Exhibit 1

Dr. Jeffrey Reed and Dr. Nishith Tripathi, *Wireless Net Neutrality Regulation: A Response to Afflerbach and DeHaven*

Wireless Net Neutrality Regulation: A Response to Afflerbach and DeHaven

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Abstract

The Federal Communications Commission ("FCC" or "Commission") has sought comments on the application of six proposed "net neutrality" regulations to broadband Internet access networks. We previously described the unique challenges of operating wireless networks to meet rapidly growing and changing consumer and business broadband demands and the many technological and operational reasons that wireless net neutrality regulations would likely undermine, rather than serve, their consumer welfare goals [ReedTripathi]. Other commentators also demonstrated that, instead of benefitting consumers and furthering goals of customer choice and service quality, such rules would significantly harm consumers and stifle wireless innovation and growth.

On behalf of the New America Foundation, Andrew Afflerbach and Matthew DeHaven of Columbia Telecommunications Corporation submitted a paper titled "Any Device and Any Application on Wireless Networks: A Technical Strategy for Evolution" [Afflerbach_DeHaven]. Afflerbach and DeHaven present arguments in favor of the FCC's proposals to require wireless networks to accommodate "any device" and "any application" and to banish network operators from their traditional roles in testing and certifying devices and in employing dynamic and evolving device and application practices and policies designed to protect service quality. We provide below a detailed response to Afflerbach and DeHaven's paper. In brief, we find that the authors (i) greatly oversimplify and mischaracterize the wireless environment and the real-world consequences of the proposed prohibitions on network-oriented testing, certification, and management, (ii) fail to comprehend the beneficial and necessary role of wireless network operators in addressing congestion and other performance issues in a shared radio environment, and (iii) advocate device and application rules that could severely degrade wireless network performance and the wireless customer experience. Hence, we continue to caution the FCC against imposing these or other net neutrality regulations on wireless networks.

Section 1 provides a brief overview of our response to the Afflerbach and DeHaven paper. Section 2 addresses problems with the device-related proposals in the paper. Section 3 discusses problems with the application-related aspects of the paper. Finally, Section 4 summarizes our conclusions.

1. Introduction

In our previous paper [ReedTripathi], we explained why applying the proposed net neutrality regulations to wireless broadband Internet access services would be a major mistake. Any attempt to impose a wireless network neutrality regulatory framework—particularly in the current environment of rapidly evolving technologies and uses, dramatic demand growth, and tightly constrained available spectrum—would reduce innovation, competition, and network efficiency. In our view, wireless consumers would undoubtedly be negatively affected in such an environment. We explained that:

(1) *Critical technical differences exist between wireline and wireless broadband networks.* These networks differ in many important respects: the technologies employed and how those technologies operate, the impact of resource limitations, the type and pace of technological evolution and its demands on the networks, the networks' susceptibility to performance problems, and the type and variability of practices required to address performance issues. Uniquely wireless issues—mobility, spectrum constraints, propagation and interference characteristics, security issues associated with over-the-air transmissions, and issues associated with wireless–wireline network integration—greatly complicate wireless network management and magnify the harm of a regulatory overlay that would limit operator flexibility.

(2) *Wireless networks are currently transitioning to entirely different fourth-generation (4G) technologies (e.g., WiMAX and LTE[1]) that are even less understood and less developed than 3G technologies, which themselves are relatively new and are the subject of continuing experimentation.* Much research and real-world, on-the-fly experimentation will be required to learn how to structure, operate, and manage networks to meet evolving quality of service ("QoS") needs in these rapidly changing wireless systems.

(3) *New services and applications with unknown QoS requirements and unknown impacts on wireless resources are rapidly emerging.* Such applications include time-sensitive public safety applications; low-latency real-time video services; and low-data-rate, large-user-base, and latency-insensitive Smart Grid and other machine-to-machine applications.

(4) *Wireless network management is an extraordinarily complex and dynamic undertaking that is not definable through regulatory metrics.* The radio environment's dynamic nature, the number and mobility of users and the diversity of users' applications, the proprietary radio resource management algorithms, and the ever-changing wireless standards and wireless networks make wireless network management complex, extraordinarily dynamic, and site-specific. A regulatory regime that enforces net neutrality regulations through after-the-fact, *ad hoc* determinations of the "reasonableness" of engineering and business decisions would be extremely damaging to the evolution of wireless technology and the incentive for innovation and investment in the wireless industry.

[1] WiMAX is an acronym for Worldwide Interoperability for Microwave Access and LTE for Long Term Evolution.

(5) *Several aspects of the FCC's specific network neutrality proposals could wreak havoc in a wireless environment.* Requiring a wireless network to allow connections of *any* devices and *any* applications at all times, without regard to current capabilities and limitations of that network or the potential impact on other users, is a recipe for disaster in the wireless environment. The FCC's proposed nondiscrimination rule is likewise infeasible in the wireless network environment. Differentiation among services, users, and resource consumption is inherent in any efficient wireless network management strategy (and, more specifically, any rational QoS implementation strategy).

(6) There are tangible, pro-consumer actions the FCC can take to promote wireless consumer welfare. For instance, the FCC can promote consumer welfare goals through the release of more spectrum and the removal of other barriers to efficient network expansion and evolution (*e.g.*, barriers to wireless tower deployment).

Other commentators expressed similar concerns. *Verizon, T-Mobile,* and *Qualcomm*, for example, stressed the need for maximum flexibility in wireless network management for the purposes of security, capacity or congestion management, and service quality optimization.

Verizon's network and technology executives explained how mobility, shared capacity, limited bandwidth, and the interdependence of networks, devices, and applications create a "constantly changing mix and volume of voice and data users and traffic at individual cell site locations" and necessitate "real-time, dynamic management of the radio frequency ('RF') 'last mile' connections" [Verizon]. They note that "a wireless device operates as an integral part of the provider's network," and wireless operators must use a variety of sophisticated, dynamic techniques, including predictive modeling, real-time queuing and scheduling algorithms, to "provide all users with fair access to the bandwidth available" as radio channel conditions change. Verizon points out that each wireless network is engineered differently, is built to accommodate different air interfaces and frequencies, and contains varying network elements: "Devices built to standards bodies' network access specifications, therefore, will not necessarily perform in the same way as those that are optimized for use on a particular network." In other words, "there is no 'legal device' concept in the wireless world other than a device that a network operator has approved or certified for use," and "[t]he devices and applications offered by a network are generally the result of an extensive development and testing process intended to ensure that they work well together and work well with the network" in accordance with its technical requirements and regulatory obligations.

T-Mobile's Performance Engineering Director explained why "wireless network managers must be free to rely on their expert judgment and employ the full range of network management techniques available" to contend effectively with "increasingly scarce spectrum, rapidly expanding yet highly unpredictable demand, interference hurdles, challenging topologies, handset and device coordination requirements, and ongoing and fast-paced technological evolution" [T-Mobile]. For example, one particular device's use of T-Mobile's network increased 1,200% due to a new application, causing network overload problems for T-Mobile and adversely affecting many users. T-Mobile observes that network capabilities, new devices, and new applications aggravate the problem of spectrum constraints. "[E]ven an application that is not inherently bandwidth 'hungry' can cause substantial network loading and congestion on a wireless network simply because it is not well-engineered to avoid establishing multiple connections." Similarly, "carriers try to work closely with their handset partners to ensure that devices are optimized to provide services over their networks using the least possible network bandwidth." T-Mobile notes that it is "evaluating techniques in UMTS[2] networks that allow for reprioritization of traffic based upon application type with the goal of providing the best user experience for all users," and expresses concern that the proposed net neutrality regulations could endanger this type of consumer-friendly experimentation. T-Mobile also points out that an engineer operating under network neutrality regulation would have to weigh prompt action (in the interest of security and QoS) against the threat of regulatory or judicial sanction and that this would waste valuable time and resources and could deter or significantly delay innovative network management techniques.

Qualcomm cautions that even the techniques that would significantly increase wireless network capacity (*e.g.*, interference cancellation, multiple-input/multiple-output ("MIMO"), and small cells, such as femtocells and picocells) will be unable to keep pace with the constant and explosive growth in data demand [Qualcomm]. Qualcomm notes that the proposed new regulations would curtail wireless operators' ability to address the issue of wireless bandwidth, adversely affecting all wireless subscribers. In particular, Qualcomm emphasizes the importance of maintaining application developer incentives to conserve bandwidth; for example, cellular voice that has been optimized to conserve bandwidth uses just a few kilobits per second, but some VoIP applications could use more than 100 kilobits per second. Regulations that reduce application developers' incentives to conserve bandwidth would worsen already severe congestion issues in wireless networks. Qualcomm urges the FCC to weigh the proposed regulations' negative impacts on innovation in new, specialized wireless devices that are not used primarily (if at all) for traditional Internet access functions.

In contrast to these other commentators, Afflerbach and DeHaven purport to offer a "strategy entailing a conservative process for evolving . . . to a more open future" based on stringent "any device" and "any application" rules [Afflerbach_DeHaven]. In large part, however, Afflerbach and DeHaven fail to confront the key issue that the FCC's proposed rules raise. The central theme of Afflerbach and DeHaven's paper is the *technical* feasibility for the wireless industry to evolve to an environment in which customers could attach any device to or run any application on any wireless network. Afflerbach and DeHaven misstate the relevant technical facts in key respects and greatly understate the time and money required to achieve the technical framework they propose. More importantly, the issue in this proceeding should not be whether it is *technically feasible* to achieve the type of wireless network environment that Afflerbach and DeHaven hypothesize, but whether it makes sense for the government to *require* it given the negative impact of doing so on wireless consumers, investment, and innovation—all of which are thriving in the current, minimally-regulated environment. Afflerbach and DeHaven all but ignore that fundamental issue, and their proposals could wreak havoc on the wireless industry and its customers:

1) *Afflerbach and DeHaven propose third-party or FCC certification of devices with no network operator involvement.* Removing network operators from the device certification process ignores the important role they play in device design and

[2] Universal Mobile Telecommunication System.

optimization, which has yielded more efficient devices that provide a better user experience. Since wireless networks are in the business of getting the most out of their limited radio resources and can succeed in the competitive wireless marketplace only if they provide a high-quality experience, they are inherently invested in ensuring adequate resources for rapid approval and optimization of the devices that they market and support. Furthermore, each network is unique in terms of technologies employed, architecture, local radio environments, and mix of users, and network operators are thus best positioned to evaluate the performance of new devices on their networks. Unlike third parties, network operators are the *only* entities that can provide a platform for real-world testing of new devices. Third parties can *somewhat predict* how devices will perform and how they may interact with the network and other devices and uses, but given the complexity and dynamic nature of different network and radio environments, actual field testing has no substitute. The network operator must have full knowledge of the device and its real-world performance characteristics to be able to provide satisfactory service quality or customer service. Sole reliance on third-party certification would also create accountability issues; if a device performs poorly, the consumer is likely to blame the service provider, not the third-party phone supplier or private certification organization.

2) *Afflerbach and DeHaven propose that "any device" be allowed to connect to the network and be activated through a standardized methodology*. Afflerbach and DeHaven envision an "any device" system in which consumers obtain all devices from third parties and can connect any device right out of the box to any wireless provider, simply by obtaining a subscriber identity module (SIM) card from a wireless provider and inserting it into the device. Contrary to Afflerbach and DeHaven's assumption, all major wireless network operators in the U.S. (including AT&T) already give customers the *choice* of bringing their own third-party-supplied (and unsubsidized), compatible devices to the network in this fashion, subject to use consistent with the network operator's terms of service. Very few customers choose this option (most instead choose to purchase subsidized, certified devices from the network operator), demonstrating that mandating a third-party supply approach for *all* devices for *all* customers is unnecessary and would invariably raise costs and reduce choices for consumers. This concern is particularly acute today in light of the explosive growth of specialized devices that hold great promise for consumers and businesses but may require different activation, business models, and network-specific optimization to be economically and technically feasible in a shared radio environment. Afflerbach and DeHaven's companion proposal to mandate the creation of individual devices that work on any and all networks (*e.g.*, GSM *and* CDMA[3]; LTE *and* WiMAX) would also raise the cost and complexity of devices for consumers; each device would require advanced software and hardware – *e.g.*, "chip-sets" and RF antennas. For related reasons, the "any device" proposal would seriously complicate the provision of E-911 services because some E-911 solutions are device-based, some are network-based, and some are device-network hybrids. Afflerbach and DeHaven seem to acknowledge this point but state that network operators "will not be liable for E-911 problems caused by device-related failures or incompatibility." Given

[3] GSM is an acronym for Global System Mobile and CDMA for Code Division Multiple Access.

this admission, how this mandatory "any device" proposal would promote the interests of wireless public safety is difficult to see.

3) *Afflerbach and DeHaven propose that the network treat all traffic in an "application-neutral" manner*. However, different applications need different levels of QoS so that user experience and network performance are optimized. For example, voice services can tolerate some errors but not delay. In contrast, email can tolerate delay but not errors. Hence, whenever possible, the network must be allowed to differentiate among applications to provide the best possible user experience. Furthermore, innovative network optimization techniques can increase network performance and user experience with no perceivable impact on less performance-sensitive applications that may temporarily receive fewer network resources.

4) *Afflerbach and DeHaven suggest "full disclosure" of highly technical and dynamic network management practices to all manufacturers.* Network management in wireless networks is extraordinarily complex, and multiple algorithms, such as a scheduling algorithm and a handover algorithm, work in parallel to address different aspects of network management. Many such algorithms are non-standardized and vendor-specific and are continuously tweaked and upgraded. Revealing such algorithms would jeopardize intellectual property and chill innovation and pro-competitive differentiation among networks. Furthermore, the details of highly complex algorithms and the varying network performance in a wireless network's dynamic radio environment would be quite difficult for typical consumers to comprehend. Security could also be compromised if these types of network management practices were disclosed.

5) Afflerbach and DeHaven imply that an authority is needed to investigate the operator's network and to verify network management practices. Network management in a wireless network (especially, inside the radio network) is so complex and the radio environment is so dynamic that it would be impossible to reliably and consistently quantify network performance and judge the "reasonableness" of particular network management decisions through an after-the-fact review process. In addition, the security of the communication and signaling links to the operator's network elements required for such verification could be jeopardized if those links are extended outside of the operator's domain. The suggested timing, cost, and feasibility of the new third-party organizations and federal bureaucracy for device specification and certification and for network operator "audits" are also quite unrealistic. By the time any "benchmarks" of the type the authors envision (*i.e.*, for all types of network features that go beyond the basic GSM and CDMA standards) could actually be implemented, they would already be obsolete or would require significant changes due to the fast pace of cellular/wireless technology evolution.

6) *Afflerbach and DeHaven recommend end user pricing as the solution to congestion and performance issues in an "any device/any application" regulatory system.* Afflerbach and DeHaven ultimately concede that some mechanism is needed to deal with congestion and localized performance issues in a shared radio environment. They suggest that network performance could be preserved by allowing *consumers* to "ration" limited resources, *i.e.*, wireless networks would prioritize users rather than applications through

the offering of "premium" tiered services to customers willing to pay a higher price for "guaranteed" performance improvement. Consumer pricing mechanisms (*e.g.*, varying data caps on different tiers of service) may evolve as one tool for managing network performance in a shared, limited-bandwidth wireless environment but can never be a complete solution. The claim that network providers could guarantee capacity or speeds to users who choose premium service fundamentally misunderstands the nature of wireless traffic demands. With mobility and constantly changing and evolving uses, guaranteeing performance at any particular time or location to any particular user is impossible, and providing absolute guarantees no matter where the user is located or what applications that user and others in the same and nearby cells are using is currently unfathomable. Furthermore, when total demand on the network at particular locations exceeds capacity to meet the performance requirements of those users, tiered pricing cannot solve the congestion problem. If most users or if the minority of heavy users of continuous, data intensive applications choose the premier tier, performance for all users in that tier would suffer. The users of the basic service, *e.g.*, those that use their devices primarily for voice or texting, could be shut out entirely in such scenarios.

7) *Afflerbach and DeHaven contend that the emergence of 4G technologies, such as LTE and WiMAX, will solve the congestion problem in wireless networks and that operators can no longer consider congestion as an obstacle to the implementation of regulations*. As the ongoing transition from second-generation (2G) to third-generation (3G) technologies has demonstrated, the increasing availability of multimedia devices and applications is likely to only increase the scarcity of wireless resources. Thus, the capacity gains expected from 4G technologies will still be inadequate to meet the needs of growing Internet Protocol traffic. Indeed, while LTE promises to be about three to six times more efficient than 3G, the introduction of innovative 3G smartphones has increased data usage by a factor of fifty to sixty. Afflerbach and DeHaven essentially put the entire burden of addressing exploding bandwidth demand on the network provider, giving the application provider no incentive efficiently to minimize the amount and rate of data transfer for its applications (*e.g.*, by using compression and/or adaptive bit rate mechanisms that "throttle back" during congestion).

In summary, Afflerbach and DeHaven fail to confront the serious, unique, and growing challenges wireless networks face and the real-world consequences of their categorical "any device" and "any application" proposals. The Afflerbach and DeHaven proposals would, in our opinion, have a grave, adverse impact on the cost and availability of mobile devices, the performance of wireless networks, the pace of wireless innovation, and wireless customer service and satisfaction. These proposals contemplate radical changes in network and handset design and management and in wireless business models without *any* analytical or experimental support. For all of the reasons summarized above, the FCC should reject the Afflerbach and DeHaven proposals. It would be particularly reckless to mandate such broad, inflexible "any device" and "any application" regulations without any real world testing to assess adverse impacts and customer reactions. We note that in the recent 700 MHz auction, the FCC conditioned a single block of spectrum – the C Block – on experimental "any device" and "any application" restrictions. It would be illogical and irresponsible to now expand those requirements to all spectrum before that experiment has even begun.

2. Problems with the "Any Device" Proposals

Afflerbach and DeHaven acknowledge that wireless customers today already have a great deal of choice and flexibility with respect to devices. As the FCC recently noted in the National Broadband Plan, more than 850 different certified mobile products were available in the U.S. in 2009. The number of specialized and machine-to-machine wireless devices available in the marketplace is growing at a rapid pace as well. Networks employing GSM and UMTS technology work with devices that have removable SIM cards, many of which are operable on networks owned by different operators. Major wireless network operators also already offer customers a "bring-your-own-device" option. The "bring-your-own-device" option means the customer can use his or her choice of device. However, the drawback of this option is that the network operator may not have certified the device. The network operator cannot guarantee interoperability of the device with the network and may not be able to provide any customer service for a device-network related problem the customer encounters. Afflerbach and DeHaven erroneously suggest that AT&T has no such policy; AT&T's website indicates that it indeed does [AnyDevice_AT&T]. In addition, a number of "global" handsets contain multiple radios and other components that allow them to be used on virtually any network worldwide.

Afflerbach and DeHaven argue for the technical feasibility of replacing the current environment—where consumers can choose from a range of devices with various levels of functionality, cost, and network compatibility—with a very different environment with several government mandates. These mandates would stipulate that (i) wireless networks, technologies, and processes evolve so that all devices are "standardized" to work on all networks, (ii) devices be based solely upon published network specifications with no interaction between the device manufacturer and individual network operators, (iii) a third party or the government would certify devices as "safe" for operation on all networks in all environments but with no network operator involvement, and (iv) customers could connect *any such device* to *any network* (and the authors quite clearly mean *any* device).

Afflerbach and DeHaven concede that the sweeping "any device" system they envision would require major changes given existing technology deployments and architectures that differ widely among network operators. For example, a variety of 2G and 2.5G (second-and-a-half-generation) technologies, such as GSM, GPRS, and EDGE,[4] are in use today. Similarly, various 3G technologies, such as UMTS, HSPA, 1xRTT, and 1xEV-DO,[5] also are in use today. In the rapidly approaching 4G future, LTE and WiMAX will also both be in use. Additionally, different frequency bands, such as cellular, PCS, and AWS[6], are used by the same or different operators. More importantly, however, Afflerbach and DeHaven's proposed system, while perhaps theoretically and abstractly possible, would severely and negatively impact wireless

[4] GPRS is an acronym for General Packet Radio Service and EDGE for Enhanced Data Rates for GSM Evolution.

[5] HSPA means High Speed packet Access, 1xRTT referrers to 1X Radio Transmission Technology, and 1xEV-DO stands for 1xEvolution- Data Optimized.

[6] PCS is Personal Communications Service, and, AWS stands for Advanced Wireless Services.

performance, device costs, customer satisfaction, network management, wireless innovation, experimentation, and investment.

2.1 Device Standardization

The Afflerbach and DeHaven paper proposes that wireless devices be designed solely based on published specifications and with no network operator participation. Such a design approach is undesirable for several reasons.

First, the standards bodies' specifications do not (and are not intended to) provide network operators with complete guidance regarding how a particular technology is to be implemented. Published standards are just the *beginning* of a complex process that ultimately determines how devices are designed and launched on a particular network. Different operators have different approaches for implementing standards and carrying out a given task. For example, the way a phone locks onto a base station during network acquisition is only loosely defined in the standards [1xEV-DO_PowerUp, UMTS_PowerUp].[7,8] Different operators have developed proprietary mechanisms for this task to enable efficient network acquisition and to avoid excessive handset power consumption. To support a VoIP call in an LTE-based device, various IP Multimedia Subsystem (IMS) signaling messages must be exchanged between the device and the network. IMS is so broad and flexible, however, that a given device and network could implement incompatible signaling exchanges and thus be unable to communicate, even though they are both following the LTE standard. Additionally, different operators (working closely with device manufacturers) may establish varying ways to reduce signaling delay and efficiently use network resources; the standards do not dictate a single solution to these issues.

Furthermore, wireless industry standards define many "optional" capabilities in the device and the network. Not all devices and not all networks support the same optional features. Attempting to make all devices and all networks support all of the same optional features in the standards would be an impossible task. Network operators play an important role in ensuring optional feature compatibility between their networks and devices and in thereby reducing interoperability issues and customer dissatisfaction. It is also important to recognize that different networks may be operating on different releases of the wireless standards, and each network operator must take steps to ensure that both legacy and new devices perform appropriately in its real world implementation of particular releases. Finally, since innovative applications and specialized devices are rapidly emerging, network operators and device manufacturers have a growing need to collaborate to ensure acceptable levels of service quality and the best possible user experience. In short, close cooperation between device manufacturers

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[7] *See* "Section 8.3.6.1.3 Network Determination State": "The specific mechanisms to provision the access terminal with a list of preferred networks and with the actual algorithm used for network selection are beyond the scope of this specification."

[8] *See* "Section 5.2 Cell selection and reselection in idle mode": "The UE shall select a suitable cell and the radio access mode based on idle mode measurements and cell selection criteria. In order to speed up the cell selection process, stored information for several RATs may be available in the UE."

and network operators beyond the 3GPP and 3GPP2 standards processes is more important now than ever before.

Second, Afflerbach and DeHaven ignore how consumers can benefit greatly from collaboration between a device manufacturer and a wireless network operator to optimize the design and operation of a particular handset to work properly with the operator's network. When a network operator/ and a manufacturer work closely to design and optimize a new device for a particular network—considering that network's technologies and architectures, the mix of users, applications, and other devices already on that network, and that network's particular localized radio environment issues specific to that network—customers benefit from the improved performance of that new device as well as from the competitive pressure that device's success puts on other operators and manufacturers to innovate and optimize new devices of their own. Government-mandated device standardization could preclude this beneficial activity.

The development process for innovative handsets is typically very collaborative between the network operator and handset manufacturers (*e.g.*, Apple and AT&T regarding the iPhone). In fact, many design concepts for devices are suggested by network operators based upon their experience and understanding of consumer preferences for particular functionalities and features. Since technologies and consumer preferences are evolving rapidly, wireless operators can and do serve as a valuable resource to device manufacturers to help guide the device design process.

Additionally, network operator and device manufacturer collaboration and optimization activity is already important with traditional and "smart" handsets and will become exponentially more important because more specialized wireless devices demand even greater optimization to maximize their performance using limited network resources. AT&T, for example, has established a new "Emerging Devices Organization" [AT&T_EDO], which functions as a single point of contact to provide manufacturers the information and support needed during various stages of the device lifecycle (*e.g.*, product development, product deployment, billing, and ongoing customer support). The development of innovative devices, such as eReaders, personal navigation devices, and smart meters, often presents the service provider and device manufacturer with unique, complex issues, such as how the device will be activated out of the box, how billing will be based (time or usage), and how to provide customer support. All of these issues require the manufacturer to work closely with the network operator in the development process.

Third, Afflerbach and DeHaven also anticipate that in their standardized wireless device regime, problems with the performance of the device would "no longer be the responsibility of the carriers," *i.e.*, wireless operators would no longer support the devices operated on their networks and consumers would need to look to the device manufacturers to address any problems in using their devices [Afflerbach DeHaven, p. 28]. This approach is a recipe for *overwhelming customer dissatisfaction* because, given the necessary interactions between the device and the network, the customer will often have no way of knowing whether performance issues are device-related or network-related. The difficulties that can arise when the wireless operator is removed from the equation were recently illustrated when Google began selling its Nexus One on a standalone basis, leading to confusion and frustration among consumers who expect one-stop customer care from the wireless operator when performance issues surface. It was widely reported in the press that customers did not know who to blame for performance problems and that Google lacked the robust live customer service resources that customers have come to expect [Google_NexusOne]. Our suggestion is *not* that customers should have no choice of purchasing devices from manufacturers or third parties (as they can do today); unlike Afflerbach and DeHaven, we believe the government should not mandate this model as the *only* option for consumers. Customers who prefer the accountability of purchasing their devices from a network operator that stands behind the devices it has directly certified, approved, and sold should continue to have that option available.

Fourth, Afflerbach and DeHaven call for a very expensive common design framework for a wireless phone, essentially one that operates on all bands and with all standards. Such phones are available today, but very few people choose to buy them, presumably due to the cost. Do-everything, work-on-any-network phones are more expensive to produce because they must include more radios and chipsets given the different spectrum bands and technologies different networks deploy. Mandating a common design framework for all devices would drive up the costs of devices, thereby suppressing demand, particularly by low-income consumers. In fact, the proposed interoperability paradigm would require major expensive hardware modifications to devices that would raise costs and make U.S. phones different from those of rest of the world, thereby requiring customization for the U.S. market. Likewise, choices would be greatly reduced since the phones would have to be specific to the U.S. market, and, manufacturers and/or retailers would also have to increase their prices to cover the increased costs of providing more complex technical support.

Fifth, the paper also consistently neglects phone cost reductions due to service provider underwriting and large volume purchases that a mandated common framework would eliminate (a change which could hit low-income customers especially hard). Most consumers today, with a choice between purchasing unsubsidized devices (that, in the case of cutting edge "smartphones," may cost $500 or more) from a retailer or purchasing the same or similar devices on a heavily subsidized basis from their wireless operator, choose the latter. Yet, Afflerbach and DeHaven would eliminate this choice for all consumers.

Finally, Afflerbach and DeHaven seriously underestimate the amount of time needed to implement the new business model they propose. The authors call for new products with removable a R-UIM (*i.e.*, a CDMA SIM-like capability) within 18 months. If this were simply a new model phone with just the addition of a new screen or software, a short design cycle might be possible, but the proposed changes are a major operating and architecture paradigm shift with impacts that would ripple throughout the wireless ecosystem. There are long lead times for new silicon spins for hardware, and the hardware requirements must be "locked" for them even to begin. There are testing requirements and training requirements that would be necessary as well as policy development that would affect almost every aspect of the overall network. It would likely take years to develop just the requirements. Ever-changing standards would further complicate such a process. The authors similarly underestimate the time required for changing registration procedures; Afflerbach and DeHaven proposes 12–24 months, which is unrealistic. Modifications would be needed throughout the network, new databases would need to be developed, new equipment would have to be purchased, and personnel training would be needed. Even the billing system would be affected by such a change. For example, registration procedures for CDMA-based systems would need to follow GSM-type SIM-based (or R-UIM-based) procedures. Authentication processes would also change since the user identity lies with the SIM/R-UIM and thus interaction between the SIM/R-UIM and the radio hardware would be required. The technical customer service personnel of wireless operators that do not currently use SIMs would have to be trained on how to troubleshoot SIM-related issues. Databases that participate in authentication and billing (*e.g.*, HLR and AAA Server) would need to be updated to reflect new SIM/R-UIM identities and new authentication algorithms. In short, a mandated "universal" phone that can connect across all bands, handle all standards, and receive software upgrades after purchase would be very expensive and would take years to develop. This paradigm shift would also render the entire existing product line of every cell phone manufacturer obsolete, and many different new phones would have to be developed from scratch. This enormous amount of work could take years to achieve the variety of phones we already have today.

In summary, the FCC has no reason to mandate the standardized device business model Afflerbach and DeHaven propose. Customers already have the option of purchasing phones and other devices from numerous third parties but have shunned this approach because such a business model offer no guarantee of sufficient support, product reliability, product performance, or cost advantages. Preserving the existing device design approach, with its close collaboration between the manufacturer and the network operator, is essential in driving innovation, enabling product and service differentiation, optimizing performance, and keeping costs low for consumers.

2.2 Device Certification

Afflerbach and DeHaven propose that a third party or the FCC be the sole entities responsible for certifying devices, thus removing wireless network operators entirely from the device certification process. This is a recipe for disaster.

Afflerbach and DeHaven contend that a third party could adequately determine whether a device is likely to harm the network. Given network technology diversity and rapid evolution, the likelihood is slim that any third party could be as effective as the network operator, familiar with its own network, at predicting (even) theoretical harm. More importantly, harm to the network broadly encompasses the impact the device will have on performance under real-world conditions specific to each network. Even with network operator collaboration with manufacturers at the design stage, certainty about how a device will perform under real-world conditions is simply unattainable until the device is tested under those conditions. No third party is in a position to make those determinations; only individual network operator testing and analysis can provide answers in the context of its particular technologies, the demands on its network, and the availability of its spectrum and other resources. As an example, FCC-certified signal boosters may theoretically cause no harm to the networks or other users, but deploying them has caused substantial harm to networks and consumers; boosters used on pleasure boats have disrupted entire cell sites (including 911 service). *Theoretical harm* and *real-world harm* are often very different, and only network operator testing and certification can ensure that both types of harm are avoided.

Afflerbach and DeHaven greatly downplay the extensive and complex handset testing that network operators perform to ensure a high-quality user experience. Afflerbach and DeHaven call for a regime of full interoperability with all service providers and suggest that a new independent testing organization can be up and running in 12–18 months maximum! Such a proposal is extremely unrealistic, even naïve, given the level of effort testing requires and the many complex issues to be examined before the mass introduction of a new handset.

To illustrate the complexity of the testing process, we provide a brief overview of the testing process at AT&T. After the device manufacturer has acquired FCC approval and is either undergoing or has completed certification from the PTCRB (an organization set up by operators to accredit testing centers), AT&T conducts its own rigorous testing and certification process.[9] The process of testing and certification spans a wide range of activities and test environments. The device is first tested in the lab in focus areas not covered by other testing to validate that it is stable enough to be tested in the field. A device is tested for interoperability with various radio access networks (*e.g.*, GSM, EDGE, UMTS, and HSPA) using test and network equipment from a variety of manufacturers. Devices are tested to ensure interoperability with all of these different types of network equipment. Voice quality and data throughput are tested. Durability of the hardware and stability of the software are tested. AT&T also "drive-tests" the device using a live network to simulate the user experience. The user interface and accessories are thoroughly tested. Testing a stocked device at AT&T may involve as many as 2500 test cases, with typical high end phones usually requiring between 1500 and 1750 test cases. We understand that for 2009, on average, 168 issues were found per phone, with an average of 33 critical issues that needed to be resolved before the handset could launch. Upon successful completion of rigorous testing, AT&T certifies the handset.

In the case of a device certified by AT&T's Emerging Device organization, after the certification is complete, AT&T schedules a "Test and Turn Up" appointment to enable the manufacturer to "connect" its devices to the AT&T network. AT&T continues to support the device manufacturer even after launch with tasks such as SIM order entry and tracking, online self-provisioning, operations and call center support, billing support, and providing training and support materials.[10] As we discuss various aspects of network operator testing below, it will become apparent that *it is neither realistic nor desirable to have a third-party solely responsible for such an intense device testing process*.

Two main types of tests are the lab test and the field test. The lab tests help iron out basic issues with the device. For example, the lab tests can help confirm that the device is able to carry out basic functions such as registration, device-originated and device-terminated call setup, and handoff/handover in a controlled environment (as opposed to the real-world environment), and that it transmits and receives at the correct signal power levels. Once the device is deemed stable during lab testing, it undergoes field testing. The real-world field testing mimics the user experience and helps troubleshoot performance problems such as access failures, call drops, data throughput issues, and handover failures. Such field tests involve different parameter settings/configurations in live networks. This requires field testers spread out around the country and an intimate knowledge of how different networks are configured. No outside entity can be expected to have this knowledge or have the resources to do this testing. The complexity of this

[9] *See* http://developer.att.com/developer/index.jsp?page=ncpOverview&id=6.3_v1_4700114.

[10] *See* http://www.att.com/edo/launch-your-device/launch.jsp.

testing would become exponentially more complex and expensive if the device is supposed to support all network operators and all different standards, as Afflerbach and DeHaven propose.

Only network operator testing can ensure interoperability between the device and its network. Not all networks are designed or configured to support all of the features that a manufacturer may decide to include in a handset. For example, the 3GPP standards specify the capability for simultaneous voice and HSUPA data transmission for devices but they make support for that capability optional at the network level. Thus, only the network operator is in the best position to judge which features should be activated in a handset, particularly since operators are continually modifying and upgrading the capabilities of their networks. To avoid customer confusion, the network operators need to test handsets to validate interoperability between the various features of the device and the network. Additionally, as more knowledge about the operation of the technology is learned from real-world experience and as more types of applications and specialized devices emerge, such feature sets need to be constantly updated. Furthermore, a wireless network operator usually has multiple technologies in its network (*e.g.*, 2G, 2.5G, and 3G) and the device needs to be tested to work well with these different technologies and to seamlessly select, reselect, or hand over between these technologies. Additionally, the operator may have more than one vendor for a given technology, further complicating the testing process. Only testing by the network operator under real-world network and device configurations can ensure seamless interworking between the device and the network.

A wireless operator may employ specific applications or enhancements that need careful testing and close coordination between the operator and the device manufacturer. These applications and enhancements designed to improve network and/or handset performance and thus enable competitive differentiation are typically beyond the scope of work performed by standard-setting bodies and thus fall outside the minimalist testing regime envisioned by Afflerbach and DeHaven. For example, an operator may choose to dynamically update a Public Land Mobile Network (PLMN) list through over-the-air provisioning of the SIM to facilitate roaming. Such an updating mechanism improves the roaming experience, but must be tested in advance to ensure it functions properly. Even when standards bodies address applications and enhancements, the standards may define several options to provide these capabilities. For example, several options exist to deliver a message waiting indicator to the user for voice mail. Only the operators can realistically know which options they use to support both legacy devices and new devices. Hence, only the network operators can do thorough testing of such network-specific options. Similarly, although standards may provide general recommendations regarding system selection approaches (*e.g.*, choosing UMTS vs. GSM), providers may develop sophisticated network selection algorithms (*i.e.*, the algorithms that determine which network the device should connect to at any given point in time) to improve network and handset performance as a means of differentiating themselves from their competitors. For example, a network operator may work with device manufacturers to design and test an enhanced network selection (ENS) algorithm designed to minimize handset power consumption, conserve network resources and provide a better user experience. The network operator can then evaluate ENS algorithms during testing. Under Afflerbach and DeHaven's proposal, however, these network operator-specific ENS algorithms and their associated benefits would presumably be prohibited.

Network operator testing produces tangible improvements to network/device performance and the user experience. Practical experience has shown that network operator testing has improved network capacity and enhanced the user experience in ways that independent third-party lab testing could not have done. For example, inefficient device design can result in a measurement reporting approach that would lead to higher utilization of the downlink power, reducing the capacity of the network.[11] Similarly, a poorly designed device that is not optimized to unique network capabilities may repeatedly switch, or "ping-pong," between 2G and 3G technologies, reducing the battery life of the device and creating a heavy signaling load on the network. Since the process of 2G/3G system selection is influenced by both the device design and network configuration parameters, only the network operator that has intimate knowledge of its network configuration can do such testing. Some devices also may be designed to be aggressive and bombard the network with extremely frequent location area updates upon initial location area update failure. Excessive signaling associated with location area updates degrades the performance of the network and affects network accessibility for other devices. Such aggressive location area updates may seemingly improve the performance of this one device, but their impact on the network is analogous to a denial-of-service attack. Live-air field tests by the network operator are the only way to discover these types of problems. No standards body or independent third-party test lab could predict the need for testing in areas such as this; only the wireless operator who has in-depth knowledge and experience with the network can do so.

The performance problems that require network operator participation in the certification process are magnified in the modern context of specialized and machine-to-machine wireless devices; that is why AT&T and a growing number of other network operators have opened emerging devices labs to test and analyze these devices before they are certified for use on the network. Thus, involving wireless operators in the device certification process is now more important than ever to ensure that network performance is as good as it can be to accommodate dynamically varying resource needs of the many different users, devices and applications in this evolving industry. It is simply not realistic to expect a third party to be as effective or efficient as the network operator in certifying devices.

Network operators learn from their extensive test experience and develop network test scripts and device test scripts to quickly identify and then resolve performance issues. Network operators encounter hundreds of new issues every day from testing and from actual users, which enables them to quickly react to problems based on their accumulated experience. For example, the location of the antenna in the handset and its interaction with the hand and head has often been the culprit behind call drops. Network operators have responded to such issues by creating a set of tests that measure the total power being transmitted by the device and the receiver sensitivity. Troubleshooting such problems requires network logs and customer device logs. An outside entity would not have these records and could not adequately test for such problems. Furthermore, these testing and debugging operations have been developed over the course of many years by field-experienced engineers. An independent outside entity could not be expected to reach this level of efficiency and expertise.

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[11] The device sends measurement reports to the network conveying the quality of the signals received from one or more cells in the neighborhood. The network uses such reports to choose the specific cell(s) with which the device should establish a radio link for reliable communication and to determine parameters related to the downlink power control mechanism.

Network operators also test for reliability of device software and hardware to ensure user satisfaction. For example, different operating systems may have different levels of reliability in certain circumstances, and operator testing can ensure that a strict mean-time-between-failures is achieved. Such testing ensures that the user does not experience frequent resets or lock-ups. Network operators also test the device for durability via dropping and shaking, and for water ingress. Although such device durability characteristics are not strictly network issues, consumers routinely look to the network operator to address any problems that affect their service, particularly when the cause of the problem is not readily apparent.

Network operators often test and certify individual device components, which significantly benefits device manufacturers. Afflerbach and DeHaven claim in their paper that AT&T requires device manufacturers to use only RF modules that have been pre-certified by AT&T, and they suggest that AT&T created this requirement as a means to restrict device development. To the contrary, we understand that AT&T does not limit device manufacturers to using only pre-certified modules. Rather, AT&T pre-certifies a range of components to help device manufacturers get to market more quickly and with less cost. Advising manufacturers in advance which RF modules have been tested and proven reliable through real world testing facilitates more rapid device deployment in a competitive device marketplace. Specifically, we understand that testing of the devices using pre-certified modules can result in 50% to 66% reduction in the time to deploy. It is our understanding that the device manufacturers still have the option to submit their device to AT&T for certification if they wish to use components that have not been pre-certified.

Network operator testing advances E-911 functionality. Some location determination mechanisms for E-911 are device-based, some are network-based, and some are hybrid approaches. Thus, deploying a successful wireless E-911 solution requires coordination between the device manufacturer and the network operator as well as between the network operator and the public safety authorities who receive the 911 calls. To the extent Afflerbach and DeHaven's proposal would restrict this coordination, the reliability of E-911 service could be jeopardized. In fact, Afflerbach and DeHaven appear to recognize this shortcoming in their proposal when they state that network operators "will not be liable for E-911 problems caused by device-related failures or incompatibility."

Finally, Afflerbach and DeHaven have not shown that the network operator certification process *has posed any real barrier to device evolution and deployment; nor have they shown that creating a third party entity to certify devices would yield benefits.*

Creating the third party regime contemplated by Afflerbach and DeHaven would require the establishment of an expensive bureaucracy which would take years to introduce and would have to depend heavily upon network operator guidance and expertise under any realistic scenario. The proposal offers no inherent checks on how this bureaucracy would perform its mission. Especially since the report calls for this new bureaucracy to hold public hearings on changes to device policy, there is a risk that politics, and not network performance, would drive network and device evolution. On the other hand, network operators have a commercial relationship with their subscribers, and the network operator is responsible for customer satisfaction at the risk of losing that customer. Thus, network operators have strong incentives to offer a wide range of high-quality, well-performing devices that work seamlessly with the operator's network.

2.3 Connecting "Any" Device

The Afflerbach and DeHaven paper proposes that "any" device should be allowed to connect to the wireless network. Section 2.2 of the paper envisions a mandatory "any device" regime where a consumer can connect literally any device, out of the box, to any wireless provider, without any limitations at all. With rapid evolution in device technologies, there is simply no way to predict the scope and magnitude of harms that could occur in a regime that truly allowed connection of "any" device determined by a third party to be theoretically "safe."

As an initial matter, we noted above that all of the major wireless network operators already offer bring your own device options, which allow consumers independently to acquire devices from third parties and purchase wireless connectivity for those devices from the network operators. As we also noted, these devices must be compatible with the network technology and the consumer's use is subject to the network operator's terms of service. Lastly, we observed that such bring your own device options have not proven popular with consumers, in significant part because of the higher costs of acquiring an unsubsidized device from a third-party, as compared to acquiring a heavily subsidized device from a network operator in exchange for making a term commitment. In the world envisioned by Afflerbach and DeHaven, the "bring your own unsubsidized device" model would become (literally) the rule rather than the exception, which would dramatically complicate the way network operators plan and manage their networks and increase customer up-front costs, making cutting edge handsets less accessible.

Under the current model where most consumers choose to acquire devices from wireless network operators, the network operators have the ability to engage in capacity forecasting and planning based on their knowledge of the devices that are working their way through the supply chain and certification processes. Even then, however, individual devices (like the iPhone) may substantially exceed usage forecasts. But in a mandatory bring your own device environment, network operators would have a limited ability (if any) to forecast bandwidth-hungry devices, and they would face obstacles to proper capacity planning. As an example, tethering technology has been available for some time, but it has only recently been introduced in network operator offerings and with some limitations. Tethering tends significantly to increase data traffic and thus requires the network to be provisioned properly to address resource requirements. Widespread and unlimited use of tethering before network resources are ready for the increased data traffic demand would degrade performance for everyone. This is often a matter of timing as network operators evaluate their capacity needs on an ongoing basis. Nonetheless, it is an important matter of timing, and it is essential that network operators retain the flexibility to evaluate and limit the use of new devices that pose a threat to overall network performance.

These dangers are magnified when it comes to specialized devices. Wireless chipsets and modules can and increasingly are being incorporated into almost anything, including vehicles, appliances, business machinery, electric meters, and medical appliances. The possibilities are essentially endless, but so are the potential harms in the "any device" regime. We cannot even imagine all of the possible devices, much less their impact on the network. There has to be some mediation and certification through a test lab and real-world testing and assurance that the network resources are available *before* the device is unleashed on the network. It is not just a matter of bandwidth hungry devices; new "low bandwidth" devices with new uses could overtax signaling resources or interact with the network in ways that would cause performance issues. Likewise, other factors, unrelated to bandwidth consumption –such as spurious transmissions or imprecise timing mechanisms within the device – may affect performance and could harm the experience of other users.

Device performance, however, is not the only problem with the proposal. The paper proposes requirements that all devices be configurable through software such that interoperability between the device and the network is universal, that they can be updated after purchase, and that they could even be reprogrammed to use different bands. The authors point to Software Defined Radio (SDR), used in conjunction with SIM cards, as the technical means to satisfy this design requirement. However, designing a device to use a certain technology affects not only software but also hardware (the so-called ASIC or chip-set and the antennas), and there are important tradeoffs between performing configuration via software vs. hardware, such as cost, speed and power efficiency. Today, processing speeds and power consumption of software-oriented approaches simply are not competitive with hardware-based solutions. Although "universal" hardware for these purposes can be manufactured today (*e.g.*, the Qualcomm's Gobi chipset mentioned by the paper), it is more expensive than hardware designed to work with a specific network technology. Thus, mandating the support for multiple dissimilar technologies in all devices, as Afflerbach and DeHaven propose, could effectively eliminate low-end and low-cost devices from the marketplace, significantly harming consumers of those devices. Although we have great hope that this multi-network technology will continue to develop, it will not be available in the foreseeable future for mass market handsets with capabilities called for by the paper, and it may never be available to meet the low-cost, low-bandwidth needs of many machine-to-machine devices and services.

SIM cards are not the panacea for interoperability as portrayed in the Afflerbach and DeHaven paper. There are some capabilities that require reprogramming of the device to work efficiently and cannot be simply done by a common SIM card configuration. For example, as mentioned earlier, some devices have a proprietary system selection algorithm, which is implemented in the chip-set. Additionally, network operators can customize the use of the SIM card to improve the battery life of the device by implementing an enhanced network selection algorithm. Some important parameters have an impact on device hardware. For example, some parameters (*e.g.*, Access Point Name (APN) for connectivity to a specific packet data network) are stored on the device and not on the SIM, and, unless such parameters are changed on the device hardware, the user cannot simply connect to different networks. This is not due to any network operator requirements; it is the way the industry developed the wireless standard, primarily driven by suppliers and not network operators. As another example, there is not just one way of delivering the message waiting indication to devices informing them they have voicemail. A device taken from one network operator to another may not show the user that they have voice messages waiting due to different implementation approaches. Afflerbach and DeHaven hint at problems with SIM cards, so they call for each network operator to have a physically separate card for specific network operator information. This is not something that any other GSM network operator in the world would need, and hence it would make GSM devices for the U.S. market more expensive and unique, thereby losing the economies of scale with GSM that have been so successful at driving device costs down over time. It would also limit the number of device choices for U.S. customers, as device suppliers would have reduced incentives to design to a new, U.S.-only requirement.

Afflerbach and DeHaven also pay little attention to assigning responsibility for the software updates necessary to keep devices functioning properly. They assert that network operators "may" continue to perform such updates, "but these may become more the responsibility of the device manufacturer, the operating system developer, and the user." It is hard to imagine that consumers really want to assume responsibility for these updates. Nor is it likely that handset manufacturers and/or operating system developers, without any coordination with network operators, would be eager to keep track of and arrange software updates for all their respective devices and operating systems. Further, in a world where the operator is not involved in device updates, the physical size of those updates, the frequency with which they are sent out, and the volume of devices that are updated simultaneously could cause extreme loads on the wireless network and could impact service to many customers. Thus, under the Afflerbach and DeHaven proposal, updating device software is likely to become a far more chaotic exercise than it is today.

The paper also has unrealistic technical expectations in the proposed Non-Discriminatory Carrier Configurations and Updates policy. One cannot update operating bands with software updates. This is a major hardware modification. Furthermore, the nondiscriminatory technical requirements proposed would prevent service providers from requesting more stringent performance specifications that could lead to better phones and/or phones with unique services such as AT&T's Video Share and Push-To-Talk capabilities.

At times, the paper seems to recognize that its proposals are a poor fit with the real world given all the different (and constantly evolving) network and handset technologies. Thus, the authors appear to suggest that to achieve the vision of complete standardization, wireless networks should be "dumbed down" so that they do not contain unique technological requirements above and beyond basic network standards (GSM, CDMA, *etc.*). That, they say, would make it easier for manufacturers to build something that operates on any network and offer all required features, and it would of course make it easier to take a device to any network. To achieve this, networks would presumably be stripped of current differentiators, and, going forward, the FCC or some third party certifier would have to approve changes to the network that go beyond the "standard," prior to implementation. In our view, that is a prescription for reduced innovation in both devices and networks, a result that plainly would not advance *consumers'* interests.

2.4 Network Operator Investment in Network Management vs. Capacity Increase

The paper states that wireless network operators are intentionally choosing not to invest in increasing capacity. This assertion completely disregards actual experience. Wireless network operators are investing tens of billions of dollars annually to upgrade and improve their networks [DataSurge_BusWk_122309].

Nevertheless, even with the substantial amount of new infrastructure being deployed, network management will continue to play an important role in enhancing capacity, and Afflerbach and DeHaven have a fundamental misunderstanding of the role of dynamic network management in improving capacity utilization. We will briefly describe the role of network management and how it complements new infrastructure deployment.

As new technologies are deployed, subscribers with new devices do not appear immediately. Extensive traffic forecasting and capacity planning is carried out to provision the network with adequate capacity. A suitable number of base stations and other pieces of equipment are purchased and deployed based on capacity estimates and coverage goals. If the network operator provisions insufficient network resources, it may adversely affect call blocking and call retention rates.

After activating new technologies, network operators actively monitor performance and resource utilization, which may dictate adding capacity as traffic demand increases. Adjustments such as sectorization, modification of antenna parameters, and optimization of other parameters (*e.g.*, those related to handover) are carried out. Eventually more base stations and/or spectrum bandwidth, if available, are added to meet growing demand. Spectrum is an extremely precious resource, and every avenue for network optimization must be explored to maximize network performance and user experience. Hence, once the initial network deployment is completed, tuning of parameters and network management algorithms follows. Investment in infrastructure and optimization of network management mechanisms are not mutually exclusive options to choose from at a given stage in network design and deployment. Both work together synergistically and must be constantly re-visited based on actual network performance and customer experience. In our view, both infrastructure expansion and deployment and optimization of network management mechanisms are critical to the success of a cellular technology. Limiting the network operators to just one of these mechanisms would be irrational.

2.5 Impact of New Technologies

Afflerbach and DeHaven are overly optimistic about the impact of emerging technologies to facilitate an unmediated "any device"/"any application" regime. For instance, the authors focus on software-based radios as an emerging technology that would permit adoption of their "any device" system. As we explained in our previous submission [ReedTripathi], this technology holds great promise, and service providers have adopted it to a certain extent for base stations; however, the development of this technology is still at a very early stage. Issues related to RF circuits, certification, tamper-resistance, and increased power consumption, among others, need to be resolved for software-defined radio to become common place for handsets. Furthermore, reducing the cost to be comparable to Application Specific Integrated Circuit solutions will take some time. Requiring wireless operators to accept software-defined radio solutions today, on an unmanaged basis and with no cost consideration, would risk major disruptions in service performance and would inhibit development of new devices and applications.

Technologies such as MIMO are also promising and have been endorsed by service providers for LTE; yet, this is not a panacea either. The performance of this approach greatly depends on the dynamics of the radio environment. Depending on the location, MIMO may provide important capacity gains but will require time before it becomes widely deployed. We will need many more years to learn how to deploy it most effectively. Network operators embrace new technologies, but it takes time between when these technologies are proposed as standards and when they can be adopted by service providers in the real world due to availability, cost and gaining sufficient experience to deploy effectively.

The Afflerbach and DeHaven paper suggests that the emergence of 4G technologies such as LTE and WiMAX will solve the “congestion” problem in wireless networks and that operators can no longer consider congestion as a problem that hinders implementation of any regulations. This argument is based on the false premise that network operators can shift entirely to 4G technologies in a short time frame and discontinue devoting resources to legacy 3G and 2G services. In fact, deployment of such technologies is only just beginning, and, because network operators have a significant number of customers with 3G and 2G devices, it will be necessary to continue devoting significant network resources to those older technologies for many years to come (otherwise millions of legacy customers would find their equipment inoperable).

In any event, although development of new spectrally efficient technologies such as LTE and WiMAX will undoubtedly help wireless operators provide a better experience to many users, even with advanced 4G technologies, wireless spectrum capacity is still expected to be a severe constraint. Furthermore, the actually achievable capacity or bandwidth in a sector/cell of a wireless network is not constant; it varies as a function of numerous factors such as radio channel conditions, geographical distribution of users, number of active users, number and types of user applications, user mobility, amount of available radio resources, network configuration of the operator (*e.g.*, 5 MHz spectrum bandwidth versus 20 MHz spectrum bandwidth) and designs of radio resource management algorithms. Hence, while theoretical peak capacity of 4G technologies may appear to be quite high relative to legacy generations, actual real world performance can be very different. Finally, data traffic in wireless networks is growing much faster than technology improvements in spectral efficiency. Capacities of current and 4G technologies are still going to be inadequate to meet the needs of ever-growing IP traffic. In fact, the increasing availability and capabilities of multimedia devices could make wireless resources scarcer in the future than they are today. Thus, contrary to Afflerbach and DeHaven’s suggestions, congestion and other performance issues will always present significant challenges in operating wireless networks.

3. Problems with the “Any Application” Proposals

Afflerbach and DeHaven envision an “any application” environment in which network operators would be prohibited from applying differential traffic handling techniques to applications with different performance needs.

> “To the extent that consumers value having certain applications prioritized, carriers can define premium service tiers, for voluntary purchase by subscribers, that guarantee a minimum data rate adequate for the application they value (such as voice-over-IP or broadcast-quality video). That is, the carrier would prioritize users, not applications or content, with demand-side price tiering” [Afflerbach_DeHaven].

Section 3.1 provides a brief introduction to the overall Afflerbach and DeHaven “any application” framework and lists some key problems associated with this framework. Section 3.2 dives into the details of the problems with the “any application” proposals.

3.1 The General Objection to an "Any Application" Environment

Afflerbach and DeHaven recognize several fundamental realities concerning modern wireless networks: (1) wireless networks are resource constrained, (2) congestion is inevitable, (3) capacity must be rationed to "to keep the networks functional" [Afflerbach_DeHaven], and (4) the need for congestion management is *increasing* as consumer use patterns shift to more data-intensive—often continuous, rather than bursty—wireless applications.

Yet they propose an "any application" requirement in which network operators would be prohibited from employing QoS management to prioritize traffic based upon participating applications' differing performance needs. We explained in our previous paper [ReedTripathi] the many reasons why QoS prioritization and other management techniques are absolutely essential in the wireless environment to provide a satisfactory customer experience. We briefly re-visit this issue and present our views on application and user prioritization.

3.2 Specific Problems with the "Any Application" Proposals

We summarize below our findings on various "any application" related proposals in the Afflerbach and DeHaven paper.

Definition of and Network Management in "Any Application" Environment

Afflerbach and DeHaven's "any application" proposal begins from the flawed premise that QoS prioritization means that non-prioritized applications *will* experience poorer performance than prioritized ones. In reality, different types of traffic have different tolerances for latency and jitter, and accommodating those differences need not result in discernible performance differences. For example, ensuring that real-time voice traffic receives priority handling in the event of congestion may have no perceptible adverse impact on the delivery of an email or a text message. Voice services can tolerate some errors but not delay, and email can tolerate delay but no errors. Hence, whenever possible, the network must differentiate among applications to provide the best possible user experience. In our original paper [ReedTripathi], we explained how a scheduling algorithm can implement differential traffic handling to benefit both end users and the network.

In our view, imposing any regulation that prohibits application differentiation would certainly degrade the user experience.

User- or Pricing-Based Prioritization as Network Management

The paper recommends achieving prioritization by using end-user pricing, and prohibiting application-based prioritization within the network. We agree that flexible tiered pricing arrangements for end users can play an important role in ensuring the efficient consumption of network resources, but that alone cannot solve all of the performance issues that network operators face today. We identify five basic principles about network management articulated by Afflerbach and DeHaven and find major problems with the proposals they base on those principles.

First, Afflerbach and DeHaven assert that network management should be closely tied to aggregate consumption because "…consumers who choose to use large amounts of bandwidth consciously make the choice to pay more than other users. This approach does not discriminate against particular uses of the service, whether by application or source or destination of the data." Although ensuring that the total amount of data consumed by users is priced in an economically rational manner is certainly an important objective, it is not the main challenge. Rather the key issue is delivering data in an appropriate and timely manner in order to optimize the user experience in an environment where users are running different applications and encountering different radio channel conditions and different levels of congestion in the network. Pricing alone cannot address these difficult technical challenges.

Second, Afflerbach and DeHaven claim that network operators can "[g]uarantee higher maximum speeds (higher rate limits) or a minimum level of guaranteed capacity to a particular user at all times, without prioritization of any particular traffic to or from that user..." [Afflerbach_DeHaven]. They argue that, "for example, in one feasible technical scenario under which carriers can enact technical measures for enhanced QoS for certain users without compromising the openness of the Internet, carriers would maintain a process by which customers (or, in theory, Internet-based service providers offering a special subscription option) can sign-up for guaranteed minimum QoS parameters for all of their traffic" [Afflerbach_DeHaven]. Contrary to this assertion, however, the mobile wireless environment is far too dynamic to permit absolute performance guarantees, including data rate guarantees. Notably, Afflerbach and DeHaven provide no real-world examples of network operators offering such performance guarantees.

Third, Afflerbach and DeHaven suggest that network operators should "allow a maximum allocation of total data transfers per user, and offer higher allocation to premium users" [Afflerbach_DeHaven]. As mentioned above, however, the absolute amount of data consumed is a useless metric for quantifying the user experience because it ignores the variability of network performance over any period of time. Performance-based metrics such as throughput (rate of data transfer), delay, and jitter are much more useful metrics for assessing service quality. If network resources are not being fully utilized at a given instant, no technical reason exists for blocking a "non-premium" user from accessing those resources. After all, the network operator is trying to provide the best possible experience to as many users as possible. The proposed approach would undoubtedly lead to customer dissatisfaction.

Fourth, Afflerbach and DeHaven state that network operators should "offer per-megabyte pricing for all data transfers and all users" [Afflerbach_DeHaven]. For some services, however, such as voice and interactive gaming, the aggregate amount of data transferred is an insignificant metric. Such applications, may have no need for high data rates but are very delay-sensitive. Hence, per-megabyte pricing cannot address all location- and time-specific congestion issues. Similarly, many specialized devices, such as eReaders (*e.g.,* the Kindle), personal navigation devices, wireless picture frames, and so on, are not overly data intensive and their manufacturers have built business models premised on consumers paying flat-rated fees or one-time charges for their wireless data connections. The same is true of many machine-to-machine devices and services, like smart meters. Afflerbach and DeHaven's mandatory per-megabyte pricing requirement would severely undermine the business case for these unquestionably pro-consumer devices.

Fifth, Afflerbach and DeHaven contend that congestion problems in the over-the-air wireless network can be solved through prioritization at the edge based upon customer preferences for price-differentiated service. According to Afflerbach and DeHaven, controlling the resource utilization by consumers through premium tiers of services (*i.e.*, "prioritize users, not applications or content" [Afflerbach_DeHaven]) can preserve network performance. However, this approach is flawed. When total demands on the network exceed capacity to meet the performance requirements of those users and applications, tiered pricing simply creates no more capacity. For example, if most users active in a particular congested cell site have chosen the premium tier or if only few are heavy users of continuous, data intensive applications, tiered pricing will not solve the congestion problem. Thus, while tiered pricing may have its place in the wireless marketplace, it is not a panacea for addressing network congestion.

Creating a network management algorithm that prioritizes the traffic of those customers that paid for the premium service would be possible but would be at best an incomplete solution to congestion and other performance issues. In fact, such prioritization would create numerous problems and dissatisfy customers. See the two cases illustrated in Figure 1.

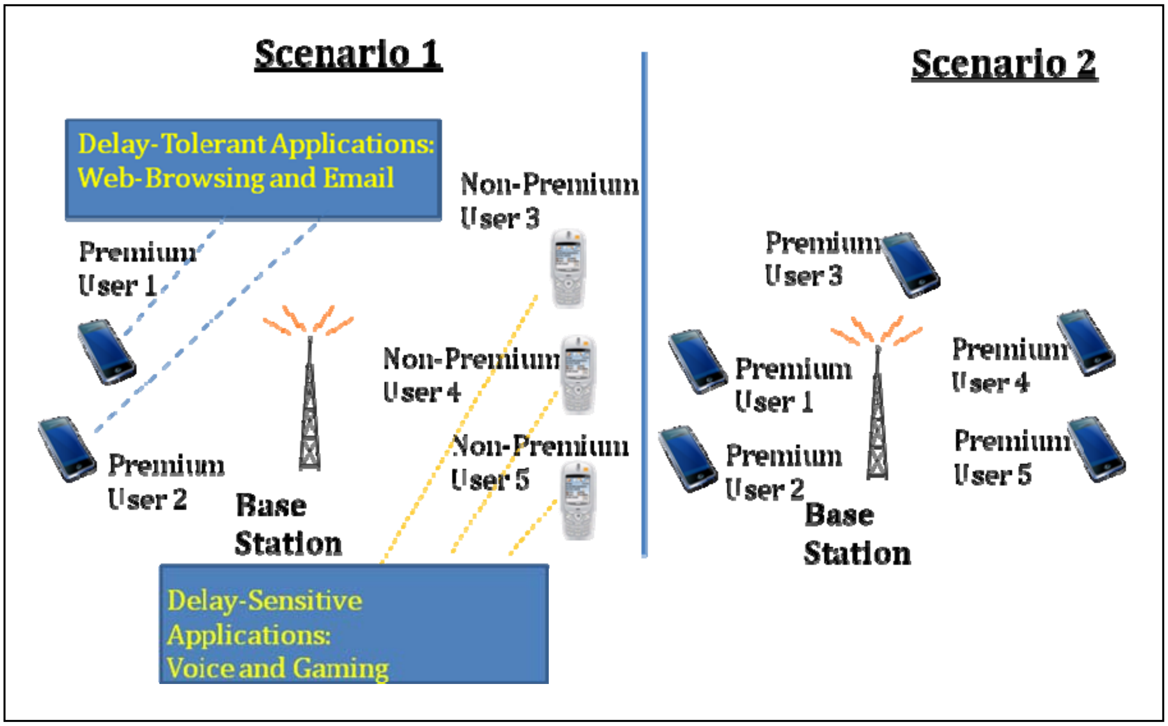

Figure 1. Operation of Use-Pricing-Based Network Management: Example Scenarios

Consider Scenario 1 in which User 1 and User 2 are premium subscribers and, at the relevant time of congestion, are using delay-tolerant services, such as e-mail and web-browsing. Users 3, 4, and 5 are non-premium subscribers. At the relevant time of congestion, however, Users 3, 4, and 5 are attempting to use real-time and delay-sensitive services, such as voice calls and interactive gaming. Afflerbach and DeHaven's approach would prioritize traffic for User 1 and User 2, severely degrading service for Users 3, 4, and 5. A high-performance scheduling strategy in such a case would take care of Users 3, 4, and 5 first and would use the remaining resources for premium subscribers 1 and 2 (or momentarily delay their transmissions). This approach would provide excellent QoS to Users 3, 4, and 5 with no noticeable degradation to User 1 and User 2. As we discussed at length in [ReedTripathi], network management should focus on QoS requirements for different applications which yields benefits for all users on average.

Now, consider Scenario 2, where a cell at a particular point in time (a time of congestion) is populated entirely by premium subscribers, User 1 through User 5, using different applications. Assuming that they belong to the same "tier" of services, which user should get priority? User pricing-based network management would break down in such a case, because the network would not be able to address the congestion experienced by all of these "equal-priority" users in a way that accounted for their needs. In the dynamic radio environment, congestion problems like these would arise very frequently, and reliance solely upon user pricing to ration scarce resources would seriously degrade the consumer wireless experience.

We also object to the suggestion that the basic concept of statistical multiplexing in cellular trunking, which the paper calls "oversubscription," is in some way deceptive to consumers. Statistical multiplexing is a time tested, mathematically and empirically proven and quite common way to share resources among many users in a fair way and has been a basic approach in telephone systems since their creation.

In our view, the nature of wireless systems and the unpredictability of data traffic would make it nearly impossible to have a sustainable business case without some degree of so-called "over-provisioning." The alternative—dedicated wireless resources for every user even when they are not active—is entirely impractical.

There is no free lunch, but to reduce the cost of the lunch, the lunch should be made at the lowest possible cost and with greatest efficiency. Sole reliance upon consumer pricing-based prioritization would reduce efficiency and ultimately cost the consumer more.

IP-Based Network Management at the Network Core: Not a Substitute for Radio Network Management

Afflerbach and DeHaven incorrectly state that management at the edge or at the core can be equally effective. Network management mechanisms are significantly different within the radio network and the core network. The core network relies upon IP-based mechanisms, such as Differentiated Services for QoS, and the radio network uses a variety of complex resource management algorithms, such as a scheduling algorithm, a call admission control algorithm, a handover algorithm, and a power control algorithm. Sole reliance on IP-based mechanisms without any radio resource management would have an unimaginably adverse impact on network performance and user experience.

The paper also implies that because the commonly used Transmission Control Protocol (TCP) is designed automatically to adjust the data rate of the end-user devices when congestion is perceived, a network operator could establish an artificial choke point in the core network to effectively control transmission speed. Afflerbach and DeHaven provide no real-world examples of a network operator having done so. Moreover, artificially creating congestion to induce a congestion avoidance response from TCP would disrupt the proper functioning of the radio access network, thus harming all users of the network. Furthermore, some applications such as VoIP may use UDP instead of TCP, and UDP does not have the congestion control capabilities that TCP has.

Transparency and Verifiability in an "Any Application" environment

The Afflerbach and DeHaven paper suggests that a new bureaucracy is needed to investigate and "audit" wireless network operators and verify their network management practices, and that there should be broad public disclosures of technical details of each operator's network management algorithms. There are many problems with these proposals.

The paper recommends audit and verification of network management practices by third parties with unrestricted access. First, wireless network management is extraordinarily complex and dynamic, involving numerous algorithms and parameters that can respond to widely varying cell site conditions, which creates immense logistical problems for uniform verification and auditing procedures. Second, wireless standards, devices, and networks are constantly evolving, resulting in never-ending re-verification. Third, many such algorithms are proprietary, and auditors would observe different results for the same set of prevailing test conditions when an operator uses equipment from different network vendors. Fourth, inserting third-party controlled portals into the network could jeopardize security of the links used for testing the operator's network elements. Fifth, mere observation of network operator practices and parameter settings would be inadequate; extensive testing procedures would need to be created, defined, and tailored to varying implementations of different algorithms. Sixth, judging whether these algorithms' actions at any particular place or time comply with whatever standards might be established would be nearly impossible due to significant variations in wireless network performance.

Quantifying baseline performance in a wireless network is a moving target. In our view, the audit proposal is technically naïve, would almost certainly provide no tangible benefits to consumers, and contemplates a level of testing that far exceeds the FCC's or any third party's capabilities. We wholeheartedly approve of third-party, non-mandatory system performance evaluations, and *Consumer Reports*, *PC Magazine*, and other publications and groups perform this function. Individual consumers can also use open-source tools to measure the performance of their connections. However, establishing a new bureaucracy to test and monitor wireless networks would be contentious, controversial, time-consuming, and costly with no tangible benefit.

Afflerbach and DeHaven suggest that full disclosure of network management practices is necessary for consumers to make informed choices. We agree that consumers should have meaningful information about the capabilities and limitations of competing wireless services in terms that they can understand, but we see no reason for network operators to disclose highly technical details of their network management practices. As we have discussed, network management in wireless networks is extraordinarily complex and multiple algorithms work in parallel to address different aspects of network management. Many such algorithms are non-standardized, vendor-specific, and continuously re-designed. Revealing these algorithms could jeopardize network owners' intellectual property; network owners make heavy R&D investments to design such algorithms. Security could also be compromised if critical network management details are disclosed. Disclosing the technical details of highly complex algorithms would provide no usable information for most consumers but would certainly be of great interest to other network operators looking to gain competitive advantage as well as to others with far more malicious intentions.

4. Conclusion

Andrew Afflerbach and Matthew DeHaven have presented arguments in favor of the FCC adopting strict and inflexible "any device" and "any application" rules. We find that the Afflerbach and DeHaven proposals are misguided, greatly over-simplify and misconceive the key issues related to wireless capacity and wireless network management, and would affirmatively harm consumers. Their proposals would require radical changes in network and handset design and management without any supporting simulation or any analytical or experimental evidence that these proposals will actually work. Afflerbach and DeHaven have also failed to confront the numerous real-world technical challenges highlighted in [ReedTripathi]. As we explained there, keeping wireless networks free from unnecessary regulations will facilitate innovation and investment in wireless networks to the benefit of both wireless consumers and the wireless industry.

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