Table 2 of the Appendix. The sheer variety is breathtaking; the application market is certainly not plain vanilla.

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[4] For a synopsis of mobile communications worldwide, see Faulhaber (2010), among many others.

[5] A few stores are older; Handango was founded in 1999 and GetJar in 2004, the same that year AT&T's debuted.

Many of these applications are specifically designed to take advantage of particular features in the devices, operating systems, and networks for which they were designed. The lesson here is clear: innovation in applications often depends critically on innovation in other segments of the industry.

And customers are using apps, particularly on the most capable devices. Stone (2009) reports that Apple has sold more than 30 million iPhones since their introduction, and customers have downloaded more than 2 billion apps (from an inventory of 85,000). This works out to 66 apps per iPhone. *Communications Daily* (2009) quotes Cole Bradman, Chief Technology and Innovation officer of T-Mobile, which sells the Google/Android phone, as saying that they support 10,000 apps for the Android, and that their customers download an average of 40 apps for their Android phones.

The outpouring of applications since the introduction of the iPhone mimics both the outpouring of applications that occurred in the decade following the introduction of Windows on the personal computer and the outpouring of applications in the decade after the widespread use of the Internet. Some argue (Wu, 2007) that applications are more difficult to write and have accepted in the wireless ecosystem than they are in the Internet/PC ecosystem. It is certainly true that applications that are sold in device vendor or carrier app stores usually must pass stringent compatibility tests,[6] which is not the case in the PC/Internet applications market. However, the number of applications available belies the assertion that these compatibility tests have been a barrier to innovation. As a practical business matter, the pace of introduction of new applications seems to be overwhelming to customers. CNET (2009) quotes Brodman of T-Mobile stating that

> T-Mobile hasn't 'cracked the code' on how to expose customers to applications among the many offered for Google Android smartphones … The importance and difficulty of aiding users' 'discovery' of apps have grown as the Android Market online has expanded to more than 10,000 offerings. (2009)

Innovation in Devices

In a recent *ex parte* filing with the FCC, CTIA documents that there are at least 33 device manufacturers selling over 630 different handsets in the United States. The worldwide figure is even higher, and device manufacturing is a worldwide business. U.S. customers can thus tap into the ingenuity and invention of manufacturers in Europe, Canada, East Asia, and elsewhere, as well as that of the U.S. in the handset market.[7]

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[6] Generally, each device vendor or carrier screens applications to verify that they will work as claimed on their system. The Android app store allegedly accepts applications without screening, in the interest of openness. Of course, independent app stores cannot verify that their products work on particular devices or carrier networks. This topic is discussed further under Business Models.

[7] A quick scan of AT&T Wireless's Web site shows 33 models for sale (not including refurbished phones and non-phone devices). A scan of Verizon Wireless's Web site shows 40 phones, 10 smartphones, and 8 Blackberry devices (Web sites visited September 18, 2009).

We take a direct approach to demonstrating innovation in handsets: We list some of the many major handset launches over the past several years in Table 3 in the Appendix. Devices now on offer were the stuff of science fiction a decade ago.

Note that, while the headlines focus on high-end phones, especially those that compete with the iPhone, new low-cost phones continue to be introduced with new features and functions. Device innovation benefits the entire product range, not just the high end.

What is most compelling about this list is how rapidly new handsets are introduced, with each one offering features undreamed of five years ago. And the pace continues: Matt Richtel (2009) of *The New York Times* reports that Google has announced that 18 new Android handsets will be introduced by EOY 2009 by device makers. Clearly, innovation is alive and well in the handheld device segment of the wireless marketplace.

Innovation in Core Networks

The carrier segment of the wireless industry is least understood by the general public, in that their service, while at the core of the business, is largely invisible. We hold handset devices in our hand and use them every day. Similarly, we experience applications very directly when we use them. But the radio signals, the receivers, the processors, and the backhaul networks are simply invisible to us. Of course, we spot the occasional cell tower as we drive, but that is usually the extent of our awareness. We know, of course, that what makes our cell phones work is radio, connecting us to the phone network and the Internet via controlled and directed electromagnetic radiation, together with the processing at both the handset and the cell tower, but what is it that really goes on? If we are in a "dead zone," we know that we are out of our carrier's coverage area and cannot make calls. We know that our calls may be dropped if the capacity of the closest tower is exceeded by lots of voice or data traffic. But most of us know little or nothing about the "magic" that happens between our cell phones and our carriers.

At its most basic, carriers are assigned radio frequencies over which our voice and data signals are sent to carrier receivers. Many customers may be using a given tower/receiver, sharing frequencies to do so. The more frequencies (more "bandwidth"), the more capacity that cell tower has to move voice and data traffic. Carriers obtain these frequencies in different parts of the country by bidding at FCC auction for licenses to use the bandwidth they need to move traffic. Of necessity, this resource is quite limited, and the FCC has limited the amount of licensed spectrum available for mobile wireless (Commercial Mobile Radio Service, or CMRS) communications. In spite of this scarcity of spectrum, carriers have been able to utilize this resource with ever-increasing efficiency to offer more voice services (and recently, more data services) over mobile phones.

Innovation in the core network, therefore, can be conceived of as *increasing spectral efficiency*. Increased spectral efficiency is manifest to customers as increased capacity to make voice calls, and as the increased speeds by which our phones access the Internet, download our e-mail, and allow us to watch video on our handsets, based on the very limited resource of spectrum. Innovation in spectrum use

takes place in laboratories[8] and research centers and real world networks around the world. It consists of scientists and engineers determining better, more efficient protocols for sending and receiving information over the air using less spectrum. In its simplest terms, spectral efficiency is about how many bits (i.e., information) can be successfully transmitted per megahertz (MHz) (i.e., bandwidth) of spectrum.

Innovation in core networks often takes the form of standard-setting, as new means of using the carrier's spectrum must be accompanied by new devices, and device manufacturers must have standards to which they build their handsets, or else the handsets won't work on the network. Therefore, we often see core network innovation manifest in an alphabet soup of protocol initials: CDMA, GSM, WiMAX, 3G, 4G, EV-DO Rev A, HSDPA, UMTS, and LTE, to name a few. Each is a network protocol, and each represents an advance in spectral efficiency, as shown in Table 4 in the Appendix, which shows the pace of network innovation over the past several years.

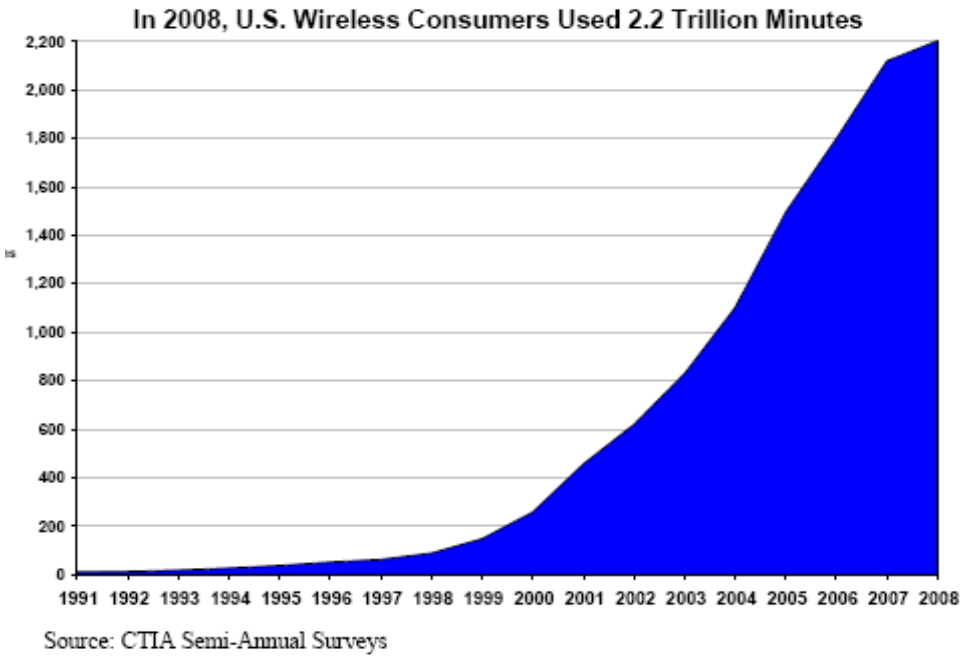
Overall, how do U.S. carriers measure up in terms of spectral efficiency? Campbell (2009) finds that the United States leads all OECD countries in subscribers served per MHz of spectrum allocated. U.S. carriers are more efficient than Japan, more efficient than Korea, and more efficient than any European country. U.S. carrier innovation in networks allows our networks to be far more efficient than any other country. Could this be because U.S. customers use less voice and less data? As it turns out, the same report shows that U.S. customers use far *more* voice and data than customers in other countries. So yes, innovation in the core network has made us a world leader in managing the scarce resource of spectrum and providing capacity to meet the world's most demanding customers.

How does this innovation in spectral efficiency affect customers? Again, we list announcements of major deployments of network innovations in Table 5 in the Appendix. Each innovation represents increased capability for customers to access voice and data applications of their choosing.

As Figure 1 shows, core network innovation has enabled U.S. carriers to keep up with soaring demand for voice traffic.

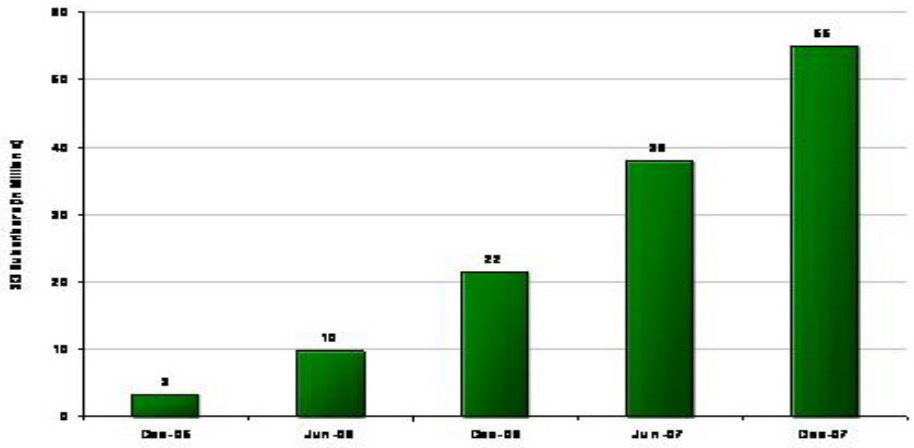
[8] AT&T Laboratories is a leader in wireless innovation, as well as in the standard-setting process in the U.S. It is a successor to Bell Telephone Laboratories, of which both authors are alumni.

Figure 1. Growth in U.S. Voice Minutes.



Data traffic is also soaring: Cisco (2009) estimates that mobile data traffic is increasing at the annual rate of 130% (both U.S. and worldwide rates). Figure 2 shows that, this increase has been accompanied by soaring numbers of U.S. data subscribers.

Figure 2. Growth in U.S. 3G Subscribers.



The one item that isn't soaring is spectrum licensed by the FCC to the carriers. So if capacity isn't increasing, how is it the carriers are handling vastly increased traffic? The answer is core network innovation, which has led to substantially increased spectral efficiency. Carriers are doing more with less.

Wireless Innovation – A Collaborative Venture

In the previous subsection, we separately reviewed innovations in each segment of the wireless industry, noting rapid introduction and deployment of new technology for applications, devices, and the core networks. But the innovation process in wireless is not at all separate; it is a collaborative venture between and among the three separate segments. Innovations in devices depend crucially upon innovations in core networks, and innovations in applications depend crucially upon innovations in devices and core networks. The applications that customers demand, though, drive innovations in all three segments. Customers demand access to the Internet and other data services, so Internet applications are developed, devices become Internet-enabled, and core networks ensure that capacity is available for high-speed data through spectral efficiency innovation. All of this innovation is driven by customer demand; it is *customer-centric innovation.* To achieve this, cooperation and collaboration is required among all three segments.

Both device manufacturers and carriers establish standards and protocols that application developers must meet. Each advertises developers' toolkits.[9] Carriers and manufacturers hold conferences and tutorials on how application developers can become certified to offer applications on their platforms, ensuring that developers can focus their efforts on applications that will work with their target platforms.

Manufacturers of handsets and carriers must work closely to ensure that the phones and the networks function in the ways that they must to maintain quality transmission and use the spectrum efficiently. Since they are innovating in a competitive environment, they must tightly control both costs and power drain. As carriers develop new protocols to increase network performance, they must work with device makers who will build the handsets that use these protocols, and they must do so with the device makers' needs in mind. The alphabet soup of standards have been developed jointly in standards committees, with carriers and device makers both party to the development of these standards, each representing the needs of their own firm to enable innovation to move forward on both sides of the market. Without devices to use standards such as 4G LTE, networks need not bother with building ultra-high-capacity data networks, and without the networks to transmit 4G LTE, the device makers need not bother building the next generation of ultra-high-speed broadband handsets. And without these collaborative innovations, developers need not bother building the applications, such as IP TV, that can use these ultra-high-speed connections.

[9] See, for example, AT&T's developers' Web site devCentral at http://developer.cingular.com/developer/?_requestid=136448, and Verizon Wireless's developers' Web site at http://developer.verizon.com/jsps/devCenters/wireless/index.jsp

A current example from McKeough (2009) brings this techno-speak down to earth:

> AT&T is developing a software tool and networking platform that will use wireless devices to record a patient's health measurements at home and send the data to the doctor . . . [using a wireless technology] named ZigBee, which receives data from medical sensors. ZigBee consumes considerably less power, so monitoring devices, including thermometers, pill dispensers, blood-pressure monitors, and pulse oximeters, can use small batteries to transmit data over long periods of time. . . . If a physician notices, for instance, that a blood-pressure medication isn't working, or if the patient isn't taking the drugs regularly, she'll be able to arrange a videoconference with the patient to discuss solutions. (2009)

By contrast, innovation in the wireline Internet can be highly compartmentalized. Innovation in transmission, either to the home or among backbone providers, is largely focused on improved fiber optic links and improved cable standards, such as DOCSIS 3, and innovation in routing is largely focused on faster Internet servers. At the customer end, hardware innovation is largely focused on PCs and other terminal devices (including WiFi), and it is independent of network innovations. Applications developers need not concern themselves with network innovations or PC innovations, and so can innovate independently. Of course, each segment must be able to forecast the capabilities of the complementary segments, but they often don't need to actually collaborate to innovate. In the wireline Internet/PC ecosystem, innovation can proceed independently. In the wireless ecosystem, innovation proceeds only through close cooperation among all segments of the industry.

The rationale for this difference resides in the nature of the interfaces among the segments of the two industries. In the case of the Internet/PC ecosystem, many application developers choose to write code for a single operating system, Windows, on which the vast majority of PCs run,[10] and one network protocol, TCP/IP. The interface between applications and the PC/OS is well-understood and time-tested; and TCP/IP has been the simple Internet standard for more than 20 years. Similarly, PC manufacturers need only consider the simple TCP/IP interface when designing hardware to work with the Internet. In both cases, the interface between segments is straightforward, standardized, and well-understood. In the wireless world, the interfaces among segments are far more complex. Devices and the core network must work together quite closely during a voice or data transmission in order to ensure that the carrier can make the most efficient use of the spectrum, as well as that the devices comply with the complex task of real-time spectrum management.[11] Applications must be vetted to ensure that they work safely with both the devices and the core network, as they can interfere with the proper functioning of the radio channel. No such concerns exist in the wired Internet/PC ecosystem. It is the complexity of these interfaces that

[10] Apologies to Mac and Linux customers; some applications are developed for both platforms, but the dominance of the Windows OS makes it the must-have platform of choice for many developers.

[11] By way of example, some wireless network systems can detect when the "noise floor" (the amount of ambient radio noise affecting transmission quality between device and cell tower) raises or lowers, and can ask devices to adjust their power level of sending and receiving to make maximum use of spectrum as the noise floor fluctuates.

demand collaborative innovation in the wireless ecosystem, a model which is simply not present in the wired Internet/PC ecosystem.[12]

Another difference between the Internet/PC ecosystem and the wireless ecosystem is that there has been much less competition in standards or operating systems in the Internet/PC world, while competition among standards and operating systems has been vigorous in the wireless ecosystem, acting as an important driver of innovation. The competitive field of handheld operating systems includes Apple vs. Google vs. Microsoft vs. Symbian vs. Blackbery vs. Palm webOS vs. Nokia Maemo vs. Linux . . . . In the PC world, there is, for all practical purposes, Windows. In the wireless core network high-speed data world, there is HSPA, EV-DO, WiMAX, and LTE. In the Internet/PC world, there is TCP/IP. Greenstein (2009) concludes that

> [B]ecause standards are extraordinarily important and valuable in introducing innovation to the value chain, their development and rollout anticipates new services and inventive activity. There are often multiple solutions to similar problems, so competition between standards proxies for multiple solutions for users.

In short, "standards competition beats the alternative" and "standards designed in the absence of competition are usually much worse."

Experienced Internet professionals often advocate the Internet model of innovation; we believe there are important lessons to be learned from the Internet, but that innovation in the wireless ecosystem is very different from innovation in the Internet. Lessons from Internet innovation must be applied to wireless innovation judiciously, with due respect for these differences.

This is not to say that collaboration is all sweetness and light; firms in different segments have different needs, and when standards are being hammered out in committee meetings, conflict can be expected. Each application provider must deliver a different product for each device using a different operating system. Each device maker must deliver a different product for each carrier using a different network standard; the process is likely contentious. But ultimately, in a competitive industry, all firms

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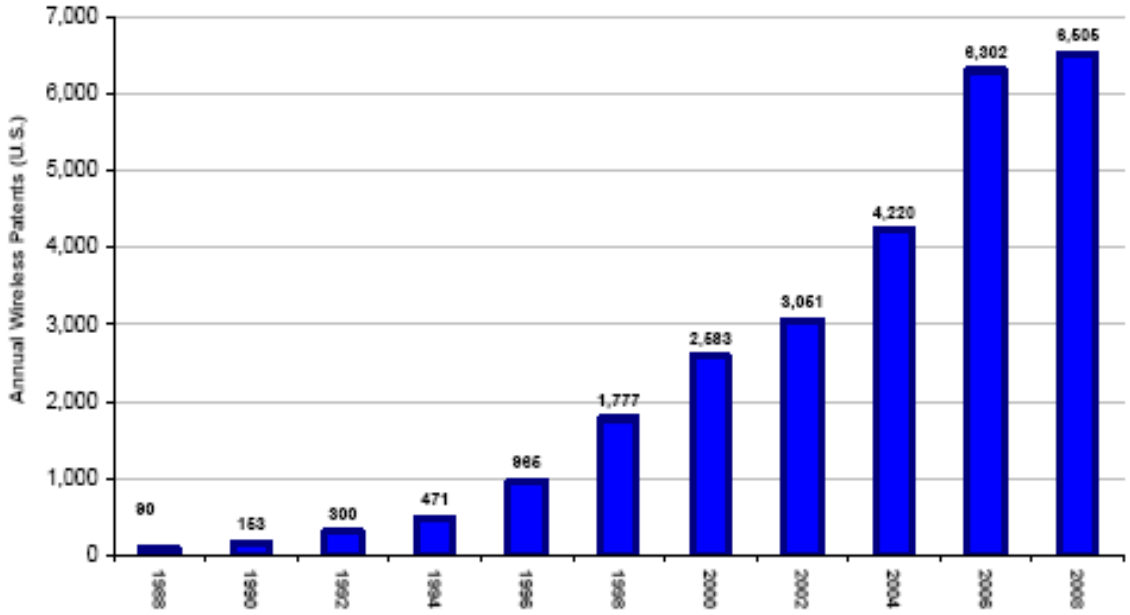
[12] The complexity/simplicity dichotomy has an interesting and instructive economic analogy. Suppose two firms are to transact business. In the first instance, suppose the transaction is simple; for example, buying copier paper. There are well-established standards for copier paper, so the purchasing firm can simply specify the standard and check that the standard has been met upon delivery. In the second instance, suppose the transaction is more complex; for example, the purchasing firm wishes the supplier to provide research and development for a common project. There is no standard, and execution of the transaction depends upon the supplier operating in good faith and in close cooperation with the staff of the purchasing firm. Simple contracts are no longer possible, and some form of long-term relationship usually characterizes such transactions, with elements of trust and common purpose that are not present in the purchase of copier paper. As in the case of the Internet/PC ecosystem (simple interfaces) vs. the wireless ecosystem (complex interfaces), the difference in collaborative innovation is marked.

have a common interest in delivering what the customer wants and needs. Only if the innovation process is customer-centric will these firms survive. Collaboration is the necessary survival strategy.

Does this complex innovation process work? Can the competitive market deliver the goods when it comes to innovation? Tables 1-5 tell us the answer: Yes, the market has delivered innovation. Another measure of innovation is the number of patents granted related to CMRS,[13] and the data show substantial and increasing patent activity in this industry.

Figure 3. Licensed CMRS Patents Granted.



Source: CTIA (2009)

The evidence tells a compelling story of innovation at breakneck speed in all segments of the industry. It also tells a story of collaborative innovation, a rather different story than that which has occurred in the wired Internet/PC ecosystem. It has been an ecosystem driven by customer-centric outcomes, one to which we now turn.

[13] Using patents as a measure of innovation has its pitfalls: increasingly, patents are applied for as defensive measures by innovative companies, and so-called "submarine" patents are a favorite tool by which persons can threaten firms that offer innovative products with patent infringement suits. Despite its faults, it is likely the best direct measure of innovative activity available.

Wireless Competition – In Products/Services and in Innovation

Wireless Competition is the subject of another proceeding, and the topic has been amply and expertly discussed by our colleagues Michael Katz (2009) and Bobby Willig (2009). However, the topic is particularly important to innovation in the wireless ecosystem, and so it bears a brief discussion in this articler. Our primary focus, however, is on competition in innovation; competition in product markets may lead to competition in innovation, but not necessarily. We ask: Has innovation in wireless markets been related to competition in those markets?

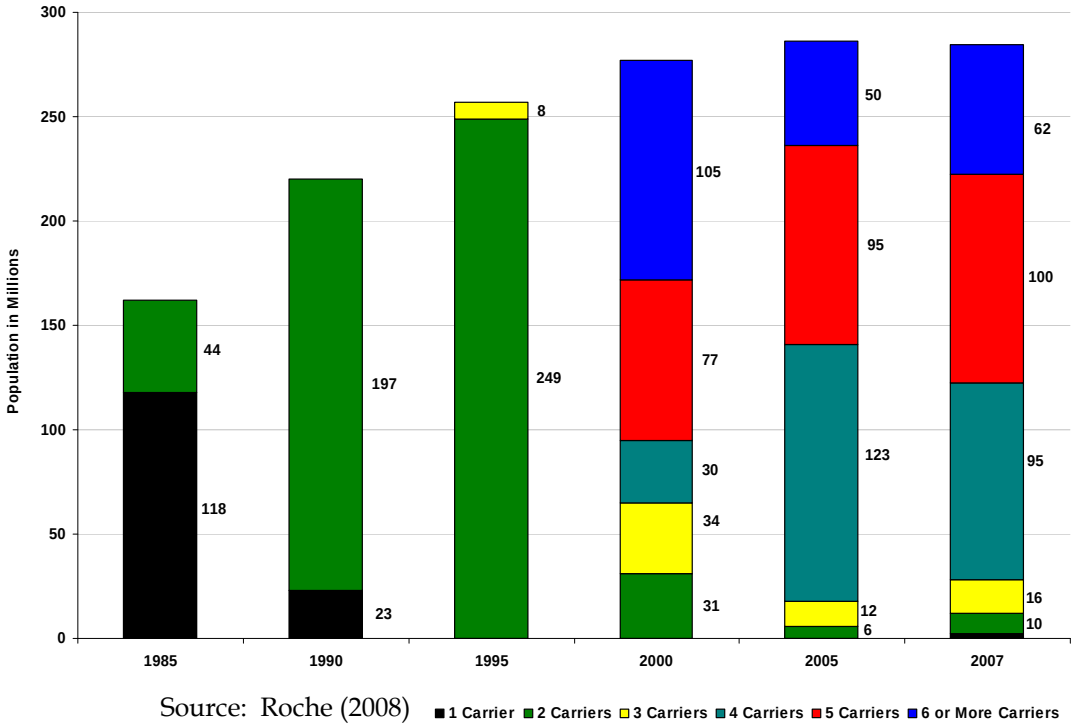
Competition in Products/Services

Of the three segments of the wireless industry, both the applications segment and the device segment compete for customers worldwide with many players which are, without question, highly competitive. We need not belabor the obvious, so we focus our attention on core network providers (carriers). The carrier segment is rather different than either the applications or device segments. Although carriers can operate nationally and globally, there may be local variations. Customers tend to buy their cell service in the metro area where they live. Competition, therefore, can be more of a local issue. For example, is the carrier segment in Philadelphia competitive? How about in Pittsburgh? In principle, the answers to these two questions could be different.[14] It is also a capital-intensive industry, requiring substantial investments in towers, radio equipment, switching, and backhaul. This might lead one to expect that the carrier segment would be highly concentrated and not very competitive. We use several simple measures to show that this is not the case; the carrier segment is not concentrated in the United States, a fact that has resulted in lower prices and higher volumes than anywhere else in the world.

Do wireless customers have choices of carriers? In spite of claims that the wireless market is an oligopoly, 95% of the U.S. population has access to three or more carriers, and 72% has access to five or more carriers (CTIA, 2009). And new carriers, such as Clear, Cricket, MetroPCS, and Boost (to mention recent entrants into the Philadelphia wireless market) are increasing customer choice.

[14] Regional/national carriers typically do marketing and pricing at a regional/national level, although competition at the local level in the form of promotions is quite active.

Figure 4. U.S. Population with Access to Multiple Wireless Carriers.



Source: Roche (2008)

And customers have no qualms about changing their carriers; the FCC (2009) found that between 15% and 40% of customers change carriers every year. With number portability, changing carriers is easy, and customers show that they are willing to move. It is no wonder that the FCC found in the same report that CMRS services are effectively competitive.

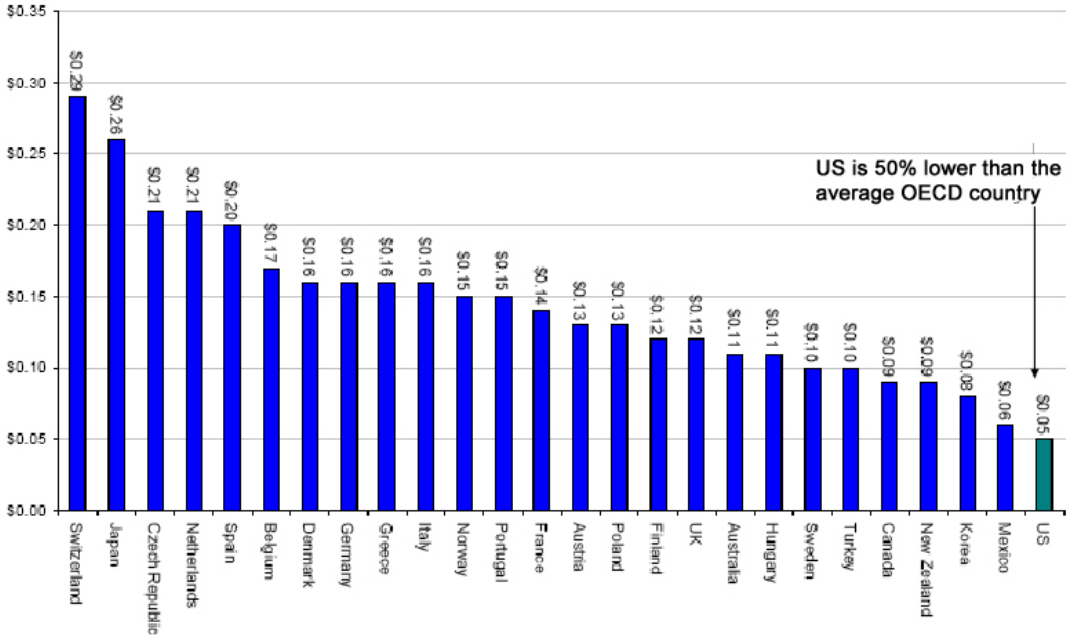
Given the capital intensity of the industry, one might expect that traditional antitrust measures would show substantial concentration. The standard measure of industry concentration is the HHI (Herfindahl-Hirschman Index)[15] which shows rather the opposite. The U.S. CMRS segment has an HHI of 2280, barely above the threshold of 1800 (below which antitrust issues are dismissed out of hand), and it is the *lowest HHI of any country in the world* (Campbell, 2009).[16]

[15] See Wikipedia (2009b) for a definition of HHI and its use in competition analysis.

[16] Simple concentration measures such as HHI are in no way dispositive of the state of competition, as discussed in Katz (2009). Indeed, in antitrust analysis at the Department of Justice and the Federal Trade Commission, HHI is simply an initial screening measure to determine if further analysis is warranted. No antitrust finding ever rests upon the HHI index of an industry.

But do these measures of competition impact customers? We use two simple measures of impact on customers, based on international comparisons. Average revenue per minute (our best proxy for *price) is lower in the United States than in any other OECD country* (Campbell, 2009).[17]

Figure 5. Revenue per minute, OECD Countries.

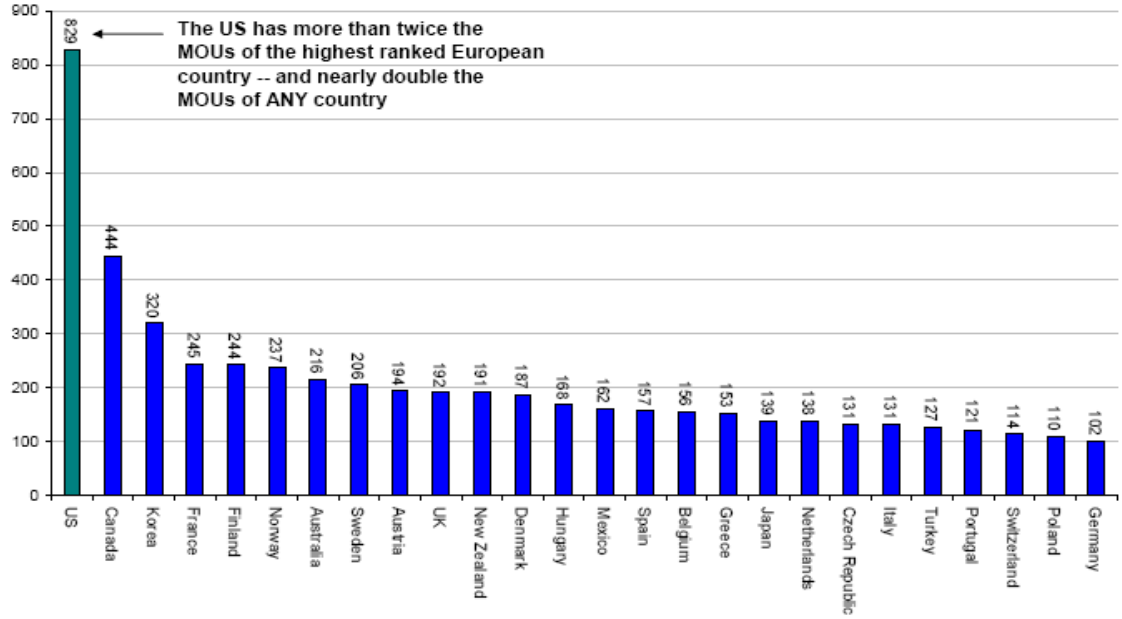


Source: Campbell (2009)

As might be expected, lower prices lead to greater demand, and the *United States has more minutes of use per customer than any other OECD country*.

[17] We are mindful that international comparisons can be misused and are, at best, indicative. We believe that the Bank of America/Merrill Lynch work is as reliable and unbiased as any available.

Figure 6. Average Minutes of Use per Customer, OECD Countries.



Source: Campbell (2009)

Again, we defer to our colleagues Michael Katz (2009) and Bobby Willig (2009), whose work on CMRS competitiveness is definitive. Our efforts here are simply indicative, easy-to-understand measures of competitiveness, which we recognize as incomplete, if nevertheless quite suggestive.

Competition in Innovation

The previous subsection considered (quite briefly) *static* competition and examined the effect of marketplace structure on prices and outputs. But a more important question in the wireless ecosystem is *dynamic* competition, or competition among firms to introduce new products, services, and network advancements.[18]

The analysis of the previous section provides us with the answers.

- In the *application* segment, we have gone from dozens of applications to more than 100,000 applications in the past decade, and one recent event stands out as the

[18] Static efficiency is sometimes referred to as Marshallian, after Alfred Marshall, a founder of modern economic analysis. Dynamic efficiency is referred to as Schumpeterian, after Joseph Schumpeter, a pioneer in identifying the role of innovation in economic growth.

driver of this explosion of innovation: the establishment of Apple's iPhone App Store. Previously, carriers were cautious about accepting new applications. Perhaps it took a new entrant (Apple) into the industry to show that customers really did want lots of applications, and that firms could turn a profit by encouraging applications. In the 15 months since the introduction of the Apple App Store, dozens of stores have sprung up, driven by the competitive necessity of matching Apple's business model innovation. As noted, most app store launches followed very quickly after the launch of Apple's App Store.

- In the *device* segment, the technology race was already on prior to the introduction of the iPhone, but clearly, the iPhone raised the bar for other device makers. Within months, manufacturers in East Asia, Canada, and Europe were rushing to market with iPhone wannabees, some quite successful. Would Blackberry have rushed the Storm and the Tour to market without the competitive push of the iPhone? Would Palm have rushed the Pre to market without the competitive push of the iPhone (and Blackberry)? In the device market, we see a virtuous circle, in which innovation begets further innovation, as manufacturers innovate in order to stay in the game. Yesterday's state-of-the-art cell phone[19] (e.g., the Palm Treo), is simply no longer salable; it is competition in innovation which has led to this cutthroat but dynamically efficient result. In his analysis of the device market, Levy (2009) states that U.S. wireless customers are the beneficiaries of a "brutal technology competition that is making the chariot race in Ben Hur look like a stroll in the park."
- In the *core network* segment, competition takes place over network capacity and coverage. From our TV commercials, we know that "more bars in more places" is important to customers, but we also know that "the fastest 3G network" is also important. Both are related to the carrier's use of advanced networking standards that provide the spectral efficiency needed to ensure capacity for both voice and data, and demonstrate that network standards of ever-increasing spectral efficiency are a competitive necessity in the core network business. Both AT&T and Verizon Wireless have announced plans to deploy LTE, a true 4G technology which promises achievable wireless broadband speeds in the 8-12 Mbps range (Segan, 2009). Sprint/Clearwire has already deployed WiMAX in Baltimore, Portland, Atlanta and Las Vegas (Davies, 2009). Firms have found out that customers want bandwidth, and that the firm which can deliver that bandwidth will get the business. Even as AT&T Wireless has invested billions of dollars to keep up with the data demands of

[19] A personal anecdote illustrates the point: The TV show *La Femme Nikita* debuted in 1997 and was the most popular cable show for several years. The heroine worked for an antiterrorist organization which was kitted out with very high-tech gear: holographic projectors, fancy computers and servers, . . . and cell phones. Viewing the show a decade later, one is impressed that everything still looks very high tech . . . except the cell phones. The show's producers used Motorola StarTac phones, the hottest phone of 1997; today, the StarTac phone seems like the mobile equivalent of a steam locomotive: quaintly old-fashioned. The cell phone is the one technology whose rapid advancement is obvious even to a TV viewer.

its iPhone customers by expanding its 3G capabilities, it is planning for its 4G LTE in the near future. It simply cannot let its competitors open up a technological lead.

Innovation and Competition – Conclusion

The Federal Communications Commission has a long tradition of keeping its hands off wireless (and the Internet) while ensuring that the fields remain competitive. The results of this policy are evident: the most innovative industry in the U.S. and the world, with lower prices, more usage, and more innovation. The competitive market has lifted the U.S. from being a wireless laggard compared to Europe and East Asia, such that the U.S. is now recognized as the leader in the wireless industry (Strategy Analytics, 2009). The FCC has allowed the competitive market to work its magic, and that is exactly what it has done. As it turns out, that policy has indeed been customer-centric. Customers are in the driver's seat; when they want better handsets, manufacturers, sometimes in collaboration with network provider partners, innovate. When they want more bandwidth, carriers innovate. When they want more applications, developers (and the other segments) innovate. In this competitive wireless marketplace, firms survive by giving customers their best value proposition, and this means innovation. We strongly recommend that this hands-off policy continue. We see no market failures in this market, so there is no rationale for government intervention. If it ain't broke, don't fix it!

Do We Need "Fixes"?

The FCC's Notice of Inquiry raises several issues which could be targets for FCC intervention. In essence, the NOI asks if there are market failures which it ought to fix. Since our previous analysis suggests that there are no market failures in this industry, the quick answer is, again, "If it ain't broke, don't fix it!" The FCC has had the wisdom in the past to let the competitive market develop without meddling, and this policy has been a successful customer-centric policy. If one carrier is not providing sufficient value by, say, encouraging application developers via an app store, then another carrier will be happy to take his business by giving customers what they want. Of course, this is precisely what happened with the Apple App Store; customers liked it, and competitors were forced to emulate it. This is precisely what happened with 3G in core networks; customers liked it, and competitors were forced to emulate it. Should the FCC opt for a more interventionist policy without rigorous justification of demonstrated market failure, the results will be clear: higher costs, less customer choice, reduced incentives to invest, and reduced incentives to innovate.

We consider each issue raised by the NOI in turn.

Mandate Spectrum Sharing

On the basis of a study conducted in Washington, DC, some years ago (McHenry & Villimpoc., 2003) that showed spectrum in the 30 MHz-3GHz bands to be underutilized,[20] the NOI asks if sharing of

[20] This is not the only study to show that spectrum is underutilized; several studies are mentioned in Faulhaber (2005, fn. 5). The conclusion in that work was not to force sharing on licensees, but rather, to

licensed spectrum should be mandated. Some suggest that underlays (low-power uses of licensed spectrum) would create little interference, and that overlays (high-power uses, such as cognitive radio, that would be "smart" and not interfere with licensed use) would increase the efficiency of licensed spectrum.

We first address the issue of whether spectrum licensed for CMRS is underutilized. Some critics have alleged that carriers are "warehousing" spectrum (that is, not leasing spectrum for which they hold licenses but are not currently utilizing) for anticompetitive reasons.[21] Our previous discussion concerning core network innovation spoke of the substantial efforts of carriers to increase spectral efficiency and operating procedures to increase capacity utilization. It would hardly make sense to undertake such capital-intensive efforts if carriers had excess spectrum lying about. It would also hardly make sense that carriers who have paid billions of dollars at auction to buy the spectrum would allow it to go to waste. So on the face of it, allegations of underutilization of CMRS licensed spectrum[22] defy all economic logic.[23]

Several other studies conducted in Chicago by Illinois Institute of Technology researchers (McDonald, 2007; McDonald et al., 2007) found that CMRS spectrum is efficiently utilized, although other spectrum was not. No one who has studied the potential for spectrum sharing ever seriously considered using the heavily-utilized CMRS spectrum; those researchers focused on lightly used spectrum as potential targets for sharing.

But we need not depend only upon economic logic; we have facts to support the view that U.S. carriers use their spectrum quite efficiently. As mentioned above, Campbell (2009) finds that U.S. carriers serve many more customers per allocated bandwidth than any other country. The following is excerpted from that study:

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establish property rights in spectrum so current licensees that are underutilizing their spectrum would have incentives, through sale or sharing, to capitalize on their asset.

[21] See for example, Eric Peterson (2009), Executive Director of the Rural Cellular Association.

[22] This is not to say that spectrum *in general* is not underutilized. The authors have argued strongly (Faulhaber & Farber, 2003) that spectrum is generally woefully underutilized, and they have advocated market measures to improve utilization. But certain bands are quite heavily utilized, such as the CMRS bands and the 2.4 GHz WiFi bands.

[23] The FCC does not set a schedule for conducting auctions, and often years go by before spectrum becomes available. Carriers are forced to buy spectrum for future use of uncertain duration, as they have no idea when more spectrum will become available. In this uncertain regime, where the FCC creates an artificial scarcity of uncertain duration, carriers must maintain a buffer of licensed spectrum in order to ensure their ability to meet future capacity demands.

Table 6. Subscribers per MHz of Spectrum Allocated.

	U.S.	Japan	Germany	UK	France	Italy	Canada	Spain	S. Korea	Mexico
Efficient Use of Spectrum -- Subscribers Served per MHz of Spectrum Allocated	651,100	312,968	347,540	214,002	148,958	290,622	103,414	144,692	194,420	630,833

Source: Campbell (2009)

Both the logic and the evidence clearly indicate that spectrum utilization by U.S. carriers is just fine; there is no evidence that suggests that a regulatory "fix" can have a positive effect; it is more likely to have serious negative effects.

We are generally of the view that low-power uses have shown their worth in practice, and we encourage their deployment. It is for this very reason that the FCC established Part 15 unlicensed bands, so that low-power uses such as baby monitors, cordless phones, garage door openers, and WiFi could flourish, as they have. In recent years, the FCC has designated large swathes of spectrum as unlicensed, and this is the appropriate location for low-power operations, as history has demonstrated. Imposing low-power applications in spectrum with existing licenses is totally unnecessary, as there is more than enough unlicensed spectrum available for such applications. If such uses are truly non-interfering, and for some reason they cannot find a home in the unlicensed space, then assuming the licensees are in the business of making money, they will surely permit such low-power uses for a market price. Mandating low-power sharing is simply regulating the price of low-power use of a licensee's spectrum to be zero. Let the licensee decide whether or not it can tolerate interference; the market will set a competitive price that fully accounts for interference or the lack thereof. This is not a suitable task for government.

We are also of the view that cognitive radio is a promising technology in its early experimental stage, and that it should be encouraged. It is not, however, a technology ready to be released in the valuable and fully-utilized CMRS bands. While some engineers and legal scholars suggest that it can be made non-interfering, it has yet to be field-tested and so remains experimental and untried. In other work, Faulhaber (2005, 2008) raises issues with cognitive radio that suggest much work needs to be done before we let it out of the regulatory box. In any case, even if cognitive radio eventually proves its worth, there is no reason that it should be *mandated* in any licensed spectrum, particularly the heavily-utilized CMRS bands. If cognitive radio is a going concern, it can certainly pay its own way; licensees (who are, no doubt, a profit-making bunch) will be happy to permit truly non-interfering uses for a competitively determined market price. There is no reason that this particular technology should get a free ride on spectrum.

In practice, carriers are quite comfortable with both transacting spectrum (there is an active secondary market in spectrum) and sharing spectrum. The entire Mobile Virtual Network Operator (MVNO) market is based on third parties using carrier spectrum in order to offer competitive mobile phone service. Indeed, virtually all the major carriers host at least one MVNO; Sprint is perhaps the most active in this market. It should be no surprise that, if a carrier thinks it can make a buck sharing spectrum, it

will certainly do so, as the MVNO experience demonstrates. Accommodating a truly non-interfering overlay or underlay should be fairly straightforward. As in the MVNO market, a market price will emerge, and parties will find it in their mutual interest to transact. Intervening in this market by setting a zero price seems a totally unnecessary and highly distortionary regulatory intervention. There is no market failure here, and therefore, there is no rationale for intervention. Should the FCC wish to mandate sharing of spectrum as a result of special pleadings at the expense of existing and future licensees and customers, there is no need to dress it up in the language of efficiency and innovation.

Develop Network Policies that Foster Wireless Broadband

Are there policies the FCC can adopt to foster the deployment of 4G and future technologies? What are they? Yes, yes, yes, there is a clear and simple policy that the FCC can adopt to foster wireless broadband: *auction off much more licensed spectrum*. If there is one policy that the FCC should adopt in this proceeding, this is it. Carriers are now approaching the theoretical limits of spectrum capacity, and yet traffic shows no sign of abating. As noted above, Cisco (2009) is forecasting wireless data annual growth rates of 130%, principally from the customer demand for TV to the handheld. At that rate, carriers will hit their maximum capacity in a few years.

A study by the ITU (2006) forecasts a

> total spectrum requirement of as much as 840 MHz by 2010, 1300 MHz by 2015 and 1720 MHz by the year 2020. Even at a lower market development rate, the projections are 760 MHz by 2010, 1300 MHz by 2015 and 1280 MHz by 2020. (2006)

The current spectrum available to CMRS is well under 500 MHz (under 400 MHz by some estimates (Rysavy, 2008). By any measure, the industry is approaching a licensed spectrum capacity crisis. The FCC must step up now and auction off lots and lots of spectrum.

Exactly how much is "lots and lots"? In earlier work, Faulhaber (2009a) suggested that an additional 1 GHz would probably be a good starting point. The ITU estimates suggest that this guess was close, and we adopt this as our recommendation: 1 GHz of spectrum should be put up for auction as licensed spectrum.[24]

Easy for us to say; what spectrum, the FCC might well ask, did we have in mind? Where do we think 1 GHz of spectrum will come from, seeing as virtually all the usable spectrum has already been

[24] Many pundits and commentators champion unlicensed spectrum as a means of ensuring our wireless communication needs. Certainly, the FCC has moved much more spectrum into unlicensed than licensed in the past few years. Faulhaber (2009a) addresses unlicensed vs. licensed spectrum as a means to meet our wireless broadband needs and concludes, based on the evidence, that unlicensed spectrum is a "regulatory cul-de-sac." I need not repeat those arguments here. The short version is that the FCC has allocated two U-NII bands (unlicensed) specifically for wireless broadband, with a total bandwidth of approximately 555 MHz, and to date, almost none of it is being used to provide wireless broadband. None.

allocated to someone or something? This brings to mind the well-known criticism that much of the spectrum is unused most of the time, an argument the authors made in Faulhaber and Farber (2003). Maybe it is time for the FCC to reclaim spectrum that is lying fallow; there will no doubt be a price to do this, but correcting past mistakes is never cheap. We have two solutions for finding spectrum; the "business as usual" solution and the "fundamental change" solution. Neither is new; both have been before the FCC for some time. But now is the time to end the procrastination and get this done.

The "business as usual" solution concerns spectrum that could be cleared and re-purposed for licensed wireless communications:

- First, get the AWS-3 spectrum (25 MHz) into the market; the FCC has had this under consideration for some time. Act now to find a paired band and auction it.
- Second, the World Radio Conference (WRC)-07 identified 400 MHz in the following bands:
  - 450-470 MHz (largely occupied in the U.S.)
  - 698-863 MHz (includes 700 MHz which has already been auctioned in the U.S.)
  - 2.3-2.4 GHz (much of which is occupied in the U.S.)
  - 3.4-3.6 GHz (used by radar in the U.S.)
- Third, approximately 555 MHz has been designated as mainly unlicensed U-NII spectrum for wireless broadband (although there are other users in these bands). There is minimal use of these bands for wireless broadband, the FCC's intended purpose for U-NII.
- Fourth, the FCC has recently freed up an *average* of 34-58 MHz of the TV white space bands,[25] dedicating it to unlicensed uses. The evidence has shown that this is not likely to result in wireless broadband actually being offered to customers.

In bringing fresh spectrum to market, the FCC needs to be mindful of bandwidth assignments internationally. Spectrum assignments that don't correlate with worldwide assignments result in lost scale economies in handset production and unnecessary costs for carriers.

The "fundamental change" solution. In Faulhaber and Farber (2003), we argued that the entire FCC process of allocating spectrum was deeply flawed, resulting in vast underutilization of spectrum. We strongly advocated a Coasian market-based solution in which property rights would be established in *all* usable spectrum, spectrum which would then become the licensees' property to be bought, sold, leased, aggregated, or subdivided as the licensee saw fit, subject to the technical (but not use) restrictions of the license. We support the Kwerel & Williams (2001) plan[26] to place all spectrum into the market, permitting

[25] This estimate was derived by Jackson & Robyn (2007); the range of bandwidth available depends upon the stringency of interference rules, with more stringent rules associated with lower capacity. It is important to note that this is an average over all metro areas in the U.S.; in some areas, there may be no available white space under strict interference rules.

[26] Their proposal is often referred to as the "Big Bang Auction."

existing license holders to sell, trade, or keep their licenses, thereby freeing up spectrum to move to its highest valued use. We still strongly favor this solution, as it promises to free up large amounts of spectrum for licensed use, harnessing the power of the market, rather than depending on the somewhat anemic response of regulators thus far. Of course, we recognize the political difficulties involved in this solution. We also recognize that it is the FCC's job to manage these difficulties to ensure the "public interest, convenience, and necessity" (Telecommunications Act of 1996).

Should the FCC be exploring alternative network architectures, such as mesh networks? We are of the view that further work in mesh networks is desirable. While mesh networks are a very interesting field of research, there are major problems that still have to be solved prior to commercial deployment. The notion of mesh networks is not a new one; past attempts have often suffered from the same difficulties that we face now. Security is one of the major issues, as well as sustaining geographic coverage. There have been a number of experiments in other countries (particularly in Japan) that focused on utilizing this technology in mobile, automobile-oriented networking. The results of these experiments are illuminating, but they still suggest caution in the belief that this technology is the solution to all of our problems. As is usual, there are advocates for mesh networking — some have commercial interests they are pursuing, and some are researchers with strong beliefs about their pet technology. Prior to any commitment of spectrum, both government and industry will need to devote considerable resources to funding a program of research in this area. This is not being done at present.

Should experimental work be undertaken in mesh networks, we believe it is best suited to deployment in unlicensed spectrum on a trial basis. Since the FCC has designated very large swathes of spectrum to unlicensed uses, these should be ample for experimentation with mesh networks. We certainly hope to see such experimentation; given the level of interest in mesh networking, we are surprised it has taken so long. Should this technology appear to have some promise after thorough experimentation and field experience, we believe it will find a home in unlicensed spectrum. Should it require licensed spectrum, we see no reason why the market will not work. Mesh operators can either buy their own spectrum or lease capacity from existing licensees, much as MVNOs lease capacity from CMRS carriers today. Even if it proves viable, there will be no need to mandate sharing of licensed spectrum in order to accommodate this technology.

In later work, Faulhaber (2005) again argued strongly that dispute resolution in a property rights regime would occur in courts rather than at the FCC, and that this would substantially reduce costs and increase both speed and efficiency. The evidence suggests that dispute resolution, for example in interference disputes mentioned in the NOI, are long, drawn-out regulatory battles, often then followed by a court case. If licensees had clearly defined property rights, then interference disputes could be resolved like trespass cases within the court system.[27] We continue to believe, based on the evidence, that

[27] The assumption in Faulhaber (2005) is that interference problems would be handled under trespass laws, not nuisance laws. The example used in this paper of lengthy and litigious regulatory procedures was the 800 MHz Nextel dispute. Apparently, the FCC handled this case on an expedited basis, and yet it still took almost two years to resolve.

resolution of interference claims in court is substantially less costly, faster, and more efficient[28] than resolution at the FCC.

Mandated "Openness"

The well-known paper by Wu (2007) argues that wireless carriers engage in various practices that hurt customers:

- Limits on which devices customers can attach to the carrier's network.
- Limits on product design, in which devices are limited in their use to a specific network and cannot be ported to other networks; also included in this category are "crippled" phones, on which carriers reduce the feature set of a device, such as WiFi.
- Discriminatory broadband services, which appears to mean that customers are limited in how they use wireless broadband, as well as in how much they may use it.
- Application "stall," by which carriers place burdens and limits on what applications can be used over their networks.

To correct these problems, Wu suggests a number of policy actions:

- Bar "locking" of a device to a single carrier, and force all carriers to permit the use of any device meeting technical specifications for network use.
- Place a general ban on blocking Internet content.
- Mandate disclosure, as customers ought to know what they are getting with their wireless service; and
- Standardize application platforms, so that application developers need only write applications to a single standard, which would run on all devices and networks.

There is a growing literature which analyzes and critiques Wu's assertions and policy recommendations for wireless Carterphone. We offer a very brief guide to this extensive literature:

Hahn, Litan, and Singer (2007) present the most comprehensive point-by-point critique of Wu's paper.

- Like Ford, Koutsy, and Spiwak (2009), this paper notes that the conditions in the 1968 wireline telephone industry (regulated monopoly) simply do not exist in wireless today, as this paper has demonstrated. Carterphone was a good answer to

[28] We recognize that this assertion depends upon technical restrictions on spectrum licenses that are both clear and measurable, so that a lay judge and jury will be able determine whether or not a property right has been transgressed.

the problem of regulated monopoly telephone access; but there is no problem in unregulated competitive wireless access to which Carterphone is an answer. In such an industry, new rules are a cost, not a benefit. There is no monopoly provider, and there is no vertical integration of carriers into the device or application markets.

- Wu suggests that carriers hold market power over device manufacturers and application providers. The wild success of Apple's iPhone suggests otherwise; an innovator with a "killer" product can write its own ticket with carriers, as Apple has done with AT&T.
- Wu also claims that carriers do not offer "obvious" services to customers, such as printing photos to a Bluetooth-enabled printer or printing a list of contacts from the mobile phone. This paper notes that many of the functions which Wu lists as not being offered by carriers are, in fact, offered by carriers, including Bluetooth printing, and questions whether other features which Wu claims are "obvious" are economic for customers relative to available alternatives. Today, virtually all of the services Wu claims are not available from most carriers are, in fact, available from all major carriers.
- The ability to use WiFi from smart mobile phones is very broadly available today; although not all smart phones have WiFi capability, dozens do. The ability to use a VoIP provider via smart phones is also available today for all major carriers, though this might not be a good economic choice[29] for customers.
- Blocking of bandwidth-intensive broadband uses is simply not anti-competitive, unless a monopoly provider blocks in a discriminatory fashion. The Supreme Court's *Trinko* decision settled the issue on duty to deal quite recently. While Wu may disagree with the Supreme Court on this issue, we side with the Court.
- The outpouring of application and device innovation since 2006 belies Wu's complaint that carriers are resistant to new applications. The evidence we present above suggests that this complaint is without any basis in the real-world wireless market. Wireless customers today are confronted with choosing among tens of thousands of applications and hundreds of devices. The problem for vendors is how to present all these choices to customers in a way that enables them to make good choices. There is no lack of choice here.
- Tying specific phones to specific carriers is not anticompetitive in unregulated competitive markets; such exclusivity deals are very common throughout the economy. A high-end fashion designer may choose to sell its product through high-end retail outlets such as Neiman Marcus or Nordstrom's. We do not require that

[29] A mobile phone connection to WiFi uses substantially more power, thus reducing battery life. Hahn, Litan, and Singer (p. 38) analyze Wu's example of Nokia phones with and without WiFi, and they show that the WiFi-activated phones have 32% less battery life.

> Prada handbags or Fendi shoes be sold in Wal-mart, and a claim by Wal-mart that Prada and Fendi should be legally required to sell through their stores would be laughable. Yet many have demanded that the iPhone be sold through all carriers, a demand that is equally laughable. The five-year exclusive deal between Apple and AT&T for the iPhone is a standard practice throughout the economy, and it amply rewarded the innovator of this revolutionary device. We do not believe that reducing the opportunity for rewards to innovation is a very good idea.

Ford, Koutsky, and Spiwak (2009) argue that major differences between wireline telephony (where Carterphone rules were successful) and wireless telephony make the analogy defective, even pernicious. Imposing Carterphone-like regulations on wireless is likely to commoditize this vibrant and competitive industry, reducing incentives both for new entry and to invest. Shoehorning today's wireless industry into a Carterphone straitjacket that is a poor fit for wireless is likely to result in a far less competitive industry which is less responsive to customer needs. In addition, Carterphone-like regulations are likely to increase the cost of devices to customers with no concomitant reduction in service prices, a clearly anti-customer result.

Are we to conclude that Tim Wu's paper caused the carriers to see the light and change their evil ways? Of course not. It was competition that did the trick. When the iPhone showed that customers really loved apps, then everyone else responded. When some customers wanted to bring their own phones, carriers responded. A competitive market imposes the discipline on firms to meet their customers' demands. Regulators and government bureaucrats can certainly impose discipline by law, but is this what customers want? If the FCC were truly customer-centric, it would let customers decide what they want. It would recognize that its job is to enable customers, not to tell customers what they ought to want.

Does it make sense to force device manufacturers and carriers to agree on a common interface so that application developers have an easier time writing software? This flies in the face of both the robust competition among device makers with a myriad of operating systems and the robust competition among carriers with multiple protocols and standards for managing their spectrum. Professor Wu's suggestion would appear to roll back this robust competition in favor on a single standard, all to make software programmers' lives a little easier. This, of course, would seriously damage competition in the handheld OS market, as well as in the carrier market, both of which are thriving, and commoditize the industry while it is still in its infancy. Is this really necessary to encourage even more application innovation? With well over 100,000 applications in the marketplace, it would appear that application developers are not really deterred from innovation in the face of multiple operating systems and multiple carrier protocols. Exactly what benefit would we expect from such a draconian intervention in the wireless business? You would be close to the mark if you guessed "zero."

Can customers tell the difference between open systems and managed systems? The Apple iPhone is well-known to be a managed system; techies take pride in "jail-breaking" their iPhones in order to use them on other networks and other off-standard uses. Apple has set up restrictions on what you

can do with your iPhone that are more stringent than, say, what you can do with your Blackberry,[30] and even more so than you can with your Android phone. Yet, the iPhone remains the most popular smartphone in the market today, after three years on the market. Customers have the choice: the managed model of Apple or the more "open" model of Android. It is true that applications from sources other than the Android store can be loaded on Android-based devices (Apple allows only iTunes apps to be loaded). It is no surprise that some customers like the more managed iPhone, and some customers like the more "do-it-yourself" approach of Android devices. In either case, these phones represent impressive innovations, and should be lauded as such. And in either case, customers choose what they want without the help of government bureaucrats forcing them to have one or the other.

Our view of network management practices is much the same. Different carriers will adopt different network management strategies; provided that customers are informed (see below) as to what their carriers are up to, they can make informed decisions about which carriers will get their business. Network management that is too restrictive, perhaps even anticompetitive, will be punished by customers. Likewise, network management that is too lax, that permits outages and dropped calls because of congestion, will also be punished. Again, let the customer decide what level of network management they prefer. And again, we expect that different customers will make different choices. What we know for sure is that this is not a choice government bureaucrats should be making for customers.

There is no market failure here. Mandating "openness" is quite unnecessary, as the competitive market will produce what customers want. The evidence in this market is that that is exactly what is happening, without counterproductive and inefficient government mandates. There is nothing broken here; there is nothing to fix. "Hands off" is the customer-centric policy in a competitive market.

Network Neutrality

On October 22, 2009, the FCC released a Notice of Proposed Rulemaking (NPRM) to make binding the four Network Neutrality principles the FCC adopted under Chairman Powell, plus two new ones: non-discrimination and transparency.

We find much to like in the NPRM. The rhetoric emphasizes that FCC actions should be "fact-based" and not in response to "imaginary" threats, and it emphasizes that the proposed rules do not constitute regulation of the Internet. And yet the substance of the NPRM belies the rhetoric. In asserting that network neutrality in the wired and wireless ecosystems was necessary to preserve innovation, there was not one shred of evidence adduced that shows innovation is being harmed. In the face of the very substantial amount of innovation occurring in all segments of the wireless industry, the allegation that innovation is under some sort of threat in wireless is demonstrably false and beyond incredible. The assertions contained in the NPRM that this does not constitute regulation of the Internet is also beyond credible: imposing constraints on carrier pricing (zero charges on application providers), on carrier product differentiation (no expedited service), and on how carriers are permitted to manage their own networks certainly sounds like regulation. Even worse, adopting "reasonable" network management as a rule introduces great uncertainly into the market; exactly what behaviors will incur the wrath of the regulator?

[30] For example, the iPhone is only available on AT&T Wireless, while Blackberry phones are available from numerous carriers.

Don't know; we'll punish you when we see it. If ever a policy was designed to increase cost, reduce customer choice, reduce incentives to innovate, and reduce incentives for carriers to invest, this would be it.[31] Where's the market failure? Where is the rigor by which the Chairman has arrived at this conclusion?

There has been a long debate over network neutrality in the policy community, to which both authors have contributed (see especially Farber & Katz, 2007), and which we need not rehash here. While network neutrality advocates are overjoyed, some have sounded alarm bells, including those most sympathetic to Internet openness. Tweney (2009) from *Wired* magazine predicts the end of unlimited Internet as a result of network neutrality regulation. His rationale mirrors the principles in this paper. He notes three problems:

- "Bandwidth is not, in fact, unlimited, especially in the wireless world. 'As long as there have been networks, people have had to engineer them to ensure that congestion doesn't occur'" (quoting interview with Farber).
- "Enforcement of neutrality regulations is going to be difficult."
- "New regulations create an additional layer of government bureaucracy where the free market has already proven its effectiveness. . . . Now the FCC is proposing taking a free market that works, and adding another layer of innovation-stifling regulations on top of that?"

But this is more than the government intervening with no evidence whatsoever of market failure. We believe that this prospective rulemaking is the *polar opposite of a customer-centric* policy. If network neutrality in wireless is something that customers want, then in the competitive carrier market, a competitor will offer a neutral network service offering, and customers will flock to it. Other carriers will be forced to follow suit, or not. In practice, we would expect that some carriers would offer a more neutral network and others would offer a more managed network, while still others would offer customers the option of either one; customers will then make different choices, reflecting their different priorities and preferences. But it appears that, under the FCC's NPRM proposal, customers will not be allowed to choose. They will get a one-size-fits-all, government-designed business plan whether they want it or not. With all due respect, this should not be an FCC decision; this decision should be left to customers, and it is the FCC's job to ensure that customers are enabled to make this decision, not to make the decision for them.

Which Business Models Promote Innovation?

The choice here is between the more "do-it-yourself" model of Google/Android and the more managed model of iPhone and Blackberry; between the more open Sprint and the more managed Verizon Wireless. And the answer is crystal clear: both models promote innovation. In the device segment, iPhone was the pioneer and Google/Android a fast follower. Both are innovators, but we must give the nod to the iPhone for being first and showing the way. Blackberry has had a strong position in the business market, but it has also moved strongly into the consumer market with its Storm and Tour models, showing impressive innovation in doing so. Its model is more traditional; neither as open as

[31] Sidak (2006) discusses the costs imposed by mandating network neutrality, including increased transaction costs, administrative costs, and opportunity costs.

Android, nor as proprietary as Apple's. Sprint has been more open in accepting devices and applications that it doesn't sell, and it has shown substantial innovation by being the first to deploy WiMAX (claiming it is 4G). Verizon Wireless has been more managed, only recently accepting phones it does not sell and setting up a developer's website. It also has shown substantial innovation in the early deployment of 3G, and it will likely be the first to deploy LTE 4G. But the point is clear; innovation is forthcoming from a variety of business models. There is no need for the FCC to choose the better business model, nor is there a need for FCC "guidance" in favoring one business model over another. The FCC's imposition of open-platform restrictions[32] in the recent 700 MHz C-block auction is an egregious example of unnecessary meddling. But having established the C Block restrictions and committed to the "experiment" in their operation, it plainly makes no sense at all to expand those restrictions to other spectrum before the experiment even begins. If customers want more open platforms, then there will be a wireless carrier that will provide service to meets their needs, gaining a competitive advantage over its rivals. There is no market failure here; if the FCC wants to mandate business models, impose costs, and eliminate customer choices, the FCC should not cloak it in the language of efficiency and innovation.

Transparency

We are very pleased that the FCC NPRM on network neutrality features transparency so prominently. We are entirely supportive of vigorous action to ensure transparency, preferably in concert with the FTC. We are disappointed that the FCC appears to believe that transparency ought to apply only to carriers. We believe transparency should apply to all segments of the wireless ecosystem: applications, devices, and carriers. We strongly recommend that the FCC (and/or the FTC) correct this oversight and broaden the transparency requirements to cover all firms operating in the Internet marketplace.

We have argued strongly that the FCC must take a customer-centric view of its role, by which we mean that the FCC needs to support the existing competitive marketplace in all wireless segments and refrain from damaging interventions that will raise costs and reduce customer choice. But in order for competitive markets to fully realize their potential to empower customers, those customers need to have the information they need to make informed purchase decisions. That information can only come from sellers: application providers, device manufacturers, and core network providers. If this information is lacking, we do, indeed, face an information-symmetry market failure. The role of information in markets is starkly presented in Akerlof's (1970) seminal paper, in which he demonstrates that a market can actually collapse in the absence of information.[33]

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[32] In the recent 700 MHz auction, the FCC required the winner of the C Block spectrum to permit customers to use any device and any application on service offered using that spectrum *(PC Magazine,* 2007).

[33] In the Akerlof example, the market collapses because each seller (of a low-quality auto, a "lemon") has an incentive to misrepresent the quality of his or her automobile, and customers cannot distinguish the good from the bad. Any method, private or public, that results in a *credible* signal of quality from the seller corrects the market failure, restores the market, and is preferred by customers and sellers of high-quality autos (but not by the sellers of "lemons").

This type of market failure is recognized in virtually all markets, and public policy intervention to correct it is well-established. A fundamental mission of the Federal Trade Commission is to ensure that firms disclose decision-relevant information to customers in an easy-to-understand format. In Faulhaber (2009b), several examples of successful disclosure mechanisms are discussed in terms of ease of use, convenience to customers, and relevant information, all of which the FTC developed (in collaboration with the FDA), including both food and prescription drug labeling. Not all of these mechanisms are good fits for other industries or situations, and none of them may be the right fit for wireless, but it behooves the entire industry to avoid prior pitfalls, such as the dreaded End User License Agreements (EULAs) that accompany boxed software, which seem designed to baffle anyone without a J.D.

If competition is to ensure a customer-centric environment in the wireless ecosystem, transparency is an absolute necessity.[34] Overall, the wireless industry has done a reasonably creditable job of providing customers with the information they need, but there is room for improvement. Although complete precision is plainly impractical in such a rapidly evolving marketplace, customers need to know what types of applications are permitted, what types of network management practices are in place, and what range of performance they can typically expect. These are complicated technical issues which must be suitably simplified for easy presentation to customers. But surely, describing a carrier's (or device's) characteristics is no more complicated than describing the benefits and risks of taking a prescription drug, and we seem to manage that task fairly well. And if the FCC is to adopt a customer-centric policy of letting the competitive market run its course, then the FCC must ensure that these markets are fully transparent. We note that the Federal Trade Commission is the agency with the most experience in the area of transparency and disclosure, and we suggest that the FCC partner with the FTC and industry to develop standards on transparency and disclosure.

Conclusion

All three segments of the wireless marketplace (applications, devices, and core networks) have extraordinary track records in innovation. This extraordinary innovation has been driven by the brutal competition that characterizes this industry. There are no classic market failures in this industry that require regulatory intervention; calls for such interventions by pundits, advocates, and special interest groups (some reflected in the NOI) are attempts to harness the regulatory power of the government to impose their personal or group agendas on customers. Our position is crystal clear: let customers decide what they want and need. In order to implement this customer-centric policy, the FCC must undertake the following:

- Put much more spectrum on auction for licensed use. While we have made suggestions as to how much bandwidth is needed (1 GHz) and where it might come from, it is really the FCC's job to find it and figure out how to clear the bands. It alone has the knowledge and ability to do this.

[34] Faulhaber (2009a, 2009b) makes this point in the context of the broadband industry (both wired and wireless); it is equally valid here.

- Ensure that all segments of this industry practice good disclosure practices with their customers, as outlined in Faulhaber (2009b). We suggest the FCC partner with the FTC in this endeavor, as the FTC has far more experience (and successful experience) than does the FCC.

We conclude by stating that innovation will best thrive with customer-centric FCC policies, ensuring that competitive markets continue to flourish, that spectrum is made available, and that transparency is assured. Regulatory interventions into markets without rigorous justification can only raise costs, reduce customer choice, reduce incentives for investment, and reduce incentives for innovation. In the absence of market failure, we see no reason for the FCC to now adopt a "bull in the china shop" strategy of dictating firms' business models and practices in a fully functional, competitive market. It ain't broke; don't try to fix it.

Appendix

Table 1. Current Application Stores and Web Sites.

Device Manufacturer	**URL to App Store**
Apple's App Store	http://www.apple.com/iphone/apps-for-iphone/
BlackBerry's App World	http://na.blackberry.com/eng/services/appworld/
Palm's App Catalog	http://www.palm.com/us/products/software/mobile-applications.html
Nokia's Ovi Store	https://store.ovi.com
Samsung's Application Store	http://www.samsungapps.com
Sony's PlayNow Arena	http://www.playnow-arena.com
LG's Application Store	http://www.lgapplication.com
Software Developers	
Google's Android Market	www.android.com/market
Microsoft's Windows Mobile Downloads	http://www.microsoft.com/windowsmobile/en-us/downloads/default.mspx
Carriers	
AT&T: MEdia Mall	http://mediamall.wireless.att.com
Verizon Wireless: Tools & Applications	http://products.vzw.com/index.aspx?id=fnd_toolsApps_all
Sprint: Software Store	http://softwarestore.sprint.com
U.S. Cellular: easyedge	http://easyedge.uscc.com/easyedge/Home.do
Cellular South: Discover Center	http://www.cellularsouth.com/DiscoverCenter/phones-apps/index.html
Cricket's Downloads	http://www.mycricket.com/cricketfeaturesdownloads/
Independent Stores	
Handango	http://www.handango.com
GetJar	http://www.getjar.com

Table 2. Selected Applications.

Application & URL Link	**Function**
AroundMe	Lists critical services based on your location
Pandora Internet Radio	Creates your own personal music station
iLightr	Creates a realistic photo of a flame).
Loopt http://appworld.blackberry.com/webstore/content/763	Uses device's GPS technology to not only identify the user's current location, but also to identify his proximity to friends using the same application
Shazam www.android.com/market/free.html#app=shazam	Identify songs heard on the radio through applications that tie into the device's microphone
X-Plane 9 Flight Simulator http://www.x-plane.com/pg_Meet_Mobile.html	Play games that use the device's accelerometer to control characters and vehicles

Table 3. Selected Handheld Device Launches

Date	Product	Announcement
6/29/07	AT&T Apple iPhone	http://en.wikipedia.org/wiki/IPhone
11/19/07	VZW LG Voyager	http://news.vzw.com/news/2007/11/pr2007-11-19.html
4/1/08	Sprint Samsung Instinct	http://newsreleases.sprint.com/phoenix.zhtml?c=127149&p=irol-newsArticle_newsroom&ID=1124417
7/10/08	Apple iPhone 3G	http://www.att.com/gen/press-room?pid=4800&cdvn=news&newsarticleid=25146
7/11/08	AT&T HSDPA iPhone 3G	http://www.att.com/gen/press-room?pid=4800&cdvn=news&newsarticleid=25923
9/23/08	T-Mobile Android G1	http://www.t-mobile.com/company/PressReleases_Article.aspx?assetName=Prs_Prs_20080923&title=T-Mobile%20Unveils%20the%20T-Mobile%20G1%20–%20the%20First%20Phone%20Powered%20by%20Android
10/21/08	AT&T Samsung Epix	http://www.informationweek.com/news/personal_tech/smartphones/showArticle.jhtml?articleID=211300247
11/4/08	AT&T Blackberry Bold	http://www.computerworld.com/action/article.do?command=viewArticleBasic&articleId=9117804&intsrc=news_ts_head
11/20/08	Sprint HTC Touch Diamond	http://www.rcrwireless.com/article/20081120/WIRELESS/811199960/1081/blackberry-storm-flying-off-verizon-wireless-shelves/htc-s-touch-diamond-sprint-nextel-adds-to-its-high-end-offerings
11/21/08	VZW Blackberry Storm	http://news.vzw.com/news/2008/11/pr2008-11-20.html
2/24/09	AT&T Matrix Pro	http://www.phonenews.com/att-launches-matrix-pro-6888/
2/26/09	VZW LG Versa	http://www.computerworld.com/action/article.do?command=viewArticleBasic&articleId=9128679&intsrc=news_ts_head
3/2/09	Sprint Palm Pre	http://www.rcrwireless.com/article/20090302/WIRELESS/902279975/1081
4/1/09	MetroPCS Samsung Finesse	http://investor.metropcs.com/phoenix.zhtml?c=177745&p=irol-newsArticle&ID=1272139&highlight=
7/13/09	VZW & Sprint Blackberry Tour	http://hothardware.com/News/Verizon-Wireless--Sprint-Launch-BlackBerry-Tour/
9/21/09	Cellular South HTC Hero (Android)	https://www.cellularsouth.com/news/2009/20090921.html
EOY 2009	LG Watch Phone	http://ces.cnet.com/8301-19167_1-10137452-100.html

Table 4. System Spectral Efficiency of Selected Network Standards.

Service	Standard	System Spectral Efficiency[35] (Bits/sec)/Hz
2G	GSM 1993	0.17
2.75G	GSM+EDGE	0.33
3G	CDMA 2000	0.172 (fully loaded)
3G	1x EV-DO Rev A	1.3 (average load)
3G	WCDMA	0.51
3.5g	HSDPA	2.88
WiMAX	IEEE 802.16	1.2
4G	LTE	16.32 max
WiFi	IEEE 802.11b/g	2.4

Source: Wikipedia (2009a).

Table 5. Selected Announcements and Market Deployments of Network Innovations.

Date	Action	Link
11/29/07	VZW announces LTE as 4G Broadband Direction	http://news.vzw.com/news/2007/11/pr2007-11-29.html
2/6/08	AT&T to expand 3G Broadband, then LTE	http://www.att.com/gen/press-room?pid=4800&cdvn=news&newsarticleid=25146
2/8/08	Stelera Wireless launches network using AWS spectrum	http://www.stelera.com/Portals/0/docs/2.08.08%20Stelera%20Wireless%20Launches%20Inaugural%20Wireless%20Network,%20Providing%20High%20Speed%20INternet%20in%20Rural%20America.pdf
5/5/08	T-Mobile begins 3G rollout in NYC	http://www.t-mobile.com/company/PressReleases_Article.aspx?assetName=Prs_Prs_20080505&title=T-Mobile%20USA%20Begins%20Commercial%203G%20Network%20Rollout
9/18/08	T-Mobile announces 3G in 21 markets (HSDPA)	http://www.t-mobile.com/company/PressReleases_Article.aspx?assetName=Prs_Prs_20080919&title=T-Mobile%20USA%20Announces%20Commercial%203G%20Network%20Availability
9/29/08	XOHM WiMAX 4G introduced in Baltimore	http://newsreleases.sprint.com/phoenix.zhtml?c=127149&p=irol-newsArticle_newsroom&ID=1203014&highlight
10/17/08	T-Mobile expands 3G network coverage	http://www.t-mobile.com/company/PressReleases_Article.aspx?assetName=Prs_Prs_20081017&title=T-

[35] System spectral efficiency differs from link spectral efficiency in that it takes into account real-world factors that affect the capacity that can be obtained in real-world applications. See Wikipedia (2009a).

		Mobile%20USA%20Further%20Expands%20Commercial%203G%20Network%20Availability%20in%202008
10/28/08	US Cellular Launches EVDO Broadband	http://www.uscc.com/uscellular/SilverStream/Pages/x_page.html?p=a_press081028
11/4/08	nTelos upgrades 70% of sites to EVDO Rev A	http://ir.ntelos.com/releasedetail.cfm?ReleaseID=345339
2/19/09	VZW details 4G plans	http://www.washingtonpost.com/wp-dyn/content/article/2009/02/18/AR2009021800747.html
2/24/09	AT&T 3G to expand to 850 MHz	http://www.intomobile.com/2009/02/24/att-3g-network-going-850MHz-nationwide-by-2010.html
7/31/09	BendBroadband enters Voice and Internet (HSPA+)	http://www.bendbroadband.com/press/BendBroadband%20Wireless%20Announcment%20--%207-31-09.pdf
8/19/09	Sprint/Clearwire deploy WiMAX 4G in Baltimore, Portland, Atlanta, and Las Vegas	http://www.slashgear.com/sprint-4g-wimax-reaches-las-vegas-portland-and-atlanta-1852602/
9/5/09	MetroPCS announces vendor for 4G LTE Launch	http://investor.metropcs.com/phoenix.zhtml?c=177745&p=irol-newsArticle&ID=1331809&highlight=
9/20/09	T-Mobile rolls out 21Mbs 3G in Philadelphia	http://gizmodo.com/5363254/t+mobile-launches-21mbps-3g-service-in-philadelphia

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