Exhibit 1

Gerald R. Faulhaber & David J. Farber,
The Open Internet:
A Customer-Centric Framework

THE OPEN INTERNET:
A CUSTOMER-CENTRIC FRAMEWORK

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Executive Summary

The Federal Communications Commission's Notice of Proposed Rulemaking, Preserving the Open Internet, is the most significant reach of regulatory power to the Internet in US history. The NPRM proposes a set of regulations for broadband ISPs corresponding to the four principles previously adopted by the Commission, plus two new ones: nondiscrimination and transparency. We strongly support customer-focused transparency by *all* Internet firms, not just broadband ISPs.

We oppose, however, the remaining five proposals to implement network neutrality for broadband ISPs as both unnecessary and harmful. Despite many colorful predictions about what evil doings ISPs *might do* in the future, we find that during ten years of experience without network neutrality regulations, there are just two incidents (the tiresomely familiar Madison River and Comcast cases) of any *actual* misbehavior by broadband ISPs. Two incidents – both remedied without the prescriptive rules proposed here - is not empirical evidence, nor are the many lurid but unrealized nightmare scenarios. We find that there is nothing here to be fixed and there is no market failure. The regulations are not only unnecessary; they would impose significant costs on broadband customers. We find that the costs that would be imposed on wireless broadband would be particularly punishing, and likely permanently to harm that industry. Likewise, we find the FCC's interest in regulating "managed services," a category the FCC has trouble even defining, to be without merit.

We instead propose that the FCC focus its energies on bringing more competition to the already rivalrous broadband marketplace, a goal which is within reach. Over a dozen wireless carriers now provide 3G service, and 4G service, which can substitute even more effectively for many Internet uses that were previously confined to wireline is imminent. It is essential that the FCC release substantial amounts of licensed spectrum into the marketplace so that this additional competition can emerge quickly. The FCC should not waste its time with pointless but very

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The research reported herein was supported by AT&T; the views expressed in this paper are solely those of the authors and not the views of AT&T.

costly regulation; it should facilitate competition so that customers can choose for themselves if and how much network neutrality they want. *Let the customers decide*; not regulators, not pundits, not advocates.

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1. Introduction

The Federal Communications Commission's Notice of Proposed Rulemaking (NPRM) in GN 09-191 Preserving the Open Internet (2009a) is potentially the most significant event in the long history of the FCC's relationship with the Internet. The stated purpose of the NPRM, as the title suggests, is the preservation of the open Internet. The FCC notes the profound impact of the Internet on not only the United States but the world, and that this impact has been driven by the substantial innovation that has characterized the growth of the Internet. The FCC attributes that outburst of innovation to the Internet's openness to new ideas, new applications and ease of entry by anyone with a personal computer. The FCC notes that anyone, large or small, huge corporation or small inventor, can equally access the open Internet and reach an audience of billions of customers.

Clearly, the NPRM reflects the view that this openness is under threat and is in need of protection. For over twenty years, the FCC has adopted a no-regulation policy with respect to the Internet, and successive Commission chairs have reinforced the message that the Internet should remain regulation-free. The tremendous growth of the Internet as well as the substantial rate of innovation has all occurred within the context of no regulation. We must therefore conclude that the FCC (or at least its Chairman) perceives a sea-change; believes that the openness is now under threat that requires pre-emptive prophylactic immediate action.

The NPRM bases its proposed regulation on the four Internet "principles" adopted by the FCC (2005) plus the addition of two more principles: transparency and non-discrimination. It also proposes language regarding "reasonable" network management practices, and seeks comment on whether to establish rules for a new and fuzzily undefined concept it calls "managed networks." These proposals are specifically addressed to one segment of the Internet ecosystem: broadband ISPs (including wireless broadband) and would not apply at all to other segments (although the FCC seeks comment on whether Internet regulation should apply more broadly).

The NPRM claims that the proposed rules are "not intended to regulate the Internet itself…" (FCC (2009a), ¶14) and that the NPRM is to begin a "data-driven on-the-record examination" (Copps (2009)) that is to be "fact-based" (FCC (2009a) ¶16). The Chairman of the Commission was also clear that this examination must be "fact-based, data-driven" and it is "not about protecting the Internet against imaginary dangers." (Genachowski (2009)). We are heartened by and fully agree with these statements.

Unfortunately, we find that the content of the NPRM is 180º out of phase with those principles. In truth, we find that:

- The rules proposed in the NPRM would, if adopted, constitute a very significant expansion of FCC regulation into the Internet. Adoption of these rules would amount to a complete reversal of a successful policy of no regulation that the FCC has maintained for over two decades, the results of which are evident in the wildly successful Internet we have today.
- Far from being "fact-based, data-driven, not imaginary", the NPRM's proposals appear to be based on speculation, fears, and scare-mongering by advocates, pundits and professors. *There is no basis in fact for any change in regulation whatsoever,* much less the significant expansion of regulation proposed in this NPRM.
- The costs of the proposed regulations in terms of reduced consumer welfare, reduced investment incentives, and reduced innovation are likely very large.
- In particular, this totally unnecessary regulation of wireless broadband threatens enormous costs to the development of a market segment that the FCC should in fact be promoting in order to encourage more broadband competition and choice. Wireless (and in particular wireless broadband) services are subject to intense competition and with a very high rate of innovation with no evidence whatsoever of market failure. Moreover, wireless is a technology for which broadband success depends critically upon tight integration and coordination between the core network and devices and applications at the "edge." Performance needs of diverse applications can only be met by dynamic and situation-specific management in an environment characterized by bandwidth scarcity, mobility and interference. Regulation is wildly ill-suited to this fluid and highly interactive environment. Even considering regulation of this market violates every tenet of good economic and engineering policy. Yet apart from noting the increasing viability of wireless as a means of accessing the Internet – a development that strong undercuts the rationale for *any* network neutrality regulation -- the FCC gives no rationale whatsoever for this egregious regulatory overreach.

This paper is organized as follows: Section 2 considers the rationale for the proposed regulations with a special focus on its evidentiary basis. Section 3 addresses the likely costs of enacting the proposed rules for both wired and wireless broadband ISPs. Section 4 addresses the additional costs associated with regulation of wireless broadband. Section 5 proposes a policy that will encourage broadband deployment and the adoption of industry practices that are *customer-centric*, designed to respond to the needs of customers, not necessarily the advice of pundits and advocates. Section 6 concludes the paper with our policy recommendations.

2. What is the problem that needs fixing?

Protecting the openness of the Internet rivals motherhood and apple pie as a social desideratum. Who could be against openness? Who could be for "closedness"? We are certainly in favor of openness,[1] and laud the FCC's interest in it. But does it need protecting? In particular, does it need protecting from broadband ISPs? What threats are we attempting to address with these regulations?

There are some *very real threats to the Internet that* cry out to be fixed. Some are best left to private sector ingenuity and competitive drive to satisfy customers' diverse and evolving needs. Others may warrant government watchfulness or intervention. But this NPRM on protecting openness does not address these actual real world problems at all. The following is an incomplete list of some of the most obvious threats to Internet customers:

Real Threats to Internet Openness NOT Addressed by this NPRM

- Spam, worms, viruses and phishing attacks take advantage of the Internet's openness and anonymity to wreak serious damage to customers' computers and ISPs' servers and obstruct customers' access to the content of their choice. The FCC's proposed network neutrality regulations may stand in the way of efficient responses to this growing threat to Internet openness.

- Virtually all Internet customers rely on search engines to access Internet content; the big search engines have thus become the true gatekeepers[2] of the Internet and the advertising dollars that fuel much Internet innovation.[3] Yet we know little about how search engines work in practice; how can a new innovative startup firm compete with more popular established firms for "eyeballs" on major search engines? What do search engines do with customers' information and search history? Are they selling search history information to others? These gatekeepers are not in the least open; there is minimal search engine

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[1] It is a canon of faith among Internet aficionados (among whom the authors count themselves) that the openness of the Internet was and is a necessary condition for this outburst of innovation. However, this assertion has yet to be subjected to a rigorous empirical test. Other industries (e.g., pharmaceuticals) have also demonstrated high rates of innovation in proprietary and managed business models. As a *general* economic rule, openness does not appear to be a necessary condition for innovation; it is an *open empirical question* whether or not the openness *of the Internet* is a necessary condition for Internet innovation (see Faulhaber (2007) and Faulhaber (2009a)).

[2] The NPRM characterizes broadband ISPs as potential gatekeepers of the Internet and states that the purpose of the NPRM is to "safeguard the benefits of the Internet for American consumers from potential gatekeeper control" (FCC, ¶72). But nowhere is the threat of search engine gatekeepers mentioned; only Commissioner Copps (Copps (2009)) alludes to potential gatekeepers other than broadband ISPs.

[3] According to Experian Hitwise (2009), Google has a 71% market share in the US; the top three search engines control 96% of all US searches.

transparency. Yet the FCC does not acknowledge these real problems, either in this NPRM or elsewhere.

- Application and content providers are privy to customer data of an especially sensitive nature, such as credit cards and Social Security numbers, in addition to customer information concerning buying behavior and what ads were viewed. Very few application or content providers tell customers how their data is used or misused in plain English; often, a customer must dig deep to read an obscure lawyer-written privacy policy. Are providers selling customer data to other firms? Using this data for behavioral targeting of ads? Using this data for spam and other malware? There is little openness among application and content providers on the Internet in revealing customer data retention and use practices. Yet the FCC does not acknowledge these real customer privacy issues, either in this NPRM or elsewhere.

The latter two issues certainly warrant government scrutiny, although we do not mean to suggest that the FCC (as opposed to, say, the FTC, which has shown some moxie in the privacy areas) is necessarily the right man for the job. Our point here is simply that if the FCC is concerned with threats to openness, perhaps it should focus on real threats.

So what is the threat to Internet openness that this NPRM *does* address?

Claimed Threats to Internet Openness that ARE Addressed by this NPRM

- Arguments have been put forward that broadband ISPs, acting as gatekeepers to the Internet, might threaten Internet openness. Some claim that broadband ISPs could restrict or "throttle" Internet content customers can access, especially content that competes with services offered by the broadband ISP. Others claim that ISPs could provide preferential access and services to some application and content providers or charge them for access to their customers.[4] All such arguments have a common thread: they are entirely conjectural.

Nonetheless, there is no shortage of pundits and advocates publishing horror stories of what *could* happen without mandated network neutrality, the policy believed by many to be necessary to ensure Internet openness. Professor Larry Lessig (2006) asserts that "broadband ISPs would be able to sell access to the express lane to deep-pocketed corporations and relegate everyone else to the digital equivalent of a winding dirt road. Worse still, these gatekeepers would determine who gets premium treatment and who

[4] We note that in the Internet, the distinction between "customers" and "application/content providers" is false. Virtually anyone can become an application/content provider; the Internet is truly a two-sided market in which anyone can play the roles of provider or consumer of content/application at any time. A similar situation occurs with online auctions such as eBay; today's buyers are tomorrow's sellers, and vice-versa. Clearly, auctions are a two-sided market, but players can and do regularly switch sides, as is true with the Internet generally.

doesn't …. Meanwhile, they could slow or even block the Web sites and services of their competitors or those who refuse to pay up … Net neutrality guarantees a free and competitive market for Internet content." Strong stuff. In a more balanced (and more scholarly) paper, Peha (2007) lists a variety of abuses that broadband ISPs could engage in, such as price discrimination, favoring some providers over others, limiting the content to which customers have access, limiting free speech, using deep packet inspection to control what customers can and cannot access, and misusing customer information.

Neither of these authors (or the many others that have written on this topic) suggests that broadband ISPs are actually practicing these abuses systematically,[5] and they adduce no evidence to that effect. They note the potential for abuses, but do not bring forth evidence that these theoretical perils are likely in practice or of any practical import.

Now if we had no experience in dealing with broadband ISPs, we would certainly need to pay close attention to possible abuses, and subject them to rigorous analysis. But fortunately, broadband ISP s have been around for a decade, during which time they have been free to engage in the various nefarious actions that advocates claim are about to occur any day now.[6] If these threats are real, then we surely would have seen them materialize in the past decade. In fact, we would be overwhelmed with such abuses. So rather than speculate about abuses that in theory might occur in the future, we have the benefit of a decade of broadband ISP history; what abuses have actually occurred in this decade?

The answer is simple and well-known: there have been two cases in which broadband ISPs acted badly, both of which are mentioned in the NPRM and which have been analyzed extensively:

> *Madison River Communications*, a telephone company and provider of digital subscriber line (DSL) service, was blocking its subscribers' ability to use voice over Internet Protocol (VoIP) using Madison River's DSL service. Vonage, a VoIP provider, complained to the FCC that Madison River Communications was blocking ports that were typically used by Vonage customers to make VoIP

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[5] But see below.

[6] Some scholars claim that "The protections that guaranteed network neutrality have been law since the birth of the Internet – right up until the Federal Communications Commission eliminated the rules that kept cable and phone companies from discriminating against content providers." (Lessig and McChesney (2006)). See also Economides (2007). This is false. The FCC classified cable broadband service as an unregulated "information service" in 2002, and it was not subjected to common carrier obligations even before this definitive service classification. This classification was affirmed by the Supreme Court in the *Brand X* decision and subsequently extended to telephone company DSL services (see Reardon (2005) for a discussion of these cases. The popular (among network neutrality advocates) idea that regulation required network neutrality of the Internet is simply false.

telephone calls.[7] The FCC's Enforcement Bureau negotiated a consent decree whereby Madison River ceased this practice (FCC (2005)).

Comcast In a very high profile case in 2007,[8] Comcast was found to have delayed some BitTorrent traffic (a P2P service primarily used for sharing video files, such as movies. Comcast claimed it did so in order to manage the capacity on its network during peak periods. Regardless, there is general agreement that the practice of throttling was cack-handed. The allegations garnered so much publicity that the FCC launched an investigation, as reported in Paul (2008). Eventually, the parties were able to reach a mutually satisfactory agreement; *see* McCullagh (2008) and Comcast voluntarily agreed to modify its network management practices on terms approved by the FCC (2008). I have recently argued that had Comcast been more transparent about its practices, this incident would likely have played out very differently, most likely more favorably to Comcast, BitTorrent and most important, to their mutual customers (Faulhaber (2009b)).

In each of these two examples, the matter was successfully resolved without the need of intrusive regulation.

Two incidents in one decade of broadband ISP experience is a slender reed upon which to build a case for regulation. The NPRM names no other incidents, and no other evidence, to support its basic contention that Internet openness is under attack by broadband ISPs.[9]

The FCC claims that the proposed rules are "not intended to regulate the Internet itself…" (FCC (2009a), ¶14). Since the NPRM is actually proposing regulations, how we are to interpret this statement is a puzzle. The only interpretation possible is that the FCC does not consider broadband ISPs to be part of the Internet, an assertion that is deeply incorrect on the face of it. The FCC and its Chairman are also clear that this examination must be "fact-based, data-driven" and it is "not about protecting the Internet against imaginary dangers." But the entirety of the evidence supporting the case for regulation is two incidents…*two incidents!* This drains the phrase "fact-based and data-driven" of all sensible meaning. It also suggests that the FCC has indeed been

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[7] This event is described in FCC (2009a), ¶32. It is presented as a "for example" when in fact it is one of only two known cases.

[8] This description of the Comcast BitTorrent affair is taken from Faulhaber (2009b).

[9] The NPRM makes much of monopoly-era cases, such as Carterphone: "[w]resting control of the network endpoints from the network owner fostered unforeseen advances in technology and network applications" (FCC (2009a), ¶25). Heroic in its day, but the monopoly environment of the old Bell System is twenty-five years in the past; the analogy is totally irrelevant to today's Internet space.

swept up in the "imaginary dangers" that advocates claim, without evidence, are about to descend upon us. Where is the data, where are the facts, that provide any evidence whatsoever that these "threats" are anything but imaginary.

It might be supposed that although only two incidents have risen to the level of public attention, there are many more incidents that have escaped the public eye, as unwitting customers may not be aware that their broadband ISP is blocking or throttling certain content. As it turns out, tools are widely available on the Internet to actively monitor ISPs' network practices. Perhaps most well-known is Glasnost (Max Planck Institute (2009a)). This tool permits customers to test if their ISP is blocking BitTorrent, and reports results back to Glasnost that compiles and reports the aggregate data. The Max Planck Institute (2009b) reports that over 250,000 users have used the Glasnost software.[10] Moreover, the universe of watchful customers and the sophistication of the monitoring tools available to them is rapidly expanding. For example, Google supports Measurement-Lab (M-Lab (2009)), a website that aggregates a number of additional transparency tools designed for customers to test whether ISPs are engaged in "traffic shaping" or are degrading the performance of some subset of customers, applications, or web destinations, as well as providing support for researchers to examine such issues and create new tools.

It is perhaps most interesting that the Max Planck Institute believes "[g]reater transparency on the Internet," not greater regulation, is what motivates service providers "to refrain from blocking data streams" (Max Planck Institute (2009b). We could not agree more. We believe transparency in all segments of the Internet puts power in the hands of customers: it is a *customer-centric* strategy which we fully support, and discuss below in more detail. Regulation is a much less effective strategy and *removes* power from the hands of customers. It is a *regulation-centric* policy.

In addition, the NPRM proposes to protect openness of the Internet by ensuring that broadband ISPs cannot charge application and content providers for Quality of Service (QoS) enhancements – or apparently anything else other than plain-vanilla best-efforts connections to the Internet.

The Internet marketplace is very dynamic and in flux at all times. The current "customer pays all" model is by no means the last word in this highly fluid two-sided marketplace, and it is foolish to close off experimentation in the pricing dimension by regulatory fiat now. The NPRM presents no evidence whatsoever that this is the most efficient pricing model and that therefore market experimentation is forbidden henceforth. There is no justification for shutting off any market experimentation in the

[10] There is at least one report that Glasnost overreports BitTorrent blocking; see Bennett (2008).

future. Establishing a zero price on the basis of no evidence is draconian and perverse in the extreme.

Likewise, we note that Internet customers and application/content providers have very diverse needs for network performance, and this diversity is increasing. Enjoining broadband ISPs from offering services that cater to this diversity seems particularly perverse. Establishing a no-new-services rule for networks and thus shutting off network service innovation on the basis of no evidence is again draconian and perverse in the extreme.

Fact-based? Data-driven? Not responding to imaginary threats? Where is the evidence that supports the alleged threats to Internet openness from broadband ISPs? If there is no evidence, how can this inquiry be "fact-based, data-driven"? If there is no evidence, how can the proposed rules be anything other that responding to "imaginary threats"? As we consider these facts, it is crystal clear that *there is not a problem with Internet openness that is addressed by this NPRM.*

Where Is the Market Failure?

Since there does not appear to be an existing problem that requires a regulatory fix, perhaps another economic approach will uncover a rationale for regulation: [11] is there a *market failure* which regulation might correct? [12,13]

The NPRM[14] does not even mention the term "market failure," let alone use a finding of market failure to justify regulation. It simply proposes regulation without any foundation in a finding of a market failure that network neutrality regulation could correct. For the FCC to abandon economic principles in contemplating regulation is seriously disturbing, and we strongly suggest the FCC reconsider. We are heartened

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[11] There may be non-economic reasons for regulation, such as public safety or national security. In this note we address only economic and engineering reasons for regulation.

[12] At the very least, regulation to correct a market failure should only be imposed after an empirical analysis of the following questions: (i) is the proposed regulation the most efficient possible for correcting the market failure? (ii) what are the costs of the regulation, in terms of compliance, reduced investment incentives, and reduced innovation incentives? (iii) will it create increased opportunities for rent-seeking by interested parties? (iv) will it create new lobbying entities, seeking to forward their objectives via the regulatory process? (v) are there possible unintended consequences? Do these costs of regulation outweigh the benefits of correcting the market failure, and is there *empirical evidence* to support this conclusion?

[13] A simple economic model by Faulhaber (1996) suggests how regulation can be substantially worse for customers than suffering a classic market failure. For a more formal analysis of regulation, see Noll (1989).

[14] The presence of a two-sided market with network effects is not necessarily a market failure. There are quite a few Internet *applications* that exhibit two-sided market network effects, such as eBay and Facebook, which no one claims involve market failure, and which no one would dream of regulating.

that Commissioner McDowell raises the issue in his comments (FCC (2009a), Statement of Commissioner McDowell) in which he states "In fact, just over two years ago the Commission launched an inquiry into the state of the broadband services market. We cast a wide net in an effort to harvest evidence of fundamental market failure, and we came up empty." In its rush to regulate, the NPRM avoids the inconvenient truth that they produce no economic justification whatsoever for regulation.

In this section, we have asked the basic question of "Why Regulate?" two ways: (i) what is the problem we are attempting to fix?, and (ii) what is the market failure that requires regulation? In both cases, our "fact-based, data-driven" analysis leads to the same conclusion: *there is no reason to regulate!* The supposed problems really are imaginary, and there is no market failure that requires a regulatory remedy. Any regulation that comes out of this proceeding will be all cost and no benefit for customers. This proceeding is not *customer-centric*, it is *regulator-centric* and *advocate-centric*.

Whatever happened to Customer-Centric Competition?

We would be remiss in not mentioning that in most markets, there are only two wireline broadband ISPs. Net neutrality regulation has been described as a temporary response to the limited number of existing wired broadband competitors: Atkinson and Weiser (2006) state outright that "[i]n essence, network neutrality rules reflect a short-term solution in the absence of a longer-term imperative: more robust competition in broadband markets." But if the concern is a need for more robust competition, then it behooves the FCC to focus on achieving that end, not to impose ill-advised network neutrality regulation. It is the core of the debate, to which we return in Section 5.

There is, of course, no such thing as "temporary" regulation. Once a regulation is put in place, it creates its own advocates and vested interests who vigorously oppose its demise. And, it is important to recognize that the net neutrality movement was spawned well before wireless broadband posed a serious threat. Ironically, rather than embracing the additional competition as the answer to their concerns, net neutrality proponents seek to *extend* the regulation they propose to wireless.

But doesn't the current wired duopoly in many markets mean we need regulation in order to forestall bad behavior envisioned in the NPRM? Certainly not; we have had the current market structure for a decade with virtually no record of the bad behavior envisioned in the NPRM. Since nothing has changed, there is no evidence-based argument that suggests the existing market structure ever has or will in the future give rise to this bad behavior. While we are in favor of increasing customer choice through more competition, we do not believe that the concerns of abuse raised in the NPRM have any basis in fact under the current market structure. The observed market conduct of rapidly increasing broadband speeds, continuous investment and

innovation, high churn[15] and aggressive advertising tell a story of a rivalrous marketplace to which the hypothetical abuses envisioned in the NPRM would come at great cost in lost customers.

A decade ago, the FCC issued a thoughtful and prescient research paper (Oxman (1999)) which reviewed the history of the FCC's treatment of data services through the various Computer Inquiries to the then-nascent Internet. He noted that the Internet owed much of its success to the FCC's consistent refusal to regulate any part of it. He noted that there would be pressures in the future to regulate; on p. 21, he states

> "Although the FCC has a long tradition of encouraging the growth and development of the Internet by nonregulation, deregulation, and certain affirmative market-opening policies, there are frequent calls from many sources for the FCC to become more heavily involved in Internet regulation. …The challenge to the FCC… is to … further the Commission's longstanding goal of promoting competition, not regulation, in the marketplace."

And on pp. 25-26, he notes that

> [The FCC must] be careful that any regulatory responses are the minimum necessary and outweigh the costs of regulation" and "Even though there are calls from numerous sources for the FCC to regulate the Internet, the Commission has a thirty-year tradition of encouraging its open and unregulated growth."

In the same year, then-Chairman William Kennard stated (Kennard (1999))

> "[T]he best decision government ever made with respect to the Internet was the decision that the FCC made . . . NOT to impose regulation on it. This was not a dodge; it was a decision NOT to act. It was intentional restraint born of humility. Humility that we can't predict where this market is going."

But this is a new FCC, one might argue; it's all different now. Is it? We note the words of the Staff Report on the National Broadband Plan of December 16 (FCC (2009b)):

> "Competition drives innovation and better choices for consumers."

We could not agree more. But we are puzzled by the disparity between the FCC of the National Broadband Plan report and the FCC of the Open Internet NPRM. We are hopeful that the former approach will prevail.

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[15] Monthly churn rates in cable broadband are reported to be between 2.4% and 3%, which corresponds to annual churn rates of 28.8% and 36% (Farrell (2007))

If there is a perceived lack of competition, the solution is more competition, not more regulation. This NPRM moves in exactly the wrong direction and a direction totally antithetical to FCC policy toward the Internet for the past decade. The FCC needs to be encouraging competition, not enacting restrictive regulations on broadband ISPs that will have exactly the opposite effect.

The experience of the last decade has shown the wisdom of encouraging competition. The FCC's policy of no regulation anywhere in the Internet has been a wild success. Are we about to throw this success over on the basis of zero evidence?

3. Likely Costs of the Proposed Regulation

Regulation is costly in general

In the presence of market failures, regulation *may* provide benefits to customers, but it always does so at a cost, often a very substantial cost. Determining if regulation should be imposed should involve a careful empirical analysis of the projected benefits and costs, to ensure the former is greater than the latter. In the case of broadband, however, the analysis is easy, as the NPRM does not even claim that there is a market failure that needs fixing, and there is no evidence of one, as Commissioner McDowell (2009) points out. All that remains are regulation's costs.

Economists have examined the costs of regulation in general for several decades. We need not repeat the arguments here, as they are well-known. The definitive references are Noll (1989) and Carlton and Perloff (2005). Regulation in practice often results in firms and customers constrained to inefficient market actions, lessened incentives to invest and often the complete elimination of incentives for entry and innovation. Regulation also opens wide opportunities for regulatory rent-seeking, in which firms seek market advantage via regulation, rather than via serving customers well. When regulators are open for business, firms understand that pleasing/manipulating the regulators is far more important than innovating, investing and pleasing customers. It is precisely because regulators have *not* been open for business on the Internet that it has been such an innovative and successful enterprise.

Advocates of regulation often ignore this seamy side of regulation, hoping that proposed network neutrality regulation will work perfectly, with no unintended consequences, implemented by an all-wise, lobby-proof, above-politics FCC. Those of us with actual experience with regulators (such as the authors) find this Pollyanna attitude naïve in the extreme. Regulators themselves are acutely aware of the serious limitations of regulation. Recently, the Federal Trade Commission (2007) warned of these costs:

> "[W]e suggest that policy makers proceed with caution in evaluating calls for network neutrality regulation. . . . No regulation, however well-intended, is cost-free, and it may be particularly difficult to avoid unintended consequences here, where the conduct at which regulation would be directed largely has not yet occurred. . . . Policy makers should be very wary of network neutrality regulation … simply because we do not know what the net effects of potential conduct by broadband providers will be on consumers, including, among other things, the prices that consumers may pay for Internet access, the quality of Internet access and other services that will be offered, and the choices of content and applications that may be available to consumers in the marketplace. Similarly, we do not know what net effects regulation to proscribe such conduct would have on consumers. This is the inherent difficulty in regulating based on concerns about conduct that has not occurred, especially in a dynamic marketplace."

Indeed, the FCC (2002) itself recognized the severe limits and costs of regulation in the broadband market space:

> "…[B]roadband services should exist in a minimal regulatory environment that promotes investment and innovation in a competitive market. We recognize that substantial investment is required to build out the networks that will support future broadband capabilities and applications. Therefore, our policy and regulatory framework will work to foster investment and innovation in these networks by limiting regulatory uncertainty and unnecessary or unduly burdensome regulatory costs."

Both scholarly research and practical experience with regulation reach the same conclusion: regulation is of necessity a costly process, not to be undertaken without solid empirical proof that the hoped-for benefits outweigh these costs.

The proposed regulations would be costly in particular

The knowledge that regulation in general is quite costly should raise alarm bells about the particulars of this NPRM's proposed regulations, which are:

- A general nondiscrimination principle,[16] under which
    - ISPs would be enjoined from providing, without charge, "discriminatory" service enhancements for any traffic.[17]

[16] The proposed nondiscrimination rule proposed by the NPRM is far broader than that to which even common carriers have been subject. Section 202 of the Communications Act, for example, prohibits only *unreasonable* discrimination.

- ISPs would not be able to provide and sell services (such as QoS) to application/content providers that could enhance their business, even if those services were offered to all similarly situated customers on an entirely nondiscriminatory basis.

- ISPs would be subject to "reasonable" network management regulation; what constitutes "reasonable" would be left undefined, to be worked out on a case-by-case basis.

- The FCC proposes to investigate, with an eye toward possible regulation, "managed" networks. However, what managed networks are and why and how they would come under regulatory purview is not defined.

- The FCC proposes a transparency principle which would require broadband ISPs to disclose practices and terms of business "as is reasonably required for users and content, application and service providers to enjoy the protections specified."

- The FCC proposes net neutrality obligations for wireless providers, a highly competitive industry.

Transparency

We address the last regulatory principle first. We are strong believers in transparency that is focused on ensuring disclosure to customers so that they may make informed purchase decisions. Although cooperative solutions to disclosure issues are a preferred alternative, in our view, we support compelling transparency via regulation should cooperative solutions fail. We believe that competitive markets can only work if customers are fully apprised of what they are buying and the terms under which they are buying it, so that they may make informed decisions. Only with good information can competitive markets work their magic, and ensure that customers are in the driver's seat. Full transparency is at least as important in markets which are not at the competitive ideal.

Since most broadband ISPs have publicly stated that they are in favor of transparency, it would appear that some form of cooperative solutions with firm regulatory guidance may offer the best solution. It may appear that our endorsement of transparency may contradict our belief that regulation is unnecessarily costly; nothing could be further from the truth. Transparency and disclosure address the serious market failure of *information asymmetry,* in which buyers know far less about a product or service than the sellers. In extreme cases, information asymmetry can lead to the total breakdown of a

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[17] The NPRM seems to make an open-ended exception for discrimination in the service of "reasonable" network management; however, the vagueness of this exception would surely chill any broadband ISP from taking any action that might be construed *ex post* as "unreasonable."

market, as described in Akerlof's (1970) seminal paper. While transparency and disclosure regulation can be costly (which is why we believe a cooperative approach is generally cost-minimizing as well as most effective), we believe the resulting benefits can be well worth the cost. In fact, there is a long tradition of disclosure regulation in all areas of the US economy, with the Federal Trade Commission at the forefront of such regulation. For a fuller discussion, see Faulhaber (2009b, pp. 762-755), Faulhaber (2009c) and Faulhaber & Farber (2009, pp. 27-28) in which we stake out a strong position on transparency.

We are so strongly in favor of transparency that we must take the FCC to task for not driving the NPRM far enough on the issue. The Internet involves many participants besides broadband ISPs that deal with retail customers.[18] In each of these segments, there are serious problems with transparency, disclosure and privacy. If we are about to require broadband ISPs to fully disclose all customer-relevant information, should we not require application and content providers do the same? To inform customers that they are being targeted by behavioral advertising? To inform customers exactly what these providers are doing with the customer information that they collect? To inform customers exactly what is happening to the search information collected by the various search engines? After all, what's sauce for the goose is sauce for the gander. Is there any reason the NPRM ignores all other Internet market participants?

Nondiscrimination

It is a canon of faith among Internet aficionados that the Internet has always been nondiscriminatory in its operations, and that this principle of nondiscrimination has recently come under threat from "gatekeeper" broadband ISPs. Nothing could be further from the truth. The Internet has always used prioritization of traffic, congestion control and other methods of network management since the earliest days, as any technologist familiar with its full history can aver. Imposing any form of nondiscrimination via regulation would be a radical change from past Internet practice. Peha (2007), now the FCC's Chief Technologist, makes the case for the following principle: "Network neutrality should not be about banning all discrimination" (p. 657). We completely agree; we advise the FCC to accept this good advice.

Service enhancements: there are many different applications that use the Internet with as many needs as there are customers. Some Internet traffic, such as voice telephony (VoIP) simply cannot tolerate delays (latency or excess jitter), while other traffic, such as movie downloads, are relatively insensitive to delay. Network engineers have always

[18] In some segments, participants do not deal with retail customers but with other large firms, which can be expected to be sophisticated and informed, and fully capable of negotiating terms and conditions of business which each other. We do not see a need for transparency regulations to be applied to these segments.

responded to these disparities by prioritizing latency-sensitive traffic; since latency-insensitive traffic cares little about short delays, such prioritization can help those who need it without cost to others.

Managing networks responsibly to respect these differences is a time-tested Internet tradition. In 1987 (pre-World Wide Web, pre-ISPs), the Internet suffered a "congestion collapse" which required immediate response by network administrators, as described by Bohn et al. (1994):

> "During the mid-80s on the 56kbps NSFNET backbone, congestion developed to a dangerous degree. In response the NSFNET engineers deployed an emergency measure to provide certain interactive network applications, specifically telnet, preferential treatment over other traffic. The priority transit allowed interactive users requiring better network responsiveness to continue working under highly congested circumstances. At the same time the NSFNET backbone established support for separate queues in the routers according to the IP Precedence value in the IP header field"

Prioritization has been used in the Internet for over two decades; it is part of how the Internet works, not some evil scheme recently cooked up by rapacious broadband ISPs. The proposed regulations could outlaw good engineering practice.

The engineers who actually set Internet standards (Internet Engineering Task Force, IETF) have long understood the importance of Quality of Service (QoS) capabilities as the best means of providing differentiated services that customers need and demand. For one example (among many), see the Delgrossi and Berger (1995) proposal to the IETF for an Internet Stream Protocol that specifies how QoS could be implemented to meet the differing needs of Internet users.

Cloonan and Won (2000) again note the need to meet the differing needs of customers using prioritization, or QoS:

> "As the industry matures, the need to offer a broader range of services to meet the needs of emerging market subsegments also increases. As a result, a new … specification was developed to provide for differentiated services and new applications such as IP-based telephony. This new version … defines a minimal set of quality-of-service (QoS) features"

IETF engineers have expressed reservations about the extreme form of nondiscrimination associated with network neutrality. In a recent IETF RFC, Floyd and Allman (2008) note

> "With *only* simple best-effort traffic, there would be fundamental limitations to the performance that real-time applications could deliver to users. In addition to the obvious needs for high bandwidth, low delay or jitter, or low packet drop rates, some applications would like a fast start-up, or to be able to resume their old high sending rate after a relatively long idle period, or to be able to rely on a call-setup procedure so that the application is not even started if network resources are not sufficient. There are severe limitations to how effectively these requirements can be accommodated by simple best-effort service in a congested environment."

And yet the FCC is proposing to impose just such "severe limitations" with its principle of nondiscrimination. Who thinks this is a good idea? Advocates and pundits, maybe; certainly not the engineers who have to make networks work well for their customers. They have been striving for years to bring such differentiation to the Internet, because they understand that this is what customers need and want. Let's let them get on with the job. Again, Peha (2007) makes the case with this principle: "Network neutrality should not be about whether network operators can differentiate their services" (p. 659). We completely agree; we urge the FCC to accept this good advice.

Providing application and content providers with enhanced services Advocates have suggested that permitting broadband ISPs to offer enhanced services to application and content providers would create an "express lane to deep-pocketed corporations and relegate everyone else to the digital equivalent of a winding dirt road." (Lessig (2006)). Really? The US Postal Service offers various classes of mail service as well as Express Mail. Do only "deep-pocketed corporations" use Express Mail? Are those of us who use first-class mail "relegate[d] to … a winding dirt road"? Even the US public highway system, that most democratic of networks, has toll roads for those in a hurry. It is hard to find an American industry in which firms do not sell quality-differentiated products or services. Customers want differentiated services, which they have proved time and time again in every industry in the global economy. Has the FCC decided that American customers and American application/content providers are not to have the benefit of quality-differentiated products? We think not; the current Chief Technologist Jon Peha (1999) states it clearly: "…application performance objectives may differ, and network service ..and pricing… should reflect these differences."

Some have argued that prioritizing some traffic necessarily disadvantages non-priority traffic. This is not the case. Traffic which is latency-sensitive (such as VoIP) can be seriously harmed if it does not receive top priority; traffic which is not latency-sensitive (such as movie downloads) can tolerate short delays without any harm whatsoever. This is the very definition of not being latency-sensitive; short delays don't matter. Again, Peha *op. cit.* expresses it well: "For some… streams, performance that exceeds

the minimum guarantees is highly desirable; for others, like video, exceeding the guarantee is of no benefit."

The NPRM appears to presume that every content provider would pay if broadband ISPs were permitted offer paid QoS. But there is every reason to believe that content providers whose offerings would be enhanced by QoS offerings would buy them and others would not. Arguments that they would be better off if they did not even have the opportunity to obtain QoS have no basis in experience or economic logic.

Henry Ford (1922) stated that "Any customer can have a car painted any color that he wants so long as it is black**."** The NPRM reprises this anti-customer attitude: "Any customer can have their Internet any way they want, as long as it is ''best efforts network neutral'".

Prohibiting broadband ISPs from charging for enhanced performance would certainly result in reducing ISP incentives to invest or innovate in performance-enhancing network capabilities. If ISPs cannot charge for enhanced performance, why would they invest in it? The losers are innovators that need enhanced network performance so that they can introduce a higher quality of service. But prohibiting ISPs from offering performance enhancements for a fee discourages "edge" innovation that could take advantage of those very network performance enhancements. Under the proposed regulations, customers will never get to choose these high-powered services, since the FCC will have regulated them away. How customer-centric is that?

The NPRM states that the Internet "does not distinguish between a budding entrepreneur is a dorm room and a Fortune 500 company." This is simply untrue. Content distribution companies, such as Akamai, offer application/content providers preferential "caching" services. In this model, Akamai establishes servers near major cities and offers to serve firms that require a fast web response for their customers at these servers. Since the servers are geographically close to broadband ISPs and their customers, firms with time-sensitive applications can buy preferential access from Akamai (and other caching service firms). The rules proposed in the NPRM could be read to assure that firms which offer broadband ISP services could never offer this service or any prioritization services that provide alternative ways of obtaining needed performance.. Apparently, the offer of preferential caching service by non-ISP firms such as Akamai (or by content providers themselves) is not a violation of Internet openness but preferential caching services by ISPs is a violation of openness, a result that beggars logic.

Is Akamai an express lane for those providers (such as Amazon, Blockbuster, ESPN, MySpace and others) that choose to pay its fees? Would these regulations bar Akamai from offering these services? If Akamai can offer caching services but Comcast cannot, where is the economic sense of that? Whose interest is furthered by such a regulation?

We know for sure that it is not the customers' interest. And since application and content providers that can afford to pay a content distribution network or build their own network enjoy better performance, what is the logic of preventing broadband ISPs from developing and offering alternative ways of enhancing performance? Especially if broadband ISPs can bring this capability to smaller application and content providers who cannot afford to pay Akamai or build their own networks. Let broadband ISPs and application and content providers make any mutually beneficial market agreements they want, and make sure that customers are aware of such deals. We see no reason why standard business practices should not apply to the Internet. The market expands value by encouraging mutually beneficial exchange; forbidding a class of mutually beneficial exchange guarantees inefficient outcomes.

Charging application/content providers for access to ISP customers The NPRM (¶¶68-69) expresses concern that broadband ISPs may charge application/content providers for access to the ISP's customers, which according to the NPRM "could drive some content, application, and service providers from the market." This, according to the NPRM, "would reduce the quantity and quality of Internet content, applications, and services, reducing the overall value of the Internet to end users and thereby reducing demand for broadband Internet access services." Is this concern based on actual marketplace behavior? No. After more than a decade of experience in the broadband market, we have not seen any ISPs unilaterally impose access fees on any application/content providers. Instead, the angst in the NPRM appears to be based on purely conjectural concerns about the dynamics of two-sided markets in the Internet environment. Most parties now recognize that the Internet supports a variety of two-sided markets, with subscribers on one side and application/content providers on the other side. [19] Is it always the case that just one side pays? In fact the market determines who pays whom in a two-sided market; in some cases, both sides pay (e.g., credit card transactions, newspapers and magazines); in some cases, one side pays and the other side *gets* paid (e.g., cable television, as between subscribers and cable networks); or one side pays but not the other (e.g., online auctions, travel agencies). Sometimes different business models prevail in the same industry (e.g., subscription-based magazines co-exist with free publications that rely entirely on advertising). The market determines the outcome, not the regulator. The balance of pricing between the two sides of a two-sided market can matter deeply in terms of customer well-being. Regulating a particular solution (in this case 100% of the price burden is on customers) without any evidence whatsoever that this is in customers' interest is almost sure to make customers worse off than if pricing is determined in the market.

[19] Noting, as above, that a customer/subscriber today can be a content provider tomorrow. This is similar to eBay, where a buyer today can be a seller tomorrow.

If the proposed rules prohibit broadband ISPs from charging application/content providers for access to their customers, are application/content providers likewise prohibited from charging broadband ISPs for allowing their customers to access their content? After all, in a two-sided market, there is no hard and fast rule regarding who charges whom. Of course, one might logically think "what's sauce for the goose is sauce for the gander," that network neutrality regulation should be symmetric, applying equally to both sides of the market. But apparently this is not the case. The content provider ESPN360, which carries sports television from around the world, recently initiated charging ISPs (rather than retail customers) for the privilege of offering access to their website. Customers of ISPs that have not paid for the service have no option to access the website (Wikipedia (2009b)). The NPRM makes no mention of this issue, so apparently ISPs charging application/content providers is a violation of Internet openness, but application/content providers charging ISPs is not, a result that again beggars logic.

The economics of two-sided markets have been subject to much economic analysis of late (see Rochet and Tirole (2007) for an excellent summary), and applying this theory to the Internet has become popular. Two-sided markets seem complex at first; the number of customers is determined by the price charged (to customers) by the ISP as well as the number of application/content providers accessible via that ISP. The number of application/content providers is determined by the price(s) charged (to application/content providers) by the ISP as well as the number of customers accessible via that ISP. If the ISP charges too high a price to application/content providers, there will be too few and therefore that ISP would not attract many customers, even if its customer price is low. If the ISP charges too low a price to application/content providers, the ISP would have to charge a high price to customers, which would dissuade them from subscribing. Clearly, the ISP wants as many customers as possible and as much content as possible. The ISP must strike a balance in pricing between the two sides. This is true whether the ISP is a monopoly, a duopoly or is in a perfectly competitive market.

A partial answer based on two-sided market theory is provided by Economides (2007), in a generally pro-network neutrality paper. His most interesting result is that in a model of ISP duopoly, *enforcing zero pricing* on the application/content provider side of the market *hurts customers and hurts ISPs, but helps application/content providers.* This should be no surprise; low or zero prices for application/content providers means higher prices to customers. Although there is thus more content, that content does not have sufficient value to keep customers from leaving the ISP (at least in this particular model). An interesting and enlightening result, shedding light on who are the advocates of network neutrality and who are the opponents. We hope the FCC is an

advocate for customers, and does the right thing.[20] Again, we turn to another Peha (2007) principle: "Network neutrality should not be about 'who pays' for Internet service or infrastructure" (p. 658). We completely agree; we urge the FCC to accept this good advice.

In recent work, Lee and Wu (2009), present a good summary of the two-sided market literature, and make the argument that the application/content provider side of the market should be priced at zero (the proposed regulation in the NPRM) as a subsidy to innovative entrepreneurs. The idea is to ensure that the barrier to new entry remains low; even if customers (us non-creative types) must pay higher prices as a result, Lee and Wu state that "a ban on payments from content providers to Internet intermediaries is this: it is a subsidy to the creative and entrepreneurial at the expense of the passive and consumptive." (p. 67). Thanks a lot, guys, from the 95%+ of us who are not running active websites.[21]

As a subsidy for the creative, it is both inefficient and unnecessary. It is inefficient, because lavishing subsidies on certain groups by manipulating market prices has a much higher cost (in terms of inefficient pricing) than the purported benefit. Further, it not only subsidizes entrepreneurs, it *really* subsidizes the large application/content providers, such as Google, eBay and Amazon.. Do we want to subsidize firms that are in fact larger than the largest cable ISP firm? And much larger than customers of ISPs that would almost surely get lower prices as a result of fees levied on application/service providers? It's not entrepreneurs that would be the big winners from a zero price regulation; it is the big application/content providers. No prizes for guessing which firms are lobbying hard against charging application/content providers to terminate traffic.

And it is also a totally unnecessary subsidy, for the simple reason that it would be an irrational business practice for any broadband ISP to price small startup application/content providers out of the market. Recall it is in the interest of the ISP to have as much content as possible, so it actively want new entrants on its network, because that makes the ISP more attractive to customers. Levying a significant charge on new entrants that would drive them away is not in the interest of any broadband

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[20] The model is, as all models are, overly simple. He does not consider the use by the ISP of price discrimination of the application/content provider side of the market, assuming that the ISP charges the same price to a startup firm as it would to Google. An ISP that price discriminates would never price a new entrant out of the market; it would be profit maximal to charge at or near zero, reserving higher prices for those application/content providers who derive more value from the market. He also assumes counterfactually that the size of the consumer base is fixed, and that lower prices would not produce greater broadband adoption.

[21] One of the authors actually does have a website.

ISP. Further, the transactions cost of chasing down little entrepreneurs is too high[22], and the public relations of doing so too negative, for any sensible ISP to do this.

Moreover, as noted above, after a decade of broadband ISP experience, the NPRM identifies not a single instance of a broadband ISP imposing a unilateral "access fee" on an application/content provider, let alone a systemic, industry-wide practice. Nore does the NPRM explain why, in any event, allowing application/content providers to enter into voluntary commercial arrangements to pay such fees in order to lower the cost to customers' broadband ISP service would be bad for customers. Consider the following hypothetical case: suppose that Disney agreed to pay access fees to subsidize the cost of an ISP's new "child-friendly tier" of broadband access. The NPRM proposed regulations would prohibit this transaction, which reduces everyone's welfare. Rather than following an *regulatory-centric* approach and outlawing potentially pro-consumer business models based purely on speculation, the FCC should adopt a *customer-centric* approach and give broadband ISPs and application/content providers the freedom to develop arrangements for the benefit of customers.

In all events, if there are situations in which a broadband ISP determines that its optimal strategy is to impose some charges on some content providers, the optimal strategy would not be to charge at a level that drives small entrepreneurs out of the market. Indeed, little guys would likely continue to get a free ride under any such scenario through some form of price discrimination. If our concern is low or zero prices for Internet startups, the market will surely take care of this, for the simple reason that broadband ISPs want as much content as possible to be attractive to subscribers. And note that the market will take care of it not because ISPs are nice guys, or devoted to Internet innovation, or any such high-sounding platitudes, but because it is in their own interest to do so. Indeed, paradoxical as it may seem, if a broadband ISP had an incentive to share application/content provider rents via charging, regulating the price to zero in all circumstances *creates* incentives for anticompetitive content blocking – assuming market conditions, regulatory or legal constraints, and transparency would sustain either practice. Absent such regulation, the incentive of the broadband ISP in this context would be not to block but to share the rents via pricing. Content blocking would not accord with the interests of the ISP,[23] unless the FCC would be so unwise as to require a zero price. We recall Adam Smith's (1776) comment: "It is not from the

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[22] Lee and Wu mention the transactions cost problem, but do not reach the obvious conclusion that price discrimination is the optimal strategy for ISPs. They also note the ESPN360 case, in which ESPN charges ISPs so their customers can access ESPN360 content. They rather don't like this, but do not state clearly that the price should be zero for all parties, not just the ISPs.

[23] An alternative strategy is for the ISP to compete directly with the Internet competitor. For example, Comcast has recently entered the Internet video market in competition with streaming video providers such as Hulu with its Fancast Xfinity TV offering (see LaVallee (2009)). The service is available at http://www.fancast.com/ .

benevolence of the butcher, the brewer, or the baker, that we expect our dinner, but from their regard to their own self-interest. We address ourselves, not to their humanity but to their self-love, and never talk to them of our own necessities but of their advantages."

"Reasonable" Network Management

Virtually all communication (and transportation) networks are characterized by links (connections that make up the network) whose capacity is fixed in the short run, subject to traffic demands that are stochastic in nature, i.e., actual demand at any second varies according to a probability distribution. If the demand to send traffic exceeds the capacity of any of the links, then that traffic is dropped or delayed; the network is said to be *congested*. During periods of congestion, the network's ability to carry the traffic offered to it actually declines. We are all familiar with rush-hour traffic on expressways; too much traffic causes the system to grind to a halt, with almost no traffic actually moving. The expressway becomes a "parking lot," in popular parlance. Similar breakdowns regularly occur in telephone networks and data networks, such as the Internet. During periods of congestion, networks must take action to mitigate the congestion; such actions often include prioritization of traffic (e.g., ambulances get to use the expressway before campers) and turning away some traffic (e.g., blocking on-ramps) until the congestion subsides. Congestion can arise in milliseconds and a responsible network operator must respond immediately. Furthermore, demand overload in one part of the network can create congestion in other parts of the network; it is not localized but can spread quickly and unpredictably.[24]

Network administrators learn over time what works; but every congestion incident may pose new threats that have not been observed before.

Network management is difficult at best; driven by exogenous shocks requiring instant reactions from experienced network administrators using what tools are available and relying on experience. The long history of network management in telephone and data networks teaches us that we learn by doing, and we are constantly surprised. In describing the response to the 1987 "congestion collapse" Yoo (2005) states

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[24] One author was conducting research in network management at Bell Laboratories in 1967, studying the traffic patterns incident to a tornado that hit Jackson, MI in March, 1966 in the early evening. Little telephone traffic resulted from the incident itself, but when reports appeared on the nightly news in New York City just after 11:00 pm, a flood of calls from New York to Jackson overwhelmed the Jackson toll switch; sender queue records note that the toll switch locked up within 45 seconds. The congestion spread within a minute to the Rockville, GA Class 1 toll switch, a much larger machine. Nevertheless, Rockville sender queue records indicate the switch locked up within 90 seconds, essentially shutting down all telephone traffic in the southeastern US. The congestion took over an hour to clear. The lesson: congestion can shut down switches and routers within seconds and the congestion spreads quickly to other switches/routers. Further, the precipitating event (in this case, the NYC broadcast of the tornado, not the tornado itself) need not be obvious.

> "This is precisely the type of technology and demand-driven exogenous shock that makes network management so difficult. NSFNET's interim solution was to reprogram its routers to give terminal sessions higher priority than file transfer sessions until additional bandwidth could be added. Indeed, such solutions need not be temporary: in a technologically dynamic world, one would expect that the relative costs of different types of solutions to change over time."

This is not a job which is amenable to rules, since it involves highly technical, complex and dynamic engineering decisions well beyond the expertise of most regulators. When an event occurs and new lessons are learned, we cannot wait for a regulatory body to write new rules, go through a 90 day comment cycle, followed by a reply comment cycle, and then possibly a court challenge to be able to use the lessons experience teaches us. This is an area for which regulation is particularly ill-suited.

Indeed, the NPRM recognized this, and suggests a more flexible standard of "reasonable" network management. Network administrators would not be given a rulebook, but would be subject to *ex post* penalties if the actions they took during a congestion emergency were later found by regulators not to be "reasonable." Having the advantage of 20-20 hindsight plus lots of "help" from advocates and competitors could punish network management actions by hard-pressed administrators. Could any network administrator do their job under such circumstances? Does introducing the uncertainty of after-the-fact judgment using open-ended rules really help protect the Internet?

One possible solution to the network management issue is that ISPs should simply expand capacity, so that congestion never occurs. It is obvious that this is not a serious suggestion for dealing with congestion when it occurs. Adding capacity to a network takes time, while congestion must be dealt with immediately. We can presume that the proponents of "just add capacity" are referring to a longer time horizon, in which ISPs add sufficient capacity so that congestion *never* occurs. Is that a reasonable option? If demand for Internet traffic capacity were relatively level and the variance of traffic were low, then this might well be an attractive option, as the amount of capacity required to avoid congestion altogether might be some small multiple (say 1.5) of *average* demand. But the reality is that Internet traffic varies by time of day and is highly variable, or "bursty." Installing capacity sufficient to carry all demand all the time could well involve providing capacity *dozens of times* larger than average demand, with a concomitant increase in costs to customers to pay for capacity that sits idle for all but an hour a year. It is the nature of stochastic "bursty" traffic that peak demand will be much larger than average demand, so providing for the peak would be very expensive,

and certainly against good engineering economic principles.[25] "Just add capacity" is a recipe for a very expensive Internet, primarily because of the bursty nature of Internet traffic.

In sum, imposing a "reasonable" network management regulation on the Internet could well destroy the ability of network administrators in broadband ISPs to successfully manage congestion. The uncertainty of ambiguous regulations, the after-the-fact enforcement of such regulations, and the complete inappropriateness of regulators usurping engineers' responsibilities marks this proposed regulation as not only uncalled for but downright dangerous.

Managed Services

The NPRM also opens the door to another major expansion of regulation: "…we recognize that there are and will continue to be Internet-Protocol-based offerings (including voice and subscription video services, and certain business services provided to enterprise customers), often provided over the same networks used for broadband Internet access service, that have not been classified by the Commission. We use the term 'managed" or 'specialized' services to describe these types of offerings." (FCC (2009a), ¶148)

Since just about every modern network uses "the same networks used for broadband Internet access service," and just about every modern network is IP-based, the NPRM apparently proposed to regulate just about all services that use a modern network, a bold and unprecedented regulatory reach. We note that the NPRM is careful to suggest that it may not be necessary to regulate such services as tightly as it proposes to regulate broadband Internet access. *But it opens the door for these services to be regulated*.[26]

What are" managed services"? The NPRM, having introduced the term managed services, then asks for help defining what they are. The definition seems to include *all* services offered over modern communications networks. Really? If Verizon sells a network (IP-based, using core network transport) to, say, Monsanto Chemical for its internal use and

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[25] The basis for dimensioning communications networks is Moe's Principle, first articulated by Jensen (1950); Moe's Principle is still in use today for dimensioning data networks such as the Internet. In brief, the efficient capacity level is that in which the marginal revenue of the last unit of capacity is equal to its marginal cost. Dimensioning for maximum peak traffic results in a capacity far beyond what good engineering economics calls for.

[26] FCC (2009a), "We recognize that these managed or specialized services may differ from broadband Internet access services in ways that recommend a different policy approach, and it may be inappropriate to apply the rules proposed here to managed or specialized services"… "In this section, we seek comment on whether and, if so, how the Commission should address managed or specialized IP-based services" ¶149.

corporate access to the Internet, is this a managed network? Apparently so.[27] Are IP-based home networks that also carry Internet traffic managed networks? Apparently so. Cable firms often use their own proprietary IP networks (using the same transport facilities as the Internet) for their VoIP voice telephony applications; are these managed networks? Apparently so. If a small firm installs a modern alarm system on its premises with an IP network connection to the alarm company, is that a managed system? Apparently so. With the advent of DOCSIS 3, some observers believe cable firms may move more of their video traffic to IP-based channels (O'Shea (2009)); if they do so, does cable TV become a managed service? Apparently so. Are telephone company IPTV services managed services? Apparently so. Is there *anything* by which people or machines communicate with each that is *not* a managed service?

A more interesting case: If AT&T sells a network to Google to enable it to deliver its web content directly to local ISP facilities (in order to speed up delivery of Google results to its customers), referred to as a content delivery network (CDN), is that a managed network? What if Google self-provides its own CDN or purchases such services from Akamai or some other company that is not considered a broadband ISP? But perhaps such CDNs are actually part of the Internet; Google would use such a network to deliver Internet content to any ISP for distribution to customers. Doesn't that make it part of the Internet? In which case, why should it not be subject to the regulatory machinery proposed in the NPRM for broadband Internet services? Of course, Google is not the only application/content provider to use CDNs to provide better service to its customers via direct connections to ISPs; the practice is quite prevalent; should these networks be considered part of the Internet and thus subject to the proposed regulations? We leave such "how many angels can dance on the head of a pin" questions to others. What we do know is that regulating the Internet *and* regulating CDNs are both bad ideas; making fine distinctions only matters in a regulatory environment, which we recommend avoiding[28] (see Section 5, below).

Why regulate managed services? We conclude above that the argument for regulating broadband ISPs is non-existent; there are no real problems to fix and there is no demonstrated market failure. The argument for regulation of any kind for managed services is also non-existent, and the NPRM makes no attempt to justify this regulation. The NPRM gives an indication of the FCC thinking: "…we are sensitive to any risk that the growth of managed or specialized services might supplant or otherwise negatively affect the open Internet." So the NPRM's argument seems to be:' the FCC intends to regulate the Internet without any evidence for doing so, and managed services may

[27] Would it be a managed service if Verizon sold/leased the network and Monsanto managed it (thus making Monsanto a regulated firm)? Or would it only be a managed service if Verizon itself managed the network under contract from Monsanto? The NPRM is silent on these issues.
[28] Except, of course, transparency regulation, a point we make above.

serve as substitutes with basic Internet services, so we have to regulate managed services as well, even though there is no evidence that there are market failures here.' The last time this argument was used was in the 1930s when the Interstate Commerce Commission justified regulating the nascent trucking industry (for which there was no market failure) for the sole reason that it competed with the railroad industry, which the ICC did regulate.[29] It took fifty years of highly inefficient transport regulation to undo this particular regulatory error. How long will it take to undo the regulation of managed services?

Noting that some managed services could compete with existing Internet services is hardly a breakthrough; cable firms' VoIP over managed networks are designed to compete with Internet VoIP offerings such as Vonage. They also compete with traditional wireline voice. In fact, having services that compete with incumbents (either the "best effort" Internet or incumbent wireline voice) is the whole public policy point. If managed services compete with the Internet, that is to be treasured by the FCC, not regulated. If there is a surefire way to stifle competition from managed networks, it is to regulate them, which appears to be what this NPRM contemplates. In fact, the policy trend of the FCC for over a decade has been to encourage such competition from alternative platforms; this NPRM seems to hearken back to an earlier era when the FCC sought to extend its regulatory reach, not rein it in. We strongly agree with the pro-competitive FCC of the last two decades (and indeed the FCC that produced the recent National Broadband Plan Report (2009b)); we strongly disagree with the FCC of this NPRM.

4. Wireless Broadband

The NPRM envisions applying the proposed regulations to wireless broadband. This appears particularly indefensible. There is no argument that wireless broadband providers operate in anything other than a fully competitive market. We have demonstrated this important point before (Faulhaber & Farber (2009)); there should be no need to repeat these arguments.[30] It is not only competitive, it is highly innovative. The broadband wireless industry is a textbook example of how competitive industries respond to customer demands. For example, wireless providers were initially reluctant to support outside developers creating software that ran on devices using their

[29] This case has become a staple in the teaching of regulatory economics. It is used to illustrate the power of lobbying, the inefficiency of regulation, and the persistence of bad regulation. A short summary is in Gale (2009).

[30] 95% of US households have access to three or more wireless carriers, and 72% of households have access to five or more carriers. Of the 21 wireless carriers that serve at least 100,000 subscribers, 18 offer 3G broadband service. The US wireless industry leads all OECD countries in measures of competition. It has the lowest concentration (as measured by HHI), the highest per customer volume of usage, and the lowest average revenue per minute of an OECD country.

network. In fact, some providers did not permit devices to be used on their networks unless they were purchased through that wireless provider. This all changed. There are now over 100,000 applications for download on the iPhone at the iTunes store (Wortham (2009)). Other vendors, device manufacturers and wireless carriers, saw that this met a strong customer demand and quickly changed their strategies to accommodate, and indeed facilitate development of outside applications. Carriers also now allow customers to bring their own device, including devices that the carrier does not itself sell, so long as it is compatible with the carrier's network technology. Customers wanted more openness regarding applications and devices, and the market produced it. The iPhone was very much the change agent, showing the rest of the industry successful customer-centric strategies which quickly diffused throughout the market.

This is how competitive markets work; firms that best meet the needs of customers are winners, and others emulate them if they can. The lesson here is simple: *if customers of wireless broadband providers want network neutrality, the competitive market will give it to them. There is no need for regulation.* Should the FCC impose network neutrality regulation on wireless broadband providers, it is admitting that customers don't really want this, but the FCC is going to force it on them anyway. *Imposing wireless network neutrality is a regulatory-centric policy, not a customer-centric policy.*

But suppose the FCC does impose these regulations on wireless broadband. What can happen? Is this somehow different than wireline?

Yes, it is different than wireline, in ways that ensure that the proposed regulations would be particularly harmful. We refer to the technical report of Reed and Tripathi (2010) for a statement of the impact of network neutrality on wireless network. Here we give a brief outline of some of the problems:

- Wireless requires a much higher degree of integration among the core network carriers, devices and applications in order to function smoothly; by contrast, wireline involves "plain vanilla" connections with relatively simple standards. We made this point in Faulhaber & Farber (2009).
- Wireless broadband traffic is more bursty then wireline broadband traffic for the simple reason that customers move in and out of cell tower range unpredictably. Tight control of device-tower transmissions is critical to ensure good quality service in wireless; wireline has no such problems.
- Wireless customers move about within a cell tower area, so controlling interference becomes an issue requiring tight integration between devices and towers.
- Wireless transmission is more complex and less well understood than wireline transmission; outside radio interference and interference among customers in

close proximity to each other presents a challenge not present in wireline transmission. Engineers must constantly experiment and flexibility is essential. This is particularly true as each network provider uses a different protocol, such as EVDO, HSPA or GSM EDGE.[31]

- The industry is moving toward new 4G systems which are even less well understood; because the market is tightly integrated, both applications and devices will change as these new systems come online. This greatly enhances the need for experimentation and flexibility.

To illustrate the how and why of close integration between devices and carriers, we include this extensive quote from Qualcomm (2009):

> "Mobile broadband systems … employ power control to optimize their spectral efficiency. For example, the power control inherent in CDMA-based networks and mobiles ensures that each mobile always transmits exactly enough power to provide decent call quality, but not more than enough. For example, on the return link, CDMA base stations constantly measure the error rate performance from each mobile transmitting a signal, and, depending on whether the error rate is trending above or below an adequate performance level, the power control circuit is told to ask for a higher or lower signal to noise ratio. A base station function measures the actual signal to noise ratio and compares it to the target, and if the actual ratio is too high or too low, an "up power" or "down power" command is sent to the mobile, which responds by increasing or decreasing its power by approximately 1 dB. All of this occurs approximately 1,000 times per second at each base station and for each operating mobile. The mobile [device] continuously measures the received signal level of the base station signal, averaged over a relatively long time interval, but with a very large dynamic range (about 80 dB). These measurements are used to set the mobile transmit power at approximately the optimal level over this very large dynamic range. The base station commands have a much smaller range, but are transmitted much faster.
>
> In addition, CDMA-based mobiles also have variable rate vocoders that vary the data rate over an 8 to 1 range since lower power can be used for lower data rates.

[31] Some (e.g., Wu (2007)) suggest that the industry should settle on a common protocol, as this would be simpler for application developers and device manufacturers. In fact, we already have this common protocol: TCP/IP. Applications which use device APIs can run on any radio protocol. For example, one author has a wireless device that can use either CDMA/EVDO (domestic) or GSM/EDGE (global), and all applications work no matter which radio protocol is in use. We strongly disagree about the need for a common radio protocol; we believe that diversity of solutions to technical problems is the hallmark of robust competition in a growing and evolving industry. When this industry is old and gray, then perhaps it is time for common standards; not now.

> This permits the mobile to adjust the power on a frame by frame basis (20 milliseconds) based on the varying data rate.
>
> For soft handoff between base stations, the relative strength of nearby base stations is continuously monitored. Although all base stations communicating with a mobile try to control its power, the mobile pays attention only to the one asking for the lowest power. CDMA uses powerful forward error correction coding and efficient modulation and implementation so that the signal to noise ratios are very low- approaching the Shannon limits. All these features ensure that CDMA-based networks and mobiles operate at the most efficient levels. OFDMA-based networks use similar techniques to achieve the same result."

This lengthy excerpt illustrates in detail the complex "dance" that goes on continuously between devices and cell towers, and the integration needed to make this all work. There is no counterpart to this in wireline broadband.

Added to this complexity is the need for constant experimentation and flexibility as network operators cope with new technology in the network (e.g., 4G), devices (e.g., iPhone) and applications (e.g., GPS-aware mapping apps).

Now let's imagine introducing regulation into this highly dynamic technology-driven market. Can we even imagine establishing a set of rules within which core networks can manage these complex interactions? How about one within which core radio access networks and device providers can accommodate new technologies on both sides of the market? Even worse, suppose the FCC adopts a loosely defined "reasonable" network management standard? Can we even imagine a standard of "reasonableness" in this highly dynamic environment, in which different carriers use different protocols with different devices? What does "nondiscrimination" mean in a radio environment in which carriers are constantly interacting with devices to manage who is using how much spectrum and how much power, based on how close customers are, and how many customers are in the cell tower's reach? Whatever network management rules are applied, they cannot help but interfere significantly with the complex "dance" needed to operate a modern wireless system.

And to what end are these regulations designed? The wireless broadband market is already highly competitive; there is no market failure. The only result that can follow imposing these regulations on wireless broadband is *less efficient use of spectrum, higher costs of operation, and lower rates of investment and innovation.* In the end, customers will get far less value from a regulated market than a competitive market. Years of FCC experience has shown that, and for years the FCC has realized this. This lesson must not be forgotten.

The wireless business involves very tight and very close integration among all its levels: core network, radio access network, applications, operating systems and devices. It also requires a high degree of flexibility in dealing with innovation and spectral efficiency. This is an environment in which the introduction of the dead hand of regulation can be paralyzing. This is no place for regulatory intervention. We fear that FCC errors would prove very durable and could cause irreversible damage to the technical evolution of wireless broadband networks and services and optimal performance delivery to consumers. While regulation of any broadband ISP is a mistake, regulation of wireless broadband would be a disaster. As we demonstrate in the next section, messing up the wireless industry with senseless regulation is killing the goose that is laying the golden egg.

5. What Is To Be Done?[32]

Is this paper simply another diatribe against regulation? Are we asserting that there is no role for the FCC in this area? Most emphatically, we are suggesting no such thing. We strongly urge the FCC to undertake aggressive *customer-centric* policies to ensure that the broadband ISP market works as efficiently and effectively as possible to meet the needs of customers.[33] The job of the FCC is *not* to impose "solutions" such as network neutrality on customers; it is to create an environment in which customers get to choose if they want network neutrality (or portions thereof).

There is a very simple and very powerful single organizing framework which can serve as a public policy touchstone for the FCC (and indeed for all government agencies): *let the customer decide*.[34] A customer-centric approach is particularly appropriate because there is no "average" customer. Each customer has unique preferences and "tastes" for broadband, and one-size-fits-all regulation poorly serves this diverse array of individual needs. A regulatory strategy which is *customer-centric*, which puts the customer at the center of decision-making, is a guarantee that the public interest will be served.

There are plenty of self-proclaimed candidates for helping the FCC decide issues such as network neutrality that deeply affect customers: application/content providers (such as Google, Skype, and eBay), government regulators and bureaucrats, competing network providers (such as AT&T, Verizon, Comcast and Sprint), resellers, consumer advocates, assorted think tanks, law professors, even business and engineering school

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[32] With apologies to L. Tolstoy and V. Lenin.

[33] But what about the needs of application developers? Content providers? Internet service providers of all kinds? We are of the view that all players in the Internet ecosystem have one purpose and one purpose only: to serve customers. The role of public policy is *not* to make choices for customers; it is to enable customers to make choices for themselves.

[34] Much of this material is excerpted from Faulhaber (2009b).

professors. But none of these groups, however well-intentioned, should be making the decisions about how broadband ISPs ought to behave: only customers should be making such decisions. It is the role of the FCC (and government generally) to ensure that it is customers who make these decisions and who therefore drive whether or not broadband ISPs adopt particular neutrality, nondiscrimination, and openness policies, not special interests on any of the many sides of the broadband debate. This is the FCC's opportunity to put the customer center stage in the network neutrality wars: it must deliver a *choice-rich market environment* to customers. It must *not* presume to make choices *for* customers.

This is by no means a call for a *laissez-faire*, let-the-market-do-it-all approach. Indeed, this approach calls for a vigorous but nuanced approach by the FCC and the antitrust agencies, focused on ensuring an array of choices that are compatible with the efficient allocation of resources in the marketplace. It is not an approach that substitutes the judgment of regulators or even legislators for the judgment of customers in a choice-rich market. It is an approach that ensures that customers *have* a choice-rich marketplace in which to make choices.

There are two key elements in building a choice-rich market environment.

1. *Removing impediments to investment and competitive entry*. This includes moving much more licensed spectrum into the market via auctions to boost wireless broadband[35], and removing right-of-way, franchise and other government restrictions on deployment of wired broadband.[36] Public and private antitrust enforcement is required to the extent necessary to maintain competition.
2. Ensuring that *all* providers (network providers as well as application/content providers) are *transparent in dealing with customers*. If customers are to make wise choices, they must be fully informed about what they are buying, how much it costs, what services are or are not included, what they have access to, what network management methods are in use, and of course the privacy of their information.

The answer is quite simple: *if customers want network neutrality, then broadband ISPs operating in a competitive market will be forced to provide it*. We have seen this occur most recently in the wireless broadband market, a fiercely competitive market (as demonstrated in Faulhaber & Farber (2009)). If *some* customers want it and others don't, then those that desire it (if there are enough) will, in a competitive market, find a

[35] Even with the very limited spectrum available to wireless carriers, in 2007 mobile broadband lines increased by 28.7 million (46%), or 77% of total broadband net adds in that year (58% using the more stringent FCC definition of broadband) (FCC (2009c)), suggesting that wireless broadband is perhaps already a larger part of the broadband picture than commonly believed.

[36] This suggestion was mooted in 2006 in Bailey, et al (2006) (one author is a signatory).

supplier to meet their niche needs. If customers want some net neutral attributes but not others, then the competitive market will provide what customers want. *It is for customers to decide how much network neutrality* (or indeed any other network attribute) *that they want; it is not up to the FCC to decide for them*.

Key to understanding how competitive entry and investment can be encouraged is to understand that *any regulation, requirement or obligation such as the proposed network neutrality regulations imposed on* an incumbent or entrant network (or any other) *provider necessarily increases their costs and thus reduces their incentive to invest or to competitively enter the market.* No matter how well intentioned, such regulations will reduce competition, reduce investment, and therefore reduce customers' choice.[37]

The FCC's own actions have provided the *irrefutable empirical evidence that imposing network neutrality regulation* on a telecommunications asset dramatically *decreases* its value, and thus *incentives to invest*. In March, 2008, the FCC conducted what amounted to a natural experiment in network neutrality regulation: it held an auction for the 700 Mhz spectrum in which it encumbered the winner of the C block to operate under open access network neutrality regulation. No such regulation was imposed on the A and B blocks of the same 700 Mhz spectrum. A perfect natural experiment of the effect on the value of a telecoms asset of imposing network neutrality regulation. The result? Verizon paid $0.76/Mhz-Pop for the encumbered spectrum; the mean winning bid price of the A and B block spectrum was $1.89/Mhz-Pop (Levin (2008)). Network neutrality regulation thus decreased the value of the spectrum asset by 60%. The evidence speaks loudly and eloquently: imposing network neutrality regulation reduces the value of the affected telecommunication asset and thus reduces the incentive to invest in such assets.[38] Again, the NPRM rhetoric is 180° out of phase with the facts; *this* is what "fact-based, data-driven" looks like, and should not be ignored.

With competition comes choice; with transparency comes informed choice. The American people can decide for themselves whether they want enhanced access to some of their preferred application/content providers or not, whether they want their network provider to block viruses and manage traffic or not, whether they want their ISPs have the flexibility to charge application/content providers (thereby enabling lower customer subscription rates) or not, and whether they want their application providers to sell their buying profiles to third parties or not. We who are regulators, providers, advocates, or various "experts" should not be making those choices for customers. We should be creating a choice-rich market environment that empowers

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[37] For an early analytic treatment of broadband market structure and the impact of regulatory obligations on carriers, see Faulhaber and Hogendorn (2000).

[38] There was a D block of the 700 Mhz spectrum at auction, which the FCC wished to commit to public safety, and encumbered the spectrum with onerous regulation and much uncertainty that there was just one bid, far below the reservation price. No one did buy the D block spectrum asset.

customers to make their own decisions regarding, among other things, network neutrality.[39]

Competition in the Broadband ISP Market

Competition among broadband platform providers has always been the Holy Grail of broadband policy. As noted, there is plenty of evidence that the wireline broadband ISP marketplace is far from a cozy duopoly; competition between the two is fierce, with providers competing on weekly offers of special deals, service differentiation, "triple play" bundling of related services, and introduction of new technologies such as Verizon's FIOS network or AT&T's U-Verse (Faulhaber (2009b), pp. 747-750). More to the point, we have ten years of experience and evidence that strongly predicts that the current market structure is unlikely to produce the hypothetical harms that the NPRM's proposed net neutrality regulations purport to target.

But wouldn't more platform competition be better? Astute industry expert Robert Atkinson (2009) in his review of broadband competition asserts that

> "...the Washington consensus in favor of more broadband competition ignores the fact that broadband displays natural monopoly or duopoly characteristics. Because of the nature of the broadband industry, there are significant tradeoffs between more competition and the goals of efficiency, innovation, lower prices, and higher speeds and broader deployment."

In one of the earliest statements of this pessimism concerning additional wireline broadband platform competition, one author co-authored a game-theoretic empirically based analysis of the emerging broadband industry and predicted that the market equilibrium consisted of two or at most three broadband providers (Faulhaber and Hogendorn, *op cit.*) assuming the network technologies and costs then current.

So is there no hope for additional platform competition? We assert that in fact not only is platform competition not dead, it is alive and well today, with actual broadband providers in the market offering service, and there are plenty of them. We have simply not focused on one of the world's most dynamic industries, mobile telecommunications, an industry which seems to have a problem being taken seriously even though it is now the pre-eminent medium electronic devices in the US and the world today. There are twenty-one wireless carriers that serve over 100,000 customers;[40] all but three offer 3G data services, such as EDGE, UMTS, and EV-DO Rev A, which now offer bandwidths in measured in multiple Mbps (for estimates of new-deployment 3G speeds, se AT&T

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[39] Of course every economist knows that while competitive markets and customer sovereignty can lead to socially desirable outcomes, this may not be the case in the presence of market failures. As noted above, the NPRM adduces no evidence whatsoever that there are market failures.

[40] For a list of US wireless operators, see Wikipedia (2009a), which includes technologies used, subsidiaries, number of subscribers, and company website.

(2010)). These bandwidths are low relative to cable and fiber, but are comparable to low-end DSL offerings, and far higher than traditional dial-up.

Clearly, wireless 3G broadband today delivers mobility but lower speeds than cable or high-end DSL. But is it *really* broadband? Don't we really want the blazing speeds of DOCSIS 3.0 or FIOS? Some have argued that since wireless 3G broadband is slow, it really doesn't count as broadband, that it cannot substitute for wired broadband at all.[41] Well, if you are a gamer or wish to watch HD television over the Internet, then yes, you really want the blazing speeds. But suppose you want to watch a live traffic cam video feed, or a YouTube video clip, send an e-mail or download a colleague's 100-page paper? One author's personal test of an EV-DO Rev A connection confirms that yes, you really can do these tasks successfully over a 3G connection.[42] No, it is not a perfect substitute for a high-speed wired broadband connection, but yes, it is good enough for what most of us want to do today.

Of greater interest, however, are the current investments of wireless firms to realize significantly higher speeds and greater focus on laptop computers. Upgrades to 4G protocols, such as LTE and WiMAX, are planned, some as early as 2010. For example, Verizon Wireless has committed to a commercial rollout of LTE in "the second half of 2010"with a "nationwide buildout complete in late 2013 or early 2014".[43] Verizon Wireless is promising peak bandwidth of 50-60 Mbps and average user speeds of 8-12 Mbps, performance comparable to today's high-end cable[44]. Verizon Wireless sees this initially as "a laptop play,"[45] focused on personal computers rather than mobile devices; this clearly would provide direct platform competition with today's broadband providers. Other wireless operators such as AT&T Mobility, T-Mobile, and MetroPCS have also announced plans to deploy LTE.[46] Additionally, Clearwire is currently deploying a WiMAX 4G broadband network, now operational in sixty-one markets. Current downstream speed is 3-6 Mbps; the firm is "…expected to reach 80 metropolitan areas and 120 million people by the end of 2009"[47] under the brand name "Clear".

The deployment of LTE certainly requires substantial investment, but virtually all wireless companies already possess much of the infrastructure they need: cell towers,

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[41] See Turner (2009). Note the differences in wireless broadband data quoted in this report relative to the Federal Communications Commission (2008).
[42] Consider this automotive analogy: if you own a Ferrari and I own a Ford Taurus, you will certainly win any Grand Prix races we both enter. But if we are driving the family to church over well-policed highways, then your Ferrari is no better than my Taurus.
[43] See Segan (2009).
[44] Motorola's demo of LTE vs. EV-DO suggests that in practice, LTE is over 12 times faster than EV-DO. See the demo at Motorola (2009).
[45] See Marek (2009).
[46] See Wikipedia article, *op cit.*
[47] See Clearwire (2009).

backhaul facilities, switching and antennas, although these facilities will need to be augmented. Entry costs into wireless broadband are significant, but significantly less than entry costs into wireline broadband, according to the Department of Justice (2010), pp. 9-10. The amount of capital expenditures to become full fledged broadband operators is substantial but it is far less than stringing wires or fiber underground. Since most wireless carriers are already 3G capable, entry costs to higher bandwidths are likely to be comparatively low.

The point is that while high fixed costs in the wireline broadband industry suggest limited entry opportunities, the entry cost in the wireless broadband industry are much lower and we expect many more entrants as 4G technology and additional spectrum become available. The barriers to entry appear to be substantially lower in wireless than in wireline.

Wireless is a consistently underestimated industry; many claimed, for example, that wireless voice was a complement to rather than a substitute for wireline voice telephony. But today, 20% of wireless subscribers wireline phone have actually substituted for a wireline phone. Let's not make the same mistake again with wireless broadband: it's here and it's real.[48]

Wireless broadband has clearly changed the economics of broadband entry since Faulhaber and Hogendorn *op. cit.* The existence of many wireless firms offering 3G broadband plus the current ramp-up of 4G broadband (competitive with current wireline broadband offerings) suggest that additional competition in this area is not only possible but is happening now. It is quite realistic to envision at least four national wireless firms offering broadband service across most of the nation's metro areas in four years time, along with multiple regional carriers. This competition can deliver a choice-rich market environment to customers that must be the objective of any public-interest-based national broadband plan.

What can be done by the FCC to encourage this new intermodal competition? What policies would speed up the process of entry and ensure adequate bandwidth for wireless to be competitive in price and service? Fortunately, the answer is obvious: *get much more licensed spectrum into the market*. Only the FCC (working with NTIA) can make this happen, and *the relative scarcity of licensed spectrum is the single greatest barrier to entry by wireless firms into the broadband market*. The need for new spectrum is evident, as is its scarcity. Because the FCC has been parsimonious with licensed spectrum, it is unnecessarily scarce and costly. It is, quite simply, the most significant barrier to entry by wireless carriers into high-bandwidth high-speed Internet access comparable to wireline broadband.

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[48] For those keeping score on how the US is doing relative to other countries, Neilson Mobile (2008) reports that the US leads sixteen other countries in mobile Internet usage penetration.

While this may seem like bad news, it is actually good news. Since the Government is the barrier to entry, the Government can fix it, and it can do it by itself, on its own authority! The very first step was the clearing the 700 MHz band via the DTV transition, a much-delayed action now completed. Now the Government needs to make more – much more – licensed spectrum available so that wireless carriers can meet the exploding demand for wireless broadband and provide even more broadband choice and competition. As part of that job, the FCC needs to identify the total needs for licensed spectrum to achieve the objective of a competitive broadband market, both now and for the future.

Wireless broadband is clearly challenging the existing cable-DSL broadband paradigm, and looks on track to deliver multiple competitors. But this is no overnight fix; development of full competition will take the better part of five years to deliver the choice-rich market environment the American people need. No doubt a part of that delay will be the time it takes the FCC to move a very substantial amount of spectrum to auction, so there is no time to waste. It appears the technology of true wireless broadband is upon us, and it would be great if the spectrum were available for license now. It is not, but the FCC needs to get this spectrum to market quickly, to remove this very large barrier to entry for wireless broadband. However, this is not an overnight fix, and what happens during the transition to full competition is critically important, as discussed below.

We are heartened that the FCC seems to recognize the problem. The latest Staff Report on the National Broadband Plan (FCC (2009b) slide 15) shows the FCC is getting the message loud and clear:

- "A large, new spectrum allocation is essential to improving broadband competition
- It takes a long time to address spectrum gaps, so we must start now
- Market forces should be applied to all bands …"

We agree completely. The market is ready to move toward higher wireless broadband speeds, but the FCC must enable this competition to happen by getting the spectrum into the market. Let's get on with the task.

The answer is pro-competition policies not pro-regulation policies. The wireless broadband market itself provides strong recent evidence of how competition drives the market to serve the needs of customers: While advocates demanded that wireless carriers should accept any devices and applications (that met standards) the customer brings (see Wu (2007)), it has been the competitive market in wireless that has delivered what customers want, not advocates. Since the introduction of the iPhone and Apple's app store, virtually all carriers and all device manufacturers have followed suit, opening up their networks to third party applications. Independently, they are now

permitting outside devices to be brought to their networks. These steps were not the result of regulation. However, other practices advocated by network neutrality pundits have not been adopted, as customers have not demanded them. Customers have had their say, and firms in this competitive market were forced to listen.

Customers end up with what they want, and eschew what they don't want. If customers valued the NPRM's view of appropriate network neutrality, some provider would offer it to gain customer acceptance and other providers would be driven to do the same. If customers do not value net neutrality, it would not appear in the market. If a sufficient number of customers were really interested in net neutrality (possibly willing to pay a premium for it), then either an existing provider or new firm would enter in order to serve this profitable market. Creating a choice-rich market environment puts the customer in charge of such decisions, not regulators and not advocates or pundits. The FCC needs to focus on encouraging a competitive, choice-rich environment, not enacting onerous regulations which will almost surely discourage more competition.

6. The Way Forward

Rather than imposing the unnecessary and very costly regulations proposed in the NPRM, let's focus on bringing more choice and competition to the broadband marketplace. Customers can choose which parts of network neutrality they want, and the competitive market will respond.

But perhaps the "problem" is so urgent that we need a quick fix. The evidence suggests otherwise. As we argue above, we have no solid evidence that any of the hypothesized harms will occur, even with the current market structure. There is no urgency and no reason to resort to damaging and unnecessary regulatory "fixes" for problems that have yet to manifest themselves.

What must the FCC do to ensure customers a choice-rich environment?

1. Enacting restrictive and unnecessary regulations now preempts customers from making choices, even as the market becomes more competitive. Don't do it.

2. Get much more licensed spectrum into the market. Much, much more. Let the wireless industry do what is champing at the bit to do: offer higher speed broadband connections to mobile phones and PCs in competition with wireline broadband ISPs.

3. Work with industry, the Federal Trade Commission and academic experts to adopt strong customer-focused transparency practices for *all* participants in the Internet market space.

Is there a role for the FCC? Let's bring more broadband competition through a very significant increase in licensed spectrum. Let's ensure that customers are fully informed so that they may make intelligent broadband market choices. This is the proven method for customers in charge. Let's *not* impose patch-up regulations that promise no benefits and substantial costs.

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PUBLICATIONS

Honors:

Distinguished Service Award, University of Florida Public Utility Research Center, Feb 16, 2007, Gainesville, FL.

"The Question of Spectrum: Technology, Management, and Regime Change," Working Paper 05-15, AEI-Brookings Joint Center, was named in Top Ten downloads from Joint Center website for October, 2005 through December, 2007.

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TALKS AND SEMINARS

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"China: A World Player," presented at Wharton China Week, Wharton School, Unversity of Pennsylvania, Philadelphia, PA, March 24, 2009.

"Mobile Opportunities for China," presented at Wharton China Business Forum, Wharton School, University of Pennsylvania, Philadelphia, PA., February 21, 2009.

"Broadband – More Is Better?" presented at Congressional Chief of Staff Briefing, George Mason University Mercatus Center, Philadelphia, PA., February 20, 2009.

"Solving the Interoperability Problem: Are We on the Same Channel?" presented at Wharton Information Security Best Practices, Wharton School, University of Pennsylvania, Philadelphia, PA., January 30, 2009.

"Deploying Cognitive Radio," presented at Korean Information Society Development Institute, Seoul, Korea, November 14, 2008.

"Economic and Social Impact of Mobile Telephony," presented at Broadcasting and Telecoms Meet the Digital Convergence, Korean Information Society Development Institute, Seoul, Korea, November 13, 2008,

"Network Neutrality: Dealing with the NetHeads," presented at Nominum Global Customer Conference, New York City, NY., October 16, 2008.

"Are We On the Same Channel?" presented at Public Safety Communications Summit, Institute for Defense and Government Advancement, Washington, D.C., April 29, 2008.

"Whatever Happened to the Spectrum Debate?" presented at Spectrum Policy: From the Foundations to the Future, Georgetown University Center for Business and Public Policy, Washington, D.C., April 25, 2008.

"Internet Video Policy," presented at Internet Video Policy Symposium, Washington, D.C., March 18, 2008.

"Broadband Deployment and Policy," presented at the Congressional Briefing, George Mason University Mercatus Center, Alexandria, VA., August 21, 2007.

"Telecommunications Regulatory Reform: Then and Now," presented at the 34th Annual PURC Conference, *A Century of Utility Regulation: Looking Forward to the Next Hundred Years*, University of Florida, Gainesville, FL, February 16, 2007.

Panelist, Plenary Session on Network Neutrality and commenter on Benkler, Y., *Wealth of Networks*, at Telecommunications Policy Research Conference, George Mason University, Alexandria, VA., September, 2006.

"Solving the Interoperability Problem: Are We on the Same Channel?" presented at The Crisis in Public Safety Communications, George Mason School of Law, December 8, 2006.

Panelist, "Open Source in the International Marketplace," Roundtable discussion sponsored by the University of Pennsylvania Law School *Journal of International Economic Law*, March 31, 2006

"Life and Death on the Radio: Thoughts on Public Safety," presented at Penn Law Ad Hoc Seminar, December 6, 2005.

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"Researchable Issues in Spectrum Management," presented at FCC-Academic Workshop on Setting the Research Agenda, Federal Communications Commission, Washington, DC, December 5, 2003.

"Wireless Telecoms in Asia," panel moderator at Wharton Asia Conference, November 15, 2003.

"Telecoms in Trouble: Can Policy Help?" presented at PrincetonSymposium on Helping Troubled Industries, October 18, 2003.

"The Chief Economist: Necessary and Sufficient Conditions to be Effective," presented at The Chief Economists Speak Out, McDonough School of Business, Georgetown University, October 17, 2003.

"Spectrum Management: Property Rights, Markets, And The Commons," with David Farber, presented at International Symposium on Advanced Radio Technologies, Boulder, CO and University of Colorado Law School Moot Court, Boulder, CO, March, 2002. Also presented at Stanford Law School Conference, "Spectrum Policy: Property Rights or Commons?" and Moot Court, March, 2003.

"Access ≠ $Access_1$ + $Access_2$,", presented at *Rethinking Access*, Third Quello Center Communications Policy & Law Symposium, March, 2002, Washington, DC

"Economics at the FCC," plenary address at the Telecommunications Policy Research Conference, October, 2001.

"Network Effects and Antitrust: FCC Analysis of the AOL-Time Warner Merger," presented at Georgetown University, March 13, 2001, American Enterprise Institute, April 25, 2001; London Business School, May 14, 2001; Wharton Applied Economics Workshop, July, 2001; Duke University School of Law, October, 2001, University of Pennsylvania Law School, October, 2001.

"Policy-Induced Competition: the Telecommunications Experiments," presented at Wharton Applied Economics Workshop, September, 2001.

"Broadband Deployment: Is Policy in the Way?" invited paper presented at AEI-Brookings Regulatory Center Conference on Broadband Deployment, October, 2001.

"Cross-Platform Competition in Telecommunications," Aspen Institute Telecommunications Workshop, Aspen, CO, August, 2001.

"FCC Analysis of the AOL-Time Warner Merger," Wharton Applied Economics Workshop, December, 2000.

"Information, Disinformation and Lobbying," presented at Institut d'Analisi Economica, Barcelona, Spain (October, 1999), Wharton Applied Economics Workshop, February, 2000.

" Lobbying, Voting, and the Political Economy of Price Regulation"; presented at INSEAD Business and Economics Seminar, Fontainebleau, France on April 24, 1997, and Séminaire Roy, CERAS-ENPC, Paris, France on April 28, 1997; Cornell Economics Dept. Econometrics Seminar, September 8, 1997; Telecommunications Policy Research Conference, Alexandria, VA, September 28, 1997; Stanford Economics Department's Economics & Political Science Seminar (November 25, 1997); the Applied Economics Seminar at Wharton (October 15, 1997); Political Science Dept, UC Berkeley, Public Policy Seminar (May 4, 1998), Tsinghua University (Beijing) (April, 1999)., Institut d'Analisi Economica, Barcelona, Spain (October, 1999).

"The Market Structure of Broadband Telecommunications: Is Regulation Necessary? ", (joint work with Christiaan Hogendorn), presented at the symposium "Bridging Digital Technologies And Regulatory Paradigms," UC Berkeley, June 27-28, 1997; Telecommunications Policy Research Conference, Alexandria, VA, September 29, 1997; Wharton Public Policy & Management Brown Bag Seminar (October 16, 1997); Wharton Marketing Department's Electronic Commerce Seminar (December 3, 1997) Tsinghua University (Beijing) (April, 1999).

"Voting on Prices: The Political Economy of Regulation," presented at the Wharton School PP&M Brown Bag Seminar, Nov., 1995; Department of Economics, Universidad Carlos III, Madrid, Spain, April, 1996; the Public Utility Workshop sponsored by Rutgers Center for Regulated Industries; the University of Warwick (UK) Industrial Organization Workshop; the Business & Public Policy Seminar at the Haas School, UC Berkeley; the Telecommunications Policy Research Conference; and INSEAD's Business and Economics Seminar, Fontainebleau, France

"The Networked Future: Market Outcomes and Policy Options," presented at Aula Fundesco, Universidad Carlos III, Madrid, Spain, April, 1996.

"Banking Markets: Productivity, Risk, and Customer Satisfaction," presented at (i) Wharton Financial Institutions Seminar, April, 1995; (ii) Institut d'analisi Economica, Universitat Autonoma de Barcelona, July, 1995, and Wharton Applied Economics Workshop, January, 1996.

"Pricing the Net: Economists' Contributions," presented at Stanford University Conference on Data Network Pricing, March, 1995.

"The Information Superhighway: Public Policy Issues," presented at Wharton School PP&M Brown Bag Seminar, November, 1994.

"Bank Efficiency: A Profitability Modeling Approach," presented at Wharton School Financial Institutions Center Seminar, October, 1993.

"Profitability and Bank Size: An Empirical Analysis," presented at Wharton School PP&M Brown Bag Seminar, November, 1992.

"Pricing Internet: The Efficient Subsidy," presented at "Information Infrastructure for the 1990s" Symposium, Harvard University, November, 1990.

"Unbalanced Growth Redux: Sectoral Productivity and Capital Markets," (with F. Allen and C. MacKinlay) presented at AEA Winter Meeting, New York, NY, December 1988.

"Quality Control in the Service Firm and Consumer Learning," presented at the Symposium on Quality in Services, Karlstad, Sweden, August 1988.

"Telecommunications and the Scope of the Market in Services," presented at the Conference on Services and World Economic Growth, Kiel, Germany, June 1988, and the Conference on Innovation in Europe 1992, Spoleto, Italy, July 1988.

"Payment Risk, Network Risk and the Role of the Fed," (with A. Santomero and A. Phillips), presented at the Richmond Federal Reserve Bank's Payment System Symposium, Williamsburg, VA, May, 1988.

"The Changing Role of R&D in Telecommunications," presented at VISIO '88, Helsinki, Finland, March, 1988.

"Rational Rationing," presented at University of Pennsylvania Transactions Cost Workshop, November, 1987, and the Federal Trade Commission, Washington, DC, April, 1988.

"Financial Services: Markets in Transition," presented at Conference on the Service Economy, Spoleto, Italy, July, 1987, and the Hungarian Academy of Sciences World Economics Institute, July, 1987.

"The American Experience with Service Sector Deregulation," presented at the Hungarian Academy of Science World Economics Institute, July, 1987.

"Optimism Invites Deception," (with F. Allen) presented at Stanford University and the University of California, Berkeley, workshops, and American Economic Association Meetings (contributed paper), New Orleans, December, 1986.

"Reputation, 'Fly-by-Night' Firms, and the Market for Product Reviews," (with D. A. Yao) presented at University of Pennsylvania Transactions Cost Workshop, April, 1985, European Association for Research in Industrial Economics, Berlin, August, 1986.

"The Market for Product Reviews: Who Pays?" (with D. A. Yao) presented at American Economic Association meetings (contributed paper), New Orleans, December, 1986.

"Communications, Information and Economic Growth," presented at the Conference on Technological Development: Causes and Consequences, United States and West Germany, Bonn, November, 1984.

"Pricing In the Twilight of Regulation," presented at the Twelfth Annual Telecommunications Policy Research Conference, Airlie, Virginia, April, 1984.

"Cross-Subsidy Control: In General, and in Telecommunications," presented at American Economic Association meetings, New York, December 1982.

"Public Policy, Corporate Strategy, and Telecommunications Restructure," presented at Association for Public Policy Analysis and Management Conference, Minneapolis, MN, October 1982.

"A Public Enterprise Pricing Primer," presented at International Institute of Management Regulation Conference, Berlin, July, 1981.

"Separate Subsidiaries, Cross-Subsidy Control, and the Restructure of Telecommunications" Panel presentation at Telecommunications Policy Research Conference, Annapolis, May, 1981.

"Subsidy-Free Prices and Anonymous Equity," presented at (a) U.C. Berkeley Ind. Org. Seminar, March, 1981, (b) U.C. San Diego Theory Seminar, March, 1981, (c) Princeton University Econometric Seminar, April, 1981, (d) NYU Theory Seminar, November 1980, and (e) American Economic Association meetings, Denver, September, 1980.

"Cross-Subsidy in Increasing Returns Industries," presented at Federal Trade Commission, September, 1980.

"Market Structure and Competitive Outcomes in Telecommunications," presented at WEA Conference, June 1980 and Telecommunications Policy Research Conference, Annapolis, May, 1980.

"Regulation and Market Structure in Telecommunications" (with J.H. Rohlfs), presented at Conference on Economics of Telecommunications: Current Research on Demand, Pricing, and Regulation, Northwestern University, January 1980; and Conference on Utility Regulation and Management for the 1980's, University of Florida, January, 1980 .

"Telecommunications: A Structural View," Princeton University. Industrial Organization Workshop, May, 1979.

"A Perspective on Telecommunications Industry Restructure" in Proceedings of the 1979 Rate Symposium on Problems of Regulated Industries.

"Peak Load Pricing and Regulatory Accountability," presented at Rutgers University Conference on Public Utility Regulation and Performance, October 1978 .

"Cross-Subsidy and Public Enterprise Pricing," presented at Telecommunications Policy Research Conference, May, 1978.

"Pareto Efficiency, Increasing Returns, and Partial Information," presented at the University of California Berkeley Industrial Organization Seminar and at Stanford University Industrial Organization Seminar, October 1977, and WEA Conference, June 1978.

"Optimal Two-Part Tariffs with Self Selection," presented at Telecommunication Policy Research Conference, April 1977, and WEA Conference, June, 1976, and Bell Laboratories Economic Discussion Paper #74, January, 1977 (with J.C. Panzar).

"Competitive Entry and Natural Monopoly," presented at Telecommunications Policy Research Conference, April, 1976.

"Optimality and Equilibrium with Increasing Returns to Scale," presented at NSF-NBER Seminar on Decentralization. Princeton University, April 1975, and Telecommunications Policy Research Conference, April, 1975.

"Some Tentative Thoughts on Cross-Subsidization," presented at White House Conference on Telecommunications, Washington, November, 1972.

"The Pricing of Warrants," presented at Princeton University Industrial Organization Seminar and Cornell University Operations Research Department, November, 1971.

"The Design of Priority Reservation System," presented at IEEE Conference, Philadelphia, January, 1968 and International Teletraffic Congress, New York, June, 1967.

PREVIOUS TEACHING EXPERIENCE

Visiting Professor, Princeton University Woodrow Wilson School, 1993, Regulatory Economics

Visiting Professor, Tsinghua University, Beijing, China, spring 1999, Technology for Managers (International MBA program).

Research Associate Professor, New York University, 1979-1983, Industry Regulation (Graduate).

Visiting Instructor, Princeton University, 1976-77, Welfare Economics and General Equilibrium (Graduate).

RESEARCH GRANTS

Institut d'Analisi Economica, Barcelona, Spain, fall, 1999. Information, Disinformation and Lobbying.

Annenberg School summer 1996. The Networked Future: Market Outcomes and Public Policy Options .

Wharton Financial Institutions Center, Summer 1994. Empirical Analysis of the Impact of Customer Satisfaction on Bank Profitability.

Wharton Financial Institutions Center, Summer 1993. Empirical Analysis of Theoretical Model of Bank Efficiencies.

PROFESSIONAL ACTIVITIES:

National Research Council Committee on the Transborder Flow of Scientific Data, 1995-96.

Editor Board member, *Journal of Industrial Economics*.

Associate Editor, *Information and Economic Policy*

Referee for *American Economic Review, Econometrica, Journal of Industrial Economics, The RAND Journal of Economics, Information and Economic Policy, Journal of Regulatory Economics*, and *Journal of Political Economy*.

Reviewer of National Science Foundation Grant Proposals.

Member of Advisory Board, Columbia University Information and Telecommunications Institute (CITI).

Chairman of Organizing Committee, 1988 Telecommunications Policy Research Conference.

Governor's Task Force on Economic Development: Service Sector Task Force, 1987.

Served on original Organizing Committee for Telecommunications Policy Research Conference, 1973-1974.

Served on Organizing Committee for Workshop on Local Access, held in St. Louis, MO, September, 1982.

DAVID J. FARBER

PERSONAL INFORMATION

Home Address: 721 Filbert St.
Pittsburgh, PA 15232

Telephone: +1 412 687 6998
Cell: +1 412 726 9889

Network address: dave@farber.net

Family: Wife

EXPERIENCE

Distinguished Career Professor of Computer Science and Public Policy at Carnegie Mellon University (2002-present)

The Alfred Fitler Moore Professor of Telecommunication Systems, Moore School, and Professor of Public Policy, Wharton School University of Pennsylvania (1988 – 2003-retired)

Chief Technologist, Federal Communications Commission (1999-2000)

Director of the Distributed Systems Laboratory, University of Pennsylvania (1988 - present)

Director of the Center for Networking Technology and Applications, University of Delaware (1987 - 1988)

Professor of Electrical Engineering and Professor of Computer Science, University of Delaware (1977 - 1988)

Associate Professor of Information and Computer Sciences and of Electrical Engineering (with Tenure), University of California at Irvine (1970 - 1977)

Founder and Vice President of Research and Planning for Caine, Farber and Gordon Inc. (1970 -)

Principal Member of the Technical Staff, Xerox Data Systems (1969 - 1970)

Member of the Technical Staff, the RAND Corporation (1967 - 1969)

Supervisor; Systems Programming Department, Bell Telephone Laboratories (1965 - 1966)

Member of the Technical Staff, Programming Research Department, Bell Telephone Laboratories (1962 - 1965)

Member of the Technical Staff, Electronic Switching Engineering Systems Department, Bell Telephone Laboratories (1956 - 1962)

ACADEMIC RESEARCH MANAGEMENT

Principal Investigator, Information and Society Project of Annenberg School, University

of Pennsylvania on Electronic Commerce

Co-Principal Investigator and conceptualized, - TeleMentoring: A Novel Approach to Undergraduate Computer Science Education, National Science Foundation 1992-1995

Principal Investigator, Aurora Project - A Gigabit Networking Testbed - effort in collaboration with Bellcore Incorporated, IBM Research Laboratories and MIT's Laboratory for Computer Science, National Science Foundation and Darpa (1989-present)

Principal Investigator, Very High Speed Switching Studies - Project DAWN - Bellcore and the Bell Regional Companies (1988- present) (effort in collaboration with Bellcore Incorporated and MIT's Laboratory for Computer Science)

Principal Investigator, Networking studies, AT&T Bell Labs 1990-1992

Principal Investigator, Project Mirage Darpa (1990-1991) studies in the formulation of high latency networking problems and models

Principal Investigator (Joint with Robert Kahn - CNRI), Study in Very High Speed Networking, National Science Foundation (1988 - 1989)

Director, Distributed Systems Laboratory, University of Pennsylvania (1988 -)

Director, Center for Networking Technology and Applications, University of Delaware

Principal Investigator, Bitnet Modernization, National Science Foundation (1986-1988)

Principal Investigator, Memnet, Northrop Corp. (1986 - 1988)

Co-Director, Educational Technologies Laboratory, University of Delaware (1985 - 1988)

Principal Investigator; Internet Mail Relays, ARPA IPTO (1983- 1984)

Principal Investigator; CSNET Phonenet and CSNET Relay, National Science Foundation (1981-1985)

Principal Investigator; Computer Message Services, U.S. Army DARCOM (1979-1984)

Principal Investigator; Overseeing of Distributed Processing Systems, National Science Foundation (1977-1980)

Principal Investigator; Research in Distributed Processing and Office Systems, General Business Systems Division of IBM (1977- 1980)

Principal Investigator; Local Network Architecture, Advanced Research Projects Agency, Department of Defense (1976-1978)

Principal Investigator; Audio Conferencing, The Institute for the Future (1974-1977)

Principal Investigator; Network Security and Secure Protocols, Advanced Research Projects Agency, Department of Defense (1974- 1977)

Principal Investigator; Distributed Computer Project, National Science Foundation (1971 - 1975)

EDUCATION

Stevens Institute of Technology Doctor of Sciences (honorary) 1999

University of Pennsylvania MA (honorary), 1988

Stevens Institute of Technology BSEE, 1956

Stevens Institute of Technology, MS in Math, 1962

Bell Telephone Laboratories Communication Development Program, 1963 (Equivalent to MS in EE)

RECENT HONORARY APPOINTMENTS and AWARDS

Fellow of the IEEE

Fellow of the ACM

Appointed as a Commissioner to the Mayor's Telecommunications Policy Advisory Committee of Philadelphia

Trustee of the Stevens Institute of Technology

Trustee of the Electronic Frontier Foundation

Elected Trustee of the Internet Society (two full terms)

Recipient of the SIGCOMM Award for Lifetime Contributions to the field

Recipient of the John Scott Award for Contributions to Humanity for work in Networking

Visiting Professor of the Glocom Institute of Japan, International University of Japan

Advisory Board at the National Institute of Informatics of Japan

Distinguished Lecturer Hawaii International Conference on System Science 2003)

Patents Awarded

Patent No. 6,072,780, 6,266,328, 6,480,474 initially filed August 26, 1996. "Telephone call-back system controlled by online data network in real time," D. Farber *et al.*

Patent No. 5,329,623 awarded July 12, 1994. "Apparatus for Providing Cryptographic Support in a Network," Jonathan M. Smith, C. Brendan S. Traw, and David J. Farber.

Patent No. 5,353,419 awarded October 4, 1994. "An Active Instruction Decoding Processor-Memory Interface," J. Touch and D. Farber.

Patent No. 6,185,678 awarded February 6, 2001. , "Secure and Reliable Bootstrap Architecture," William A. Arbaugh, David J. Farber, Angelos D. Keromytis, and Jonathan M. Smith.

SELECTED PUBLICATIONS (* - student co-author(s))

Books

The Office of the Future: Communication and Computers, R.P. Uhlig, D.J. Farber and J.H. Bair, North Holland Press, 1979.

National Reports

The Markle Foundation Task Force report on National Security in the Information Age

Realizing the Information Future, National Research Council

Toward a National Research Network, National Research Council

Transport Protocols for Department of Defense Data Networks, National Research Council

Report on the Evolution of a National Supercomputer Access Network - Sciencenet, National Science Foundation

Journal Articles

SNOBOL, A String Manipulation Language, Co-authored with R.E. Griswold and I.P. Polonsky, Journal of the ACM, 1964.

SNOBOL 3, Co-authored with R.E. Griswold and I.P. Polonsky, Bell System Technical Journal, 1966.

APAREL - A Parse Request Language, Co-authored with R. Balzer, Communications of the ACM, 1969.

Software Considerations in Distributed Architectures, D.J. Farber, IEEE COMPUTER Magazine, vol. 7, pp.31-35, 1974.

A Parallel Mechanism for Detecting Curves in Pictures, P.M. Merlin * and D.J. Farber, IEEE Transactions on Computers, vol.24, pp.96-98, 1975.

Recoverability of Communication Protocols - Implications of a Theoretical Study, P.M. Merlin * and D.J. Farber, IEEE Transactions on Communications, vol.24, pp. 1036-1043, 1976

The Overseer, a Powerful Communications Attribute for Debugging and Security in Thin-Wire Connected Control Structures. David J. Farber, J. B. Pickens* ICCC 1976: 441-451

On the Design of Local Network Interfaces. Paul V. Mockapetris*, Michael Lyle*, David J. Farber IFIP Congress 1977: 427-430

The Convergence of Computing and Telecommunications Systems, D.J. Farber and P. Baran, SCIENCE, Special issue on Electronics, vol. 195, pp.1166-1170, 1977. Invited Article. (Also published in #5 of the AAAS Science Compendia, 1978.)

SODS/OS: Distributed Operating System for the IBM Series/1. W. David Sincoskie*, David J. Farber Operating Systems Review 14(3): 46-54 (1980

The National Research Network, D.Jennings, L. Landweber, I. Fuchs, R. Adrion, D. Farber, SCIENCE Feb 28, 1986. Invited article.

NOAH NET, An Experimental Flood Local Area Network. David J. Farber, Guru M. Parulkar* ICCC 1986: 265-269

Design and Implementation of a Trusted Mail Agent. Marshall T. Rose, David J. Farber, Stephen T. Walker ICCC 1986: 103-107

The World of Computer Networking in the 1990's, International Congress of Radio Sciences, Israel 1987

Performance models for Noahnet. Guru M. Parulkar*, Adarshpal S. Sethi, David J. Farber SIGCOMM 1988: 262-273

An analysis of Memnet - an experiment in high-speed shared-memory local networking. Gary S. Delp*, Adarshpal S. Sethi, David J. Farber SIGCOMM 1988: 165-174

A Taxonomy-Based Comparison of Several Distributed Shared Memory Systems. Ming-Chit Tam*, Jonathan M. Smith, David J. Farber Operating Systems Review 24(3): 40-67 (1990)

Traffic Characteristics of a Distributed Memory System. Jonathan M. Smith, David J. Farber Computer Networks and ISDN Systems 22(2): 143-154 (1991)

Memory as a Network Abstraction Gary Delp*, David Farber, Ronald Minnich*, Jonathan M. Smith, and Ming-Chit Tam*, IEEE Network, Vol. 5(4), pp. 34-41 (July, 1991).

An Overview of the AURORA Gigabit Testbed. David D. Clark, David L. Tennenhouse, David J. Farber, Jonathan M. Smith, Bruce S. Davie, W. David Sincoskie, Inder S. Gopal, Bharath K. Kadaba INFOCOM 1992: 569-581 1991

: The AURORA Gigabit Testbed. David D. Clark, Bruce S. Davie, David J. Farber, Inder S. Gopal, Bharath K. Kadaba, W. David Sincoskie, Jonathan M. Smith, David L. Tennenhouse1992 Computer Networks and ISDN Systems 25(6): 599-621 (1993)

An Experiment in Latency Reduction. Joseph D. Touch*, David J. Farber INFOCOM 1994: 175-181

Gigabit Telerobotics: Applying Advanced Information Infrastructure, Ruzena Bajcsy, David J. Farber, Richard P. Paul, and Jonathan M. Smith, "," in 1994 International Symposium On Robotics and Manufacturing, Maui, HI (August 1994).

A new congestion control framework for large bandwidth-delay product networks. Hyogon Kim*, David J. Farber HPN 1995: 294-304

State Caching in the EROS Kernel. Jonathan S. Shapiro*, David J. Farber, Jonathan M. Smith POS 1996: 88-100 1995

The Measured Performance of a Fast Local IPC Jonathan S. Shapiro, David J. Farber, and Jonathan M. Smith, in Proceedings of the 5th International Workshop on Object Orientation in Operating Systems, Seattle, WA (November 1996),

Communications Technology and its Impact by 2010. David J. Farber (Invited) CACM 40(2): 135-138 (1997)

Security for Virtual Private Intranets. William A. Arbaugh*, James R. Davin*, David J. Farber IEEE Computer 31(9): 48-55 (1998)

EROS: a fast capability system. Jonathan S. Shapiro*, Jonathan M. Smith, David J. Farber SOSP 1999: 170-185

Predicting the unpredictable: Future directions in internetworking and their implications", David J. Farber IEEE Communications Magazine, no. 7, Jul 2002

Balancing Security and Liberty. David J. Farber (Invited) IEEE Internet Computing 5(6): 96 (2001)

Fame, but No Riches, For Cybersecurity -- It's time for government and industry to put their money where their mouths are, David J. Farber (invited) IEEE Spectrum Jann 2003

Conference and other papers

Farber, D.J. "A Survey of Computer Networks." Datamation 18, 4 (April 1972), 36-39.

Farber, D.J. and F.R. Heinrich. "The Structure of a Distributed Computer System -- The Distributed File System." Proc. International Conference on Computer Communications, (Oct. 1972), 364-370.

Farber, D.J., M.D. Hopwood, and L.A. Rowe. "Fail-Soft Behavior of the Distributed Computer System." Technical Report #24, Department of Information and Computer Science, University of California, Irvine, California, (November 1972).

Farber, D.J. and K. Larson. "The Structure of a Distributed Computer System -- The Communications System." Proc. Symposium on Computer-Communications Networks and Teletraffic, Microwave Research Institute of Polytechnic Institute of Brooklyn, (April 1972).

Loomis, D.C. "Ring Communication Protocols." UC Irvine Distributed Computer Project, Memo 46-A, (May 1972).

Farber, D.J., J. Feldman, F.R. Heinrich, M.D. Hopwood, K.C. Larson, D.C. Loomis, and L.A. Rowe. "The Distributed Computing System." Proc. Seventh Annual IEEE Computer Society International Conference, (Feb. 1973), pp. 31-34.

Rowe, L.A., M.D. Hopwood, and D.J. Farber. "Software Methods for Achieving Fail-Soft Behavior in the Distributed Computing System." 1973 IEEE Symposium on Computer Software Reliability, (April 30, May 1-2, 1973), pp. 7-11.

Mockatetris, P., Lyle, M. and Farber, D. "On the Design of Local Network Interfaces", IFIPS 1977

Sincoskie, W. and Farber, D. "The Series/1 Distributed Operating System", Local Networks Conference 1981

Farber, D. "An Overview of Distributed Processing Aims." 1974 COMPCON.

Merlin, P., Farber, D. "Recoverability of Communications Protocols - Implications of a Theoretical Study" IEEE Transactions on Communications 1976

Farber, D. "Software Considerations in Distributed Architecture." COMPUTER 1974 (March).

Farber, D. "Information Engineering Perspectives", The NSF Conference on Information

Technology, 1978

Farber, D. , Caine, S. "A Modular Office System", MICRODELCOM 1978

Von Glahn, P., Farber, D. and Walker, S. "The Trusted Office of the Future", Compcon '84

"CapNet - An Alternate Approach To Ultra-high Speed Networks", Ming-Chit Tam, David J. Farber International Communications Conference, April 90, Atlanta Georgia.

"A Taxonomy Comparison of Serveral Distributed Shared Memory Systems" Ming-Chit Tam, Jonathan Smith, David J. Farber. ACM Operating Systems Review, June 1990.

"Mirage: A Model for Ultra High-Speed Protocol Analysis and Design" Joseph D. Touch and David J. Farber Proceeedings of the IFIP WG 6.1/WG 6.4 Workshop on Protocols for High-Speed Networks, Zurich, Switzerland, 9-11 May 1989 also avail as: UPenn Dept of CIS Tech report MS-CIS-89-79, DSL-1, Dec.1989. This is under revision for IEEE Computer:

"The Mether System: A Distributed Shared Memory for SunOS 4.0" Ronald G. Minnich and Dave Farber Usenix- Summer 89

"Reducing Host Load, Network Load, and Latency in a Distributed Shared' Memory Ronald G. Minnich and David J. Farber Proceedings of the Tenth {IEEE} Distributed Computing Systems Conference 1990

"The Gigabit Network -- does it fill a much needed gap?" presented as a Keynote and published in the proceedings of the International Workshop on Advanced Communications and Applications for High Speed Networks March 16 - 19 1992 in Munich Germany

Many additional conference and symposium papers.