

**WIRELESS BROADBAND TECHNOLOGY DECLARATION  
TIA REPLY COMMENTS – OPEN INTERNET DOCKET**

## **1 Introduction**

My name is Matt Grob. I am a Senior Vice President of QUALCOMM Incorporated (“Qualcomm”), and I lead Corporate Research & Development at Qualcomm. I joined Qualcomm in August 1991 and since then, I have worked in a variety of engineering positions in the Company working on various wireless communications technologies.

Qualcomm is a world leader in developing innovative digital wireless communications technologies and enabling products and services based on the technologies that it develops. Qualcomm is the pioneer of code division multiple access (“CDMA”) technology, which is utilized in the 3G CDMA family of wireless technologies. These technologies include CDMA2000 and HSPA/WCDMA, which are used in today’s 3G wireless networks and devices to provide ubiquitous, wide area high speed mobile broadband service across the United States and around the world. In addition, Qualcomm is deeply involved in the development and launching of the Long Term Evolution (“LTE”) technology, which many carriers in the US and around the world are in the midst of deploying.

In fiscal 2009 alone, Qualcomm spent a total of \$2.4 billion, or approximately 23% of its revenues, on all of our Company-wide research and development activities. This enormous funding of research and development enables Qualcomm to continue to invent many of the technologies that are fueling the mobile broadband boom. Today, Qualcomm holds or has applied for approximately 11,600 U.S. patents (3,600 issued and 8,000 pending) and 54,100 foreign patents (18,500 issued and 35,600 pending). Every division and subsidiary of Qualcomm has multiple research and development teams working on projects which will hopefully lead to patentable inventions. In particular, the Corporate Research and Development Group that I lead has research centers in San Diego, Silicon Valley, and other offices and labs in the U.S. and abroad.

### **1.1 Overview of Declaration**

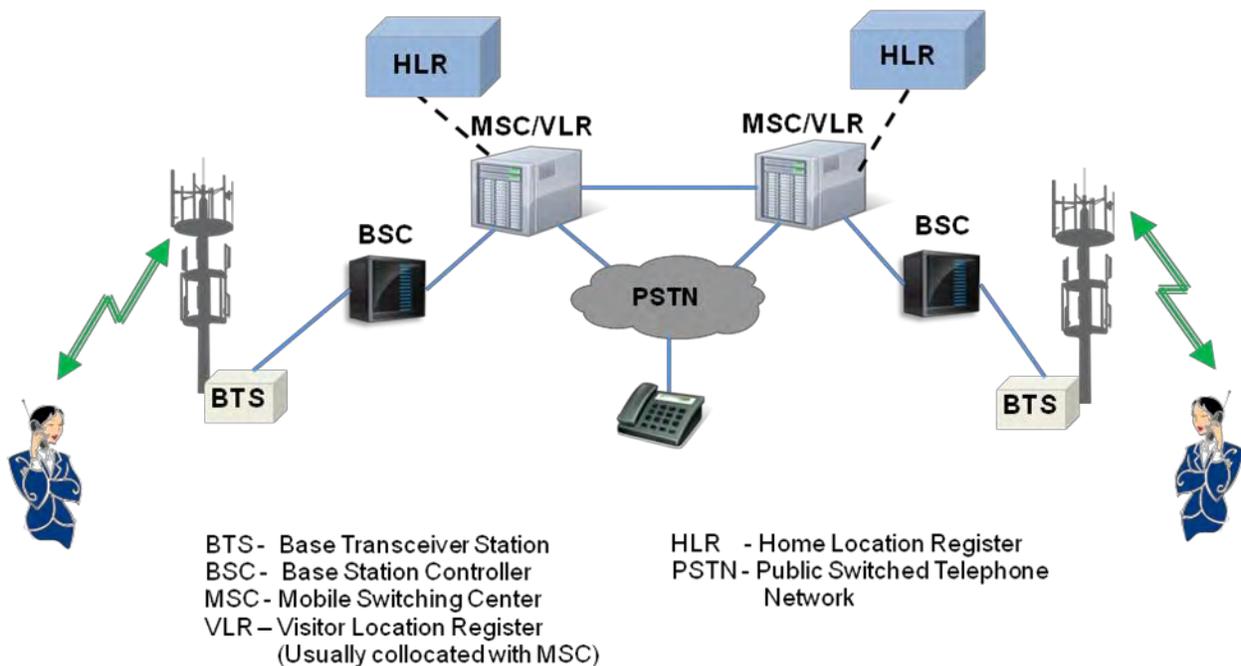
I am submitting this declaration to provide the Commission with information on wide area wireless technologies, such as 3G and LTE, in connection with the Commission’s Open Internet proceeding. My declaration proceeds in five parts. First, the declaration addresses the architecture of wireless networks and the history of mobile broadband technologies. As described herein, there have been continuous efforts to innovate and enhance mobile broadband technologies in the face of bandwidth limitations. Next, the declaration discusses the exponential growth in mobile data usage and the challenges that such growth presents to the wireless ecosystem. The declaration then describes the inherent bandwidth and capacity challenges of wireless networks. This section details both the efforts that have been undertaken to optimize the capacity and spectral efficiency of mobile broadband systems as well as the fundamental tension between available spectrum and wireless network capacity. The declaration next outlines the economic and technical measures that wireless operators have had to employ in

order to encourage bandwidth conservation. Finally, the Declaration recaps how the Commission’s proposed rules would impact wireless broadband network deployment and restrict providers’ ability to implement necessary network management tools and techniques. In sum, wireless broadband network providers require the utmost flexibility in network management given the evolving and rapidly rising demands of consumers.

## 2 Wireless Broadband Network Basics

### 2.1 Network Architecture / Voice Call Flow Diagram

#### Wireless Voice Call Flow Diagram



A flow diagram of the key network elements that are used to complete a wireless voice call is shown above. In a typical cellular wireless system, geographic areas are divided into cell sites, each of which is served by a base transceiver station (“BTS”). To complete a call, a wireless user connects to the local BTS, which interfaces to the Mobile Switching Center (“MSC”) via a Base Station Controller (“BSC”).

A BSC together with its base stations comprises a base station system. The BSC contains switch functionality to support handover, cell configuration, and control of RF power levels in the base stations. In this way, the BSC provides the control functions and physical links between the MSC and the BTS.

The MSC manages the routing of wireless calls and it serves as a gateway to the Internet. When routing a voice call, the MSC first determines whether the called party is served via a wireline or a wireless connection. To connect to a wireline user, the MSC interfaces with the Public

Switched Telephone Network (“PSTN”); to connect to another wireless user, the call may be routed directly to another MSC or use the PSTN.

In order to meet the growing user demand and support increased capacity in the face of bandwidth limitations, network providers implement a variety of technical tools, including those detailed in the remainder of this declaration.

## **2.2 Improving Mobile Broadband Technologies in the Face of Bandwidth Limitations**

As operators began deploying the first mobile broadband networks and technologies, EV-DO and HSPA in its initial forms—EV-DO Release 0 and HSDPA—Qualcomm, along with the vast ecosystem of manufacturers who develop and support these technologies, was simultaneously working on upgrades to these mobile broadband technologies. There is a constant and never-ending drive to enhance these technologies in the face of bandwidth limitations, which continues to the present and shows no sign of slowing down into the future. The networks rapidly migrated to the first upgrade—EV-DO Revision A and HSUPA, which presently is widely deployed throughout the United States.

Today, Verizon Wireless, Sprint, and others provide mobile broadband service via EV-DO Revision A, which supports peak data speeds of 3.1 Mbps on the downlink and 1.8 Mbps on the uplink. Likewise, AT&T upgraded to HSUPA, which will support peak data speeds of up to 1.8 Mbps to 5.6 Mbps on the uplink, and is already working on the upgrade of its HSPA network to support peak downlink speeds of 7.2 Mbps. Likewise, T-Mobile USA is moving forward rapidly with its HSPA deployment on the AWS-1 spectrum. The EV-DO and HSPA technologies are not standing still. Both EV-DO and HSPA technology are being enhanced substantially, and these enhancements will all be backwards compatible with prior versions of the technology.

The next upgrades to EV-DO and HSPA will result in dramatically faster data rates. EV-DO Revision B enables the aggregation of three 1.25 MHz EV-DO carriers in one 5 MHz channel. In its Phase I, EV-DO Rev. B will support downloads at a peak rate of 9.3 Mbps and eventually, in Phase II, at 14.7 Mbps, while supporting uploads at up to 5.4 Mbps. This technology will undergo an additional upgrade, now known as EV-DO Advanced, which, if implemented with four carriers, will support downloads of up to 19.6 Mbps and uploads of 12.4 Mbps. The net result of these upgrades to CDMA2000 will be wireless broadband service with data rates that are up to five times faster than what today’s fastest EV-DO-based networks can achieve.

Likewise, there are substantial upgrades for HSPA technology on its roadmap. The initial version of the technology known as HSPA+ (also called HSPA Evolved—HSPA Release 7) will support peak downloads of 28 Mbps and uploads of 11 Mbps. Future release of HSPA, Release 8, will increase the peak downlink speeds to 42 Mbps in 10 MHz of adjacent spectrum. Release 9 allows 42 Mbps across multiple bands and also allows peak rates to increase to 84 Mbps. In addition, Release 10, which is now in development, is expected to allow more flexibility for operators and also to increase the peak rates to up-to 168 Mbps.

Moreover, Qualcomm and many other vendors around the world are working on LTE, an OFDM-based technology, which achieves higher data rates and is optimized for wider

bandwidths. This technology is not backwards compatible with other air interfaces, but Qualcomm is developing multi-mode chips that will support both 3G and LTE.

These mobile broadband technologies are not limited to terrestrial wireless networks. Last year, Qualcomm announced that it would develop a satellite-based variant of EV-DO Revision A, known as S-DO, which will be included in the firmware of select Qualcomm multi-mode chips, thereby integrating satellite and cellular technology for use pursuant to the Commission's ATC (ancillary terrestrial component) rules.

It is important to note that data rates, by themselves, only deal with one aspect of user experience. Latency is another important factor in any broadband network, including mobile broadband networks. Indeed, consistently low latency is also critically important to the user experience, especially for applications such as web browsing or others which involve a high degree of interactivity. Rate and latency are effectively a unified concept in broadband networks.

Stated differently, whether a network appears slow while web browsing because the underlying data rate is slow or because of a latency issue is irrelevant to a broadband user. Driving network upgrades to achieve the fastest possible data rates in mobile broadband networks is a worthwhile goal, but increases in data rates alone, especially those which might only occur in a small percentage of a given network's coverage and/or traffic, do not dramatically improve user experience unless latency is also improved. As a result, improving latency on wireless networks is another important aspect of Qualcomm's research and development efforts.

Of course, speed and latency should be viewed separately from the overarching concept of network capacity. Without sufficient capacity, the user experience will also suffer. And, as described in greater detail in section 4, wireless network capacity is inherently limited by the finite amount of spectrum available. Thus, it is incumbent on mobile broadband providers to vigorously manage their networks to ensure that capacity is allocated to the benefit of the most customers possible. Although Qualcomm has substantial research and development efforts dedicated to addressing new techniques to gain more capacity from currently available spectrum, at the end of the day, having additional spectrum available is critically important to addressing capacity constraints.

### **3 The Exponential Growth in Mobile Data Usage**

The wireless industry is experiencing exponential growth in mobile data usage, which is greatly straining wireless networks. Mobile broadband providers require high levels of flexibility in order to properly support a variety of network technologies and user demands.

ABI Research now projects that monthly worldwide mobile data traffic in 2014 will exceed the total for all of 2008. See "Report: 2014 Monthly Wireless Data Traffic to Exceed Total for 2008," Wireless Week, August 4, 2009. 1.3 exabytes were sent and received on global mobile networks during 2008, and by 2014, the data sent and received each month on mobile networks will be 1.6 exabytes.

Wireless providers in the U.S. also have reported a very rapid rise in the use of mobile phones to access the Internet in recent years; mobile data demand could outstrip network capacity as early as 2011 or 2012. See, e.g., Ruth Bender and Gustav Sandstrom, “Wireless Carriers Refine 4G Technology,” Wall Street Journal (Mar. 9, 2010). The Pew Research Center found in April 2009 that usage of mobile devices to access the Internet had grown 73% from their prior study, which was completed just 16 months earlier. The April 2009 study found that on a typical day, approximately 19% of all Americans use the Internet on a mobile device. See Wireless Internet Use, July 22, 2009, at [www.pewinternet.org/Reports/2009/12-Wireless-Internet-Use.aspx](http://www.pewinternet.org/Reports/2009/12-Wireless-Internet-Use.aspx). In the second quarter of 2009, smartphone sales grew by 47% year-over-year. See “U.S. Smartphone Sales Grew by 47% in Q2,” August 19, 2009, available at <http://www.fiercewireless.com/story/u-s-smartphone-sales-grow-47-q2/2009-08-19xt>.

This growth also can be seen with respect to the usage of particular devices. For example, Amazon announced that on December 25<sup>th</sup>, more customers purchased Kindle books than physical books, and the Kindle is the most gifted item in the history of Amazon. See “Amazon Kindle Is the Most Gifted Item Ever on Amazon.com,” December 26, 2009, at <http://phx.corporate-net/phoenix.zhtml?c=176060&p=irolewsArticle&ID=1369429&highlight=>. In the case of books offered on both the Kindle and on Amazon’s website, Kindle sales are now 48% of the total, up from 35% in May, a much faster growth rate than Amazon expected. See “New Amazon Kindle to Download Books Beyond U.S.,” October 7, 2009, New York Times, available at <http://www.nytimes.com/2009/10/07/technology/companies/07amazon.html>.

Finally, with respect to wireless applications, the rate of growth in usage is staggering. For example, as of October 2009, Facebook had 65 million mobile users. One year earlier, Facebook had only 6 million mobile users. See “Marketers Salivating Over Smartphone Potential,” October 21, 2009, [http://www.usatoday.com/tech/news/2009-10-20-social-network-smartphone\\_N.htm](http://www.usatoday.com/tech/news/2009-10-20-social-network-smartphone_N.htm). Nielsen projected that the number of people who use social networks from smartphones grew in July 2009 was 187% more than those who did so in July 2008. Id. In June 2009, YouTube reported that uploads from mobile phones grew by 1700% during the first six months of the year.

In short, the growth in mobile usage in the United States has been, and continues to be, enormous. As explained below, network congestion management techniques are essential to addressing this exponential growth as well as constantly changing traffic patterns across networks.

## **4 Bandwidth and Capacity Limitations of Wireless Networks**

### **4.1 The Reality of Spectrum Availability**

Wireless network operators – which necessarily operate on licensed spectrum – cannot simply add bandwidth on an as needed basis. Licensed spectrum is limited in availability. Moreover, if a wireless network becomes congested in a given geographic area, the operator may not hold rights to any more spectrum in the area. Even if the operator does have available spectrum in the area, the operator cannot just add capacity instantly. Rather, wireless operators invest billions of

dollars each year on the costly, time consuming process of expanding wireless coverage and capacity where they do have spectrum.

When wireless networks migrated from analog to 2G digital air interfaces and then again from 2G to 3G, the networks were able to make large gains in capacity (upwards of 20 to 30 times the original analog capacity). But, today, the speed of an individual wireless radio link is approaching the theoretical limit. Vast gains in capacity are no longer technologically possible simply through deployment of a new air interface. Accordingly, the gains in capacity by migrating a 3G network to an enhanced 3G air interface or by deploying LTE are marginal when compared to the enormous gains achieved from the analog to digital and 2G to 3G migrations.

Wireless network capacity is inherently limited by the finite amount of spectrum on which the networks operate (which ultimately is a regulated input) and the theoretical limit of an individual radio link (to which we currently are quite close). These factors explain why there is now, and will continue to be until considerable amounts of additional spectrum are made available, a wireless bandwidth shortage. New spectrum is part of the solution, but it cannot be made available to operators overnight. Rather, the process of identifying, allocating, and auctioning new spectrum can take a decade or longer. As a result, wireless operators require absolute flexibility to manage their networks in light of spectrum and bandwidth limitations. Without this flexibility, the experience for all users will suffer.

#### **4.2 Wireless Broadband Network Management Techniques**

Wireless broadband service providers engage in network management techniques in order to provide particular quality of service levels required by end users. In contrast to wireline services, network management in the wireless broadband context is especially critical and particularly challenging because there is a limited amount of spectrum that must be used by the entire population of users, each of whom may be located anywhere. Also, the wireless channel for each user is affected by RF interference, multipath, and channel blockage. These impairments, which vary by location and occur randomly, introduce added complexity and variability in the wireless broadband context and require service providers to implement a variety of tools in order to provide the best service to the greatest number of users.

For these reasons, wireless broadband network management is an extraordinarily complex undertaking that requires very high levels of flexibility. Operators use sophisticated queuing and scheduling algorithms in order to optimize throughput and operate the network efficiently. In addition, different wireless providers have different views as to the best approach, and the best approach will vary depending upon the network configuration, user location, and user equipment, among other things.

At Qualcomm, we are working on facilitating measures that the wireless operators can implement to encourage the conservation of scarce wireless bandwidth. Technically, the 3G and LTE technologies will support different qualities of service for different applications based on their respective needs for bandwidth. This allows operators to provide more bandwidth for those applications that require it, and less for those that do not. For example, some applications do not require low latency and others will fail without it. The technology exists to allow operators to

distinguish between such applications to provide in real time the bandwidth that is necessary and appropriate for each given application, ensuring that all subscribers on a wireless network are accorded an appropriate, acceptable quality of service. We believe that the Commission should allow wireless operators the flexibility to implement current measures and future advances that enable the efficient use of scarce wireless bandwidth.

### **4.3 Technical Approaches**

*Power Control.* Mobile broadband systems employ power control to optimize their spectral efficiency. For example, the power control inherent in CDMA-based networks and mobiles ensures that each mobile always transmits just enough power to provide acceptable call quality. On the return link, CDMA base stations constantly measure the error rate performance from each mobile transmitting a signal, and, depending on whether the error rate is trending above or below an adequate performance level, the power control circuit makes adjustments to the signal to noise ratio. A base station function measures the actual signal to noise ratio and compares it to the target, and if the actual ratio is too high or too low, an “up power” or “down power” command is sent to the mobile, which responds by increasing or decreasing its power in 1 dB increments. All of this occurs approximately 1,000 times per second at each base station and for each operating mobile.

The mobile continuously measures the received signal level of the base station signal, averaged over a relatively long time interval, but with a very large dynamic range (about 80 dB). These measurements are used to set the mobile transmit power at approximately the optimal level over this very large dynamic range. The base station commands, which have a much smaller range, are transmitted much faster.

*Vocoders.* CDMA-based mobiles also have variable rate vocoders that vary the data rate over an 8 to 1 range since lower power can be used for lower data rates. This permits the mobile to adjust the power on a frame by frame basis (20 milliseconds) based on the varying data rate.

*Strength of Signal.* For soft handoff between base stations, the relative strength of nearby base stations is continuously monitored. Although multiple base stations communicating with a mobile try to control the mobile’s power, the mobile pays attention to the one asking for the lowest power. CDMA employs powerful forward error correction coding and efficient modulation so that the signal to noise ratios are very low – approaching the Shannon theoretical limits. All these features ensure that CDMA-based networks and mobiles operate at the most efficient levels. OFDMA-based networks use similar techniques to achieve the same result.

*Spectrum Capacity.* The latest enhanced 3G technologies, such as multi-carrier HSPA and EV-DO Rev. B as well as LTE, achieve higher data rates by using more spectrum. The availability of suitable spectrum for these networks is limited both inherently (only spectrum up to 3 GHz is suitable technically and economically for wide area wireless networks) and as a result of regulation (most of the suitable spectrum is allocated for other uses).

#### **4.4 Efforts to Gain More Capacity for Today and Tomorrow**

Qualcomm and its partners are dedicating substantial research and development efforts on new techniques to gain more capacity for wireless networks.

*Interference Cancellation.* Qualcomm and its partners have developed: (1) interference cancellation in base stations and handsets, for both the downlink and uplink; (2) software and hardware upgrades that comprise 1X-Advanced, DO-Advanced, (3) LTE-Advanced, which will increase voice capacity; and (4) MIMO and other smart antenna technologies, which can also increase overall wireless network capacity. As important as these techniques are, the capacity gains they produce will only be marginal if mobile broadband usage continues to grow at the current, exponential rate.

*Femtocells and picocells.* The biggest technological challenge faced in wireless networks is to improve the capacity and performance on the uplink and downlink. Qualcomm and its partners also are working on enabling the use of a denser wireless network topology based on the widespread deployment of femtocells and picocells to achieve greater frequency reuse. Such a topology would increase uplink and downlink capacity and performance and, indeed, overall capacity and performance by offloading traffic from the macro-cellular network to the much smaller radius femtocells and pico cells. But, in order to achieve capacity gains in a wireless network across a wide area (such as a city or even a town), large numbers of these femtocells and picocells will have to be deployed on a home-by-home, office-by-office basis. Qualcomm is working hard to enable such deployments, but again, our concern is that the growth in mobile usage may well continue to accelerate at a pace that will outstrip the capacity gains eventually achieved once a massive deployment of femtocells and picocells is completed.

*Traffic Offloading.* In addition, Qualcomm has several initiatives under way to enable wireless operators to offload certain traffic from their wide area wireless networks, thereby gaining some capacity, and to improve performance in local areas, such as inside the home or office. First, as already noted, femtocells can serve this purpose. Femtocells use a non-3G (i.e., wireline) connection for backhaul and offload traffic from an operator's macro-cellular network. Qualcomm's femtocell solutions will enable operators to avoid interference between the femtos and the macro cells within a given network.

Second, Qualcomm is developing 3G-based repeaters. Unlike femtos, the repeaters will not offload traffic, but they will substantially improve performance indoors, will not require any new spectrum or backhaul, and will not need to be upgraded when the operator deploys an air interface upgrade since the repeater simply repeats the signal it receives. Operators will be able to monitor and control the repeaters at all times, remotely.

Third, Qualcomm's solutions will support the offloading of traffic onto Wi-Fi. These solutions permit wireless operators to leverage the installed base of Wi-Fi access points. We are working on enabling seamless handoff between cellular networks and Wi-Fi access points to ensure a high quality user experience.

Fourth, Qualcomm's FLO TV mobile broadcast network today delivers one-way mobile video and, in the future, may deliver one-way data on a point to multipoint basis. By using FLO to broadcast video or data of interest to large numbers of users, the traffic need not take up capacity on the macro-cellular, unicast networks.

*Summary.* We believe that all of these techniques for offloading traffic and improving indoor performance are important tools as operators strive to avoid short-term network congestion and to improve the experience for consumers using wireless devices in record number. However, if usage continues to double on an annual basis, even with the capacity enhancement techniques described herein, wireless operators are going to face an extreme capacity crunch. Moreover, while these capacity enhancing techniques are being refined, commercialized, and deployed on a mass scale, the increase in the usage of wireless networks is not likely to subside.

## **5 Economic and Technical Measures to Conserve Bandwidth**

The confluence of the two major factors described above, namely the exponential growth in mobile broadband usage combined with the inherently limited bandwidth on which wireless networks must operate, means that wireless operators must use both economic as well as technical measures to encourage the conservation of scarce wireless bandwidth. It is important to note that wireless network operators have both the incentives and the ability to encourage bandwidth conservation because of existing capacity demands on the network. This is clearly demonstrated today with respect to voice service. Cellular voice has been optimized to use as little bandwidth as possible so that operators can use as much bandwidth as possible for value-added, data applications, whereas non-cellular voice (i.e, VoIP) application developers do not have any corresponding incentive to conserve bandwidth. As a result, internet VoIP applications, even with their own optimization, are using roughly five to ten times more bandwidth than cellular voice.

Economically, Qualcomm is working on enabling the widespread use of so-called sponsored connectivity. In this business model, cellular-embedded devices, including e-readers, tablets, smartbooks, and others, would be sold without any data plan, and third party content owners and service providers would sell content and services to consumers owning the devices. This business model, which Amazon and others are implementing today, is pro-consumer, for many consumers may not want to pay for Internet access as such for these devices, and it will encourage bandwidth conservation as it allows consumers to buy the particular content or services they want without forcing them to buy an "all you can eat" access plan, which by its very nature encourages bandwidth use.

## **6 Potential Implications of Proposed Rulemaking**

If implemented as proposed, the Commission's principles will have a detrimental impact on wireless broadband service providers' ability to manage their networks and it will stymie both existing and future innovative business models. Wireless broadband providers use network management techniques – which are constantly evolving– in order to provide the level of service demanded by a broad spectrum of customers and other users. FCC regulation that restricts providers to "reasonable network management" practices necessarily introduces uncertainty and

will undermine the providers' ability to best serve customers. In view of the current strain on wireless broadband networks, providers will continue to need the utmost flexibility without fear of government sanctions. Any such regulation will limit providers' ability to implement new practices and network management tools for they will be fearful of making a choice that the Commission may deem "unreasonable."

When it comes to network management tools, there is no set menu of tools that carriers look to implement. The congestion management techniques that carriers use are constantly changing and evolving. In addition, each carrier takes a different approach to network management, which depends upon the network configuration and deployed service (which vary on a customer-by-customer basis), as well as end-user demands, equipment, and location. Therefore, the proposed regulations will inhibit advances in management techniques and have direct, unintended, and likely harmful consequences upon wireless broadband service deployments, applications, devices, and innovative business models.