The Internet's Capacity To Handle Fast-Rising Demand for Bandwidth

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Formed in 1994, the US Internet Industry Association is the primary trade association for companies engaged in Internet commerce, content and connectivity. USIIA serves its members through legislative advocacy and professional services. The association is headquartered in Washington, D.C.

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EXECUTIVE SUMMARY

Industry and academic experts are increasingly concerned about the Internet's capacity to continue to handle the fast-rising demand for bandwidth, unless investments in Internet infrastructure accelerate substantially. However these elements are measured, the growth in demand for bandwidth is outpacing the growth in supply. This begins with the rapid growth in broadband access.

- Between 2004 and 2006, U.S. broadband access increased from 27 percent of households to 44 percent, and it continues to expand here and around the world.
- Industry estimates suggest that between 2006 and 2010, broadband use will grow another 80 percent in the U.S., reaching 90 million households, and by 90 percent worldwide, reaching 474 million households.

The spread of broadband access has been accompanied by large increases in the use of bandwidth-intensive applications, especially voice, music and video. Absent a significant expansion in network infrastructure, the Internet's capacity could be strained, limiting consumers' ability to fully enjoy its services.

- One minute of text browsing requires an average of 2-200 KB of bandwidth, compared to some 1,000 KB for audio and 9,000 KB for video in the MPEG-2 compression format.
- Music file swaps and downloads are growing at an annual rate of 50 percent to 60 percent.
- Video downloading and streaming are so bandwidth intensive that they already may account for 50 to 60 percent of all bandwidth traffic.
- Experts estimate that by 2010, video transmissions could account for as much as 80 percent to 90 percent of all worldwide bandwidth traffic, especially with the spread of IPTV and HDTV Internet-based TV.
- New ways of accessing the Internet for text, music and video – especially through mobile phones and appliances – also are driving up demand for bandwidth in major developing countries as well as the U.S., Europe and Japan.

Accommodating the fast-rising demands on bandwidth will require a significant acceleration in industry investments – totaling $300 billion to $1 trillion for the United States alone – that current pricing models discourage.

- Monthly flat-fee pricing and strong competition helped to accelerate the spread of Internet access by driving down prices, and generated sufficient revenue to support the investments to serve the new users. In the U.S., the drop in prices has helped spread broadband to previously underserved populations.
- Now, bandwidth traffic demands are rising much faster than new subscribers, even as competitive pressures keep driving down prices. As a result, demand is now increasing much faster than investment.
- For example, Internet traffic across borders has been rising at an average rate of 75 percent a year, while bandwidth capacity to handle this traffic is expanding by about 45 percent a year. Projections by TeleGeography suggest that international Internet traffic will continue to grow much faster than deployment of new international bandwidth will.

In most markets, as demand increases so does revenue, which in turn stimulates the investments needed to meet higher demand on a sustained basis. With the Internet, increases in demand for bandwidth by *existing*

users do not translate into higher revenues for the companies providing the bandwidth and access to it, because access to the Internet has spread through fixed-fee pricing. This pricing model supported the necessary investments in bandwidth infrastructure when increases in overall demand were driven mainly by the rapidly-rising numbers of Internet users, and most individuals and applications used little bandwidth. As these factors have changed – the number of new user-subscribers has begun to plateau and the average bandwidth used by subscribers has risen – a mismatch between demand and investment is emerging.

Under this scenario, the quality of Internet services could decline as congestion causes transmissions to slow, which in turn would discourage the development and introduction of new high-bandwidth services.

Accelerated investment is necessary to meet the growth in capacity demand. New business models that can monetize part of the sharp increase in bandwidth traffic can help ISPs, telecoms and backbone companies expand their investments sufficiently to meet the fast-rising demand for bandwidth. Without prejudging what would be the most economically-efficient and socially-beneficial pricing arrangements, the potential options include:

- The development by ISPs of service packages tailored for content providers that transmit high bandwidth content
- A separate fee schedule for consumers whose Internet use requires large bandwidth
- Higher flat fees for all broadband users.

* The impact of various pricing models on Internet access by different groups of consumers, including low-intensity users and low-income users who might be priced out by some options, is a worthy area for future study.

INTRODUCTION

Among Internet pioneers and many industry experts and observers, the web's capacity to handle rising U.S. and worldwide demand has become a matter of increasing concern.[1] David Tansley, who examined the issue for Deloitte, Touche, Tomahtsu, said recently, "2007 may be the year of the tipping point where growth in capacity cannot cope with use."[2] A recent report by UBS warned investors that "Level 3 and other participants in the [web infrastructure] industry have suggested that existing Internet backbone capacity is insufficient to transport high-quality commercial video,"[3] and Bret Swanson of the Discovery Institute has written, "[w]ithout many tens of billions of dollars worth of new fiber optic networks, thousands of new business plans in communications, medicine, education, security, remote sensing, computing, the military and every mundane task that could soon move to the Internet will be frustrated."[4] These views support the conclusions of the Broadband Working Group of the Massachusetts Institute of Technologies' Communications Futures Program, which has warned,

> The broadband value chain is headed for a train wreck. Any business that expects to reach its customers or employees through ever-better mass-market broadband Internet access, whether wired or wireless, is in for a rude awakening. (Under) today's prevailing business models … many commonly foreseen broadband developments are unlikely to happen as planned.[5]

The Internet-based services which the MIT Working Group believes could be in peril from inadequate online capacity include the next generations of a large number of important and popular services, including "videoconferencing, interactive video and television, collaborative gaming, peer-to-peer applications, grid-oriented computing, network-based backups, data-capable wireless networks (3G and beyond) and the sophisticated portable networked gadgets that will use them, and fiber-to-the-home networks."[6] In a recent report, the Federal Trade Commission similarly noted,

> Some observers suggest that the use of bandwidth-intensive applications like certain peer-to-peer file-sharing protocols by even a small minority of users is already consuming so many network resources as to be worrisome. This situation is of particular concern to some experts, who believe that the use of such applications by even a small portion of Internet users may effectively degrade service for the remaining majority of end users ... and may even potentially crash the Internet, or parts of it.[7]

No definitive, standardized global data exists on either the capacity of the critical elements of the web's infrastructure or the total demand on these elements, so we reviewed the available data. These data show that over the last two to three years, U.S. and global demand for bandwidth has expanded at an accelerating rate, as both broadband access and the use of bandwidth-intensive video and audio applications have increased sharply. Moreover, a number of very important and popular applications –

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[1] The author gratefully acknowledges the research assistance of Gregory Tenentes.
[2] *Chicago Tribune*, February 23, 2007.
UBS Research Report, January 18, 2007, quoted in McClure, David, "The Exabyte Internet," *US Internet Industry Association,* May 1, 2007. http://www.usiia.org/pubs/The%20Exabyte%20Internet.pdf.
[4] *Wall Street Journal*, January 20, 2007.
[5] Broadband Working Group. "The Broadband Incentive Problem." *MIT Communications Futures Program,* September 28, 2005.
[6] *Ibid.*
[7] Federal Trade Commission, "Broadband Connectivity Competition Policy," FTC Staff Report, June 2007.

including Internet-based telemedicine, high-definition television, and music – require not only large bandwidth but also perform satisfactorily only if sufficient additional bandwidth is available to preclude delays or fluctuations in their transmissions. In our judgment, very substantial increases in industry investments will be required to ensure that these and other bandwidth-intensive applications do not strain the Internet's capacity in the near future. Providers and backbone infrastructure companies continue to upgrade, expand and otherwise build-out their networks, including the development of bandwidth-efficient "smart" networks. But the economic incentives built into the prevailing U.S. pricing models for Internet access may not support the levels of additional investment needed to scale up the infrastructure to meet the demand from the widespread use of high-density applications. These pricing arrangements will likely have to evolve in the near future to ensure the future levels of investment required by the U.S. and global Internet infrastructures.

THE DIMENSIONS OF CURRENT AND FUTURE DEMAND ON INTERNET CAPACITY

The Rising Incidence of Internet Access and Broadband. The growth in consumer and business demand for Internet bandwidth can be gauged in many ways. However it is measured, that growth has been considerable and appears to be far greater than the corresponding growth in bandwidth capacity. The first aspect of this demand growth is the rising numbers of Internet users in the U.S. and worldwide. The number of U.S. Internet users rose from 124 million, or 44 percent of the population, in 2000 to more than 211 million, or nearly 70 percent of the population, in 2006. However, this growth has slowed substantially since 2004. With a large share of the population already online, the impact of new online subscribers will naturally diminish.

Table 1. U.S. Internet Access, Individuals, 2000-2006[8]

Year	Population	Internet Users	Share Online
2000	281,421,906	124,000,000	44.1%
2001	285,317,559	142,823,008	50.0%
2002	288,368,698	167,196,688	58.0%
2003	290,809,777	172,250,000	59.2%
2004	293,271,500	201,661,159	68.8%
2005	299,093,237	203,824,428	68.1%
2006	302,014,429	211,108,086	69.9%

This slowdown in the growth of the online population is evident also in data from the United Kingdom, which show Internet use increasing only modestly from mid-2003 (58.0 percent of U.K. households) to September 2006 (62.3 percent).[9] Moreover, one survey found a majority of U.K. non-users express little interest in acquiring access.[10] Surveys show Internet penetration reaching roughly the

[8] U.S. Census Bureau, American Community Survey and Current Population Survey, http://factfinder.census.gov/servlet/DatasetMainPageServlet?_program=ACS&_lang=en&_ts=143547961449; and http://www.census.gov/population/www/socdemo/hh-fam.html; FCC, "High-Speed Services for Internet Access," 2007. http://www.fcc.gov/wcb/iatd/.

[9] Deloitte, Touche, Tomahtsu, "Telecommunications Predictions," 2007 www.usiia.org/news/dtt_TelecomPresidctions%202007.pdf.

[10] *Ibid.*

same plateau in other countries, including 62 percent in Finland in September 2005,[11] and 66.5 percent in South Korea in December 2006.[12] While Internet penetration rates may have substantially topped out in America, Britain, Finland and South Korea, those rates are expected to continue to rise rapidly in many other countries for some time. A study by Deloitte estimates that the numbers of worldwide Internet users, which reached 1.1 billion in 2006, will increase another 45 percent over the next four years to 1.6 billion in 2010.[13]

Moreover, Federal Communications Commission data show that even as U.S. Internet access rates have stabilized, the share of U.S. households with broadband access continues to rise sharply – from some 27 percent in 2004 to 34 percent in 2005 and nearly 44 percent in 2006 (Table 2, below). Surveys by the Census Bureau suggest that an even larger share of U.S. households may now have broadband –56.5 percent in 2006.[14] The Organization for Economic Cooperation and Development uses different techniques to measure broadband access; both its findings and the recent trends in the FCC data suggest that the broadband users in the U.S. will continue to rise significantly. The OECD estimates that a much smaller share of people currently subscribe to broadband in the U.S. than in Canada, Denmark, Finland, South Korea, the Netherlands, Norway, Sweden and Switzerland, suggesting that the U.S. broadband penetration has significant room to increase.[15] The OECD further found that the rate of broadband penetration in all advanced countries, including the U.S., was still rising sharply in 2006, just as the FCC found for the U.S.

Table 2. U.S. Broadband Use, Households, 2000-2006[16]

Year	Population: Share Online	Number of Households	Households with Broadband	Share with Broadband
2000	44.10%	104,705,000	3,163,666	3.0%
2001	50.00%	108,209,000	7,812,375	7.2%
2002	58.00%	109,297,000	13,984,287	12.8%
2003	59.20%	111,278,000	20,645,769	18.6%
2004	68.80%	112,000,000	30,088,091	26.9%
2005	68.10%	113,343,000	38,615,489	34.1%
2006	69.90%	114,384,000	50,262,193	43.9%

By one industry estimate, U.S. broadband access will rise by almost 80 percent, from the 50.2 million households found at the end of 2006 to 89.9 million households in 2010; while worldwide broadband use will soar nearly 90 percent from 251.1 million households in late-2006 to 474.4 million households in 2010. [17] The continued growth in broadband access as more of the online population shifts from dial-up service is significant, because broadband users tend to consume greater amounts of

[11] Data from International Telecommunications Union, 2007, www.itu.int.net.
[12] "Usage and Population Statistics," *Internet World Statistics,* http://www.internetworldstats.com.
[13] Deloitte, Touche, Tomahtsu, "Telecommunications Predictions," *op. cit.*
[14] U.S. Census Bureau, American Community Survey and Current Population Survey, *op cit,* FCC, "High Speed Services," *op. cit.*
[15] OECD, www.oecd.org/document/7/0.2340.en_2649_34223_38446855_1_1_1_1.00.html.
[16] U.S. Census Bureau, American Community Survey and Current Population Survey, *op cit*. ; FCC, "High Speed Services," *op. cit.*
[17] Macklin, Ben. "Broadband Services: VoIP and IPTV." *eMarketer*, April 2007. http://www.emarketer.com/Reports/All/Emarketer_2000406.aspx?src=report_head_info_sitesearch; Macklin, Ben. "IPTV: The Global Picture." *eMarketer*, August 2006. http://www.emarketer.com/Reports/All/Em_iptv_sep06.aspx?src=report_head_info_sitesearch.

bandwidth. Even if the total online population is static, capacity consumption will continue to grow as a larger proportion of those who are online use high-speed connections.

The Increasing Intensity of Internet Use. The second factor driving rising demand for Internet bandwidth is the increasing bandwidth-intensity of people's Internet use. Again, there are no definitive international data covering intensity, but the available data point to very sharp increases in average number of bytes used when people go online. Since the Internet's beginnings, the most common use has been email, and industry experts estimate that in 2006, the world's 1.6 billion email mailboxes sent and received some 6 exabytes of legitimate email (equivalent to 6 quintillion bytes of information or $6 * 10^{18}$), plus another 18 exabytes of spam mail.[18] Even this total of 24 quintillion bytes over the course of a year, however, requires a relatively small portion of current bandwidth.

The significant increases in Internet demand come from the fast-rising use of broadband applications, especially video and music/voice, which require much greater bandwidth than email text or normal web browsing. By one estimate, one minute of text-and-graphics browsing consumes 2 to 200 KB of bandwidth, compared to more than 1,000 KB for audio and 9,000 KB for video in MPEG format.[19] In 2006, there were an estimated 5 billion legal mp3 music file swaps in the United States, up 47 percent from 3.4 billion in 2005.[20] Further, iTunes have become the dominant mode of music distribution, now outpacing CDs, and the Recording Industry Association of America reports that in the U.S., downloads of single music tracks increased 60 percent from 2005 to 2006, when it reached 586 million downloads, and downloads of albums more than doubled from 13.6 million to 27.6 million.[21]

The use of the Internet for transmitting voice as well as music is also rising rapidly. As of March 31, 2007, Vonage had 2.4 million subscribers and completed well over 5 billion calls from the U.S., Canada and the U.K. The use of Voice over Internet Protocol services for low-cost international phone service, such as Skype, is also expanding rapidly. Skype's free software has been downloaded 178 million times, and on a typical day in 2006, some 6,570,000 subscribers used the service.[22] TeleGeography estimates that U.S. subscribers to Skype and other VoIP services, which reached 9.6 million in 2006, will rise to 23.7 million by 2010.[23] Other industry experts estimate that worldwide, some 37.8 million people subscribed to VoIP services at the end of 2006 and by 2011, the number could reach 152.6 million.[24]

While music and voice create new and significant demands on the Internet infrastructure that are very likely to continue to increase rapidly, the prospect of Internet capacity problems unless investment increases substantially primarily involves the sharply-rising use of video online. The fast-expanding use of

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[18] Macklin, Ben. "IPTV: The Global Picture," *op. cit*. McClure, David. "The Exabyte Internet." *US Internet Industry Association,* May 1, 2007. http://www.usiia.org/pubs/The%20Exabyte%20Internet.pdf; "Spam and Virus Partnership Still Strong." *eMarketer*, May 29, 2007. http://www.emarketer.com/Article.aspx?id=1004972.

[19] "Developing Media for Low Bandwidth," http://www.learningcircuits.org/2001/mar2001/ttools.html; see also www.htmlgoodies.com/tutorials/web_graphics/articles.php/3481951.

[20] NPD Group, "Legal Music Downloads Were Fastest Growing Digital Music Category in 2006," www.npd.com/press/releases/press_0703141.html.

[21] "2006 U.S. Manufacturers' Unit Shipments and Value Chart," Recording Industry Association of America, April 7, 2007, www.riass.com/keystatistics.php.

[22] Sidak, J. Gregory, "A Consumer-Welfare Approach to Network Neutrality Regulation of the Internet." *Journal of Competition Law and Economics*, Vol. 2, No. 3, pp. 349-474, September 2006.

[23] U.S. VoIP Report." *TeleGeography*, 2006, http://www.telegeography.com/ee/supplemental_files/pdf.php?pdf_file=usvoip06_execsum.pdf&pub_code=free_resources.

[24] Macklin, Ben. "Broadband Services: VoIP and IPTV." *eMarketer*, April 2007, *op cit*.

video online is a direct result of the sharp increases in broadband access. The growing audience for online video also has stimulated the development of more video-based Internet services with wide appeal, such as YouTube and VideoEgg, online transmission of network television programming in both standard and high definitions formats, and transmissions and downloads of full length feature films. These expanded offerings, in turn, will further drive up demand for these very high bandwidth services.

Video downloads and transmissions are so bandwidth intensive – consuming 8 to 10 times per minute the bandwidth of voice or music – that the Internet infrastructure firm Level 3 reports that video now accounts for 50 to 60 percent of the traffic it manages on its backbone network.[25] That share is probably fairly typical, based on other recent estimates. For example, Deloitte estimates that peer-to-peer video use alone will account for more than one-third of all global Internet traffic this year.[26] That does not include any video streaming and downloading from independent websites. A recent analysis by CacheLogic similarly attributes more than 60 percent of all Internet traffic to peer-to-peer transmissions, of which 60 percent involve video.[27] In the peer-to-peer area, VideoEgg went from zero to transmitting 15 million videos a day for online social-networking sites in two years.[28] Further, the 100 million video streams accessed each day through YouTube are said to consume as much bandwidth as the entire Internet in 2000,[29] and on top of that are the downloads of programming on television network sites or direct Internet transmissions of sports and other programming. Other experts forecast that by 2010, 157 million people worldwide will view video online at least once a month – including tens of millions who will do so every day – and their video downloads and transmissions may account for as much as 80 to 90 percent of all bandwidth traffic.[30]

This last forecast is based in part on the advent and spread of digital television, which enables the largest mass medium in every country to begin to migrate to the Internet. Major League Baseball has offered live Internet feeds of most games for a fee since 2001. By 2003, 550,000 people had subscribed to live streaming video broadcasts of games on MLB.TV, and those numbers rose to 850,000 in 2004.[31] Since October 2005, Apple has offered several TV programs for download in the QuickTime video format on its website for a small fee, and reported selling 8 million downloads in the first four months.[32] Major and niche television networks also offer downloads now of their programs on their websites, well-advertised at the end of their regular broadcast.

The most important development in this area, however, is Internet Protocol TV, which can transmit all channels directly over the Internet. According to one industry expert, 300,000 Americans and 4.9 million people worldwide subscribed to IPTV services in 2006. With services such as AT&T's U-verse service and British Telecom's BT Vision coming online, some industry forecasters predict that IPTV subscriptions in 2011 will reach 4.8 million in the U.S. and 41.1 million worldwide.[33] In addition to regular television programming, films also are increasingly available online. Amazon, Netflix, and Wal-Mart all have announced plans to transmit DVDs over the Internet,[34] and Adams Media Research estimates that

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[25] Duffy, Jim. "Don't expect video to exhaust fiber glut." *Network World,* February 19, 2007. http://www.networkworld.com/news/2007/021507-dont-expect-video.html?t51hb.
[26] Deloitte, Touche, Tomahtsu, "Telecommunications Predictions," *op cit.*
[27] McClure, David. "The Exabyte Internet." *op. cit*.
[28] Ante, Spencer, "Telecom: Back from the Dead," *Business Week*, June 25, 2007.
[29] Swanson, Bret, "The Coming Exaflood," *Wall Street Journ*al, January 20 2007.
[30] Norton, William. "Video Internet: The Next Wave of Massive Disruption to the U.S. Peering Ecosystem, v1.3." *Equinix,* 2007.
[31] Sidak, J. Gregory, "A Consumer-Welfare Approach to Network Neutrality Regulation of the Internet," *op. cit.*
[32] *Ibid*.
[33] Macklin, Ben. "Broadband Services: VoIP and IPTV." *eMarketer*, April 2007, *op cit.*
[34] McClure, David. "The Exabyte Internet".o*p cit*.

consumer spending on such video downloads will increase from $111 million in 2006 to more than $4 billion over five years.[35]

Internet television will create huge new demands on bandwidth. Standard television video, for example, requires 450 times the bandwidth of a web-browsing session, while HDTV requires 2,700 times the bandwidth, and the newest video format, 4K, requires over 10,000 times the bandwidth of browsing.[36] These metrics use the current MPEG-2 compression standard, which requires 4 Mbps for standard format TV and 19 Mbps for HD TV. MPEG-4 is expected to replace MPEG-2 shortly, reducing the requirements to 2 Mbps for standard format and 10 Mbps for HDTV.[37] That will help, but television and films also require virtually continuous transmission with no more than a few milliseconds of fluctuation in delivery speed. Therefore, reliable transmissions require connections that provide not just sufficient bandwidth on average, but much greater bandwidth to avoid small delays and variations.[38]

With most countries moving to all-digital television broadcasting by 2010, HDTV-equipped homes are expected to rise worldwide from 48 million in 2006 to 151 million in 2011, and in the U.S. from 28 million to 63 million.[39] The spread of HD technology will create new markets for HDTV services over the Internet, including HD videos as well as Internet-based HDTV for households with HDTVs and no HD cable or satellite service. The spread of IPTV also will likely add new and potentially far-reaching interactive aspects to television not possible with traditional broadcasts. For example, viewers could register responses, purchase products portrayed in programming or commercials, and choose the angle for watching sporting events or concerts. Such applications could further increase the attraction and demand for television over the Internet. Surveying these prospects, John Chambers, CEO of Cisco Systems, recently predicted that video applications could cause network loads to grow at rates of 100 to 500 percent annually.[40]

The challenge in managing the fast-increasing demand for bandwidth presented by video relates to not only the increases in total traffic, but also to the magnitude of the spikes in that traffic. Network infrastructure must be capable of handling not average demands, but peak demands. A system's financial efficiency is enhanced if its peak and average usage are relatively close. However, popular video files often spread "virally," producing sudden and very sharp spikes in bandwidth demand. As a result, video applications create a wedge which, by one estimate, roughly doubles the ratio of peak traffic to the system's mean traffic.[41]

The increase in bandwidth demand tied to music and video is also driven by new ways of accessing the Internet, especially the mobile web. One mobile web exchange companies, Bango, estimates that mobile Internet use in the U.S. tripled in the last year. By another report, 30 million Americans used mobile

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[35] Pociask, Stephen. "Net Neutrality and the Effects on Consumers." *The American Consumer Institute,* May 9, 2007. http://www.theamericanconsumer.org/ACI%20NN%20Final.pdf.

[36] McClure, David. "The Exabyte Internet," *op cit.*

[37] Clarke, Richard N. "Costs of Neutral/Unmanaged IP Networks." May 2006.

[38] *Ibid*.

[39] Murray, Simon and Adam Thomas. "150 Million HDTV Homes by 2011." *Information Telecoms & Media,* April 20, 2007. www.informatm.com/itmgcontent/icoms/s/sectors/media-entertainment/20017418912.html/; Gantz. John. "The Expanding Digital Universe: A Forecast of Worldwide Information Growth Through 2010," IDC White Paper, May 2007. http://www.emc.com/about/destination/digital_universe/.

[40] Internet Innovation Alliance, press release, June 26, 2007; also GCN, http://www.gcn.com/online/vol1_no1/44513-1.html..

[41] Norton, William B. "Video Internet: The Next Wave of Massive Disruption to the U.S Peering Ecosystem, v1.3, Equinox 2007.

devices to access the web in January 2007, compared to 159 million using PCs.[42] Moreover, in July - September 2006, 37 million American mobile phone users had music-capable phones, 23.5 million had phones with integrated music players, and more than two million subscribers reported purchasing music via mobile downloads from wireless carrier music stores.[43] These numbers could rise sharply with the introduction of the new music-capable iPhones.[44]

The number of mobile video subscribers in the U.S. also increased by 145 percent in 2006, reaching 6.2 million.[45] In the final quarter of 2006, nearly 17.4 million American mobile customers downloaded a mobile game.[46] Third Generation cellular phone broadband services currently offer speeds of 400 to 700 Kbps for data and television-like services, and Verizon Wireless, AT&T Wireless (formerly Cingular), Sprint and others all have launched multimedia wireless services. Users browse content on 3G network and access news, 3D games, music videos and episodes of television programs adapted for phones, as well as email.[47] By 2006, wireless 3G broadband was accessible to 160 million people in the U.S. alone. These cellular services are used even more broadly and intensely in Europe and Japan.[48]

Web access through cellular phones is also a particularly fast-growing area in developing nations where fixed-line Internet systems are still underdeveloped and PCs are too expensive for most people.[49] At the end of 2005, when there were an estimated one billion Internet users? worldwide, there were also 2.2 billion mobile phones compared to about 800 million PCs. Bango, which operates its mobile web exchange in 190 countries, estimates that the top mobile Internet-using countries include, in addition to the U.S. and U.K., South Africa, India and Indonesia. Mobile-web usage in India alone is expected to top European levels within the next few years.[50]

INVESTING IN THE INTERNET INFRASTRUCTURE TO SUPPORT FAST-RISING DEMAND

In most markets, as demand increases, so does revenue, which in turn stimulates the investments needed to meet higher demand on a sustained basis. The Internet, however, does not always operate like

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[42] "Mobile Web Audience Already One-Fifth the Size of PC Based Internet Audience in the U.K.," *Telephia*, May 14, 2007, www.telephia.com/html/comscorejanuary2007UK.html.

[43] "One in Ten Mobile Subscribers Have Music-Capable Phones, but Over the Air Music Purchasing Still Slow to Catch Hold." *Telephia*, January 8, 2007. http://www.telephia.com/html/DeviceApplepress_release_template.html.

[44] Gertzen, Jason. "Gauging the iPhone's Ripple Effect." *The Kansas City Star*, May 29, 2007. http://www.macnewsworld.com/story/57578.html.

[45] "Telephia Supports Consumer Research Initiatives for Industry-Leading Mobile Television and Music Provider, MobiTV." *Telephia*, March 27, 2007. http://www.telephia.com/html/Telephia_Release_MobiTV_Approved_FINAL_3-27-07.html.

[46] "Mobile Game Revenue in the U.S. Hits $151 Million in Q4 2006 with Strong Year-Over-Year Growth." *Telephia*, March 5, 2007. http://www.telephia.com/html/GDC07_press_release_template.html.

[47] Sidak, J. Gregory, "A Consumer-Welfare Approach to Network Neutrality Regulation of the Internet," *op. cit.*

[48] "Building Broadband's Future." *Verizon – Corporate Responsibility,* 2006. http://multimedia.verizon.com/responsibility/service/cstmrSatisfaction.aspx.

[49] Roto, Virpi. "Web Browsing on Mobile Phones – Characteristics of User Experience." Doctoral Dissertation, *Helsinki University of Technology*, December 8, 2006. http://lib.tkk.fi/Diss/2006/isbn9512284707/isbn9512284707.pdf.

[50] "Mobile web use in the US surges ahead with three fold increase in last 12 months. Search fuels appetite for mobile web surfing." *Bango*, June 5, 2007. http://bango.com/news/pressreleases/143_mobilewebgrowth.aspx.

most other markets. The critical difference is that increases in demand for bandwidth by *existing* users do not translate into higher revenues for the companies providing the bandwidth and access to it, because basic access to the Internet has spread through fixed-fee pricing, usually on a monthly basis, rather than charges based on how much bandwidth individuals use. The pricing model supported the necessary investments in bandwidth infrastructure when increases in overall demand were driven mainly by the rapidly-rising numbers of Internet users, and most individuals and applications used little bandwidth. As these factors have changed – the number of new user-subscribers has begun to plateau, and the average bandwidth used by subscribers has risen – a mismatch between demand and investment is emerging.

This result is already evident in industry data on traffic and investment across national borders (Table 3, below). These data show very strong growth over the last three years in average and peak Internet traffic across national borders, measured by bits per-unit of time. They also show that while Internet traffic across borders has increased at an average rate of 75 percent a year, the bandwidth capacity to handle this traffic across borders, measured by the capacity of the fiber carrying the traffic, has expanded at much lower rates of about 45 percent a year. This presents a particular challenge for web infrastructure in the U.S., as 94 percent of all interregional traffic – traffic between Europe and the U.S., Europe and Asia, Asia and the U.S., Asia and Latin America, Latin America and the U.S, and Latin America and Europe – runs through the United States.[51]

Table 3. Annual Growth in International Internet Traffic and Bandwidth[52]

	6/2003 – 6/2004	6/2004 – 6/2005	6/2005 – 6/2006
Average Traffic	104%	50%	75%
Peak Traffic	105%	57%	58%
Internet Bandwidth	45%	43%	47%

There is also evidence that suggests that this mismatch may grow more serious.[53] The most recent data on bandwidth demand inside Europe clearly show large increases, despite the sharp slowdown in the numbers of new Internet customers. The volume of traffic flowing through the Amsterdam Internet Exchange, the world's largest Internet hub carrying 20 percent of all European Internet traffic, grew at an average compound *monthly* rate of 7.4 percent in 2006.[54] There is every reason to expect that those large, 2006 increases in traffic are continuing or even accelerating, as video transmissions and downloading through a range of applications and appliances continue to increase. This mismatch is also evident in recent projections by TeleGeography, forecasting that international Internet traffic will continue to grow much faster than the deployment of new international bandwidth. Moreover, demands on bandwidth inside the major countries, including the U.S., Germany, Britain, Japan and South Korea, are likely increasing at least as quickly as bandwidth use that crosses borders.

South Korea may be a leading indicator of what lies ahead for Internet users in other major markets. By OECD measures, Korea has substantially greater broadband subscription rates than the U.S. or most of Europe, ranking third in the world in broadband access behind only Denmark and the

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[51] *Ibid.*
[52] "TeleGeography Report," *TeleGeography*, 2007, www.telegeography.com/ee/supplemental_files/pdf.php?pdf_file=tg2007_exec_sum.pdf&pub_code=free_resources.
[53] *Ibid.*
[54] "Telecommunications Predictions." Deloitte Touche Tomahtsu, 2007, *op. cit.*

Netherlands.[55] One major broadband provider, Korea Telecom, reports that as the national broadband market has matured and new subscriptions have slowed, total traffic has continued to nearly double every year. This suggests that the average intensity of Korean households' Internet use is doubling every year. The company has found, however, that much of that increase is attributable to a small share of total users; about 5 percent of its subscribers account for about half of the total traffic, including tens of thousands of younger Koreans who subscribe to massive multi-player online games. These sharp increases in bandwidth traffic, while new subscriptions slow, have produced predictable financial pressures. Korea Telecom's average monthly revenue per-user have been stable, while the average traffic per-user and consequent costs have continued to rise sharply. In order to finance the upgrades in the system's capacity required to handle the additional traffic, Korea Telecom has announced plans to replace traditional flat-fee pricing with a menu of usage-based charges.[56]

However it is financed, more investment is the answer to capacity issues. The cost estimates for building out the Internet infrastructure to reach all U.S. businesses and households and meet their expected rising bandwidth demands range from $300 billion to $1 trillion.[57] To keep up with rapid growth in traffic volume, ISP and backbone providers will have to develop new technologies, upgrade existing switching and other facilities, and lay new fiber – all expensive and time-consuming programs. Some network operators already are developing new technologies for "smart" networks that differentiate among packets to better ensure transmission without delays or fluctuations for applications such as telemedicine, VoIP and IPTV. One study found that a network that cannot differentiate between packets in this way would require 60 percent greater capacity than one that did.[58]

The major providers also are investing large amounts to upgrade their networks, especially to support "triple play" services that bundle Internet access, television and phone service. This substantially involves the ongoing investments of regional carriers to replace lower-capacity copper cables with higher-capacity fiber optics, under "fiber to the premises" programs for the "last mile" between their core fiber networks and the homes or offices of customers. Verizon, for example, invested a reported $22 billion in its wireline infrastructure between 2003 and 2005, and its FTTP network upgrades were expected to reach 6 million U.S. customers by the end of 2006.[59] Over the same period, Verizon also reported investing $16.5 billion in its wireless infrastructure, in part to support much greater bandwidth for cellular platforms.[60] Similarly, from 2003 to 2006, AT&T spent nearly $26 billion on wireline investments, as well as more than $13 billion in wireless infrastructure.[61] These investments will provide faster and more reliable video downloads and streaming. However, they also will likely stimulate even greater demand for those downloads.[62]

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[55] OECD, www.oecd.org/document/7/0.2340.en_2649_34223_38446855_1_1_1_1.00.html. Some estimates suggest that 95 percent of Koreans age 20 to 29 years and nearly 90 percent of those age 30 to 39 have access to broadband. Usage and Population Statistics." *Internet World Stats*. http://www.internetworldstats.com/.

[56] Broadband Working Group, "The Broadband Incentive Problem." *MIT Communications Futures Program,* September 28, 2005.

[57] McClure, David. "The Exabyte Internet." *US Internet Industry Association,* May 1, 2007, *op. cit*.

[58] Yuksel, Murat; Ramakrishnan, K.K.; Kalyanaraman, Shivkumar; Houle, Joseph D.; and Sadhvani, Rita; "Value of Supporting Class of Service in IP Backbones," www.cse.unr.edu/~yuksem/my-papers/iwqos07.pdf.

[59] "Building Broadband's Future." *Verizon – Corporate Responsibility,* 2006, *op cit*.

[60] *Ibid.*

[61] www.att.centralcast.net/cingularenwsarchive/Release.aspx?ID-4193.

[62] "Telecommunications Industry Overview." *Verizon – Investor Relations,* November 2006. http://investor.verizon.com/profile/industry/; Adegoke, Yinka and Robert MacMillan "DirecTV may try broadband on power lines." *Reuters*, May 14, 2007. http://www.reuters.com/article/technologyNews/idUSN1433448320070514?feedType=RSS&rpc=22.

Investment *is* increasing, but the pricing structures of the current business models for ISPs and backbone providers may not support the full level of additional investments required to meet growing capacity requirements over the near future. For many years now, the Internet service prices charged by ISPs have been falling. The Bureau of Labor Statistics reports that those prices declined 27 percent between February 1998 and February 2007.[63] The FCC has found that the average monthly price for broadband service decreased from an average of $80 in 1999 to an average of $25 in 2005.[64] Industry analysts similarly report that between 1999 and 2005, the price of 1.5 Mbps DSL monthly service declined from about $80 to $30, while Cable Internet speed more than doubled with little change in average monthly charges.[65] The following (Table 4, below) shows this path of declining prices for DSL service.

Table 4. Average Monthly Price of DSL Service

	February 2000		**May 2005**		**April 2006**	
	1.5 Mbps	***3.0 Mbps***	***1.5 Mbps***	***3.0 Mbps***	***1.5 Mbps***	***3.0 Mbps***
AT&T/SBC	$45		$19.95	$29.95	$12.99	$17.99
Bell South			$42.95	$54.95	$32.95	$37.95
Verizon	$79.95		$29.95		$14.98	

The falling price of Internet service also has driven down the transit prices for basic transmissions that backbone providers can charge. From mid-2003 to mid-2004, the average IP transit lease prices for 155.52 Mbps, the basic transmission on standard fiber optic networks, (fell about 50 percent in the United States and Europe and 44 percent in the major Asian markets. The following year, mid-2004 to mid-2005, those prices fell another 23 percent in the U.S., 33 percent in Europe and 27 percent in the major Asian markets. From mid-2005 to mid-2006, STM-1 transit prices fell another 23 percent in the U.S., 22 percent in Europe, and 14 percent in the major Asian markets.[66] As a result, the average monthly transit prices for STM-1 ports decreased from $101/Mbps in New York and $204/Mbps in Hong Kong in the mid-2003, to $29/Mbps in New York and $69/Mbps in Hong Kong in mid-2006.[67] There also were similar prices declines for higher-capacity ports, such as the Gigabit Ethernet.[68]

The economic dynamics here are clear. The Internet-access revenues of the ISPs and telecoms are generally stagnating, because even as the number of new broadband subscribers increases, the competition for them drives down prices. In the U.S., the price decline has enabled previously underserved populations, especially Americans with lower incomes, to acquire broadband services.[69] Still, new broadband subscriptions will level off in the next few years, even as the demand on bandwidth from those subscribers continues to rise. But as that demand rises, the intense competition within a mature market will constrain

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[63] Pociask, Stephen. "Net Neutrality and the Effects on Consumers," *op cit*.
[64] Sidak, J. Gregory, "A Consumer-Welfare Approach to Network Neutrality Regulation of the Internet," *op. cit*.
[65] Hahn, Robert and Robert Litan. "The Myth of Network Neutrality and the Threat to Internet Innovation." *The Milken Institute Review,* First Quarter 2007. http://www.aei-brookings.org/admin/authorpdfs/page.php?id=1342.
[66] "Global Internet Geography Report." *TeleGeography*, 2007, *op. cit.*
[67] *Ibid.*
[68] "Global Internet Geography Report." *TeleGeography*, 2006. http://www.telegeography.com/ee/supplemental_files/pdf.php?pdf_file=gig06_exec_summ.pdf&pub_code=free_resources.
[69] Horrigan, John B. and Aaron Smith, "Home Broadband Adoption 2007," Pew Internet & American Life Project, June 2007, http://www.pewinternet.org/pdfs/PIP_Broadband%202007.pdf.

the capacity of the ISPs and telecoms to invest in new networks, at least under current pricing models. Stagnant revenues also will cap or drive down the prices that ISPs pay backbone providers, reducing their capacity to invest in new backbone infrastructure.[70] All the while, the flat-fee monthly pricing for consumers, which helps drive broadband access, also encourages consumers to use increasingly bandwidth-intensive applications, increasing the costs of network operators. These dynamics are sustainable so long as the Internet infrastructure can accommodate the increasing demand with investments consistent with stagnating revenues.

The sharp increases in Internet traffic seen around the world, associated with rapidly-rising demand for bandwidth-intensive video transmissions and downloads, will likely continue and accelerate as Internet television and film applications increase. At its present capacity, this year, next year, or the year after, the Internet could reach its limits at peak times, and the backbone of terabit-capable pipes connecting the continents could be overwhelmed. Capacity wholesalers anticipating this crunch may compete heavily for spare capacity on key routes, but the declining prices that ISPs and telecommunications companies can pay for wholesale capacity will discourage the capacity wholesalers from investing in new capacity at the rate required. Under this scenario, the quality of Internet services will decline as congestion causes transmission to slow down, which in turn will discourage the development and introduction of new high-bandwidth services.[71]

As a vital part of the commercial, financial and political infrastructure of most nations and the global economy, the Internet will adjust to these pressures, probably by changing its pricing arrangements in order to support the investments necessary to serve not only growing demand, but also innovations that will further expand demand. For example, TeleGeography Research projects compound growth rates in international bandwidth demand of 21 percent a year over the next five years, based on the explicit assumption that "markets will migrate to a cost-plus model, recouping operating costs and incremental upgrade costs, plus a net margin."[72]

Since the current fee structure may not support the investments required to manage the fast-rising traffic, new pricing structures may emerge in the normal course of business.

Without prejudging what would be the most economically-efficient and socially-beneficial pricing arrangements to ensure the increases in investment required to avoid Internet capacity problems, one option involves the development by ISPs of service packages that could be tailored for content providers that transmit high bandwidth content. Such packages would presumably involve higher revenues and, from a purely economic standpoint, could provide at least part of the funding for required investment.

Another alternative is a separate fee schedule for consumers whose Internet use requires large bandwidth. As noted earlier, Korea Telecom is currently shifting to a pricing system that will charge some Internet users based on the bandwidth they actually use. In Norway, where a small portion of users are responsible for 80 percent of broadband traffic, one operator now offers both two monthly rates – one higher with unlimited use and the second lower with metered fees based on the bandwidth a consumer uses.[73] British telecom offers three pricing plans with the same download speed but different ceilings of total monthly usage.

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[70] "Telecommunications Predictions." Deloitte Touche Tomahtsu, 2007, *op cit.*
[71] *Ibid*.
[72] TeleGeography Research, "Global Bandwidth Forecast Service," April 2006.
[73] "Telecommunications Predictions." Deloitte Touche Tomahtsu, 2007, *op.cit.*

A third option would be higher flat charges by access providers fees for all broadband users. However, this approach could price low-intensity users or lower income groups out of the Internet.[74] Indeed, the impact of various pricing models on different groups of consumers may be a worthy area of future study.

ISPs and backbone providers will be able to help fund the Internet's future development if they can monetize at least part of the sharp increases in the use of Internet bandwidth which they provide. Moreover, there is good reason to expect that such price increases will be temporary, as higher rates of use of cables will allow for lower per-circuit costs, creating the room for renewed price declines.[75] Allowing new business models to emerge will help insure the additional investments necessary to support the development and spread of the next generation of bandwidth-intensive Internet applications, and the goods and services which they will provide.

Conclusion

The rapid pace of innovation on the Internet, as businesses, governments and non-profit organizations take advantage of broadband capacity to provide new goods and services to larger groups of consumers, has produced enormous benefits in information exchanges, entertainment, communications, political action, and life-quality services. The explosion in Internet-enabled services, especially those using video, music and voice, also has produced very sharp increases in demand for bandwidth, raising serious concerns about the capacity of the U.S. and global Internet infrastructure to handle the demand. The growth in demand for bandwidth appears now to be outpacing the growth in the supply of bandwidth capacity. Sharp increases in investment will be required to avoid Internet congestion and slowdowns that would limit people's ability to access new innovations, and thereby discourage their future development.

The current Internet pricing models used by ISPs may not provide the necessary incentives to expand these investments, because they may not generate the necessary revenues without pricing millions of consumers out of the Internet. To preserve broad access and promote the investments required to support bandwidth for the next generation of Internet innovators, new business models must emerge to better match demand and investment.

[74] Broadband Working Group, "The Broadband Incentive Problem." MIT, *op cit.*
[75] TeleGeography Research, "Global Bandwidth Forecast Service," *op. cit.*

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