DIS-EMPOWERING USERS VS. MAINTAINING INTERNET FREEDOM: NETWORK MANAGEMENT AND QUALITY OF SERVICE (QOS)

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I. INTRODUCTION

The investigation by the Federal Communications Commission ("FCC" or "Commission") of Comcast's network management practices regarding traffic from BitTorrent applications prompted an intense debate regarding the extent to which Internet Service Providers ("ISPs") can manage traffic over their networks.[1] Although the Commission found that Comcast's interference with BitTorrent was unreasonable, it declined to prescribe specific rules or guidelines for reasonable network management practices or prohibit ISPs from engaging in practices that discriminate against particular Internet applications, content, or technologies.[2] While the ruling signaled that explicit blocking of applica-

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1 *See, e.g.*, Declan McCullagh, *FCC Formally Rules Comcast's Throttling of BitTorrent Was Illegal*, CNET NEWS, Aug. 1, 2008, http://news.cnet.com/8301-13578_3-10004508-38.html. The article notes the likelihood of court challenges, as well as the "unusually pointed dissent" of Commissioner Robert McDowell, who "said the order would invite far more extensive FCC regulation of the Internet, with the rules varying by which political party controls the White House." *Id.*

2 *See In re* Formal Complaint of Free Press and Public Knowledge Against Comcast Corporation for Secretly Degrading Peer-to-Peer Applications; Broadband Industry Practices, Petition of Free Press et al. for Declaratory Ruling that Degrading an Internet Application Violates the FCC's Internet Policy Statement and Does Not Meet an Exception for "Reasonable Network Management," *Memorandum Opinion and Order*, 23 F.C.C.R. 13,046 at ¶ 32 (Aug. 1, 2008) [hereinafter *Comcast P2P Order*] ("Deciding to establish policy through adjudicating particular disputes rather than imposing broad, prophylactic rules

tions was an unacceptable practice, it provided ISPs with considerable latitude to manage traffic across their networks. In this regulatory vacuum, ISPs have implemented substantially different network management systems and practices. First, in response to the FCC's decision, Comcast announced it was implementing a non-standard network management system that would deprioritize the traffic of bandwidth intensive users when the network was in a congested state.[3] Then Cox Communications announced it was testing a new method for managing traffic in times of congestion that would prioritize "time-sensitive" Internet traffic such as Web pages, voice calls and streaming video, while delaying what it determined to be non-time sensitive traffic such as file uploads and peer-to-peer ("P2P") activity.[4] Most recently, Time Warner amended its subscriber's agreement to permit the company to use network management tools to suspend or reduce a subscriber's throughput rate to ensure that its service operates efficiently.[5]

As Internet traffic continues to increase and consumers access applications and content that demand more and more bandwidth from their broadband connection, some ISPs argue their networks are becoming increasingly congested—creating a need for network management or quality of service ("QoS") mechanisms to limit subscriber's usage or prioritize certain traffic.[6] On the surface, such mechanisms appear like a benign attempt by ISPs to assure the quality of certain applications and improve their customers' experience on the network. However, the focus on network management obscures a fundamental problem with the majority of residential broadband networks: some ISPs have excessively oversold their broadband services—promising unrealistic speeds given the capacity limitations of the networks.[7]

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comports with our policy of proceeding with restraint in this area at this time.").

3 *See* Letter from Kathryn A. Zachem, Vice President, Regulatory Affairs, Comcast Corp., to Ms. Marlene H. Dortch, Sec'y, Fed. Commc'ns Comm'n, File No. EB-08-IH-1518, WC Docket No. 07-52, at 1-2 (Jan. 5, 2009), *available at* http://fjallfoss.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6520192552.

4 Peter Svensson, *Cox to Test New Way to Handle Internet Congestion*, FOXNEWS.COM, Jan. 28, 2009, http://www.foxnews.com/wires/2009Jan28/0,4670,TECCoxInternet,00.html.

5 K.C. Jones, *Time Warner Under Fire For New Terms Of Service*, INFORMATION WEEK, June 2, 2009, http://www.informationweek.com/news/showArticle.jhtml?articleID=217701343.

6 *See The Future of the Internet: Hearing Before the S. Comm. on Commerce, Science and Transportation,* 110th Cong. 7–9 (2008) (statement of Kyle McSlarrow, President and CEO, National Cable & Telecommunications Association) [hereinafter McSlarrow Statement].

7 *See infra* notes 48–51 and accompanying text. *See also* Posting of Luc Ceuppens, *Running Networks Hot: Urban Myth or Viable Strategy?*, to XCHANGE MAGAZINE, Luc Ceuppen Blog, http://www.xchangemag.com/articles/501/running-networks-hot-urban-myth-strategy.html (Apr. 8, 2009, 08:15 EST) (noting that while the traditional "rule of thumb" for oversubscription ratios was 4:1, current ratios of 12:1 or 20:1 are becoming the norm as ISPs cope with increasing demand).

Such limitations are conflicting with a shift in Internet applications and usage from low-resolution pictures to high-quality streaming video and from passive web browsing to more participatory applications such as Facebook, YouTube, and online gaming.[8] Although, P2P applications[9] such as BitTorrent may serve as easy scapegoats for these congestion problems, the lack of sufficient capacity on some residential broadband networks to handle present as well as future uses of the Internet is a more direct causal factor. In response to this bandwidth crunch, a number of providers have opted for complex traffic management or QoS mechanisms to ration limited bandwidth among subscribers.[10] Ultimately, however, ISPs could and should resolve this congestion more effectively by adding sufficient capacity and providing end-users with accurate information regarding the performance capabilities of their broadband connection.

The focus of ISPs on network management and QoS further raises concerns among network neutrality advocates, who view prioritization through QoS and deep packet inspection ("DPI")[11] as fundamentally altering the end-to-end design of the Internet.[12] Although not directly tied to previous efforts to charge content and application developers for access to a provider's customers, prioritization of certain traffic would have implications for shaping the future devel-

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8 McSlarrow Statement, *supra* note 6, at 5–6.

9 *See infra* notes 15–17 and accompanying text.

10 McSlarrow Statement, *supra* note 6, at 8–9.

11 Nate Anderson describes deep packet inspection as:

> move[ing] beyond the IP and TCP header information to look at the payload of the packet. The goal is to identify the applications being used on the network, but some of these devices can go much further; those from a company like Narus, for instance, can look inside all traffic from a specific IP address, pick out the HTTP traffic, then drill even further down to capture only traffic headed to and from Gmail, and can even reassemble e-mails as they are typed out by the user.

Nate Anderson, *Deep Packet Inspection Meets 'Net Neutrality, CALEA*, ARS TECHNICA, July 25, 2007, http://arstechnica.com/hardware/news/2007/07/Deep-packet-inspection-meets-net-neutrality.ars. *See also* Rob Frieden, *Internet Packet Sniffing and Its Impact on the Network Neutrality Debate and the Balance of Power Between Intellectual Property Creators and Consumers*, 18 FORDHAM INTELL. PROP. MEDIA & ENT. L.J. 633, 652 n. 57 (2008) (citation omitted) ("Deep packet inspection (DPI) technology allows service providers to peer inside next-generation network (NGN) packets to see what users are up to—what applications they are using, where their traffic is going, and so on.").

12 *See* M. CHRIS RILEY & BEN SCOTT, FREE PRESS, DEEP PACKET INSPECTION: THE END OF THE INTERNET AS WE KNOW IT 7–8 (2009), *available at* http://www.freepress.net/files/Deep_Packet_Inspection_The_End_of_the_Internet_As_We_Know_It.pdf; *see also* Brett M. Frischmann & Barbara van Schewick, *Network Neutrality and The Economics of an Information Superhighway: A Reply To Professor Yoo*, 47 JURIMETRICS J. 384–86 (2007) ("If infrastructure providers follow the broad version of the end-to-end arguments, they cannot distinguish between end uses, they cannot base access decisions or pricing on how those packets may be used; nor can they optimize the infrastructure for a particular class of end uses.").

opment and innovation on the Internet—allowing ISPs to make value judgments in terms of which applications, services, and content are the most important to subscribers. Network management and QoS systems further cement ISPs as gatekeepers on last-mile networks, building in the necessary mechanisms to monitor and monetize traffic.

Such negative implications have prompted calls for regulatory protections to ensure all Internet content, applications, and services are treated equally by ISPs.[13] Although neutrality regulations may be necessary to protect consumer freedom on the Internet, current residential networks, if left unimproved, may be unable to keep pace with users as applications and content consume greater and greater amounts of capacity. This could cause dramatic slowdowns on some networks.[14] These realities require focused attention and an in-depth assessment of both ISPs' claims and potential solutions offered by network neutrality proponents to facilitate constructive solutions that will ensure innovation continues in the U.S. Within this context, the very future of the Internet as an open, participatory medium will rest upon how we answer the fundamental question, "Who will make network management and prioritization decisions, end-users or network operators?"

This paper will examine the issue of congestion and the impact of network management and QoS prioritization, both in terms of its validity as a solution to congestion on residential broadband networks and its implications for changing the Internet. Part I of the paper will examine the capacity limitations of most residential broadband networks and the impact of changing broadband usage patterns and applications such as P2P and streaming video. Although it is clear that such applications are exposing the capacity limitations of certain networks, the degree to which ISPs' business decisions and network design are contributing to the problem has been obscured in the current discussion. Part II will explain the current network management practices of prominent ISPs and assess their validity as a solution to congestion. Part III will examine the implications of network management and QoS for altering the end-to-end design of the Internet and the strong incentive network operators have to exert control over the applications and content that flow over their networks. The final part

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[13] Frischmann & van Schewick, note that

> [N]etwork neutrality rules would prevent network providers from excluding applications or content from their networks or from discriminating against them . . . . [however] network neutrality proponents disagree whether certain practices should be considered "discrimination" under a network neutrality regime. In particular, network neutrality proponents disagree whether a network neutrality regime should allow Quality of Service, and, if yes, whom network providers should be allowed to charge for it.

Frischmann & van Schewick, *supra* note 12, at 389 n.22.

[14] Peter Svensson, *Comcast Blocks Some Internet Traffic*, MSNBC.COM, Oct. 19, 2007, http://www.msnbc.msn.com/id/21376597/.

of the paper will attempt to strike a balance between a blanket prohibition on network management and the capacity realities of some last-mile networks. It will recommend policy solutions that address congestion on networks, empower end-users, and promote continued innovation on the Internet.

II. CONGESTION AND THE CAPACITY LIMITATIONS OF LAST-MILE NETWORKS

The current debate over congestion began in large part when Comcast was discovered blocking traffic from BitTorrent users.[15] P2P applications such as BitTorrent are file-sharing applications that take advantage of the two-way communications capability of the Internet, i.e., the ability to send and receive data, to more efficiently share large files among users.[16] Rather than relying on a single server to download a file, BitTorrent users download small chunks of a file from other users—or "peers"—on the P2P network, and in turn, this often requires peers to also upload files to others.[17]

The FCC's investigation found that Comcast was sending forged reset packets to P2P users who attempted to upload files to other peers.[18] Reset packets ("RST" packets) are a type of transmission control protocol ("TCP")[19] message "that is normally sent when a computer receives 'TCP' packets that it believes it should have not received, or when it thinks it has closed a connection but keeps receiving traffic from the other side."[20] In response to receiving RST packets, a host closes its side of the TCP connection and signals an error to the application that was using the connection.[21] Comcast sent forged RST packets that impersonated the host IP address of the distant peer needing pieces of a file.[22] The impact of the forged RST packets caused the TCP connection to die

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15 *See id.*

16 Posting of Marguerite Reardon, *ISPs Prepare for Video Revolution*, to CNET NEWS BLOG, http://news.cnet.com/8301-10784_3-9983861-7.html?tag=nefd.lede (July 7, 2008, 4:00 EST).

17 *Id.*

18 *See Comcast P2P Order*, *supra* note 2, ¶ 41.

19 PETER ECKERSLEY, FRED VON LOHMANN & SETH SCHOEN, PACKET FORGERY BY ISPS: A REPORT ON THE COMCAST AFFAIR 1 (Electronic Frontier Foundation, Version 1.01, 2007), http://www.eff.org/files/eff_comcast_report2.pdf. TCP is "a standard protocol that computers use to exchange information on the Internet." *Id.*

20 *Id.*

21 *Id.*

22 *See id.*; *see also* Posting of Seth Schoen, *EFF Tests Agree with AP: Comcast Is Forging Packets to Interfere with User Traffic*, to DeepLinks Blog, http://www.eff.org/deeplinks/2007/10/eff-tests-agree-ap-comcast-forging-packets-to-interfere (Oct. 19, 2007).

as soon as the peer requested data.[23]

In response to the FCC's investigation of their network management practices toward BitTorrent traffic, Comcast argued that its discriminatory treatment was a reasonable network management practice to limit congestion given the nature of P2P.[24] As Comcast offered in their initial comments to the Commission, "[b]ecause these P2P protocols are designed to devour any and all available bandwidth on the network, it is not possible to build one's way out of the need for reasonable network management."[25]

The notion of P2P applications and users as "bandwidth hogs" has resonated with policymakers, regardless of the accuracy of the characterization.[26] P2P applications like BitTorrent often establish multiple download and upload connections to other peers.[27] Although it is unlikely for a user to reach a large number of these connections, the fact that these applications are often run in the background without active participation from the user and can often "continuously upload pieces of files" from computers means that P2P users may generate considerably more traffic compared to non-P2P users.[28] This by itself does not cause congestion; Internet traffic on networks regularly doubled in the 1990s before the advent of P2P technology and continues to grow at a rate of fifty percent each year.[29] The more relevant issue is the degree to which increased consumption of Internet video and other applications—and not just P2P traffic—conflict with the capacity limitations and design of most residential broadband networks.

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23 ECKERSLEY ET AL., *supra* note 19, at 1.

24 *In re* Broadband Industry Practices, *Comments of Comcast Corporation*, WC Docket No. 07-52, at 25 (Feb. 12, 2008) (accessible via FCC Electronic Comment Filing System) [hereinafter *Comcast Comments*].

25 *Id.* at 16.

26 *Peer-to-Peer Piracy on University Campuses: Hearing Before the Subcomm. on Courts, the Internet, and Intellectual Property of the H. Comm. on the Judiciary*, 108th Cong. 5 (2003) (statement of Rep. Howard L. Berman, Member, House Comm. on the Judiciary) ("P2P piracy consumes an enormous amount of college bandwidth, and as a result, increases bandwidth costs while draining resources available for research and academic purposes.").

27 *Comcast P2P Order*, *supra* note 2, ¶ 4.

28 Reardon, *supra* note 16.

29 *See* MINTS - Minnesota Internet Traffic Studies, Internet Growth Trends & Moore's Law, http://www.dtc.umn.edu/mints/igrowth.html (last visited Oct. 31, 2009) [hereinafter Internet Traffic Studies]; *In re* A National Broadband Plan for Our Future, *Comments of Comcast Corporation*, GN Docket No. 09-51, at 36 (June 8, 2009). Comcast disclosed that their Internet traffic increased 42 percent last year. *Id.*

A. Throughput, Contention, and Congestion

Throughput refers to the average rate or maximum rate of successful message delivery, measured in bits per second.[30] Throughput is a function of the capacity or bandwidth (the maximum possible quantity of data that can be transmitted) of the transport medium (i.e., copper wiring, co-axial cable, or fiber-optic cable) and the processing power of the routers or switches that move traffic on the network.[31] Unlike the traditional telephone network, the amount of throughput on a packet-switched network such as the Internet fluctuates as demand on the network increases.[32] The actual throughput a user may receive depends upon how many users and how much traffic is on the network at any given time.[33] Whereas a telephone network is made up of individual circuits between two or more users, each with a limited but constant level of throughput, on a packet-switched network like the Internet, users share available throughput allocated to the entire network.[34] Although the telephone network guarantees a specific level of throughput for each circuit, it also requires the network operator to provide enough circuits to accommodate all or most of the anticipated callers.[35] If all the circuits on network are being used, callers receive an "'all circuits busy' message."[36] Users on residential broadband networks do not receive such a message; instead throughput on the network decreases as the number of users and the amount of traffic increases.[37]

With a few exceptions, throughput on residential broadband networks is not guaranteed. Most residential services advertise broadband speeds on an "up to" basis, with a qualification that speeds may vary depending upon the amount and type of network usage, time of day, and numerous hardware and infrastructure-related factors.[38] Throughput fluctuation depends in part on the capac-

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30 *See* NEWTON'S TELECOM DICTIONARY 1120 (25th ed. 2009); *see also* GEORGE OU, MANAGING BROADBAND NETWORKS: A POLICYMAKER'S GUIDE 26 (2008), *available at* http://www.itif.org/files/Network_Management.pdf. Throughput and bandwidth are often conflated, but bandwidth is more a measure of capacity of the connection. *See id.* at 4. Higher bandwidth connections such as fiber-optic cable are often described as "fat pipes" when in reality "they're not actually fatter; they are simply deliver more bits per second." *Id.* at 26.

31 *See* NEWTON'S TELECOM DICTIONARY at 1120; *see also* OU, *supra* note 30, at 8–11.

32 OU, *supra* note 30, at 2.

33 *See id. at* 3.

34 *See id.* at 2, 8, 10.

35 *Id.*

36 *Id.* at 8, 10.

37 *Id.* at 2.

38 *See* Dirk Grunwald & Douglas Sicker, *Measuring the Network—Service Level Agreements, Service Level Monitoring, Network Architecture and Network Neutrality,* 1 INT'L J. COMMC'N 548, 553–54 (2007), http://www.ijoc.org/ojs/index.php/ijoc/article/viewFile/163/98; *see also* Time Warner Cable

ity of a network link and the degree to which capacity is shared, often measured in terms of a contention ratio.[39] The contention ratio is the potential maximum demand to the actual capacity.[40] Thus, if ten users are all attempting to access a 50 Mbps link at 15 Mbps, the link has a contention ratio of 3:1, as users have the potential to demand three times the amount of throughput available.

1. Oversubscription and the Capacity Limitations of Current Residential Broadband Networks

Contention ratios can also be referred to as oversubscription ratios. Oversubscription is a measure of the advertised or expected rate of throughput and the amount of actual throughput the network can provide if all the subscribers are accessing the network during the same period.[41] Thus, a provider may sell ten subscriptions for a 15 Mbps downstream service on a link with only 40 Mbps of total throughput capacity. If all those users access the link at the same time, the actual amount of throughput available to each user may be substantially less than advertised. Most operators tend to treat contention ratios as proprietary information, making it difficult to compare among different broadband services and networks.[42]

Cable broadband networks are likely to have some of the highest oversubscription ratios, given the intrinsic shared architecture of the network. Cable modems utilize the same fiber-coax cable that carries video programming to subscribers.[43] Traffic travels from a cable modem at the subscriber's residence

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Residential Services Subscriber Agreement, Time Warner Cable, § 6(a), http://help.twcable.com/html/twc_sub_agreement.html (last visited Sept. 15, 2009) ("I also understand that the actual Throughput Rate I may experience at any time will vary based on numerous factors, such as the condition of wiring at my location, computer configurations, Internet and TWC network congestion, the time of day at which I use the HSD Service, and the website servers I access, among other factors.").

[39] *See* OU, *supra* note 30, at 10 ("If very few users are on a packet-switching network, then those few users get a lot of resources allocated to them. If many users are on the network, then each user gets fewer resources but at least is not locked out of the system."); *see also* ORG. FOR ECON. CO-OPERATION & DEV., OECD COMMUNICATIONS OUTLOOK 112–13 (2009) (illustrating how contention ratios may cause speed variations, depending on the number of subscribers utilizing the network), *available at* http://browse.oecdbookshop.org/oecd/pdfs/browseit/9309031E.PDF.

[40] *Cf.* Grunwald & Sicker, *supra* note 38, at 553–54.

[41] *Cf. id.*

[42] ORG. FOR ECON. CO-OPERATION & DEV., *supra* note 39, at 113. "Only a few operators publish data relating to contention levels on their lines but it is becoming more common as subscriber demands on the network increase." *Id.*

[43] *See* Richard N. Clarke, "Cost of Neutral/Unmanaged IP Networks," 8 REV. NETWORK

to an "Optical Node" in the neighborhood, and then to a "Cable Modem Termination System" ("CMTS"), called a "data node."[44] The CMTSs are "then connected to higher-level routers, which in turn are connected to [the providers'] Internet backbone facilities."[45] Cable modem links can generally provide a maximum usable throughput of 38 Mbps down and 9 Mbps up for Data Over Cable Service Interface Specification ("DOCSIS") 1.x and 38 Mbps down and 27 Mbps up for DOCSIS 2.0.[46]

Cable network architecture includes a coaxial cable loop that connects all the houses and buildings in a neighborhood.[47] This means that available bandwidth is shared across all cable subscribers in neighborhoods served by the same node.[48] Each neighborhood node can have anywhere from 250 to 2000 houses on it, but not every household will subscribe to the cable company's Internet service.[49] However, it is not uncommon to have upwards of 500 subscribers signed up for the high-speed Internet service on a single loop.[50] Therefore, the actual amount of throughput available to each customer during times of peak usage can be considerably less than advertised. Assuming a maximum download speed of 3 Mbps per customer, a loop utilizing DOCSIS 1.x or 2.0 providing 38 Mbps of downlink capacity can accommodate a maximum of only twelve simultaneous users without contention.[51] On the other hand, if 500

ECON. 61, 64 (2009).

44 Letter from Kathryn A. Zachem, Vice President, Regulatory Affairs, Comcast Corp., to Marlene H. Dortch, Sec'y, Fed. Commc'ns Comm'n, File No. EB-08-IH-1518, WC Docket No. 07-52, Attachment B, 3–4 (Sept. 19, 2008), *available at* http://fjallfoss.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=652016975.

45 *Id.* at 4.

46 *See* Cisco Support Community, https://supportforums.cisco.com/docs/DOC-1239 (last visited Oct. 21, 2009); *see also* BRIAN O'NEILL & ROB HOWALD, BETTER RETURNS FROM THE RETURN PATH: IMPLEMENTING AN ECONOMICAL MIGRATION PLAN FOR INCREASING UPSTREAM CAPACITY 3 (2008), *available at* http://www.motorola.com/staticfiles/Business/Solutions/Industry%20Solutions/Service%20Providers/Cable%20Operators/Broadband%20Access%20Networks%20(BAN)/Fiber%20Deep/_Documents/Static%20files/Better%20Returns%20from%20the%20Return%20PathWhitepaper092008.pdf. DOCSIS 2.0 doubled the channel width for upstream channels from 2.3 MHz to 6.4 MHz and increased the modulation from 16 to 32 or 64 QAM, and improvements in the modulation scheme can allow cable operators to significantly increase the transmission speed over a single channel. *Id.* at 3, 5.

47 *See* Letter from Kathryn A. Zachem, *supra* note 44, at Attachment A, p. 2.

48 *See* Todd Spangler, *Comcast Opens Up Wideband*, MULTICHANNEL NEWS, Apr. 7, 2008, at 3.

49 *See id.*

50 *See* Posting of Saul Hansell, *The Cost of Downloading All Those Videos*, to N.Y. TIMES BITS BLOG, http://bits.blogs.nytimes.com/2009/04/20/the-cost-of-downloading-all-those-videos/ (Apr. 20, 2009, 15:55 EST).

51 *See* Clarke, *supra* note 43, at 71.

subscribers are all sharing 38 Mbps of capacity, the maximum throughput available to each user is just 76 Kbps.

ISPs often sell different tiers of Internet service,[52] making it difficult to calculate exact oversubscription ratios. However, assuming a DOCSIS 2.0 cable loop has 32 subscribers at a 15 Mbps tier, the oversubscription ratio is 12:1, without even accounting for any other subscribers on the loop. An "aggressive cable operator" may have 75 higher-tier subscribers on a loop, resulting in a contention ratio of nearly 30:1.[53] The problem is exacerbated on the upstream link, where DOCSIS 1.1 can only support 9 Mbps for uploading data.[54] DOCSIS 2.0 increased this upstream bandwidth to 30.72 Mbps (maximum usable throughput of 27 Mbps), but in 2008, most cable operators had not fully upgraded to the DOCSIS 2.x standard.[55] With 125 subscribers sharing 9 Mbps, just 72 Kbps is available to each user. Even those providers using DOCSIS 2.0 may not be fully utilizing the increased modulation or wider upstream channels that can increase throughput by three to five times their current levels.[56] This low upstream bandwidth is, in large part, why Comcast focused on limiting uploads from P2P users and why Cox's QoS has indicated its trial is currently limited to subscribers' upstream traffic.[57]

Cable providers can mitigate the capacity limitations and reduce their oversubscription ratios by performing a virtual/logical, modular, or physical node split to reduce the number of subscribers sharing capacity. A virtual or logical node split involves eliminating the sharing of a laser between two or more cable nodes to reduce the number of subscribers sharing capacity at the CMTS.[58]

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52 For example, Verizon offers three plans for its DSL service; a starter plan (1 Mbps down/384 Kbps up), power plan (3 Mbps down/768 Kbps up), and a turbo plan (7.1 Mpbs down/768 Kbps up). Verizon, High Speed Internet: Plans, http://www22.verizon.com/Residential/HighSpeedInternet/Plans/Plans.htm (last visited Oct. 22, 2009). Comcast offers four tiers of service, ranging from a "Performance" plan (12 Mbps down/2 Kbps up) to an "Extreme" plan (50 Mbps/10 Mbps). Comcast, The New Comcast High-Speed Internet: Speed Comparison, http://www.comcast.com/Corporate/Learn/HighSpeedInternet/speedcomparison.html (last visited Nov. 14, 2009).

53 *See* Victor Blake, *Chasing Verizon FiOS: The Race Is On*, COMMC'NS TECH., Aug. 2008, at 23.

54 Cisco Support Community, *supra* note 46.

55 *See* O'NEILL & HOWALD, *supra* note 46, at 5.

56 *Id.*

57 *See Comcast P2P Order*, *supra* note 2, ¶ 9; Congestion Management FAQs, Cox Communications, http://www.cox.com/policy/congestionmanagement/default.asp (last visited Oct. 22, 2009). *See also* Svensson, *supra* note 4.

58 *See* Leslie Ellis, *2007 CTO Roundtable: How Sexy is HFC? (Answer: Plenty)*, CED MAGAZINE, May 2007, at 40. Tony Werner, Comcast's Chief Technology Officer, explained:

> We can take two nodes in an area with low take rates for HSD, and combine them with a node in another area, with a high take rate. One laser feeds all three nodes. Put an-

If a particular node has high uptake of subscribers, the provider may place that node on an unused downstream port from another CMTS.[59] The provider can also add another laser and move the node over to a separate channel.[60] Most providers have two nodes on an upstream channel and four nodes on a downstream channel.[61] If subscribership and usage is particularly high on a node, the provider may split off the less utilized nodes to a separate laser.[62] Operators can also assign subscribers on a congested node to another DOCSIS channel, known as a modular node split or adding a "carrier."[63] The provider re-assigns half the subscribers' modems to a new channel, thereby halving the number of users sharing capacity on a single DOCSIS channel.[64] Nonetheless, most operators still utilize a single downstream channel.[65] A cable operator can also perform a physical node split. Most providers installed four to six strands of fiber to every node allowing them to connect a separate strand of fiber from the node to the CMTS.[66] Thus, rather than a single node with potentially 500 subscribers, there would be two nodes with 250 subscribers each.

A number of large cable operators such as Comcast are also upgrading to DOCSIS 3.0, a standard that bonds multiple channels together to increase the available throughput.[67] Rather than a single channel of 38 Mbps, four channels bonded under DOCSIS 3.0 can facilitate maximum download speeds of 152 Mbps, while eight channels can handle 304 Mbps.[68] However, DOCSIS 3.0 is still limited by the number of households sharing capacity on a node. For example, Comcast currently offers a 50 Mbps down/10 Mbps up tier to subscrib-

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> other way—there's one downstream channel of 38 Mbps coming off of a CMTS (cable modem termination system). If, all of a sudden, we get to full utilization on a node, we can take a look at it: Which in that group of three is pushing you over the limit? Then, you either add a laser or you add a downstream port from another CMTS, which is now directed at those other two nodes. And you've doubled your bandwidth.

Id.

59 *Id.*

60 *Id.*

61 *Id.*

62 *Id. See also* ADAM LYNN, FREE PRESS, A REPORT ON U.S. CABLE OPERATORS NETWORK ARCHITECTURE AND UPGRADE POSSIBILITIES 5 (forthcoming 2009).

63 Tony Werner, Remarks at the CMCSA - Comcast Investor Day P.M. Session 6–7 (May 1, 2007) (transcript at http://files.shareholder.com/downloads/CMCSA/0x0x299562/2314a32a-936d-4b36-bcc0-0698427a9457/050107am.pdf).

64 *See id.*

65 *Cf.* Saifur Rahman, *DOCSIS Migration Methodology: From A to B to "3,"* COMMC'NS TECH., Nov. 2007, at 35–36.

66 Ellis, *supra* note 58, at 38; Leslie Ellis, *Hey You with the Big Node, Splitting Gets More Bandwidth*, MULTICHANNEL NEWS, Nov. 17, 2003, at 44, *available at* LEXIS, News & Business Library.

67 Spangler, *supra* note 48.

68 Cisco Support Community, *supra* note 46.

ers in areas that have been upgraded to DOCSIS 3.0.[69] However, even with 152 Mbps of capacity, a single high-tier subscriber shares the total downstream throughput on the loop with other subscribers.[70] DOCSIS 3.0 can also bond four channels to boost uploads speeds to 120 Mbps, but utilization of upstream channel bonding has not yet been deployed.[71]

Digital subscriber lines ("DSL") networks can also have high-contention ratios, although users share capacity later in the network.[72] DSL utilizes the same copper infrastructure as traditional telephone service.[73] Data travels from a subscriber's modem through the copper wiring to the Digital Subscriber Line Access Multiplexer ("DSLAM") that aggregates data from other subscribers' DSL connections in a neighborhood.[74] That data is then typically sent to a regional node, and from there to the "Internet backbone."[75] At the connection from the DSL modem to the DSLAM, subscribers are not sharing capacity with their neighbors as each modem has a dedicated point-to-point connection over the copper wiring.[76] DSL links using ADSL technology generally have a maximum throughput of 6 Mbps down and 1.5 Mbps up.[77] VDSL, an advanced DSL system, can provide maximum throughput of 25–30 Mbps.[78] However, customers located further than 4000 feet from the DSLAM will tend to experience slower speeds as the throughput on copper diminishes greatly with distance.[79]

Once a particular user's data arrives at the DSLAM, it is combined with the packets from all other customers in a neighborhood.[80] The DSLAM is typically

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69 Jacqui Cheng, *Comcast: 50Mbps Speeds to 65% of Territory by End of 2009*, ARS TECHNICA, Feb. 19, 2009, http://arstechnica.com/telecom/news/2009/02/comcast-50mbps-speeds-to-65-of-territory-by-year-end.ars.

70 Eric Bangeman, *160MBps Downloads Move Closer for US Cable Customers*, ARS TECHNICA, May 8, 2007, http://arstechnica.com/old/content/2007/05/160mbps-downloads-move-closer-for-us-cable-customers.ars.

71 Michael Robuck, *D3 Upstream: What's the Hurry?*, CED MAGAZINE, Sept. 2009, at 18–19.

72 *See* Lesley Hansen, The Rural Challenge, InterComms, http://www.intercomms.net/AUG03/content/net2net.php (last visited Nov. 14, 2009).

73 *See* Clarke, *supra* note 43, at 64.

74 *See id.*

75 *Id.*

76 ROBERT WOOD, NEXT-GENERATION NETWORK SERVICES 353 (2006).

77 *See* Clarke, *supra* note 43, at 65–66.

78 *Id.*; *see* Brad Reed, *Qwest Rolls Out 40Mbps VDSL2 Service*, INFOWORLD, July 20, 2009, http://www.infoworld.com/d/networking/qwest-rolls-out-40mbps-vdsl2-service-968. In addition, companies such as Qwest and AT&T have rolled out VDSL2 service, the "most advanced standard of DSL technology available in the United States." *Id.* Qwest has advertised download speeds of 40 Mbps for its VDSL2 offering. *Id.*

79 Clarke, *supra* note 43, at 65–66; Daniel L. Rubinfeld & Hal J. Singer, *Open Access to Broadband Networks: A Case Study of the AOL/Time Warner Merger*, 16 BERK. TECH. L.J. 631, 651 (2001).

80 Clarke, *supra* note 43, at 71. A DSLAM usually will serve "several hundred" sub-

equipped with a fiber connection that can range from 150 Mbps to 1 Gbps, though in some rural areas, DSL providers may utilize remote terminals that may only be equipped with a 45 Mbps connection.[81] The amount of throughput that is available for subscribers sharing a DSLAM is dependent upon the capacity of the DSLAM connection and the number of subscribers utilizing the link. For example, if a 150 Mbps DSLAM is serving customers with a maximum connection speed of 2 Mbps (typically 1.5 Mbps down and 500 Kbps up) then the DSLAM can provide 2 Mbps of throughput to 75 users even if they all are utilizing the link at the same time. But as noted above, a DSLAM can serve upwards of 1000 subscribers and if they are all utilizing the link at the same time, the maximum throughput per user is just 75 Kbps and the contention ratio is 13:1.

Fiber-to-the-Home ("FTTH") or Fiber-to-the-Premise ("FTTP") networks such as Verizon's FiOS have some of the lowest contention ratios, in part because they limit the number of subscribers served by a node.[82] FiOS utilizes a passive optical network ("PONs") to deliver voice, video, and data.[83] A single high-capacity fiber strand extends from an optical line terminal ("OLT") out to the neighborhoods where an optical splitter connects up to thirty-two fiber strands from individual subscribers.[84] At the subscriber's residence, an optical network terminal ("ONT") transfers the data onto the corresponding wiring for phone, video, and Internet access.[85]

The total throughput for the fiber strand connecting the optical splitter in the neighborhood to the provider's central office varies whether the provider is using a broadband passive optical network ("BPON") or a gigabit passive optical network ("GPON").[86] Most FiOS deployments have been based on BPON,

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scribers. *Id.*

[81] *See* Nate Anderson, *Bell's P2P Traffic Issues 'easily and inexpensively solved,"* ARS TECHNICA, June 29, 2008, http://arstechnica.com/old/content/2008/06/bells-p2p-traffic-issues-easily-and-inexpensively-solved.ars; *see* DAVID HIRST, IP DSLAM BACKHAULING SOLUTIONS OVER BONDED COPPER 2–3 (2008), *available at* http://www.virtualpressoffice.com/JPContentAccessServlet?fileContentId=1208550769571&source=sd&showId=1181060943757.

[82] Clarke, *supra* note 43, at 65–66.

[83] *Id.*

[84] *See* NEWTON'S TELECOM DICTIONARY 873 (25th ed. 2009). Some optical splitters allow for sixty-four fiber strands. RUDOLF VAN DER BERG, DEVELOPMENTS IN FIBRE TECHNOLOGIES AND INVESTMENT, ORG. FOR ECON. CO-OPERATION & DEV. 23 (2003).

[85] *See* Verizon FiOS Internet—About Your Optical Network Terminal (ONT), http://www22.verizon.com/ResidentialHelp/FiOSInternet/General+Support/Getting+Started/QuestionsOne/121496.htm (last visited Oct. 24, 2009).

[86] *See* Clarke, *supra* note 43, at 75; News Release, Verizon, Verizon Wins Telephony Magazine Innovation Award for Aggressively Deploying GPON, Most Powerful Fiber-Optic Transmission Technology in Use Today (Sept. 30, 2008), http://newscenter.verizon.com/press-releases/verizon/2008/verizon-wins-telephony.html [hereinafter Verizon News Release].

which is capable of providing throughput of 622 Mbps down and 155 Mbps up.[87] Because it is shared by a maximum of thirty-two subscribers, BPON can provide non-contentious speeds of 19.4 Mbps down and 4.8 Mbps up to each subscriber.[88] GPON, which Verizon announced it would deploy to 400 regional wire centers by the end of 2009, is capable of delivering throughput of 2.4 Gbps downstream and 1.2 Gbps upstream.[89] At this capacity, the network can provide non-contentious speeds of 75 Mbps down and 37.5 Mbps up for thirty-two subscribers.[90] Verizon currently offers three tiers of service of 15/5 Mbps, 25/15 Mbps, and 50/20 Mbps for their highest tier service.[91] However, because the throughput is shared among just thirty-two subscribers, Verizon's FiOS contention ratios are considerably lower than cable or DSL. Even if all thirty-two subscribers on a node opt for the highest and most expensive 50 Mbps download tier—an unlikely scenario—the oversubscription ratio is only around 2:1 for BPON and is non-existent for GPON. Fiber also has near infinite capacity because technologies such as wavelength-division multiplexing ("WDM") allow for multiplicative increases in the capacity of a network without laying additional fiber.[92]

2. Oversubscription and the Impact of Changing Usage Patterns

Oversubscription is a common business model for operators. The expectation of the operator is that most traffic will not be coincidental and not all users will access the link at the same time.[93] In cases where this does occur, various methods of statistical multiplexing are used to allocate throughput between the average and peak rates and buffer the traffic to and from users in a queue when demand exceeds the capacity on the network.[94] Packet queues from multiple users on a network are typically handled on a "first-come, first-serve ("FCFS") basis."[95] Small queues can result from coincidental traffic or the instantaneous

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87 Clarke, *supra* note 43, at 66; Verizon News Release, *supra* note 86.

88 Clarke, *supra* note 43, at 66; Blake, *supra* note 53.

89 Verizon News Release, *supra* note 86.

90 *See id.*

91 Posting of Eric Rabe, *VZ Raises FiOS 2-Way Speeds; Extends HSI Offer*, to Verizon PolicyBlog, http://policyblog.verizon.com/BlogPost/631/VZRaisesFiOS2-WaySpeedsExtendsHSIOffer.aspx. (Aug. 21, 2009, 7:22 EST).

92 NEWTON'S TELECOM DICTIONARY 1221 (25th ed. 2009).

93 *See* Grunwald & Sicker, *supra* note 38, at 553–54.

94 Kavitha Chandra, *Statistical Multiplexing*, in WILEY ENCYCLOPEDIA OF TELECOMMUNICATIONS 1 (John G. Proakis ed., 2003), *available at* http://morse.uml.edu/~kchandra/publications/stat-mux-EOT-02.pdf.

95 *Id.* This is also referred to as a first-in, first-out basis ("FIFO"). NEWTON'S TELECOM DICTIONARY 467, 478 (25th ed. 2009).

arrival of packets from different users.[96] Larger queues arise when multiple users transmit at their peak throughput or burst packets for a sustained period of time.[97] The result of a large packet queue is an increase in transmission time for a packet (latency) or dropped packets if the queue exceeds the allotted buffer.[98] Both incidents of congestion on networks are directly related to contention on the network; that is, the more users sharing capacity on a network, the greater the likelihood of coincidental traffic and throughput demands of users will exceed available capacity.

When most consumers utilized their Internet connections for web-browsing and e-mail, providers could utilize larger oversubscription ratios. Such traffic is characterized by multiple short bursts of data—to download a Web page or e-mail—separated by periods of idleness, where a particular user will not generate much traffic.[99] Given that this type of Internet traffic does not require sustained data rates, it can be feasible to utilize higher-contention ratios and provide close to advertised speeds. Under this scenario, ISPs could expect the average user to only consume around 50 Kbps, far less than their broadband connection would allow.[100]

However, streaming applications for Internet video and video conferencing consume a steady amount of throughput during use.[101] When a subscriber is utilizing their broadband connection for such purposes, there are potentially no periods of idleness. Internet videos, such as those offered through Hulu, stream at 480 Kbps to 700 Kbps for low-resolution and 1000 to 2500 Kbps for high-definition.[102] If ten subscribers on a DOCSIS 2.0 loop (38 Mbps) shared by

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96 *See* Chandra, *supra* note 94, at 3. Chandra refers to this as "packet or cell level congestion." *Id.*

97 *Id.* Chandra refers to this as "burst level congestion." *Id.*

98 *See* OU, *supra* note 30, at 14; John Evans & Clarence Filsfils, *Deploying Diffserv at the Network Edge for Tight SLAs, Part 1*, IEEE INTERNET COMPUTING, Jan.–Feb. 2004, 61, 61–63, *available at* http://www.employees.org/~jevans/je-cf_ieee-int-comp_part1.pdf (describing performance factors affecting service level commitments).

99 Grunwald & Sicker, *supra* note 38, at 554.

100 *See* Fred Goldstein, *The Dismal Reality of Internet Management*, TECH JOBS, Mar. 5, 2008, http://jobs.tmcnet.com/topics/broadband-comm/articles/22237-dismal-reality-internet-management.htm; *see also* Clarke, *supra* note 43, at 71. Clarke writes:

> [B]ecause typical customer usage is much, much less than the full capacity of their DSL access connections, signals from the individual DSL lines may be statistically-multiplexed (combined) into a signal that requires much less transmission bandwidth than the simple sum of the many DSL lines' capacity that they serve (for example, if a DSLAM serves 600 1.5 Mbps DSL lines—or 900 Mbps of total digital loop capacity, it likely needs less than 45 Mbps of capacity back to the Internet to adequately serve this total demand).

Id.

101 Clarke, *supra* note 43, at 66–67.

102 Hulu, Support/FAQ, http://www.hulu.com/support/technical_faq (last visited Sept. 10, 2009). Meanwhile, Microsoft's XBox's streaming of high-definition 1080p video con-

upwards of 125 subscribers are accessing a 2500 Kbps (2.5 Mbps) streaming video, this already consumes 78 percent of capacity available for downstream traffic on the network.

P2P applications can be equally demanding, although they are inherently limited by the minimal amount of throughput available to users for uploading data.[103] Like most file transfer applications and Internet browsers that utilize the TCP/IP protocol, they are designed to burst packets to the maximum allowable throughput available to a user.[104] However, the amount of throughput between two end-users is dictated by the slowest link on a connection.[105] For example, suppose peer A, with a cable modem connection capable of downloading at 15 Mbps, connects to the cable modem of peer B who only is capable of uploading traffic at a maximum of 2 Mbps. Here, the maximum throughput of that connection would only be 2 Mbps. If peer B is uploading to multiple peers, then they are all sharing the 2 Mbps of throughput available to that user. Given that DOCSIS 1.x only provides 9 Mbps of throughput for uploading data from users and DOCSIS 2.0 provides 27 Mbps,[106] just five P2P users uploading at 2 Mbps can fill the upstream pipe of DOCSIS 1.x and twelve P2P users can fill the upstream pipe for DOCSIS 2.0.

The impact of this shift in consumer usage and Internet applications is that during periods of peak usage, many broadband networks cannot deliver speeds anywhere near advertised. This was reflected in a 2007 article from *PC Magazine* that found the "actual speeds of large providers was somewhere between 150 Kbit/s and 200 Kbit/s," significantly below the two to four megabit speeds often advertised.[107] Subscribers may have little understanding of the degree to which their speeds are attributable to capacity limitations of the network and

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tent will require 8–10 Mbps of throughput for full-quality. Dan Rayburn, *Microsoft XBox 360: 1080p Streaming Will Require 8-10 Mbps Connection for Full Quality*, SEEKING ALPHA, June 9, 2009, http://seekingalpha.com/article/142041-microsoft-xbox-360-1080p-streaming-will-require-8-10-mbps-connection-for-full-quality.

[103] *See* AKAMAI TECHNOLOGIES, INC., HOW WILL THE INTERNET SCALE? 5 (2008).

[104] Mark Allman et al., *An Evaluation of TCP with Larger Initial Windows*, 28 ACM SIGCOMM COMPUTER COMM. R. 41 (1998).

[105] *See* Posting of Eric Rabe, *Some Thoughts on Cablevision 101's Mbps Speed*, to Verizon PolicyBlog, http://policyblog.verizon.com/BlogPost/614/SomeThoughtsonCablevisions101MbpsSpeed.aspx (May 1, 2009, 17:09 EST). As Rabe notes, "[e]ffective speeds of networks depend on the speed available on the slowest link." *Id.*

[106] *See supra* note 46 and accompanying text.

[107] Art Reisman, *Analysis: The White Lies ISPs Tell About Broadband Speeds*, PCMAG.COM, July 5, 2007, http:// www.pcmag.com/article2/0,1895,2155140,00.asp; *see also* OFCOM, UK BROADBAND SPEEDS 2009: CONSUMERS' EXPERIENCE OF FIXED-LINED BROADBAND PERFORMANCE 9 (2009), http://www.ofcom.org.uk/research/telecoms/reports/broadband_speeds/broadband_speeds/broadbandspeeds.pdf (finding that average broadband speeds in the UK were 57 percent of the average advertised headline speed).

the level of oversubscription the provider has chosen. This lack of understanding allows ISPs to distort the expectations of consumers as well as inhibit the ability of consumers to compare speeds across networks.

Given the current market, providers may have every incentive to substantially oversubscribe their networks. Many consumers may have little understanding to the extent to which providers may be overpromising on speeds. Although consumers may clearly recognize that their Internet is slow or slower during certain times, how many actually have an understanding of the average or typical throughput they are receiving? Without any sense of measuring "broadband quality,"[108] that would reflect actual throughput and other measures such as latency and jitter, consumers will continue to find it difficult to make accurate comparisons among providers.

Further, in most local markets, most consumers have only two options for broadband Internet service: DSL and cable.[109] As Robert D. Atkinson of the Information Technology and Innovation Foundation stated, "[F]or the foreseeable future, the 'last mile' of broadband services is, for most consumers, at best a duopoly and sometimes a monopoly."[110] Thus, even if consumers are dissatisfied with the service, their options are quite limited. Any disciplining effects of competition are further limited by switching costs incurred by consumers to move from service to service, such as "search costs, transaction costs, learning costs, loyal customer discounts, and customer' habit[s]."[111]

To the extent providers may be competing, it is in terms of advertised speeds. In this fashion, oversubscription can be utilized as a marketing tool for operators. For example, an aggressive cable provider utilizing DOCSIS 1.x or 2.0 may put seventy-five subscribers on a node on its 15 Mbps tier. Given that the DOCSIS 2.0 can only provide 38 Mbps of throughput, the oversubscription ratio would be nearly 30:1. If Verizon FiOS with BPON-622 Mbps of downstream capacity-utilized a similar oversubscription ratio as the cable provider they could advertise their lowest tier-15 Mbps service-as providing download

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[108] *See In re* A National Broadband Plan for our Future, *Comments of Cisco Systems, Inc.*, GN Docket No. 09-51, at 11 (June 8, 2009), http://fjallfoss.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6520219971.

[109] Robert D. Atkinson, *The Role of Competition in a National Broadband Policy*, 7 J. ON TELECOMM. & HIGH TECH. L. 1, 11 (2009).

[110] *Id.*

[111] Thomas A. Burnham et. al., *Consumer Switching Costs: A Typology, Antecedents, and Consequences*, 31 J. ACAD. MARKETING SCI. 109, 110 (2003). Atkinson points outs another example—"Some broadband subscribers, for example, use their providers' e-mail services for their e-mail address (e.g., johnsmith@verizon.com). This makes switching broadband providers more difficult for these subscribers than for broadband subscribers who use platform-independent e-mail services (e.g. johnsmith@hotmail.com)." Atkinson, *supra* note 109, at 13.

speeds of up to 233 Mbps.[112] Even assuming the provider was utilizing DOCSIS 3.0 with four bonded channels and maximum download speeds of 152 Mbps, the oversubscription ratio is still 7:1. Utilizing the same oversubscription ratio, FiOS could advertise their lowest 15 Mbps tier as "up to" 58 Mbps. Such a disparity is reflected in a public exchange between Cablevision and Verizon in April 2009, after Cablevision announced that it would offer download speeds of 101 Mbps as part of its upgrade to DOCSIS 3.0.[113] This prompted a response from Verizon on its policy blog, where a company representative stated that, "[G]iven the inherent limits of the cable platform, a cluster of bandwidth junkies living near each other could be a real problem. One estimate is that a single 101 Mbps customer would use some 60% of the capacity in a neighborhood. Other users? Outta luck."[114]

The current focus on speed is also driven in part by the declining growth of new subscribers.[115] In such an environment, the average revenue per user ("ARPU") becomes increasingly important. Providers have a decision to make: should capacity upgrades be devoted to limiting congestion or to offering consumers higher speeds? The decision seems to be the latter as a number of ISPs in recent years have abandoned incremental speed upgrades and instead began to double or triple advertised speeds in an effort to entice consumers to switch to higher tiers.[116] In pursuing this strategy, providers can sell more expensive tiers and boost their APRU.[117]

However, the oversubscription model only works to the extent that subscribers will substantially underutilize their broadband connection. P2P conflicts with this assumption, as does streaming video. ISPs have, in large part, targeted P2P users for this reason. But if P2P programs suddenly ceased to exist, the traffic from those applications would not disappear but simply shift to existing client-server technologies such as RapidShare or Megaupload and providers would still need to account for the demand from those users.[118] The rea-

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[112] Blake, *supra* note 53.

[113] Posting of Saul Hansell, *Cablevision Goes for U.S. Broadband Speed Record*, to N.Y. TIMES BITS BLOG, http://bits.blogs.nytimes.com/2009/04/28/cablevision-goes-for-us-broadband-speed-record/ (Apr. 28, 2009, 0:01 EST).

[114] Rabe, *supra* note 105.

[115] Marguerite Reardon, *Broadband Growth Plummets in Q2*, CNET NEWS, Aug. 12, 2008, http://news.cnet.com/8301-1023_3-10015275-93.html.

[116] *See* Karl Bode, *Cox Doubles Speeds For Some*, BROADBANDREPORTS.COM, June 26, 2008, http://www.dslreports.com/shownews/Cox-Doubles-Speeds-For-Some-95601; *see also* Press Release, Cox Communications, Cox's Network Enhances Enable New Services and Power Second Quarter Growth (June 26, 2008), *available at* http://coxenterprises.mediaroom.com/index.php?s=43&item=44.

[117] Om Malik, *As Broadband Growth Slows, Expect Speed Boosts*, GIGAOM.COM, Apr. 29, 2008, http://gigaom.com/2008/04/29/as-broadband-growth-slows-expect-speed-boosts/.

[118] RapidShare allows users to upload big files and make them available to others via a URL. RapidShare, http://rapidshare.com/wiruberuns.html (last visited Nov. 22, 2009). Non-

son for many ISPs' focus on P2P is that it conflicts with the limited capacity that most ISPs have allocated to users for uploading data.

B. Asymmetric Networks

The decision of providers to build asymmetric networks—allocating disproportionate levels of throughput to downloading versus uploading—is just as important to understanding congestion on last-mile networks. The Internet began as a data-sharing network for academics.[119] Thus, symmetrical networks that allowed users to download and upload data at the same speed were essential. Symmetrical networks are still the norm for institutional, commercial, and educational broadband connections; however telecommunication and cable companies built their residential broadband networks with asymmetric download and upload speeds, apportioning upwards of three to four times more throughput for downlink capacity than for uplink.[120]

The consequences of such asymmetry are that residential last-mile networks are biased towards delivering data to subscribers. This bias is due in part to early ISPs that viewed the Internet as means to deliver content to end-users, particularly given early consumer usage centered on Web pages and the reli-

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paying users are required to wait 30 to 134 seconds, depending on the file size, before the download starts and their download-speed is limited from 25 Kbps up to 250 Kbps. Justin Häne, *A Tangled Web of File Sharing*, SWISSINFO.CH, Nov. 15, 2008, http://www.swissinfo.ch/eng/front/A_tangled_web_of_file_sharing.html?siteSect=105&sid=9972609&rss=true&ty=st. There is also the waiting time of fifteen minutes between each download. *See* Posting of Raymond, *RapidShare Enforces 15 Minutes Wait Time Download Limit for Free Users*, to Raymond.cc Blog, http://www.raymond.cc/blog/archives/2008/10/09/rapidshare-enforces-15-minutes-wait-time-download-limit-for-free-users/ (Oct. 9, 2008). Registered users receive unlimited download speeds, and can download several files simultaneously. Rapidshare, Become a Premium Member | Benefits, http://www.rapidshare.com/premium.html (last visited Nov. 16, 2009). RapidShare has also been implicated in several cases of copyright infringement. For example a user uploaded the Album "Death Magnetic" from Metallica onto the service, one day before the worldwide release of the album. *Rapidshare: Cease & Desist-Letter for Uploader through Civil Law Based Information Claim*, GULLI.COM, Apr. 30, 2009, http://www.gulli.com/news/rapidshare-cease-desist-letter-2009-04-30/. This prompted a cease and desist letter from lawyers representing the copyright owners. *Id.* Such occurrences are common on RapidShare and Megaupload, who will take down files after receiving notices of copyright infringement. *See* "Megaupload FAQ," http://www.megaupload.com/?c=faq (last visited Nov. 22, 2009); Janko Roettgers, *Piracy Beyond P2P: One-Click Hosters*, NEWTEEVEE, June 17, 2007, http://newteevee.com/2007/06/17/one-click-hosters/.

[119] *See* Internet Society (ISOC), All About The Internet: History of the Internet, http://www.isoc.org/internet/history/brief.shtml (last visited Oct. 27, 2009).

[120] Grunwald & Sicker, *supra* note 38, at 558–59.

ance on the client-server model for delivering content.[121] In the case of cable networks, the entire infrastructure was designed to broadcast video programming to subscribers.[122] Thus, a greater emphasis was placed on being able to download content such as text and graphics quickly, with minimal bandwidth allocated to uploading data, generally limited to sending e-mails and short browser directives.[123] In addition, "many of the technologies used to access the Internet [over existing telephone infrastructure] were adopted before the technology to provide higher speed symmetrical access was firmly developed."[124] The first satellite and cable residential offerings featured a broadband download capability that was coupled with a dialup modem handling upstream data.[125]

The asymmetric legacy on residential networks continues. Verizon's FiOS provides downlink speeds of 15, 25, or 50 Mbps but only uplink speeds of up 5, 15, and 20 Mbps.[126] For DSL service offerings, "the division of capacity between upstream and downstream is basically arbitrary; there are symmetric flavors available but Asymmetric DSL is the [sic] typically sold to consumers,"[127] even as consumers increasingly utilize the uplink capacity for P2P applications and uploading content to social media Web sites such as Facebook. Such asymmetry is why many ISPs' Terms of Service include bans on subscribers utilizing their connection to host a server.[128]

The asymmetry is particularly lopsided on cable networks, which were designed to broadcast television programming and where downloading and uploading data are spilt into separate channels.[129] The current allocation of throughput capability reflects the original intent of cable systems—to retransmit broadcaster signals.[130] The over-the-air television frequencies were mapped

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121 *Id.* at 559; *see also* Fred Goldstein, *The Dismal Reality of Internet Management*, TECH JOBS, Mar. 5, 2008, http://jobs.tmcnet.com/topics/broadband-comm/articles/22237-dismal-reality-internet-management.htm."

122 *See* Lynn, *supra* note 62, at 5.

123 *See* Grunwald & Sicker, *supra* note 38, at 558–59.

124 *Id.* at 559.

125 Joseph Moran, *Battling the Upstream Bottleneck of Broadband Connections*, WIN-PLANET, http://www.winplanet.com/article/3541-.htm (last visited Nov. 13, 2009).

126 Verizon FiOS Internet: Plans, http://www22.verizon.com/residential/fiosinternet/Plans/Plans.htm (last visited Nov. 22, 2009).

127 Goldstein, *supra* note 121. Goldstein also notes that "[i]t also keeps cheap DSL from cannibalizing business sales of costly T1s," which provide symmetric connectivity. *Id.*

128 *See, e.g.*, Time Warner Cable Residential Services Subscriber Agreement, *supra* note 38, § 4(b)(iii).

129 *See* Leslie Ellis, *Translation Please: Upstream Bandwidth And Symmetry*, MULTICHANNEL NEWS, Aug. 3, 2008, http://www.multichannel.com/article/talkback/134208-Translation_Please_Upstream_Bandwidth_And_Symmetry.php.

130 *See* History of Cable – NCTA.com. http://www.ncta.com/About/About/HistoryofCableTelevision.aspx (last visited Oct. 25,

directly onto the cable line, where channel 2 is located at 54 MHz, and the rarely utilized upstream portion of the network was relegated to the 5–42 MHz range.[131] One of the problems with using this spectrum for uploading data is interference in the band.[132] The noise interference can be so problematic that 5–15 MHz of the spectrum is unusable with 15–20 MHz requiring a lower modulation rate that reduces the amount of throughput.[133]

As a consequence, although DOCSIS 1.x is capable of delivering upload speeds of 9 Mbps and DOCSIS 2.0 of 27 Mbps, those speeds are rarely achieved.[134] Factor in that between 125 and 500 subscribers on a cable loop could be sharing less than 9 or 27 Mbps and it becomes increasingly likely for congestion to occur on the uplink side, leading to precipitous declines in throughput. As one study found, the "downstream bandwidths exceed upstream bandwidths by more than a factor of 10 for some ISPs."[135]

The result of this asymmetry is the upstream traffic becomes increasingly congested, creating much longer queues. For example, one report found that "[m]ost DSL links exhibit queues of 600 ms or higher, and many cable links allow their upstream queues to grow to several seconds."[136] These "excessive lengths will negatively affect interactive traffic like VoIP" that require a low, but steady level of throughput for two-way streaming.[137] Such asymmetry was acceptable when Internet usage consisted of passive surfing, but the advent of P2P applications, online gaming, VoIP, femtocells,[138] and other interactive applications requires networks to provide robust two-way communication that allows for both downloading and uploading of comparable amounts of data.

This shift is particularly problematic for cable networks, as the allocation of capacity provided for upstream data is minimal, and what little is available is potentially shared by hundreds of users on a local loop.[139] As a consequence

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2009) ("Cable television originated in the United States . . . in 1948 to enhance poor reception of over-the-air television signals in mountainous or geographically remote areas. 'Community antennas' were erected on mountain tops or other high points, and homes were connected to the antenna towers to receive the broadcast signals.").

131 Ellis, *supra* note 129.

132 *See* NOAM GERI & ITAY LUSKI, OPTIMIZING TRANSMISSION PARAMETERS IN DOCSIS 2.0 WITH A DIGITAL UPSTREAM CHANNEL ANALYZER (DUCA) 1–2 (2002), http://focus.ti.com/lit/wp/spay008/spay008.pdf.

133 *See* O'NEILL & HOWALD, *supra* note 46, at 6; Lynn, *supra* note 62, at 4.

134 *See supra* note 46 and accompanying text. *See also* Goldstein, *supra* note 121.

135 MARCEL DISCHINGER ET AL., CHARACTERIZING RESIDENTIAL BROADBAND NETWORKS 7 (2007), *available at* http://www.mpi-sws.org/~ahae/papers/broadband.pdf.

136 *Id.* at 11.

137 *Id.*

138 NEWTON'S TELECOM DICTIONARY 471–72, 873 (25th ed. 2009). A femtocell is "a small box—also called an indoor base station—that will take the cellular calls you make or received and route them via your DSL or cable modem line." *Id* at 471.

139 Goldstein, *supra* note 121.

just a few subscribers on a local node utilizing P2P applications or larger numbers participating in online gaming or utilizing VoIP could cause considerable congestion in the uplink pipe. DOCSIS 3.0 can mitigate this somewhat by upgrading capacity from 27 Mbps to 108 Mbps.[140] However, cable providers are also increasing subscriber upload speeds for their highest tier, from 2 to 10 Mbps.[141]

The asymmetric capacity of most residential broadband networks, and particular cable networks, reflect why most of the attention for congestion issues has been placed on P2P applications and users. Even so, the trend of subscribers increasingly utilizing their broadband connections for uploading data will continue to increase, with or without P2P.[142] Whether it is to share or upload pictures to sites such as Google Picasa or Facebook, make a VoIP or video call, or work remotely through cloud applications that allow users to access their home or work computer, demand for upstream capacity will continue to increase.

III. CONGESTION, NETWORK MANAGEMENT, AND QOS

In response to congestion problems, a number of ISPs have sought to limit what they deem as excessive use of the network by certain subscribers or applications. These efforts have included establishing monthly usage or bandwidth caps as well as implementing network management or QoS systems to either limit ("throttle") the amount of throughput a subscriber can consume or prioritize specific traffic that is considered more important or time-sensitive.[143] These network management or QoS mechanisms generally breakdown into two categories: protocol-agnostic and protocol-specific.

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140 Ed Oswald, *Comcast Plans Aggressive Push for Ultra-Fast Internet*, BETANEWS, June 6, 2008, http://www.betanews.com/article/Comcast-plans-aggressive-push-for-ultrafast-Internet/1212780770.

141 *See, e.g.*, Press Release, Comcast, Comcast Rolls Out Extreme 50 Mbps High-Speed Internet Service in Washington, D.C. and Metro Area (June 9, 2009), *available at* http://www.comcast.com/About/PressRelease/PressReleaseDetail.ashx?PRID=876.

142 O'NEILL & HOWALD, *supra* note 46, at 4. Consumption trends for upstream bandwidth are increasing at an annual rate of 30–50 percent. *Id.*

143 *See* Comcast, Frequently Asked Questions about Network Management, http://help.comcast.net/content/faq/Frequently-Asked-Questions-about-Network-Management#changetime (last visited Nov. 22, 2009) [hereinafter Comcast customerCentral]; *see also* Congestion Management FAQs, *supra* note 57 (last visited Nov. 22, 2009).

A. Protocol-Agnostic: Throttling Individual Users

Protocol-agnostic approaches seek to place limits on the throughput consumption of individual users by de-prioritizing a specific user's traffic or slowing the data rate of their broadband connection.[144] Comcast's "Fair Share" system is a recent example of this type of approach. As part of its compliance with the FCC's ruling, Comcast implemented the protocol-agnostic "Fair Share" to slow down the traffic of heavy Internet users during times of congestion.[145] Whereas Comcast specifically targeted specific protocols—that is, specific applications—in their previous system that placed an allegedly disproportionate burden on network resources, this congestion management system targets any user who, according to Comcast's limits, over-utilizes the network compared to others.[146]

Comcast explains the new network congestion management practices as follows:

> If a certain area of the network nears a state of congestion, the technique will ensure that all customers have a fair share of access to the network. It will identify which customer accounts are using the greatest amounts of bandwidth and their Internet traffic will be temporarily managed until the period of congestion passes. Customers will still be able to do anything they want to online, and many activities will be unaffected, but they could experience things like: longer times to download or upload files, surfing the Web may seem somewhat slower, or playing games online may seem somewhat sluggish.[147]

Furthermore, Comcast notes that:

> [s]oftware installed in the Comcast network continuously examines aggregate traffic usage data for individual segments of Comcast's HSI network. If overall upstream or downstream usage on a particular [network] segment . . . reaches a predetermined level, the software . . . examines bandwidth usage data for subscribers in the affected network segment to determine which subscribers are using a disproportionate share of the bandwidth.[148]

The system creates 'two QoS levels for Internet traffic going to and from the

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144 *See* OU, *supra* note 30, at 20.

145 Michele Robart, *Comcast's Proposed "Fair Share" Plan Affects Heavy Internet Users*, CABLE.TMCNET.COM, Aug. 20, 2008, http://cable.tmcnet.com/topics/cable/articles/37590-comcasts-proposed-fair-share-plan-affects-heavy-internet.htm. As of December 31, 2008, Comcast ceased its previous congestion management techniques. *See* Letter from Kathryn A. Zachem, Vice President, Regulatory Affairs, Comcast Corp., to Dana Shaffer, Chief, Wireline Competition Bureau, and Matthew Berry, Gen. Counsel, Fed. Commc'ns Comm'n (Jan. 30, 2009), available at http://fjallfoss.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6520194593 (stating that Comcast had implemented a "protocol-agnostic" mode of network management).

146 *See* Letter from Kathryn A. Zachem, *supra* note 44, at Attachment B, p. 2.

147 Comcast customerCentral, *supra* note 143.

148 *See* Letter from Kathryn A. Zachem, *supra* note 44, at Attachment B, p. 2.

cable modem: (1) "Priority Best-Effort" traffic ("PBE"); and (2) "Best-Effort" traffic ("BE") . . . [the] "PBE [level] "will be the default status for all Internet traffic coming from or going to a particular cable modem."[149] Traffic will be designated BE for a particular cable modem only when two conditions are met. First, the usage level of a particular upstream or downstream port of a CMTS, as measured over time, approximately fifteen minutes of time, must be nearing the point where congestion could degrade users' experience.[150] This is called a "Near Congestion State," and the utilization threshold or bandwidth capacity for a downstream port is 80 percent and 70 percent for upstream.[151] Second, a particular subscriber must be in an "Extended High Consumption State," which is defined as utilizing 70 percent and above of a subscriber's provisioned upstream or downstream bandwidth over a fifteen minute period.[152] When both conditions are met, "a user's upstream or downstream traffic (depending on which type of port is in the Near Congestion State) will be designated as BE."[153] The user's connectivity level is released from this state when their 'bandwidth consumption "drops below 50 percent of his or her provisioned upstream or downstream bandwidth for a period of approximately fifteen minutes."[154]

As Comcast notes, the system works:

> [b]ecause of the way that the CMTS handles traffic. Specifically, CMTS ports have what is commonly called a "scheduler" that puts all the packets coming from or going to cable modems on that particular port in a queue and then handles them in turn. A certain number of packets can be processed by the scheduler in any given moment; for each time slot, PBE traffic will be given priority access to the available capacity, and BE traffic will be processed on a space-available basis.[155]

Comcast admits users could experience a variety of effects if their traffic is delayed, depending on that given user's usage habits.[156] A user's traffic designated as in the BE state "during actual congestion may find that a webpage loads sluggishly, a peer-to-peer upload takes somewhat longer to complete, or a VoIP call sounds choppy."[157]

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[149] *Id.* at Attachment B, p. 6.

> Each Comcast HSI subscriber's cable modem has a "bootfile" that contains certain pieces of information about the subscriber's service to ensure that the service functions properly. For example, the bootfile contains information about the maximum speed (what we refer to in this document as the "provisioned bandwidth") that a particular modem can achieve based on the tier (personal, commercial, etc.) the customer has purchased.

Id.

[150] *Id.* at Attachment B, p. 7–8.

[151] *Id.* at Attachment B, p. 8.

[152] *Id.* at Attachment B, p. 7–9.

[153] *Id.* at Attachment B, p. 7.

[154] Letter from Kathryn A. Zachem, *supra* note 44, at Attachment B, p. 10.

[155] *Id.* at Attachment B, p. 12.

[156] *Id.* at Attachment B, p. 13.

[157] *Id.*

Time Warner Cable, although not announcing explicit plans to follow Comcast's network management system, appears to be building in the option to use a similar congestion management to suspend or reduce the speeds of users that exceeds a certain limit.[158] In June, Time Warner amended its subscriber agreement to allow the company to use "Network Management Tools as it determines appropriate . . . including but not limited to suspending or reducing the Throughput Rate of [the customer's] HSD Service, to ensure compliance with its Terms of Use and to ensure that its service operates efficiently."[159]

The effectiveness of Comcast's or a similar network's management system is uncertain. Most Internet applications utilizing TCP/IP have built-in congestion mechanisms to cut the data rate of the sender in response to a substantial delay or packet loss.[160] This congestion management mechanism, also known as Jacobson's algorithm, evolved in response to several "congestive collapses" that the early Internet experienced.[161] The Internet's early congestive collapse concerns centered around TCP connections or end-points on the network "unnecessarily retransmitting packets that were either in transit or that had already been received at the receiver."[162] Another variety is "[c]ongestion collapse from undelivered packets [that] arises when bandwidth is wasted by delivering packets through the network that are dropped before reaching their ultimate destination."[163]

An unintended consequence of this behavior was that as congestion increased and more packets were dropped or delayed, the sending end-points continued to re-send their packets, only worsening the congestion.[164] The solution was to instruct the end-points to cut their data transmit rate in half when they failed to receive acknowledgement of packet delivery (signaling congestion), and then to gradually increase the transmit rate until the network becomes congested at which point the process repeats itself.[165] Although applications that use the BitTorrent protocol are often labeled "bandwidth hogs," they also incorporate a congestion control algorithm to limit to three to four upload

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158 Time Warner Cable Residential Services Subscriber Agreement, *supra* note 38, at Section 6 (a)(iii).

159 *Id.*

160 OU, *supra* note 30, at 13–15.

161 Van Jacobson & Michael J. Karels, *Congestion Avoidance and Control* 1, in PROCEEDINGS OF SIGCOMM '88 (Aug. 1988), ACM, *available at* http://www-nrg.ee.lbl.gov/papers/congavoid.pdf; *accord* OU, *supra* note 30, at 13–15.

162 Sally Floyd & Kevin Fall, *Promoting the Use of End-to-End Congestion Control in the Internet*, 7 IEEE/ACM TRANSACTIONS ON NETWORKING 458, 460 (Aug. 1999), http://delivery.acm.org/10.1145/320000/316740/00793002.pdf?key1=316740&key2=6466780521&coll=GUIDE&dl=GUIDE&CFID=48336314&CFTOKEN=88450988.

163 *Id.*

164 *See id.*

165 *See* OU, *supra* note 30, at 14.

slots in the specification used by nearly all of the BitTorrent applications.[166] The so-called "Slot-and-Choking" algorithm was "a design decision to facilitate [c]ongestion [c]ontrol . . . ."[167]

The effect of the TCP/IP congestion mechanism is that it creates a yo-yo effect on congested networks, wherein the network becomes congested, applications cut their data rate, the queue is emptied, and the process repeats itself. In Comcast's network management systems a link is a considered in "a near congested state" when the utilization is 80 percent for downstream port and 70 percent for an upstream port.[168] A utilization rate of 70 or 80 percent means that at certain times the link is being utilized at 100 percent, and there is some level of congestion occurring.[169] For those applications incorporating congestion control mechanisms, they may have already cut their data rate in half several times as packets continue to be delayed or dropped.[170] At this point, the congestion is not only at the CMTS router, but on the applications at the edges where an increasing queue of packets is waiting to be sent.[171] Thus, by the time the mechanism kicks in, most users are likely to notice their Internet connection has substantially slowed.[172]

In addition, Comcast is essentially selling subscriptions for certain tiers of services on the contingency that fewer subscribers actually utilize the network or users not utilize the full capacity allowed by their broadband connection. Although a subscriber is purchasing a 15 Mbps down/2 Mbps connection, they are essentially only entitled to use that service at times of when network utilization is below 80 percent for downstream or 70 percent upstream.[173]

Protocol-agnostic systems do not increase capacity; they only seek to limit the amount of throughput an individual subscriber can consume[174]—something

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[166] Position paper by Robb Topolski, *Framing Peer to Peer Filesharing*, presented at the IETF Workshop on P2P Infrastructure (May 28, 2008), *available at* http://trac.tools.ietf.org/area/rai/trac/attachment/wiki/PeerToPeerInfrastructure/10%20topolski-p2pi.txt.

[167] *Id.*

[168] Letter from Kathryn A. Zachem, *supra* note 44, at Attachment B, pp. 7–8.

[169] *See id.*

[170] *See* David P. Reed, Opening Statement to Fed. Commc'ns Comm'n (Feb. 25, 2008), *available at* http://www.fcc.gov/broadband_network_management/022508/reed.pdf.

[171] *See* Victor S. Frost, *Quantifying the Temporal Characteristics of Network Congestion Events for Multimedia Services*, 5 IEEE TRANSACTIONS ON MULTIMEDIA 458, 462–64 (2003) (suggesting that the performance of edge networks is more susceptible to effects of congestion).

[172] Frost, *supra* note 171, at 458.

[173] *See* Letter from Kathryn A. Zachem, *supra* note 44, at Attachment B, p. 8.

[174] *In re* Request for Comments on Petition for Declaratory Ruling Regarding Internet Management Policies, *Comments of The Information Technology and Innovation Foundation*, WC Docket No. 07-52, at pt. VIII, (July 15, 2008) (accessible via FCC Electronic Comment Filing System).

that ISPs do already by selling users different tiers of service.[175] Assuming traffic and consumption for users will continue to grow,[176] the system will increasingly come up against capacity constraints as subscribers across the board continue to increase the utilization of their broadband connection. Users that consume 70 percent of their upstream bandwidth and 80 percent of their downstream bandwidth over a 15 minute period are considered to be in "Extended High Consumption State."[177] While this may be a minority of users right now, what happens when being in an extended high consumption state becomes more the norm? Assuming Comcast and other ISPs continue to substantially oversubscribe their networks, absent sufficient capacity upgrades and a reduction in the oversubscription ratios, the outcome is inevitable.

B. Protocol Specific – Prioritizing Favored Applications

Protocol-specific or application-specific QoS technologies seek to prioritize certain applications.[178] The intent of many QoS mechanisms is to prioritize the delivery of traffic for real-time applications such as VoIP, video conferencing, and streaming media applications.[179] ISPs add traffic shaping mechanisms at the router and identify what kind of packet it is (i.e., streaming media, P2P, website text, etc.) and decide whether to move it up or down in a queue depending upon its perceived priority.[180] Such mechanisms act as a selective traffic cop, prioritizing certain packets or placing specific rate limits on others. Supporters argue that certain applications and content given their sensitivity to delay and issues with high jitter should be prioritized at times of congestion in order for the provider to assure a QoS.[181]

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175 *See supra* note 52 and accompanying text.

176 *See* Internet Traffic Studies, *supra* note 29 (noting that Internet traffic has grown at least 50 percent since the early 1990s).

177 Letter from Kathryn A. Zachem, *supra* note 44, at Attachment B, p. 7–9.

178 See OU, *supra* note 30, at 2–3.

179 *See* Evans & Filsfils, *supra* note 98, at 61; *see also* Ou, *supra* note 30, at 4. Ou writes:

> "Packets should be ordered logically with priority given to real-time applications first, streaming applications second, interactive applications third, and background applications last. In order for all applications efficiently and fairly share an Internet connection, those with higher duration and higher bandwidth consumption (e.g., P2P) are given lower priority than applications with lower duration and lower bandwidth consumption (e.g., VoIP applications).

Id.

180 *See* Evans & Filsfils, *supra* note 98, at 64–65. For example, Diffserv defines forwarding behaviors into per-hop behaviors (PHBs) including expedited forwarding, assured forwarding, and default forwarding. *Id.* at 65.

181 *See* OU, *supra* note 30, at 33.

In early 2009, Cox Cable ("Cox") announced it was testing a new network management system in Kansas and Arkansas "designed to ensure that all time-sensitive Internet traffic—such as Web pages, voice calls, streaming videos and gaming—moves through without delay."[182] It was suspected that Cox was using a similar system as Comcast to block P2P uploads until August 2008, but "Cox never revealed the details of its system but said it used '"protocol filtering,' a strategy also used by Comcast."[183]

Cox's test system divides traffic "into two categories: time sensitive and non-time sensitive."[184] Time sensitive traffic includes Web surfing, VoIP, e-mail, streaming of "Web-based audio and video programs," "[o]nline interactive games," "[t]unneling & [r]emote [c]onnectivity (VPN-type services for telecommuting)," and "[a]ny service not categorized into another area."[185] Non-time sensitive traffic includes "[f]ile access ([b]ulk transfers of data such as FTP)," "[n]etwork [s]torage ([b]ulk transfers of data for storage)," P2P, "[s]oftware [u]pdates ([m]anaged updates such as operating system updates)," and Usenet content.[186] During times of congestion, "time-sensitive traffic—"applications or uses that are naturally intolerant of delay (loading web pages, instant messages, voice calls, email and gaming)—continues as usual."[187] During those same times, speeds for "less time-sensitive traffic" may be temporarily curtailed, but only until the congestion is resolved.[188] According to Cox, this network management system is limited to upstream traffic.[189]

This is similar to an approach suggested by George Ou in his paper on network management.[190] Ou offered a tiered QoS to manage all Internet traffic over networks in times of congestion: "(1) Platinum—real-time applications such as VoIP, online gaming, video conferencing, and IPTV; (2) Gold (buffered video streaming applications ranging from YouTube to Xbox HD); (3) Silver (interactive applications); and (4) Bronze (background applications such as BitTorrent and Kazaa) . . . ."[191]

Arguments for prioritization or application-specific QoS are driven by two

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[182] Cox Communications, Cable, High Speed Internet and Telephone Services in Cox Communications, http://www.cox.com/policy/congestionmanagement/default.asp (last visited Sept. 10, 2009).

[183] Peter Svensson, *Cox to Test New Way to Handle Internet Congestion*, USA TODAY.COM, Jan. 28, 2009, http://www.usatoday.com/tech/products/2009-01-28-cox-net-neutrality_N.htm.

[184] Congestion Management FAQs, *supra* note 57.

[185] *Id.*

[186] *Id.*

[187] *Id.*

[188] *Id.*

[189] *Id.*

[190] OU, *supra* note 30, at 22–24.

[191] *Id.*

concerns: the latency requirements of applications such as VoIP, video conferencing, online gaming and streaming media, and the notion that traffic will increase faster than improvements in the capacity of networking technologies.[192] The main argument for prioritization is to provide a QoS for certain applications. Applications in a QoS scheme are often classified in terms of their sensitivity to latency (delay) and jitter, the latter a term that characterizes variation in the latency that often occurs as a result of congestion on a network.[193] Although VoIP is not a throughput intensive application (only requiring between 27 Kbps and 88 Kbps, depending on the codec used),[194] it requires both low-latency on a network and a stable level of throughput.[195] Thus, if a link is congested, causing substantial delays or dropped packets, a VoIP call will become choppy or unintelligible.[196] However, the normal stop and start of everyday conversation often means that no data packets are being sent at all during the course of a VoIP call.[197] Similarly, online gaming generally does not require a high-level of throughput, but does need low latency.[198] Some applications, such as video conferencing and pure streaming video IPTV, require both a consistent and high-level of throughput. Standard definition streaming video requires approximately 2 Mbps of throughput and high-definition video requires at least 10 Mbps.[199]

However, most current Internet video services like YouTube and Hulu that appear to be streaming are, in fact, utilizing faster-than-real-time transfers and a buffer to accept minor incidences of jitter.[200] A buffer allows a user to

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192 *Id.* at 1–4. Ou writes:

> Packet-switched networks like the Internet were invented for their flexibility and efficiency, characteristics which are optimum for data applications. But they have two key deficiencies in the absence of network management: 1) inability to equitably allocate bandwidth; and 2) high jitter, which are essentially micro-congestion storms that last tens or hundreds of milliseconds, and which can disrupt real-time applications such as VoIP, online gaming, video conferencing, and IPTV.

Id. at 1.

193 Evans & Filsfils, *supra* note 98, at 62. Jitter is "generally computed as the variation of the one-way delay for two consecutive packets." *Id.* Congestion delay—also referred to as scheduling delay—occurs "as scheduling queues oscillate between empty and full." *Id.* Propagation delay, and switching delay can also contribute to jitter. *Id.*

194 *See* Bandwidth Consumption, http://www.voip-info.org/wiki/view/Bandwidth+consumption (last visited Oct. 27, 2009).

195 *See* Evans & Filsfils, *supra* note 98, at 62–63.

196 *Id.* ("For VoIP, codecs commonly support concealment algorithms, which can hide the effects of losing 30 ms of voice samples. The loss of two or more consecutive 20-ms voice samples thus results in a noticeable degradation of voice quality.).

197 Bandwidth Consumption, *supra* note 194; *see also* Evans & Filsfils, *supra* note 98, at 62–63.

198 OU, *supra* note 30, at 23–34.

199 Clarke, *supra* note 43, at 66–67.

200 *See* Hulu – Support, http://www.hulu.com/support/technical_faq (last visited Oct. 27, 2009). Hulu notes that "[d]ue to legal reasons, [it] currently does not buffer more than a

download videos at faster that real-time and then stores it temporally on a local cache.[201] Even if there is substantial congestion and throughput drops to zero, the user can play whatever has been downloaded into the buffer.[202] This is an important distinction, given that most QoS discussion is centered on delivering video over the Internet the same way it is over the air or over cable TV—in real-time streaming mode. Although there is growth in this type of traffic through IPTV services, real-time streaming currently represents a small fraction of the total.[203] Similarly, video conferencing remains a lightly used application.[204]

The vast majority of traffic on the Internet is from applications utilizing the Internet's standard TCP/IP protocol including Web-browsing, back-up services, streaming video and audio, and P2P applications.[205] Such applications were designed to deal with occurrences of delay and loss, incorporating mechanisms for the end-points to signal they had received packets successfully, and if not, to re-send.[206] This is due to the fact that the Internet was designed as a best-effort network with no end-to-end guarantees of specific levels of throughput for users or applications.[207] QoS attempts to overcome this by prioritizing the packets in a queue or creating a flow, which, in essence, attempts to make "the packet-switched network act more like a circuit-switched network."[208]

Various incarnations of QoS systems have been proposed throughout the Internet's history. Two decades ago, telecom operators proposed Broadband ISDN, a "network that would carry voice, data, and even high-definition video to the home, at speeds of 155 Mbps" and "would provide different [QoS] options for different prices . . . ."[209] However, it was overtaken by the much more

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small portion of a video at a given time." *Id.*

201 *See* Andrew Odlyzko, The Delusions of Net Neutrality 6 (revised Aug. 31, 2008), (unpublished manuscript), *available at* http://www.dtc.umn.edu/~odlyzko/doc/net.neutrality.delusions.pdf.

202 *Id.*

203 *Id.* at 6. Odlyzko notes reports that alleged software for AT&T's IPTV U-verse services incorporated a 15 to 30 second delay or buffer to live video streams to allow some time for dealing with packet loss. *Id.* at 5.

204 *Id.* at 6.

205 SANDVINE INTELLIGENT BROADBAND NETWORKS, 2009 GLOBAL BROADBAND PHENOMENA 4 (2009), *available at* http://www.sandvine.com/downloads/documents/2009%20Global%20Broadband%20Phenomena%20-%20Executive%20Summary.pdf.

206 Ou, *supra* note 30, at 14.

207 Marjory S. Blumenthal & David D. Clark, "*Rethinking the Design of the Internet: The End-to-End Arguments vs. the Brave New World*, 1 ACM TRANSACTIONS ON INTERNET TECH. 70, 71–73 (2001).

208 *See* John G. Waclawsky, *IMS: A Critique of the Grand Plan*, BUS. COMM. REV. 54, 55 (Oct. 2005).

209 *See* Goldstein, *supra* note 121.

scalable and efficient, protocol-neutral Synchronous Optical Networking ("SONET").[210] Integrated services ("IntServ") allowed applications to use the Resource Reservation Protocol ("RSVP") to request and reserve resources through a network.[211] However, core routers, where Intserv would be required to accept, maintain, and break reservations, were designed with the singular goal to switch or forward packets as fast as possible.[212] Differentiated services ("DiffServ") require packets to be marked according to the type of service they require, enabling the router to prioritize packets in queue on the basis of those requirements.[213] Although, Diffserv is used on enterprise networks, it has not been widely deployed on the Internet because of various deployment obstacles including "coordinating upgrades, changing network operations, peering arrangements, and business models . . . ."[214] This has been the fate of most QoS systems; their inherent complexity created substantial obstacles to scale and were eventually overtaken by far simpler, cost-effective capacity upgrades.[215]

As John Waclawsky stated, QoS is "in a race with Moore's Law, which says the link queue can empty faster than [a router can run QoS]."[216] Moore's Law refers to doubling of processing power, "per dollar, of a microchip . . . every 24 months."[217] Its equivalent on the bandwidth side is known as "Gilder's Law," which states that "'bandwidth grows at least three times faster than computer capacity.'"[218] In turn, "these capacity increases have been accompa-

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[210] *See* JON CROWCROFT ET AL., QOS'S DOWNFALL: AT THE BOTTOM, OR NOT AT ALL! 109, 111 (Aug. 2003).

[211] *See id.* at 111; Cisco Systems, Inc., Internetworking Technologies Handbook 763 (4th ed. 2004).

[212] *See* CROWCROFT ET AL., *supra* note 210, at 111.

[213] *See* Evans & Filsfils, *supra* note 98, at 64–65.

[214] STEVEN C. CORBATÓ & BEN TEITELBAUM, INTERNET2 AND QUALITY OF SERVICE: RESEARCH, EXPERIENCE, AND CONCLUSIONS 2 (May 2006), *available at* https://www.educause.edu/ir/library/pdf/CSD4577.pdf; *accord* CROWCROFT ET AL., *supra* note 210, at 111.

[215] CROWCROFT ET AL., *supra* note 210, at 110.

[216] E-mail from John Waclawsky, Chief Software Architect, Motorola, Inc., to David Farber, Professor Emeritus, College of Engineering at Carnegie Mellon University (June 23, 2008), http://www.interesting-people.org/archives/interesting-people/200806/msg00147.html.

[217] *See* John G. Waclawsky, *The Revolution at the Network's Edge*, BUS. COMM. REV. 30, 30 (Sept. 2007); *see also* Internet Traffic Studies, *supra* note 29.

> The original Moore's Law, formulated by Gordon Moore in 1965, referred just to the number of transistors that could be placed on a single chip, and predicted that this number would continue doubling every year for the next few years. A decade later, based on more data, Moore revised his "law" to predict a doubling of transistors on a chip every 18 months, a prediction that held true for an astonishing quarter of a century. Recently, however, the doubling of transistor counts has slowed down to about once every two years . . . .

Id.

[218] Waclawsky, *supra* note 216, at 31.

nied" by a drop in the "effective [bandwidth] cost per bit. . . ."[219]

The result is that throughout the evolution of the Internet, numerous QoS mechanisms have been proposed, including ATM, Intserv, Diffserv, and others, only for such proposals to become irrelevant as the capacity of networking technology increased.[220] This has been backed up by practical experience from the Internet2 technical community, which initially assumed that bandwidth-intensive applications such as streaming video or video conferencing would require QoS prioritization.[221]

Experience demonstrated the most cost-effective means to ensure high-performance networks was to provision the networks with sufficient capacity. As Internet2 researchers Corbató and Teitelbaum note, adding capacity avoids "practical deployment obstacles to implementing any effective QoS across a multiple network environment such as the Internet."[222] However, there is a dramatic difference between the Internet2 environment and the residential broadband market regarding the throughput available to end-users. For instance,

> [t]he slowest network connection between any two desktops within the Internet2 community is typically the 100 [Mbps] link between the computer and the local area network and many of these links are moving to a gigabit, or 1000 Mbps. Regional and nationwide networks are increasingly using 10 gigabit per second (10,000 Mbps) technology, with 40 and 100 gigabit per second technologies expected to be available within the next few years.[223]

Some advocates of QoS contend that Internet traffic will increase faster than routing technology.[224] They offer that traffic is doubling each year, while Moore's law only allows the cost of processing a bit to drop by one half every eighteen months—potentially doubling the "cost of Internet capacity . . . every three years without some key new innovation."[225] Similar predictions that the Internet would suffer "gigalapses" or massive network failures in the wake of a tidal wave of new traffic have proven to be less than accurate.[226] Claims that traffic is doubling each year are also questionable, as estimates peg current traffic growth rates at 50 percent and expect future traffic growth to remain in

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219 CORBATÓ & TEITELBAUM, *supra* note 214, at 2. John Waclawsky notes that "[t]he price per bit also keeps falling, so that many expect the marginal cost of communication eventually will tend to $0." Waclawsky, *supra* note 216, at 31.

220 CROWCROFT ET AL., *supra* note 210, at 110–11.

221 CORBATÓ & TEITELBAUM, *supra* note 214, at 1.

222 *Id.* at 2.

223 *Id.* at 3.

224 *See* Lawrence G. Roberts, *"Routing Economics Threaten the Internet,"* INTERNET EVOLUTION, Oct. 25, 2007, http://www.internetevolution.com/author.asp?section_id=499&doc_id=136705&.

225 *Id.*

226 Nate Anderson, *The Coming Exaflood, and Why It Won't Drown the Internet*, ARS TECHNICA, Dec. 16, 2007, http://arstechnica.com/articles/culture/the-coming-exaflood.ars.

that range.[227] As Andrew Odlyzko argues, "[a]nnual traffic growth rates of 50 percent, when combined with cost declines of 33 percent, result in no net increase in costs to provide the increased transmission capacity [on routers] . . . ."[228]

QoS does not create capacity nor does it serve as a substitute for capacity upgrades on networks.[229] It simply serves as a means to ration limited capacity among competing applications. In essence, QoS rearranges the furniture in a room in an effort to create more space, but does not make the room any bigger. In this sense, QoS can only be done once. Without additional capacity upgrades, providers cannot ensure QoS for prioritized applications, if those packets cannot move fast enough to the end-users because of network congestion. In addition, given the scalability issues of QoS, prioritization does little except to ensure that certain favored packets in a queue are bumped to the front of the line along a specific link or hop on the network. Attempts to layer QoS mechanisms over the Internet's existing routing mechanisms, which are focused on switching packets as quickly as possible, has demonstrated to be impractical, if not impossible.[230]

Among the ironies of QoS is that it can increase the propensity of congestion on a network. Because QoS systems manage traffic in the packet queue at the router, the queue has to be long enough in order to provide enough time to run the necessary processes to determine priority and reorder the packets. If a link has ample capacity and throughput, by the time the router runs the necessary processes and functions to carry out the QoS decisions, the packets may have already left the queue.[231] This necessitates long packet buffers to inspect (and possibly re-order) many sequential packets in any particular flow. Packet queues that last any longer than a few seconds would trigger the TCP congestion control, meaning those applications "would experience serious service degradation."[232] Added to the inefficiency is the degree to which QoS mecha-

[227] *See* Internet Traffic Studies, *supra* note 29; *see* also Cisco Visual Networking Index: Forecast and Methodology, 2008-2013, June 9, 2009, http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-481360_ns827_Networking_Solutions_White_Paper.html ("Overall, IP traffic will grow at a compound annual growth rate (CAGR) of 40 percent.").

[228] Andrew Odlyzko, *Threats to the Internet: Too Much or Too Little Growth?*, INTERNET EVOLUTION, Feb. 25, 2008, http://www.internetevolution.com/author.asp?section_id=592&doc_id=146747&.

[229] JUNIPER NETWORKS, QUALITY OF SERVICE (QOS) FOR WX & WXC APPLICATION ACCELERATION PLATFORMS 3 (2005), *available at* http://www.juniper.net/solutions/literature/feature/210006.pdf/.

[230] CROWCROFT ET AL., *supra* note 210, at 110.

[231] John G. Waclawsky, *Innovation, Competition and the Internet: A Lens to View the Continually Emerging Market at the Edge of the Network* 9 (2009) (advance copy on file with the author).

[232] *Id.*

nisms increase the payload of packets, requiring additional information to be carried in every packet.[233] John Waclawsky notes that, "A single message [for a QoS mechanism] could require more overhead packets to track, send, and bill for it than are contained in the message itself."[234]

In many respects, QoS reflects a value judgment by an operator of which applications deserve priority or which applications are the most valuable to subscribers. But what happens when all the traffic could be considered important? A VoIP call may be important to one subscriber, but another subscriber working from home may need to quickly upload a file to a co-worker on an FTP server. In such a situation, the ISP has already decided for the user.

IV. IMPLICATIONS OF A DPI/QOS MANAGED NETWORK

Early on in the development of the Internet and its precursor networks, users recognized the need to keep the architecture of networks as transparent and simple as possible.[235] This gave rise to what David Isenberg called the "stupid network," wherein "the network would be engineered simply to 'Deliver the Bits, Stupid,'"[236] placing the intelligence or control of the bits at the edges of the network, with the end-users. This arrangement meant that "the network was application-blind; [preventing] infrastructure providers from distinguishing between the applications and content running over the network . . . ."[237] But underlying QoS systems is the use of deep packet inspection ("DPI").[238] "While ISPs previously lacked the technological" capacity to distinguish among packets, thus helping to facilitate the Internet's inherent neutrality, DPI now allows ISPs to "inspect traffic on a packet-by-packet basis," providing operators with the ability to monitor and monetize Internet traffic "on the basis of allocate bandwidth, routing priority, and performance guarantees."[239]

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233 *Id.*

234 Waclawsky, *supra* note 208, at 55.

235 David P. Reed, Jerome H. Saltzer, and David D. Clark, *Commentaries on "Active Networking and End-to-End Arguments,"* IEEE Network, May/June1998, at 69, 70.

236 David Isenberg, *"Rise of the Stupid Network," available at* http://www.hyperorg.com/misc/stupidnet.html (last visited Oct. 31, 2009).

237 Frischmann & van Schewick, *supra* note 12, at 386.

238 *See* Frieden, *supra* note 11, at 637, 642–44.

239 *Id.* at 642–43.

A. Unraveling the End-to-End Design of the Internet

Reed, Saltzer, and Clark first formalized the concept known as the end-to-end argument.[240] It centered on keeping the lower layers of the network involved in the process of moving packets and utilized by all programs and applications as basic and transparent as possible—only including a function or service "if it is needed by all clients" and thus allowing networks to be able "to support the widest possible variety of services and functions, so as to permit applications that cannot be anticipated."[241] This simple and flexible architecture differed greatly from circuit networks utilized for traditional voice telephony. Even as computers replaced the manual routing of telephone calls, the networks retained their centralized architecture, requiring "intelligence" inside the network to transport data from one user to another.[242] The Internet placed the intelligence at the "edges" of the network, keeping the "functions implemented 'in' the Internet by the routers that forward packets" plain and simple.[243] This fundamental difference was the key to the intrinsic flexibility of the Internet allowing for the continued development of new applications and services from simple file-transfers, to e-mail and now to VoIP and streaming video.[244]

By ceding the control of more complex tasks to end-users, networks promoted innovation by removing obstacles to new uses that could be hardwired into the network. QoS and network management that seek to put more functions inside the network jeopardize that generality and flexibility as well as historic patterns of innovation. The impact of ISP's utilizing QoS on their network would be to fundamentally alter this functionality—building in biases for particular applications and solidifying network owners as gatekeepers for future innovations. Prioritization of certain applications, whether based on technical requirements such as sensitivity to jitter, or judgments from ISPs on what applications consumer's value the most, will shape the future direction of the Internet.[245]

As Reed, Saltzer and Clark note, "an end-to-end argument . . . serves to re-

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[240] Thomas M. Chen & Alden W. Jackson, *Commentaries on "Active Networking and End-to-End Arguments,"* IEEE Network, May/June1998, at 66.

[241] Reed et al., *supra* note 235, at 69–70.

[242] TREVOR R. ROYCROFT, ECONOMIC ANALYSIS AND NETWORK NEUTRALITY: SEPARATING EMPIRICAL FACTS FROM THEORETICAL FICTION 5 (Issue Brief Prepared for Consumer Federation of America, Consumers Union and Free Press) (2006), http://www.freepress.net/docs/roycroft_study.pdf.

[243] Blumenthal & Clark, *supra* note 207, at 72.

[244] Reed et al., *supra* note 235, at 70; *see* also Joseph Farrell & Philip J. Weiser, *Modularity, Vertical Integration, and Open Access Policies: Towards A Convergence Of Antitrust And Regulation In The Internet Age*, 17 HARV. J.L. & TECH. 85, 91 (2003).

[245] *See* Bill D. Herman, *Opening Bottlenecks: On Behalf of Mandated Network Neutrality*, 59 FED. COMM. L.J. 103, 110 (2006); *see also* RILEY & SCOTT, *supra* note 12, at 8.

mind us that building complex function into a network implicitly optimizes the network for one set of uses while substantially increasing the cost of a set of potentially valuable uses that may be unknown or unpredictable at design time." [246] For example, "had the Internet been optimized for telephone-style virtual circuits . . . it would never have enabled the experimentation that led to protocols that could support the World-Wide Web, or the flexible interconnect that has led to the flowering of a million independent Internet service providers (ISP's)."[247] QoS prioritization systems pick the winners and losers of congestion.[248] Those applications receiving priority become favored on the network, leading to potential quality declines for those applications deemed secondary to the QoS system.[249] This creates distortions in the development of applications, as QoS imposes a quasi congestion tax on de-prioritized applications, forcing users of those applications to internalize the congestion costs imposed by all applications and users on the network.

Similarly, use restrictions do not encourage developers of prioritized applications to improve the bandwidth-efficiency of their applications.[250] For example, although streaming media appears to be the preferred application of QoS systems, it is a largely inefficient means to deliver video—in times of limited network utilization, it does not allow users to download at faster than real-time levels.[251] This approach actually requires more expensive networks as it necessitates users to constantly demand a certain level throughput from their broadband connection, rather than downloading the file and becoming idle.[252] In the same way, de-prioritizing P2P ignores the fact that downloading large files via applications such BitTorrent can help to reduce congestion, given those applications ability to route around congested paths.[253] Compare that to streaming media and single-stream transfers that have no such ability and must "power through" a congested route until a transfer is completed.[254] In addition, it also ignores the benefit of optimized P2P applications that limit peer uploads and downloads to users on the same network, reducing transit costs for ISPs that do not have peering arrangements.

QoS would further undermine the unified standards and protocols at the core

246 Reed et al., *supra* note 235, at 70.

247 *Id.*

248 RILEY & SCOTT, *supra* note 12, at 6–7.

249 *Id.*

250 Frischmann & van Schewick, *supra* note 12, at 403.

251 *See* Odlyzko, *supra* note 201, at 1, 4–5.

252 *Id.* at 5–7.

253 Topolski, *supra* note 166 ("[I]t is quite possible that downloading via BitTorrent has a positive effect owing to its ability to route around congested paths while single-stream transfers have no such ability and must 'power-through' a congested route until a transfer is completed.").

254 *Id.*

of the Internet, which facilitate the interconnection of both networks and users across those networks.[255] DPI-enabled prioritization departs from non-standard network management practices and potentially leads to a "balkanization" of the Internet, where every ISP routes traffic according to their own QoS standards.[256] The ability of Internet users to access YouTube, upload pictures to Facebook, or communicate to each other using VoIP, regardless of whether they live in Washington, D.C. or Topeka, Kansas, and whether they are using AT&T's or Comcast's network, is dependent upon a unified system of standards and protocols. This creates the ubiquitous nature of the Internet, allowing engineers to create applications and programs that will work on all networks, among all users.[257] As individual operators introduce their own unique network specific traffic mechanism, the development process for new applications becomes more complex, requiring innovators and users to spend considerable time and resources to accommodate an ISP's particular network management practices.[258]

Prioritization and DPI would also create incentives for users to encrypt their data or utilize obfuscation technologies to undermine the ISP's packet inspection or traffic shaping mechanisms. Encryption of data to avoid detection by DPI could lead to a potential "'arms race' between users and ISPs who are attempting to control them."[259] The response from ISPs might be to slow down encrypted packets or possibly block the transmission of a packet that cannot be recognized by DPI. This, in turn, "would result in a great loss of privacy for" users, as well as undermine the other security benefits of encryption.[260] To a certain extent, this is already occurring. For example, BitTorrent now allows users to enable an encryption protocol to prevent ISPs from identifying BitTorrent traffic.[261] Plusnet, a UK ISP, that utilizes traffic prioritization to limit P2P traffic, classifies traffic from "any application not using its standard port" as 'other' traffic which receives a lower priority on the network.[262]

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255 *See* RILEY & SCOTT, *supra* note 12, at 7–8.

256 *Cf. id.* at 7–8.

257 *See id.* at 8.

258 *Comcast P2P Order*, *supra* note 2, ¶ 20.

259 Blumenthal & Clark, *supra* note 207, at 95.

260 *Id.*

261 BitTorrent, Connection Guide, http://www.bittorrent.com/btusers/guides/bittorrent-connection-guide (last visited Oct. 31, 2009).

262 Plusnet, Traffic Prioritisation, http://www.plus.net/support/broadband/quality_broadband/traffic_prioritisation.shtml (last visited Oct. 31, 2009).

B. DPI and ISPs as Gatekeepers

John G. Waclawsky notes "[t]he relationship between the Internet and the underlying [residential] networks [that facilitate connectivity] can certainly be viewed as symbiotic, but, unfortunately for the operators, the applications are where the value is."[263] As a result, operators continue to look for means to exert greater control over the bits that flow over their networks.[264] This is the overriding issue in the network neutrality debate. The most blatant expression of this was former AT&T CEO Ed Whitacre's argument that Google should not be allowed to use AT&T's "pipes [for] free."[265] Although Whitacre's effort to create slow and fast lanes to access AT&T's broadband customers was shelved,[266] that does not mean ISPs have abandoned related efforts to create additional billable moments for end-users.

In many respects, ISPs previously lacked the capabilities to specifically identify packet contents and bill content providers or subscribers to access specific Internet content, applications, or services. But QoS with DPI now provides a mechanism to differentiate traffic deemed to be premium, and build-in the necessary mechanisms to monetize traffic. Many QoS mechanisms were designed to tightly control and monitor traffic, with built-in mechanisms to bill customers for specific services and tightly control access to outside applications and content.[267]

This is reflected in marketing materials from DPI manufacturers that include references to the design of devices that allow for new methods to charge for tiered services. For example, Andrew Harries, the CEO of Zeugma Systems, a DPI manufacturer, offers that his equipment enables ISPs to "'insert themselves into the over-the-top value chain . . .'" and "'enable our customers to see, manage and monetize individual flows to individual subscribers' —for example, 'to deliver video quality over the Net, to either a PC or a TV, that convinces consumers to pay a little extra to the broadband service provider.'"[268] Meanwhile, "[a]nother DPI equipment manufacturer, Allot, published a marketing brochure touting its ability to increase [an ISP's] ARPU . . . through "'Tiered Services'and 'Quota Management' . . . that allow providers to meter

263 Waclawsky, *supra* note 208, at 57.

264 *See* Frieden, *supra* note 11, at 637.

265 Arshad Mohammed, "*SBC Head Ignites Access Debate*," WASH. POST, Nov. 4, 2005, at D1.

266 Marguerite Reardon, *FCC Approves AT&T-BellSouth Merger*, CNET NEWS, Dec. 29, 2006, http://news.cnet.com/FCC-approves-ATT-BellSouth-merger/2100-1036_3-6146369.html.

267 *See* Waclawsky, *supra* note 208, at 54–55.

268 RILEY & SCOTT, *supra* note 12, at 10.

and control individual use of applications and service.'"[269] The brochure went so far as to list among its "Service Provider Needs",the need to "'reduce the performance of applications with negative influence on revenues (e.g. competitive VoIP services).'"[270] Another equipment manufacturer, Camiant, offers a "Multimedia Policy Engine" that purports to provide "'an intelligent platform for applying operator-defined business rules that determine which customers, tiers and/or applications receive bandwidth priority, at what charge and how much they may use.'"[271] These developments are part of a continuing effort to remake the wired world to look more like the wireless world, where operators exercise considerably more control over the content, applications, and services that run over their networks.[272]

A number of QoS systems reflect a focus in the wireless world on tightly managing the flow of bits across networks and billing for access to specific application and services on the public Internet. The ultimate expression of this is the IP-Multimedia Subsystem ("IMS"), which attempts to provide "an operator-friendly environment for real-time, packet-based calls and services that not only will preserve traditional carrier controls over user signaling and usage-based billing, but also will generate new revenue via deep packet inspection of protocols, URI and content."[273] Although it was conceived for cellular telephone networks, IMS features like billing controls have caught the eye of wireline network operators and standards makers, including cable companies and prominent telco network equipment suppliers.[274]

IMS, like other QoS prioritization systems, assists the packet flow of certain applications such as voice or multimedia—making "the packet-switched network act like a circuit-switched network."[275] But it could also be utilized to "limit the availability of bandwidth" for those non-prioritized applications, even if excess capacity is available and/or the network is not congested.[276] As Waclawsky contends,

> This is the dark side of QoS . . . . With IMS, you will never know if you are getting the advertised broadband capacity you think you are paying for. The actual bit rate will be a function of what IMS thinks you are doing. It will provision a QOS-enabled packet bearer (*aka* a circuit) for you with a specific capacity and nothing more, which

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[269] *Id.* at 11.

[270] *Id.*

[271] *Id.*

[272] *See In re* Skype Communications S.A.R.L., Petition to Confirm A Consumer's Right to Use Internet Communications Software and Attach Devices to Wireless Networks, RM-11361, at i–ii (Feb. 20, 2007), (accessible via FCC Electronic Comment Filing System).

[273] John G. Waclawsky, *IMS 101: What You Need to Know Now*, BUS. COMM. REV. 18, 21 (June 2005).

[274] *Id. at* 18.

[275] Waclawsky, *supra* note 208, at 55.

[276] *Id.*

could be far less than your advertised broadband connection rate.[277]

Notably, "[n]etwork operators do not have to install all of IMS to extract some value from its concepts."[278] The incentive for providers to exert influence has only increased as broadband adoption rates flatten out and ISPs face additional pressure to boost earnings by increasing the ARPU.[279] Thus, rather than selling a user just connectivity, they can further charge subscribers for preferred or priority handling of certain traffic.[280]

Among the other concerns with respect to network management and QoS is the incentive for vertically integrated operators to utilize issues related to congestion to degrade applications and services that compete with their own subscription offerings.[281] DSL and cable providers, like other vertically integrated providers and platform monopolists benefit from a robust applications market and "internalize complementary efficiencies arising from applications created by others."[282] In the case of broadband, providers clearly benefit from the innovation in applications that will drive increased demand of broadband.[283]

However, those benefits are limited when firms engage in price discrimination.[284] Farrell and Weiser note restrictions or "[c]ontrol over applications can help a platform monopolist to engage in price discrimination, charging different markups on combinations of the platform with different sets of applications."[285] All cable and telephone companies "practice price discrimination by offering different tiers of packages or sets of offerings to different customers" and have a strong incentive to protect that pricing regime for services such as voice or VoIP and subscription video programming.[286] The Internet facilitates analogous services without this pricing regime, allowing consumers to either access those services for free or purchase them individually from a multitude of competing firms.[287] Thus, "[e]ven where price discrimination itself *enhances* efficiency, the platform monopolist may impose highly inefficient restrictions on applications competition in order to engage in price discrimination."[288]

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277 *Id.*

278 *Id.*

279 Malik, *supra* note 117.

280 *See* Waclawsky, *supra* note 208, at 54; *see also* Frieden, *supra* note 11, at 661.

281 *See Comcast P2P Order*, *supra* note 2, ¶ 5.

282 *See* Farrell & Weiser, *supra* note 244, at 101.

283 *Id.* at 103.

284 *Id.* at 107–08.

285 *Id.* at 107; *see also* Frischmann & van Schewick, *supra* note 12, at 411 ("Similarly, while the monopolist generally profits from the presence of independent producers in the complementary market, it sometimes profits even more by excluding them from the market.").

286 Farrell & Weiser, *supra* note 244, at 108–09.

287 *See* Kim Hart & Sara Kehaulani Goo, *Tech Faceoff: Net Neutrality, In the Eye of the Beholder*, WASH. POST, July 2, 2006, at F4.

288 Farrell & Weiser, *supra* note 244, at 109.

There is a legitimate concern that providers utilize QoS and DPI to either limit consumer access to, or degrade the quality of, low-cost alternatives to their expensive service. Comcast's interference with BitTorrent traffic provides an illustrative example. As the FCC noted in its Comcast order:

> Peer-to-peer applications, including those relying on BitTorrent, have become a competitive threat to cable operators such as Comcast because Internet users have the opportunity to view high-quality video with BitTorrent that they might otherwise watch (and pay for) on cable television. Such video distribution poses a particular competitive threat to Comcast's video-on-demand ("VOD") service. "VOD . . . operates much like online video, where Internet users can select and download or stream any available program without a schedule and watch it any time, generally with the ability to fast-forward, rewind, or pause the programming."[289]

Comcast argued their network management practice was only for the purpose of limiting excessive utilization during times of congestion.[290] However, congestion was hardly the criteria for Comcast's network management actions regarding P2P traffic from BitTorrent. Although Comcast initially claimed that it interfered with BitTorrent traffic "only during periods of peak network congestion,"[291] evidence submitted to FCC clearly refuted this assertion – leading Comcast to recant and admit that it interfered with BitTorrent traffic "regardless of the level of overall network congestion."[292]

In addition, Comcast's "Fair Share" system de-prioritizes or throttles traffic for users that consume seventy percent of their provisioned upstream or downstream bandwidth.[293] This includes traffic from applications such as VoIP that could compete with Comcast's Digital Voice offering.[294] As an October 2008 filing to the Commission from Free Press noted, Comcast stated its VoIP service "will not be affected by the throttling."[295] According to Comcast, its "Digital Voice is a separate facilities-based IP phone service that is not affected" by the congestion management system.[296] However, the exception is not extended to other competing VoIP applications, a point that Comcast readily admits:

[C]ustomers who use VoIP providers that rely on delivering calls over the public Internet who are also using a disproportionate amount of bandwidth during a period when this network management technique goes into effect may

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289 *Comcast P2P Order*, *supra* note 2, ¶ 5 (citation omitted).

290 *Id.* ¶ 9.

291 *Id.*

292 *Id.*

293 Comcast customerCentral, *supra* note 143.

294 *Id.*

295 Letter from Ben Scott, Policy Dir., Free Press, to Ms. Marlene H. Dortch, Sec'y, Fed. Commc'ns Comm'n, at 3 (Oct. 14, 2008) [hereinafter Free Press Letter], *available at*, http://fjallfoss.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6520175587.

296 Comcast customerCentral, *supra* note 143.

experience a degradation of their call quality at times of network congestion.[297]

Free Press noted they had "received conflicting reports regarding the operation of Comcast's network," and asked the FCC to investigate whether the facilities were actually separate and that customer use of Comcast VoIP service was not actually contributing to the to congestion on the network.[298] As the filing put it, "is Comcast Digital Voice being given a free pass around the congestion to which it contributes?"[299] This prompted the Commission to send a letter to Comcast requesting an explanation of "how Comcast Digital Voice uses Comcast's broadband facilities, and, in particular, whether . . . Comcast Digital Voice affects network congestion in a different manner than other VoIP services."[300] Whether Comcast is advantaging its VoIP service through operating it on separate pipe than other Internet traffic, or prioritizing its packets, as the Commission noted, "it would appear that the fee Comcast assesses its customers for VoIP service pays in part for the privileged transmission of information of the customer's choosing across Comcast's network."[301] Time Warner appears to be taking similar steps to exclude its VoIP and video services from any network management or bandwidth limitations that may be imposed on its high-speed Internet service.[302]

In particular, the ability of operator to charge or limit competition from Internet-based, low-bandwidth services such as VoIP is very lucrative since it consumes just a tiny fraction of the capacity that modern broadband links provide. As Andrew Odlyzko notes,

> In trying to face a future in which the very profitable voice of today is just an inexpensive service riding on top of a broadband link, it is very tempting to try to control current and future low bandwidth services. And to control those, you do need "walled gardens" and DPI."[303]

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[297] *Id.*

[298] Free Press Letter, *supra* note 295, at 3.

[299] *Id.*

[300] Letter from Dana R. Shaffer, Chief, Wireline Competition Bureau, and Matthew Berry, Gen. Counsel, Fed. Commc'ns Comm'n, to Kathryn A. Zachem, Vice President, Regulatory Affairs, Comcast Corp. (Jan. 18, 2009), *available at* http://www.fcc.gov/ComcastLetter011809.pdf.

[301] *Id.* In response to the Commission's letter, Comcast replied that the service was separate from Comcast's HSI service; it does not run over Comcast's HSI service. Because it is a separate service, it was not implicated in any way by Free Press's original "Complaint" or Petition for Declaratory Ruling, by the Commission's August 20 Order, or by Comcast's September 19 Disclosures. CDV, like Vonage or Skype, is an *IP-enabled* voice service (i.e., it uses Voice-over-Internet-Protocol to deliver the service). However, unlike Vonage, Skype, or several other VoIP services, CDV is *not* an application that is used "over-the-top" of a high-speed Internet access service purchased by a consumer."
Letter from Kathryn A. Zachem, *supra* note 145.

[302] Time Warner Cable Residential Services Subscriber Services Agreement, *supra* note 38, at § 6(a)(iii).

[303] Odlyzko, *supra* note 201, at 10–11.

For example, text messages sent over wireless networks consume very little capacity, given their limit of 160 characters.[304] The restriction was necessary given the bandwidth constraints of early wireless networks.[305] But even as the capacity of cellular networks has exponentially increased, operators still charge $0.20 to $0.25 a message, or $20 for unlimited texts of just 160 characters each.[306] As result, the revenue associated with text messaging on a per megabyte basis is estimated to be $1000 compared to just $0.01 per megabyte for residential broadband services.[307]

V. POLICY RECOMMENDATIONS: EMPOWER END-USERS

In testimony to Congress on the issue of network management, Lawrence Lessig offered:

> [W]hile there are plenty of legitimate reasons why a network owner might need to "manage" network behavior, there are anti-competitive, or strategic reasons as well. Which reason motivates a network owner turns upon the business model that the network owner has adopted—either a business model of abundance and neutrality, serving whatever legal applications and content users and innovators want, or a business model of scarcity and control, leveraging financial return out of the scarcity their gatekeeping role allows them to create or maintain. If policymakers were confident network owners were following a model of abundance, there would be less reason to be concerned about how they manage the packets on their network. But because policymakers are uncertain about the ultimate motive for this "management," extensive inquiry into the technical questions of network management become important.[308]

It is difficult not to conclude that some operators have chosen the later model of scarcity, given their preference for network management and QoS to ration increasingly limited capacity among individual users or applications. Given that telecommunications firms have often appropriated new technology to maintain and reinforce their control of networks, it will be necessary to protect and promote innovation and choice at the edges of the network. Within this debate, the very future of the Internet as an open, participatory medium will rest upon how we answer the fundamental question, "Who will make network management and/or prioritization decisions: end-users or network opera-

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304 Posting of Mark Milian, *Why Text Messages are Limited to 160 Characters*, to L.A. TIMES TECHNOLOGY, http://latimesblogs.latimes.com/technology/2009/05/invented-text-messaging.html (May 3, 2009 13:28 PST).

305 *Id.*

306 *Id.*

307 Odlyzko, *supra* note 201, at 10–11.

308 *The Future Of The Internet: Hearing Before the S. Comm. On Commerce, Science and Transportation*, 110th Cong. 3 (2008) [hereinafter Lessig Testimony] (testimony of Lawrence Lessig, C. Wendell and Edith M. Carlsmith Professor of Law, Stanford Law School).

tors?"

In the Comcast decision, the FCC declined to prescribe rules on reasonable network management practices, although it also declined to "foreclose the possibility" of doing so "should future circumstances warrant such a step."[309] The Commission stated its belief in the Comcast decision that the "case-by-case, adjudicatory approach comports with congressional directives and Commission precedents" of preserving a "'vibrant and competitive free market'" for Internet and interactive computer services," and the Commission's view that "broadband services should exist in a minimal regulatory environment that promotes investment and innovation in a competitive market."[310]

The drawback of this approach is that it provides ISPs with an incentive to build-in network management and QoS mechanisms that are difficult to turn-off or remove in an effort to resist *ex post* regulations. As long general ambiguity remains in terms of what constitutes reasonable network management practices, providers have a considerable incentive to establish the facts on the ground by integrating such systems in their networks as much as possible. The current regulatory uncertainty also can restrain investment and innovation in the Internet applications market by the possibility that an ISP may in the future be able to discriminate against newly developed applications.[311] Users, innovators, and even ISPs would benefit from clear guidelines on what constitutes reasonable network management practices. This section does not seek to formulate those specific guidelines. Rather, it suggests two key recommendations that attempt to address concerns of network management and empower end-users to handle congestion issues: network transparency and consumer-driven prioritization.

A. Network Transparency

The current debate over network management and QoS—both in the United

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309 *Comcast P2P Order*, *supra* note 2, at ¶ 40.

310 *Id.* ¶ 32.

311 *See* Lessig Testimony, *supra* note 308, at 7–8. Lessig notes:

Venture capitalists don't chose [sic] whether to invest in new innovation based upon what is happening on the Internet *today*. They base their decisions upon what they expect behavior on the Internet will be *tomorrow*. They decide, for example, whether to fund a new Internet application today based upon whether they believe the entrepreneur will be able to deploy that application profitably in 2 or 5 years. That question in turn will depend upon whether network owners will be free to discriminate against that application in the future."

Id.

States and abroad—has generally been less than transparent.[312] With the exception of Comcast, which was compelled to disclose their practices by the FCC,[313] the majority of ISPs have provided relatively little information regarding their network management practices and the capacity limitations of their broadband networks.[314] Contention or oversubscription ratios remain proprietary information, inhibiting the ability of policymakers and consumers to understand the causes and impacts of congestion on networks and the Internet.[315] Providers have not offered enough specifics regarding the impact of their QoS systems they intend to or already have deployed. All of this has the effect of creating further acrimony between ISPs, network neutrality supporters, network engineers and innovators, rather than facilitating constructive solutions to congestion issues.

What is needed in the current discussion is much greater transparency. This transparency begins with ISPs fully informing their subscribers of the capabilities, limitations, and specific network practices of their broadband connection. As Former FCC Chairman Martin offered in testimony before the Senate Committee on Commerce, Science and Transportation:

> Consumers must be fully informed about the exact nature of the service they are purchasing and any potential limitations associated with that service. For example, has the consumer been informed that certain applications used to watch video will not work properly when there is high congestion?
>
> Particularly as broadband providers begin providing more complex tiers of service, it's critical to make sure that consumers understand whether broadband network operators are able to deliver the speeds of service that they are selling.[316]

In general, consumers may have little understanding of the extent to which providers may be overpromising on speeds. How many consumers actually have an understanding of the average or typical throughput they are receiving? Consumers have access to none of this information, and providers have no regulatory requirement to disclose such information.[317] Rather it is the industry

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[312] Rosalie Marshall, *European Net Neutrality Set to be Restricted*, V3.CO.UK, Sept. 23, 2009, http://www.v3.co.uk/v3/news/2249945/european-net-neutrality-set; Tim Conneally, *FCC Chair Lays Down Groundwork for Net Neutrality Rules*, BETANEWS, Sept. 21, 2009, http://www.betanews.com/article/FCC-chair-lays-down-groundwork-for-net-neutrality-rules/1253541999; Tim Scannell, *FCC Continues to Wrestle with Net Neutrality*, INTERNETNEWS.COM, Feb. 25, 2008, http://www.internetnews.com/government/article.php/3730191.

[313] *Comcast P2P Order*, *supra* note 2, ¶ 54.

[314] *Id.* at 58 (Comm'r Tate, dissenting).

[315] *See* Grunwald & Sicker, *supra* note 38, at 554.

[316] *The Future of the Internet: Hearing Before the S. Comm. On Commerce, Science and Trans.*, 110th Cong. 6 (2008) (statement of Kevin J. Martin, Comm'r, Fed. Commc'ns Comm'n).

[317] *See In re* Formal Complaint of Free Press and Public Knowledge Against Comcast Corporation for Secretly Degrading Peer-to-Peer Applications, *Ex Parte Filing of Free Press*, WC Docket No. 07-52, at 1 (Oct. 24, 2008), http://fjallfoss.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=652019484

norm to only provide offerings in terms of "up to" speeds, which have the impact of inflating consumer expectations and the capabilities of some broadband networks.[318] Such asymmetric information is a clear impediment to facilitating competition in the broadband market.[319]

The current lack of transparency has the impact of insulating providers from their contention and oversubscription ratio choices. Thus, it would seem a reasonable policy option is to empower consumers with the appropriate information regarding their broadband connection.[320] Just as the Food and Drug Administration requires food manufacturers to appropriately label products with a list of ingredients and the nutritional information,[321] consumers should be afforded a similar understanding of their broadband connection. Consumers should have access to the contention ratio on their broadband connection, what are the actual speeds (both upload and download) at various times of day, and as a consequence, the average speeds they can expect to receive. Some ISPs in the U.K. include the contention ratio of their offerings.[322] This disclosure could come in the form of a service level agreement ("SLA") often utilized to provide broadband service to businesses.[323]

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7 [hereinafter Free Press *Ex Parte*].

318 Grunwald & Sicker, *supra* note 38, at 553–54..

319 *See* Free Press *Ex Parte*, *supra* note 317, at 6.

320 *Id.* at 4–5. Free Press notes in their filing:

> For example, the Telecommunications Industry Association observes "the market will function best if users are made aware of the capabilities and limitations associated with competing broadband offerings," and "current disclosure practices are uneven and often insufficient." AT&T notes "disclosure of network-usage restrictions" can "give [consumers] the information they need to make informed decisions among alternative providers."

Id. at 5.

321 *See, e.g.*, Nutrition Labeling and Education Act of 1990, Pub. L. No. 101-535, 104 Stat. 2353 (codified as amended in scattered sections of 21 U.S.C.). *See also* Food Labeling Guide, U.S. Food and Drug Administration, http://www.fda.gov/Food/GuidanceComplianceRegulatoryInformation/GuidanceDocuments/FoodLabelingNutrition/FoodLabelingGuide/default.htm (last visited Nov. 4, 2009). The agency Web site states,

> The Federal Food, Drug, and Cosmetic Act (FD&C Act) and the Fair Packaging and Labeling Act are the Federal laws governing food products under FDA's jurisdiction.
>
> . . . .
>
> The Nutrition Labeling and Education Act (NLEA), which amended the FD&C Act requires most foods to bear nutrition labeling and requires food labels that bear nutrient content claims and certain health messages to comply with specific requirements.

Id.

322 Ofcom, the telecommunications regulator in the United Kingdom, created a Voluntary Code of Practice for ISPs, which includes a provision describing disclosure to consumers of "accurate and meaningful information on [a provider's] broadband speeds . . . before [consumers] enter into any agreement." Voluntary Code of Practice: Broadband Speeds, Ofcom, http://www.ofcom.org.uk/telecoms/ioi/copbb/copbb/ (last visited Nov. 4, 2009).

323 *See* Grunwald & Sicker, *supra* note 38, at 555.

In the Comcast order, the FCC required Comcast to "disclose to the Commission and the public the details of the network management practices that it intends to deploy . . . including the thresholds that will trigger any limits on customers' access to bandwidth."[324] However, it declined to impose similar obligations on other providers, even though the order acknowledged that "fellow providers have also been cryptic as to their practices."[325] For example, although Cox describes the generalities of its QoS system, it does not provide any specifics to what congestion thresholds will trigger its prioritization nor how much or little throughput those de-prioritized applications may receive, providing only that they "may be momentarily slowed."[326] In addition, on its Congestion Management FAQs page, Cox offers that "most Internet video competition comes in the form of downloadable and streaming video from the Internet. Our congestion management practices should actually help ensure that these and other applications run smoothly on our network," except that that Cox's trial is "only focused on upstream congestion."[327] Thus, the QoS system should have no impact on streaming video being downloaded by a subscriber.

Both consumers and developers would benefit from a full disclosure of network management and QoS practices. This would help consumers understand why a particular application is not working and minimize user frustration.[328] Sufficient disclosure of the network management tools used by ISPs is also critical to the designers of Internet applications, as it allows them to predict whether their application will function appropriately on a given network.[329] This will facilitate the development of integrated solutions and best practices among developers. For example, BitTorrent is modifying its P2P protocol to tell applications "to stop seeding the network with content when" there is congestion.[330]

B. Consumer Driven-Prioritization

QoS prioritization is based on a value judgment by the ISP of what applica-

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324 *Comcast P2P Order*, *supra* note 2, ¶ 54.

325 *Id.* ¶ 31.

326 Congestion Management FAQs, *supra* note 57.

327 *Id.*

328 *See* David D. Clark, MIT Computer Science and AI Lab, FCC Public Hearing on Network Management (Feb. 25, 2007), http://www.fcc.gov/broadband_network_management/022508/clark.pdf.

329 *In re* Comcast P2P Order, *supra* note 2, app. at 46.

330 Reardon, *supra* note 16.

tions or services are the most important to consumers. For example, Cox decided what traffic is time-sensitive by the following process:

> Our engineers reviewed the traffic on our network, analyzed the requirements of various services and reviewed available research from third-party organizations. We also took into account our customers' expectations of how these services and applications should perform. For example, customers surfing the Internet expect that web pages should load quickly, so requests for web pages should process rapidly, and therefore fall into the time-sensitive category. However, uploading a file to an FTP site would be minimally affected by a brief delay, so that's classified as non-time-sensitive.[331]

However, what happens when a subscriber needs to upload a large file to a FTP site? As a Free Press report noted:

> One person may use FTP to upload a photo album from a recent vacation to a Web server to share with friends and family; another may use the protocol to upload real-time images of a security system. The former can fairly be considered "low priority," but the latter cannot. The service provider, sitting in the middle of the network and using DPI to determine that the protocol in use is FTP, cannot make that distinction—only the user can.[332]

The issue for QoS is that any given form of traffic, at different times, may be very important to a consumer. At one moment, a user may want to make sure their VoIP application has priority, but at another, the user may need to download a patch to debug a piece of software or make sure their computer is protected from a new virus. Consumer choices are dynamic, and QoS prioritizations are static.[333] The framework that "represents the most direct lineage from the Internet's roots is to try to meet these new objectives by modification of the end-node."[334] Congestive solutions must empower end-users to make capacity allocation decisions. By failing to do this, network operators are creating inefficiencies that fail to maximize the utility of these networks for their users.[335] An end-user solution parallels approaches to the technical and congestive crises on the Internet that relied upon end-users to develop integrated solutions and best practices.[336] By creating similar transparent processes that place

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331 Congestion Management FAQs, *supra* note 57.

332 RILEY & SCOTT, *supra* note 12, at 8.

333 *See id.*

334 Blumenthal & Clark, *supra* note 207, at 81.

335 *Cf.* Waclawsky, *supra* note 216, at 32. ("When you look from the core of the network out to the edge, and you don't consider the end users, you miss the end users' perspective . . . ."). Waclawsky also doubts "that any scalable, reliable means of centralized management and control could be created that is also innovation-friendly, cost effective and able to keep up with changing technology and usage trends." *Id.* at 35.

336 *See* CROWCROFT ET AL, *supra* note 210, at 111–13 (listing proposed QoS architectures that were not implemented since ISPs asked, "who needs it anyway in the . . . bandwidth glut?"). The authors go on to analogize end-user empowerment to the London, England traffic congestion plan implemented in 2003, noting that in that traffic system, "the users themselves have proposed schemes including plans to share vehicles (compression), to trade travel days (deferred download), and to vary parking versus driving costs (caching)." *Id.* at 113.

decision-making in the hands of end-users, ISPs can achieve the same throughput efficiencies without disempowering their customers. In this way, end-users can develop a more widespread consensus regarding congestive solutions, rather than providers imposing solutions.

At a minimum, providers could offer consumers various QoS plans, allowing them to pick which applications they would prefer to prioritize during peak usage periods or periods of congestion. For example, Plusnet, a U.K. ISP, offers consumers various plans for unlimited downstream or upstream speeds and provides the specific speeds that will be provided to applications.[337] Although this could be beneficial to advanced users, it would not likely maximize utility for less-sophisticated users who may lack the technical knowledge to make an informed decision. Worse, it does not allow users to opt out of the QoS scheme.[338]

A better approach would allow users to dynamically prioritize applications over their broadband connection. For example, Sandvine has proposed a network management system to give control over access to bandwidth to both the service provider and end-user.[339] In the application and user-based optimization system:

> The service provider enforces user-to-user fairness allocation and the end-user controls how their individual traffic operates within that allocation.
>
> . . . .
>
> To increase subscriber satisfaction through personalization of service, the service provider may wish to give each user more control over their own priorities. This may involve a "quota" of QoS points or a web page which gives specific weightings per application or per application class.[340]

Sandvide states, "[t]his scheme is clearly the best because it provides a network-neutral and consumer-transparent sharing of network bandwidth resources."[341] User-controlled DiffServ at the subscriber's modem could also be utilized to prioritize time-sensitive traffic leaving the subscriber's modem, allowing the network access link to run at a much higher utilization levels without impacting time-sensitive traffic flows.[342]

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[337] Plusnet, Broadband Download Speeds, http://www.plus.net/support/broadband/quality_broadband/speed.shtml (last visited Nov. 5, 2009).

[338] *See id.*

[339] SANDVINE, THE EVOLUTION OF NETWORK TRAFFIC OPTIMIZATION: PROVIDING EACH USER THEIR FAIR SHARE 1 (2008), http://www.sandvine.com/downloads/documents/Evolution_of_Traffic_Optimization.pdf.

[340] *Id.* at 4.

[341] *Id.*

[342] *See* Evans & Filsfils, *supra* note 98, at 61, 64.

VI. CONCLUSION

In testimony before Senate Commerce Committee, Lawrence Lessig opined that "in the world of digital communication infrastructures, the Internet is everything, supporting a multiplicity of content, applications and services"[343] The evolution of the Internet to this level of primacy was driven by an end-to-end design that placed the intelligence and decision-making at the edges of the network and kept the lower layers of the network involved in the process of moving bits as basic and transparent as possible—allowing networks to be able "to support the widest possible variety of services and functions, so as to permit applications that cannot be anticipated."[344]

In the current debate, it is evident that certain residential broadband networks have substantial capacity constraints. As Internet usage continues to grow and consumers access applications and content that demand more and more from their broadband connection, these networks will becoming increasingly congested without sufficient capacity upgrades. Such a scenario directly conflicts with high oversubscription ratios by providers that assumes subscribers will continue to consume less throughput than their broadband connections allow. Rather than upgrading capacity to reduce contention or offering speeds on the basis of actual—not peak—rates, some ISPs have turned to network management or QoS systems to limit subscribers' use of the network or to prioritize certain applications.

But QoS does not create capacity—it only rations existing capacity among competing network users or uses. At best, it serves as a short-term means to defer capacity upgrades, and at worst, a way for ISPs to increasingly control the flow of bits over their networks. The use of DPI for network management and QoS poses legitimate concerns for network neutrality supporters, given the focus of DPI manufacturers as well as the strong incentives operators have to monitor and monetize Internet traffic.

In this current environment of uncertainty and alarm, innovation and consumers would substantially benefit from clear guidelines from policymakers on reasonable network management practices and greater transparency from ISPs regarding their network management practices and network capabilities. End-user prioritization, along with greater transparency, would facilitate constructive solutions to congestion on networks, paralleling earlier approaches to technical and congestive crises on the Internet that relied upon end-users to develop integrated solutions and best practices. By creating similar transparent processes that place decision-making in the hands of end-users, ISPs can

[343] Lessig Testimony, *supra* note 308, at 7.
[344] Reed et al., *supra* note 235, at 70.

maximize the utility of the subscriber's broadband connection and continue to drive innovation on the Internet.