BROADBAND PERFORMANCE

OBI TECHNICAL PAPER NO. 4

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EXECUTIVE SUMMARY

This paper analyzes residential consumer usage of broadband and the performance of fixed[1] broadband connections in the U.S. The data and analyses in this paper were used to create the National Broadband Availability Target described in the National Broadband Plan (NBP), and therefore represent key inputs into the calculation of the broadband availability gap. The paper also explains how networks have evolved and could evolve over time and what drives network usage and performance demands.[2]

This paper is organized into three sections. The first section examines how residential consumers use their broadband service and classifies consumers into four distinct broadband use profiles. The second discusses the performance of U.S. broadband connections that consumers have purchased—today, in the past and projected for the near future. Finally, the paper explains how the data in the first two sections led to the National Broadband Plan's National Broadband Availability Target.

SUMMARY OF FINDINGS

Data indicate a diverse broadband consumer population with several different usage patterns:

- The average Internet user has been online for 10 years and spends roughly 29 hours per month online at home, double the amount in 2000.
  - Faster connections are correlated with more time online.
- In the first half of 2009, the *median* broadband user consumed almost 2 gigabytes of data per month, whereas the *average* (mean) user consumed over 9 gigabytes per month.
  - Mean usage is driven by a small set of users who consume large amounts of data.
  - Overall, per-person usage is growing substantially (30-35% per year).
- Based on FCC analysis, there are four distinct use profiles among U.S. consumers, each with different usage characteristics.
  - For these four use profiles, actual download speed demands range from 0.5 to 7 megabits per second (Mbps), with varying quality-of-service requirements.
  - Data indicate that 80% of broadband use falls into three of these profiles, which require actual download speeds of no more than 4 Mbps.
  - Usage is increasing with greater use of video and two-way, interactive applications.

The evolution of the broadband network highlights several key points:

- Since 1997, consumer-purchased broadband connection speeds have doubled roughly every four years, with advertised fixed broadband download speeds growing at a 20% annual rate.
- In 2009, U.S residential consumers subscribed to broadband connections across a range of technologies, with average (mean) and median *advertised* download speeds of 7–8 Mbps:
  - Fiber-to-the-premise (FTTP): 10–15 Mbps;
  - Cable modem: 8-11 Mbps;
  - DSL: 2.5-3.5 Mbps (including fiber-to-the-node (FTTN)); and
  - Satellite or fixed wireless: approximately 1.3 Mbps.
- FCC analysis shows that average (mean) *actual* speed consumers received was approximately 4 Mbps, while the median actual speed was roughly 3 Mbps in 2009. Therefore actual download speeds experienced by U.S. consumers lag advertised speeds by roughly 50%.
  - This gap is similar across technologies.
  - The gap is due to a variety of factors, some controlled by users (computer performance, home Wi-Fi set-up, etc.), some within the span of control of providers in their network, and some due to the unpredictability of the Internet.
  - This gap may cause confusion among consumers, as actual speeds, which largely determine the end-user experience, lag advertised speeds considerably.

The National Broadband Availability Target developed for the universal service recommendations of the National Broadband Plan meets several key principles:

- The Target must be future ready, taking into account the rapid evolution of the way Americans use broadband; to ensure the Target meets demand over time it must be revisited periodically.
- The Target should reflect information about today's residential broadband usage to determine performance requirements.
- The Plan sets a forward-looking Target to guide public funding, recognizing that usage is evolving and that it will take time to extend broadband networks to unserved areas.

The paper finds that the National Broadband Availability Target should be 4 Mbps for actual download speeds and 1 Mbps for actual upload speeds and should evolve as the data underlying the Target are periodically updated and reevaluated.

I. CONSUMER USE PATTERNS

How consumers use the broadband connections they purchase has evolved as broadband connections have become more commonplace. Although consumers spend more time online, access larger amounts of data and use a broader array of applications, the typical user still focuses primarily on e-mail and Web browsing, the most widely-used applications. Thus consumers generally may not be using the full capacity of the broadband connections they purchase.

TIME ONLINE

While the commercial Internet was still new at the turn of the century, today the average Internet user has been online for 10 years and spends roughly 29 hours per month on the Internet at home, or almost 1 hour per day.[3] This is roughly double the amount of time that a user spent online in 2000. While substantial, home Internet use is still dwarfed by the average time most Americans watch television—almost 5 hours per day.[4] Like speeds, hours online have grown rapidly since 1994, when the average Internet user was online for just one hour each month at home (*see* Exhibit 1).

Since 1994, the average number of hours each person spends online has increased at a 25% compound annual growth rate. And the amount of hours online is correlated with the speed of a residential connection—higher purchased actual speeds correspond to more hours online per month (a discussion of actual speed appears in the next section); *see* Exhibit 2.[5]

Exhibit 1:
Hours Online per Internet User (Home Use Only)

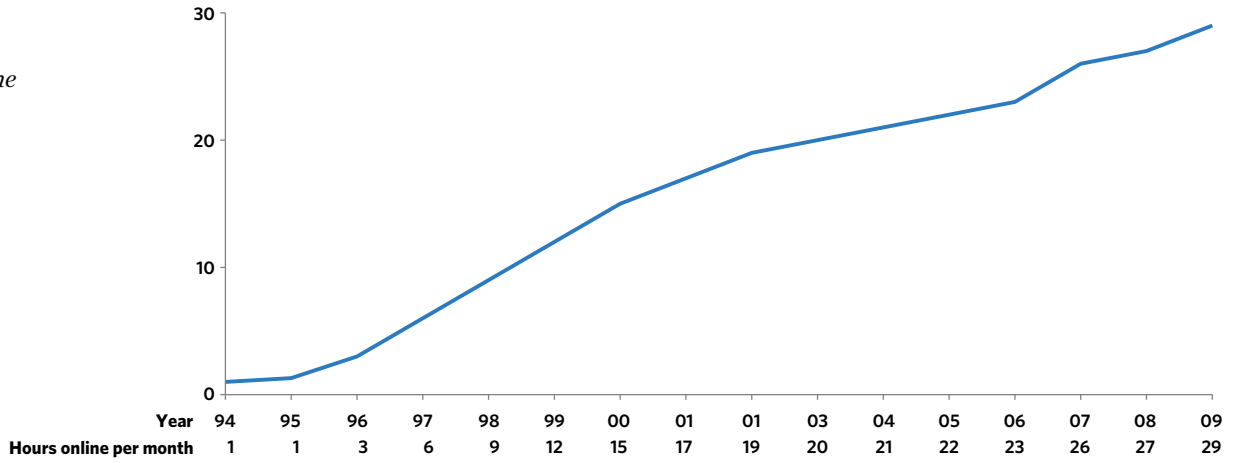
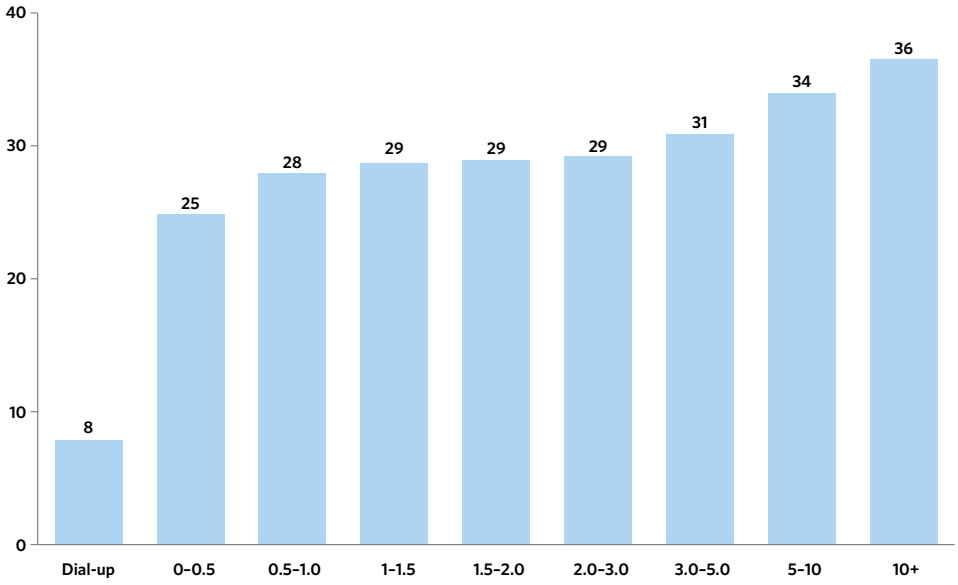


Exhibit 2:
Hours Online per Month, by Actual Download Speed of Residential Internet Connection (Mbps)



DATA CONSUMPTION

Average usage is often described in gigabytes (GB) per month, a figure that reflects the total volume of data that a user consumes during an entire month. In 2009, though estimates vary,[6] data suggest that the *median* user consumed less than 2 GB/month on her home connection, while the *average* (mean) U.S. Internet user consumed more than 9 GB/month (*see* Exhibit 3).[7] At the prevailing growth rates discussed below, consumers on average could use close to 15 GB per month by the end of 2010.

The extreme difference between average and median data usage is principally due to a relatively small number of users who consume very large amounts of data each month – sometimes terabytes (a terabyte is 1,000 GB) per month. The most data-intensive 1% of residential consumers appear to account for roughly 25% of all traffic, the top 3% consume 40%, the top 10% consume 70%, and the top 20% of users consume 80% of all data. While half of all users consume less than 2 GB per month, the last 6% of users consume more than 15 GB each month (*see* Exhibit 4).[8]

Like speeds and hours spent online, data usage has grown rapidly, driven by the increasing data-intensity of applications and greater utilization of broadband. Applications may use very different amounts of data over similar time periods due to different underlying performance demands. For example, a user surfing the Web clicks on links to download textual or pictorial information, which the user then views. Over an hour, a user could click on many different sites but consume a fraction of the data that a user downloading one movie in a ten-minute period would consume. And the data consumed in those two instances is far less than that consumed by a third user participating in a two-way, high definition videoconference over the entire one-hour period. As the Internet has become more content-rich—through graphics and video—and interactive communications applications have become more popular, intensity of usage has increased.

Exhibit 3:
Average (Mean) and Median Data Usage (GB per Month, 1H 2009)

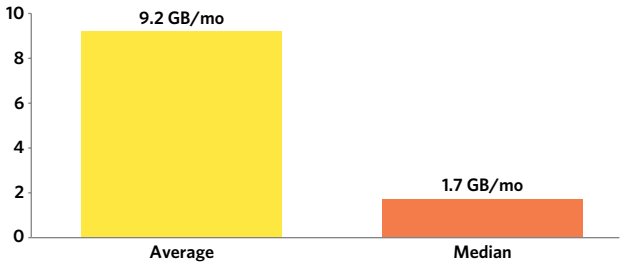
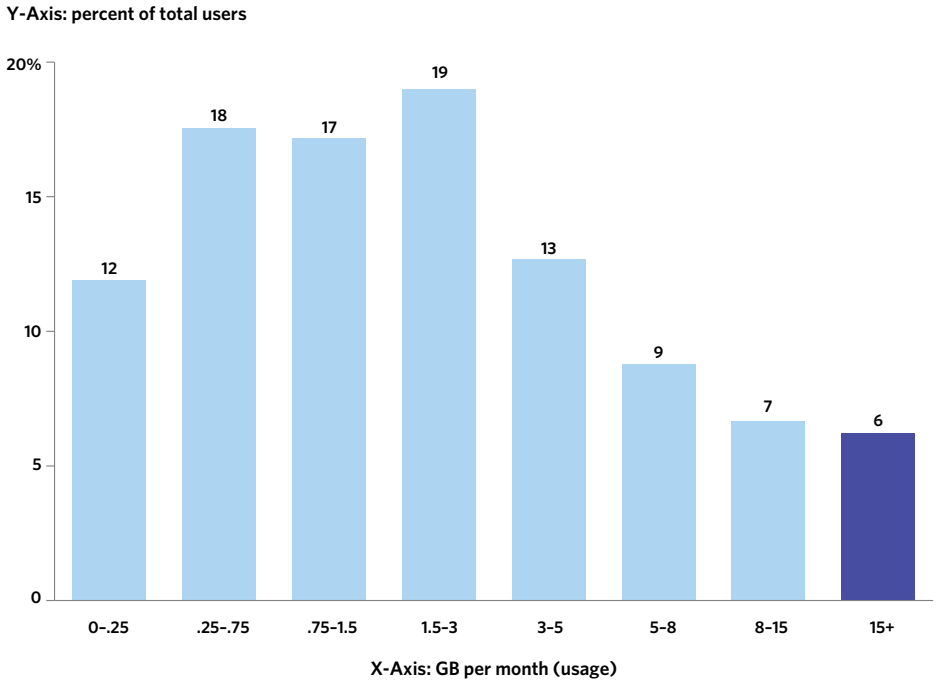


Exhibit 4:
Distribution of Users by Data Usage (GB per month)



Overall, these factors have combined to fuel rapid growth in Internet data consumption. Annual growth was 40–50% in 2009, with several sources noting a slowdown from the mid-1990s when data usage was growing 100% or more annually.[9] Once the impact of new users has been excluded from the growth rate, annual growth is closer to ~30–35% on a per-user basis (*see* Exhibit 5).[10]

Similar to hours spent online, gigabyte usage per month appears to be correlated with actual broadband download speeds. A user with a broadband connection that delivers 5–10 Mbps of actual download speed on average uses 11 GB per month, while a user with a broadband connection that delivers less than 500 kbps of actual download speed on average only uses 5 GB per month (*see* Exhibit 6).[11]

While data consumption, usage growth and connection speed provide some insight into the demands that consumers place on broadband networks, it is the way that consumers actually use their broadband connections that drives network performance demands. In other words, consumer-use profiles drive the requirements for connection speeds.

CONSUMER-USE PROFILES

Consumers access a variety of applications and resources on the Internet and have varying speed and performance demands. Exhibit 7 shows the percentage of home broadband users who have engaged in activities ranging from online shopping to communicating with government to Internet gaming.[12]

The Internet has a "long tail" of many different applications that allow innovation and exploration; but the typical experience includes similar baseline applications and activities, with the most time spent on communications, entertainment, local and international news, and social networking (*see* Exhibit 8).[13]

Not all users take advantage of online applications equally. Some people engage only in more basic online activities, such as checking e-mail or reading news headlines.[14] Others explore next-generation applications, accessing the latest content and heavily using different information devices and tools, such as e-book readers.

Based on Pew broadband user survey results and FCC analysis, U.S. consumers can be categorized into four distinct broadband-use profiles, based on usage characteristics and speed demands:

Exhibit 5:
Data Usage Annual Growth Rates, Overall and Per-User (2009)

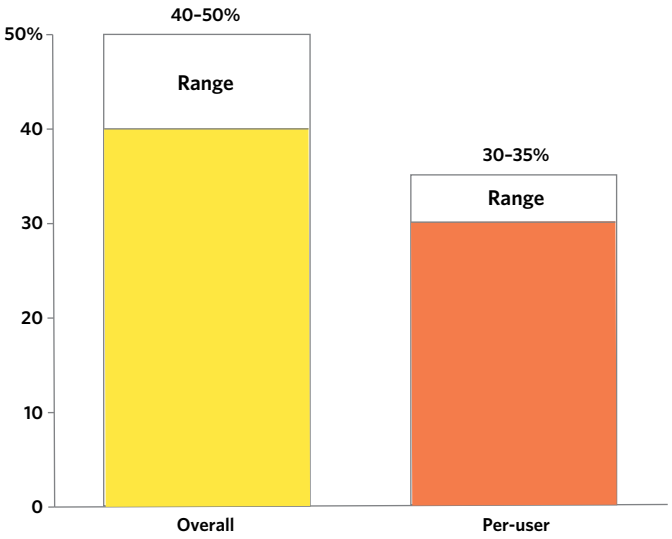
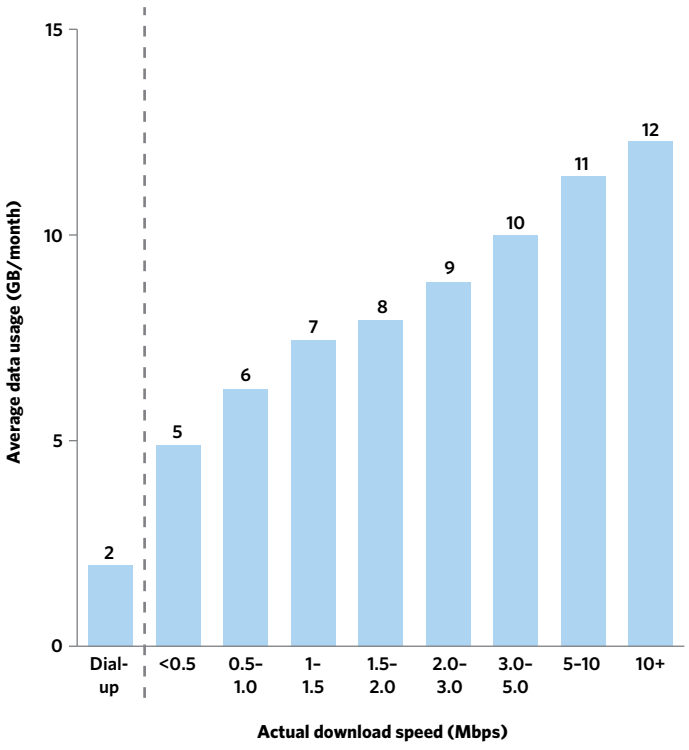


Exhibit 6:
Average Data Usage (GB per month), by Actual Download Speed of Connection (Mbps) (1H 2009)



- *Advanced*. These consumers use large amounts of data and tend to use the highest quality voice, video, and other cutting-edge applications.
- *Full media*. These consumers are moderately heavy users of broadband and mobile applications, seeking to access high-quality voice, data, graphics, and video communications but, typically not in the most cutting-edge forms.
- *Emerging multimedia*. These consumers utilize some video and graphical content but still see the Internet primarily as a way to communicate and access news and entertainment in a richer format than found in offline content.
- *Utility*. These consumers are largely content to access the Internet for basic news, communication, and basic entertainment.[15]

Members of each of these use profiles generally access a different mix of applications, each of which place distinct demands on the consumer's broadband connection. These demands are often expressed in terms of "speed" needs. For example, in Exhibit 9 below, the first highlighted set of applications—basic downloads and uploads, such as e-mail and Web browsing—has relatively low download speed needs—no more than 100–300 kbps. More complex applications such as standard-definition (SD) quality streamed video require faster download speeds—typically approximately 1 Mbps,[16] though depending on the video application and compression technology used, SD video may consume up to 5 Mbps. At the high end of the range, an application such as enhanced high-definition (HD) video teleconferencing could require 5–10 Mbps, or more along with significant quality of service (QOS) performance (*see* Exhibit 9, where "Symm."—short for symmetrical—indicates that the download speed is also required for upstream traffic).

Download speeds are only one measure of broadband performance. For example, HD quality videoconferencing requires very fast upload speeds to allow a person to transmit her image and voice while simultaneously receiving the image and voice of another person. In addition to upload and download speeds, measures of QOS such as availability, latency and jitter (variation in latency among different packets) may be important. Some applications, like e-mail or text-based Web surfing, are generally insensitive to these other measures of network performance, but for other applications, such as videoconferencing, these measures may be important (*see* Exhibit 10).[17]

Taking different user needs as well as speed and performance demands together, there emerge distinct profiles of what different consumers demand from their network connection. Each use profile has a "basket of applications" that reflect typical uses of the Internet for that set of users.[18] These follow the four primary user types laid out above: basic utility, emerging multimedia, full media, and advanced. The basic utility user would require actual download speeds of approximately 500

Exhibit 7:
Percentage of Home Broadband Users Who Have Ever Engaged in Selected Online Activity

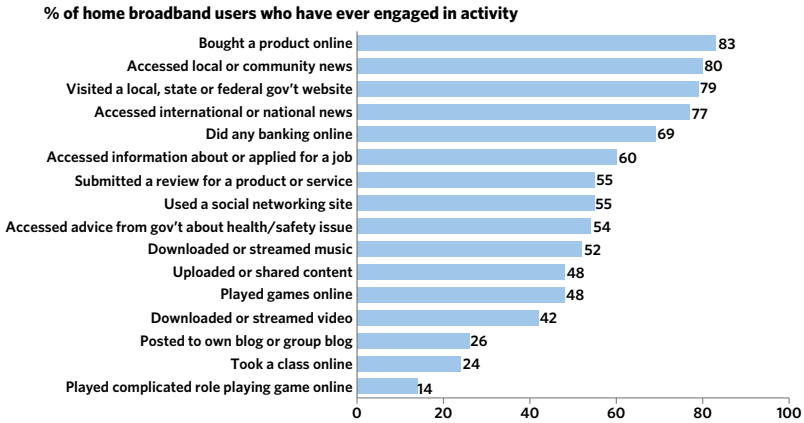


Exhibit 8:
Distribution of Hours Online by Type of Activity

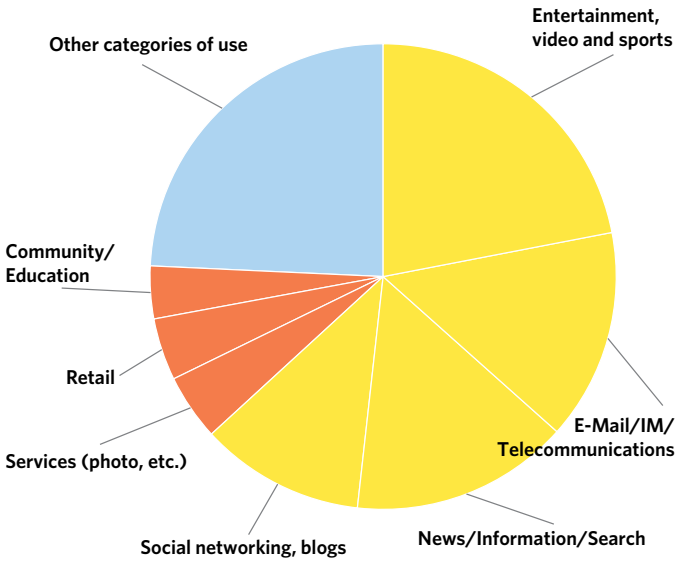


Exhibit 9:
Actual Download Speed Demands (Mbps) by Different Content and Application Types

	Content type	Example applications/ content providers	Actual download speed demands (Mbps)	
Non real-time	• Basic download (or upload) usage	• Basic email, E-book download • Web-browsing, job search, government website access	0.1-0.3 *(Speed impacts down/up time and render)*	
	• Large download (or upload) usage	• Advanced web browsing, iTunes • Social Networking, P2P, etc • Medical Records download/sharing	0.5-5+ *(Speed impacts down/up time and render)*	
Near-real-time	• Streamed audio	• PBS, Rhapsody	0.1-0.3	
	• Basic streamed video	• Consumer generated education videos	0.3-0.5	
	• SD-quality streamed video	• Streamed classroom lectures • Hulu	1-5	
	• HD-quality streamed video	• Broadcast quality HDTV • HD streamed University lecture	5-10+	
Real-time	• Voice over the Internet (VOIP)	• Skype, Vonage	0.1-0.3	Symm.
	• Basic interaction	• Aleks (Online interactive education) • Pogo online games	0.3-0.5	Symm.
	• Video-conference + VOIP	• Lower definition telemedicine	0.6-1.0	Symm.
	• IP TV	• IPTV	1-5+	Symm.
	• 2-way advanced video interaction	• Real-time interactive experiences & gaming	2-5+	Symm.
	• Enhanced video teleconferencing (HD quality or similar)	• Video teleconference and TeleLearning • HD Telemedicine (diagnostic imaging)	5-10+	Symm.

Sources: FCC analysis, California Broadband Task Force report, Adtran FCC submission, Speedmatters.com report, Technet Broadband Primer, ITIF report March 2009, Discussions with content providers

Exhibit 10:
Performance Demands for Different Types of Applications

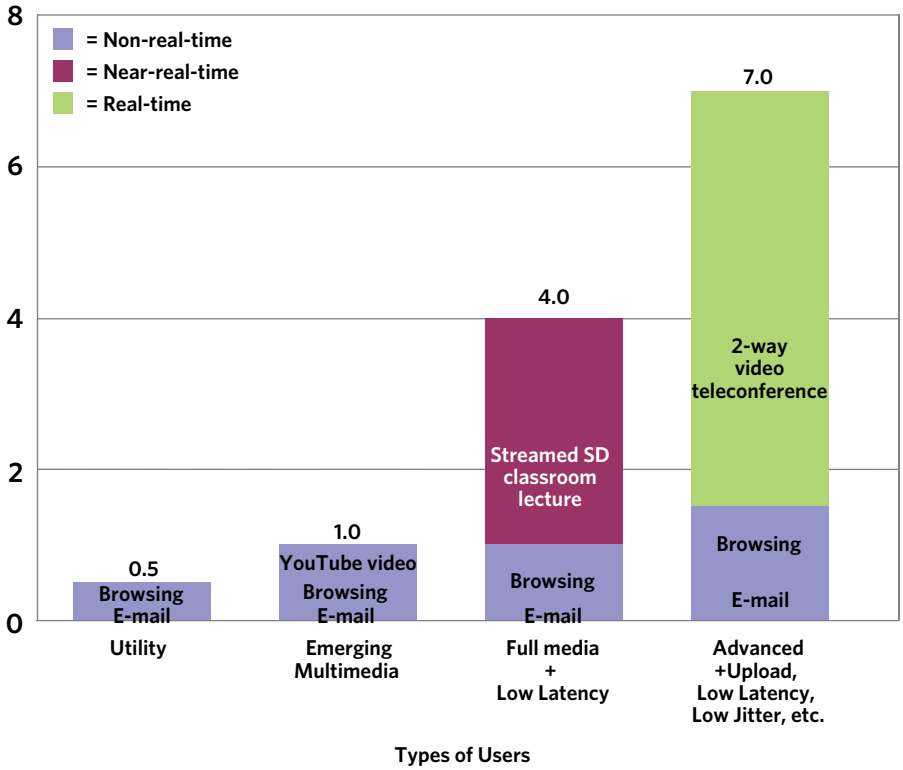
	Non real-time	Near-real-time	Real-time
Typical applications:	• Email • Web browsing—entertainment, social networking, news, photos, etc. • SD and HD video download	• Streamed music • Streamed SD or HD video • Some IP TV	• VOIP (+ video) or teleconference • Some IP TV • 2-way video gaming
Primary performance drivers:	• Throughput—actual download and upload speeds • Availability/reliability • *Latency (as part of speed)*	• Throughput—actual download speeds • Availability/reliability • QOS—Latency, Packet loss, Jitter, Etc.	• Throughput—actual download and upload speeds • Availability/reliability • QOS—Latency, Packet loss, Jitter, Etc.
	Actual download and upload speed primarily determines user experience (latency, but only as part of speed)	**Actual download speed and other QOS** determine user experience	**Actual download and upload speed and other QOS** determine user experience

kbps, while emerging multimedia and full media users would require actual download speeds of 1–4 Mbps, depending on the quality demands of particular applications they might use. Data indicate that 80% of broadband users fall into these first three use cases.[19] Advanced users accessing applications such as enhanced two-way videoconferencing and HD video streaming could require actual symmetric (*i.e.*, upload and download) speeds of 5 Mbps or more and significant QOS (*e.g.*, low latency) from the network (*see* Exhibit 11).

Users' speed and performance demands may change over time as applications become more data-intensive and the "common basket" of applications in each use profile evolves. The analysis above is a baseline for understanding existing consumer behavior and usage profiles.

Analysts project sizeable additional growth of online video watching by consumers, which may considerably increase demands on broadband networks.[20] Increased consumption of online video already has had an impact on broadband use patterns, but an increase in data demands from "traditional" websites is also reflected in the analysis above. E-mail and Web activities account for almost 80% of the typical (median) consumer's data usage.[21]

Exhibit 11:
Actual Download Speeds Necessary to Run Concurrent Applications (Mbps)



II. PERFORMANCE OF U.S. BROADBAND NETWORKS

Since the consumer Internet revolution in the mid-1990s, access technologies and speeds to reach the Internet have evolved considerably. In 1994, few consumers had Internet access at home, and if they did have access it was likely via a 14 kbps or 28 kbps dial-up modem. Today, over 72% of U.S. households purchase Internet connections and most use broadband technologies that deliver much faster speeds than dial-up (*see* Exhibit 12).[22]

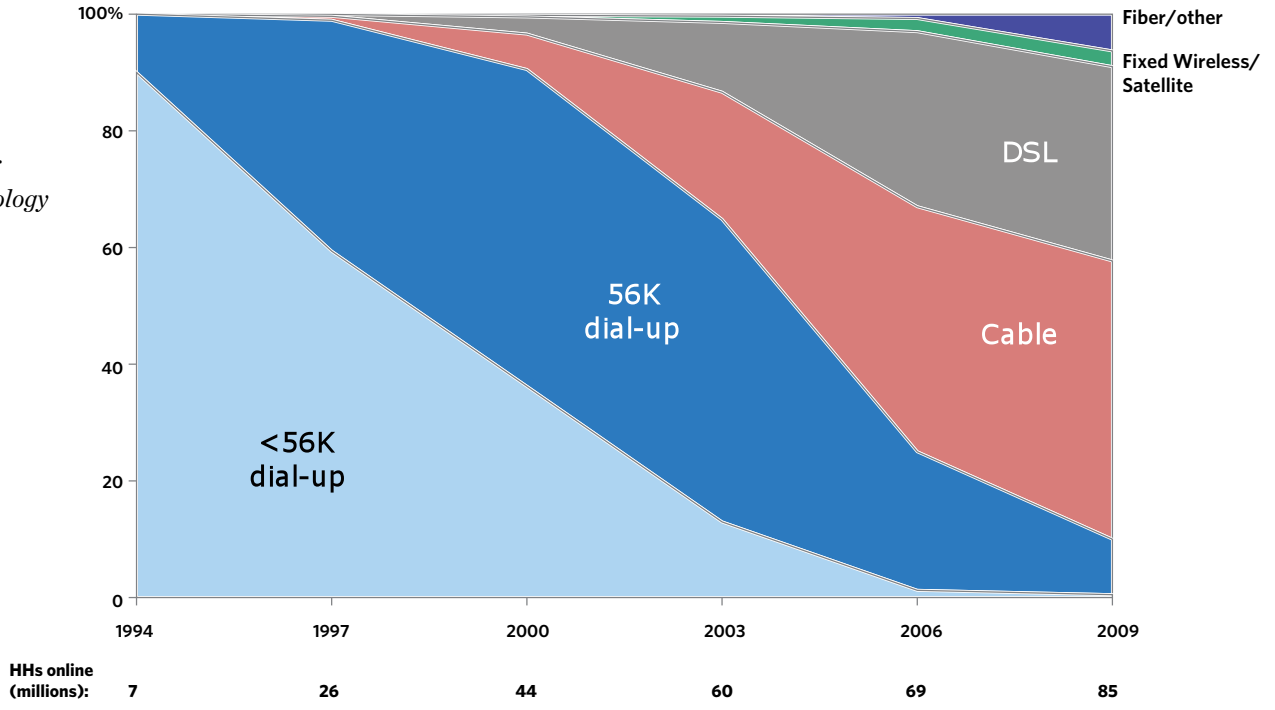
Since 1997, advertised fixed broadband download speeds that consumers purchase has grown at roughly a 20% annual rate, doubling every 4–5 years. Including dial-up in the analysis, average advertised Internet connection download speeds have increased more than 50% annually. Faster speeds are driven by several factors, including the migration of consumers to faster technologies, the evolution in speeds of each technology and the investments of Internet service providers (ISPs) in building out broadband networks in new areas. Consumers have embraced new technologies, first migrating to faster 56 kbps dial-up modems, then to new broadband technologies such as DSL, cable, fiber, satellite and fixed wireless.

In addition, Internet connection technologies themselves have evolved to offer faster services. Cable broadband is a good example: In 1997, a consumer could typically purchase advertised cable speeds of up to 1 Mbps; by 2006, this was 5 Mbps, and today, it is close to 10 Mbps—a roughly 20% compound annual growth rate.[23] The pattern is similar across other technologies: as dial-up modems grew from 14 kbps to 56 kbps, DSL speeds have increased from 384 kbps to several megabits per second and fiber offerings have continually increased speeds.

Median advertised broadband speeds in the United States increased from 800 kbps in 1997 to 7 Mbps in 2009 (*see* Exhibit 13).[24] Including dial-up, the median advertised speed of Internet access service increased from roughly 14 kbps in 1994 to 6,300 kbps (6.3 Mbps) in 2009.

Historical speed growth indicates a doubling of speed roughly every four years for broadband technologies. Including dial-up, data indicate a doubling in speed roughly every two years for Internet access (*see* Appendix 2 for greater detail). Comments in the record, publicly available data and other FCC analysis support similar conclusions.[25] Importantly, this speed increase has continued as strongly in the last few years as it did with the introduction of widespread broadband in the late 1990s.[26]

Exhibit 12: Internet Access Connections Purchased by Consumers over Time, by Technology (Households)



ADVERTISED DOWNLOAD SPEEDS

In 2009, U.S residential broadband consumers subscribed to connections with average (mean) and median advertised download speeds of 7–8 Mbps.

As discussed previously in this paper, there are important speed and performance factors other than advertised download speeds that impact a user's experience, including actual speeds and QOS measures. However, for the vast majority of consumers, advertised speeds are often the only performance data available for decision-making when comparing broadband offerings.

There are various estimates for average advertised speeds in the U.S. in 2009, ranging from 6.7 Mbps to 9.6 Mbps (*see* Exhibit 14).[27] comScore data show an average (mean) advertised speed of 8 Mbps and a median of 7 Mbps. The Organisation for Economic Co-operation and Development (OECD) data show an average of 9.6 Mbps. By averaging the mid-points from speed tiers in FCC Form 477 data, the average (mean) advertised download speeds purchased by U.S. consumers appears to be 6.7 Mbps (taking the midpoint of the range of 4.4–9.2 Mbps as indicated in Exhibit 14; *see* Appendix 2). Each measurement has its strengths and weaknesses, but taken together, these estimates indicate the average advertised broadband service offerings available to U.S. consumers in 2009.

Substantial differences emerge when data are further disaggregated to compare the average advertised speeds of different broadband technologies. FTTP connections average 10–15 Mbps, cable connections average 8–11 Mbps, and DSL connections average 2.5-3.5 Mbps (including FTTN-based DSL). Satellite and fixed wireless connections average approximately 1.3 Mbps (*see* Exhibit 15).[28]

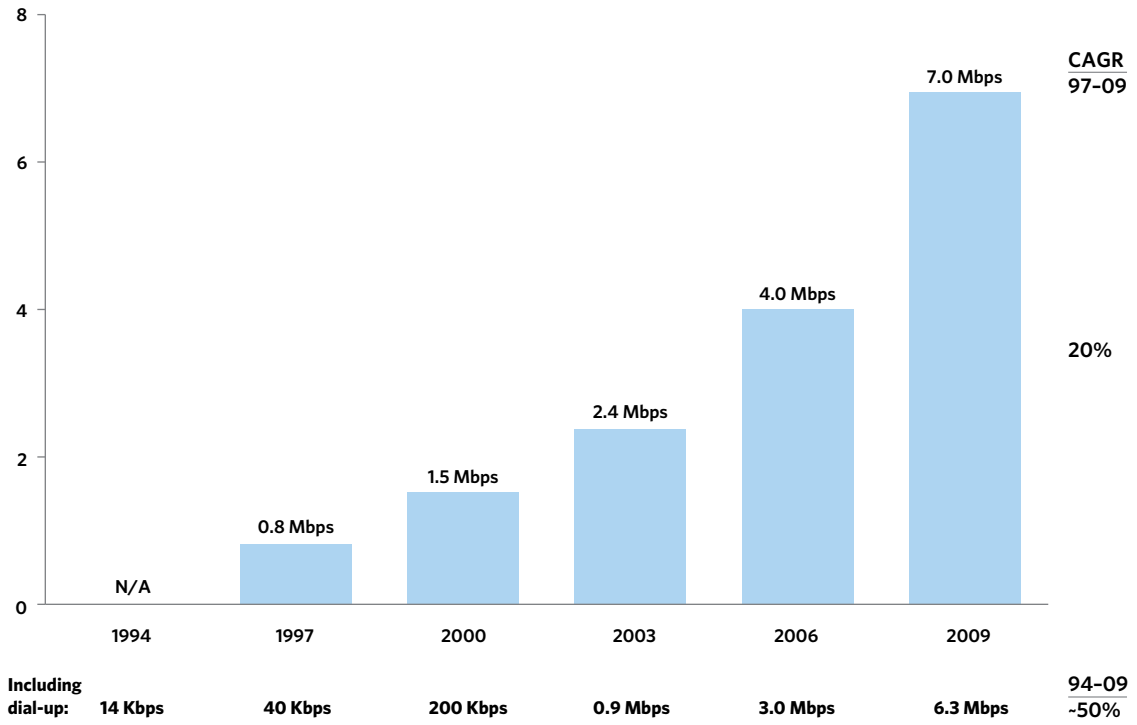
While advertised speeds offered by different technologies offer insight into consumers' purchasing decisions, actual performance experienced on a broadband connection is what drives a consumer's ability to access and utilize the Internet's resources. Therefore, it is important to understand how these network connections perform in practice.

ACTUAL DOWNLOAD SPEEDS

As noted above, in 2009, average (mean) and median advertised download speeds were 7–8 Mbps, across technologies. However, FCC analysis shows that the median actual speed consumers experienced in the first half of 2009 was roughly 3 Mbps, while the average (mean) actual speed was approximately 4 Mbps. Therefore actual download speeds experienced by U.S. consumers appear to lag advertised speeds by roughly 50%.

The actual speed that consumers experience influences their ability to access and utilize applications and content. The most commonly cited speed for broadband connections is the maximum *advertised* speed.[29] But maximum advertised speed

Exhibit 13:
Median Advertised Download Speed of Broadband Connections Purchased by Consumers over Time (Mbps)



does not take into account congestion or degradation of service over the connection line. This metric also does not account for performance degradation due to user devices (*i.e.*, slow- or low-performing computers, under-functioning wired and wireless home routers, etc.) or the performance of websites and applications, all of which are typically outside of the control of the ISP. Yet this "up to" speed is commonly the only metric that can be used to compare the speeds of different broadband offerings.

The "up to" speed, however, does not provide an accurate measure of likely end-user broadband experience. That experience depends on multiple factors, including the *actual* speed that consumers realize, taking into account the impact of network congestion; and other metrics like the availability of the network, latency, jitter and packet loss (*see* Appendix 3).[30]

In other words, consumers need a better, publicly agreed-upon measure of broadband performance that reflects the network operation and end-user experience. The NBP's Recommendation 4.3, calling on the FCC to work with the National Institute of Standards and Technology, consumer groups, industry and other technical experts to develop broadband measurement standards is designed to address this issue.

The key characteristics for technical speed and performance definitions will likely include:

- Actual speeds and performance over the broadband service provider's network (points 2–5 in Exhibit 16) and end-to-end points of the connection (points 1–6);[31]
- Actual speeds and performance at peak-use hours;[32]
- Actual speeds and performance achieved with a given

Exhibit 14:
Advertised Download Speeds by Various Data Sources (Mbps)

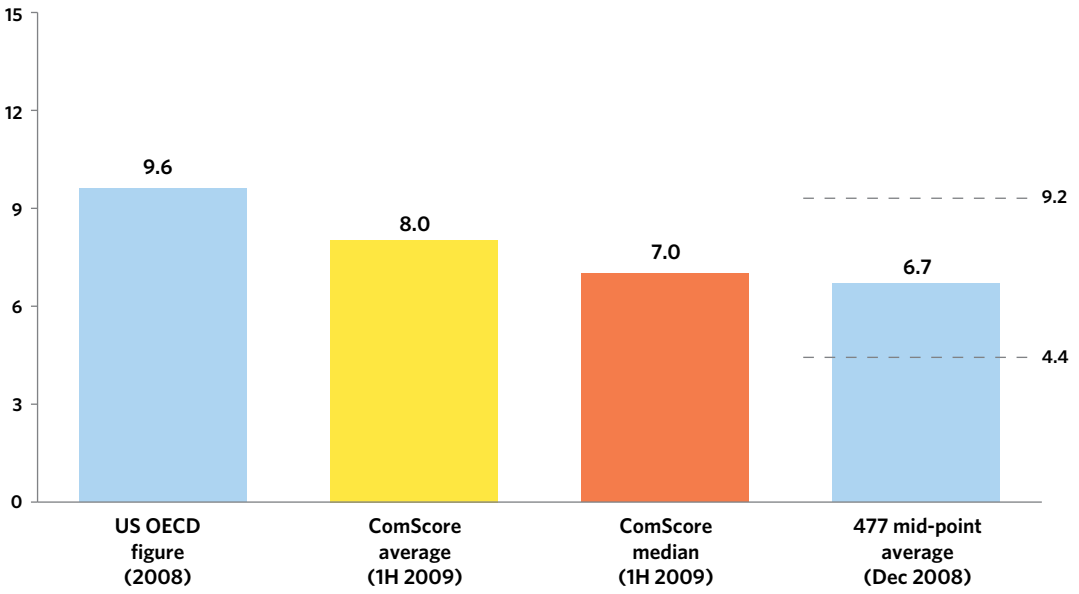
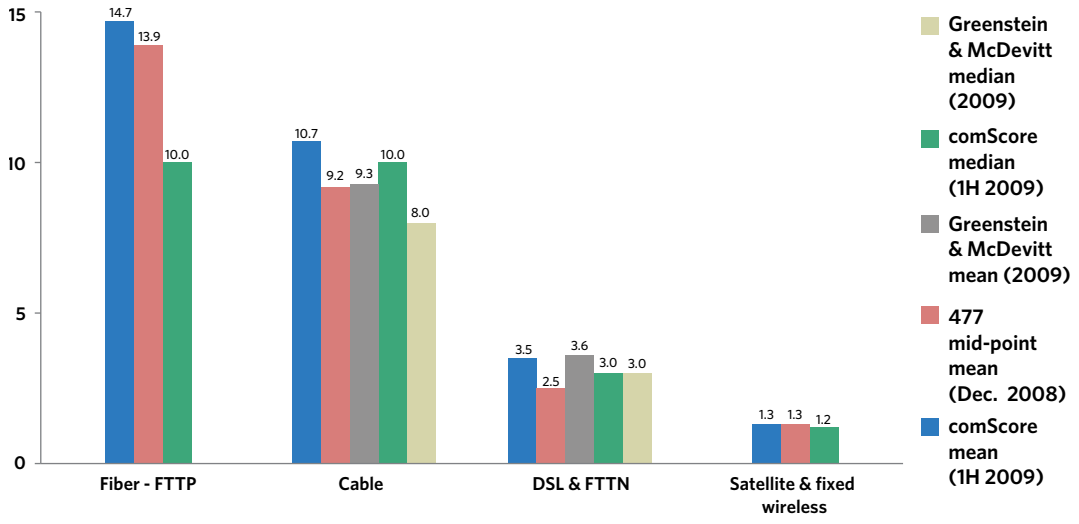


Exhibit 15:
Average (Mean) and Median Advertised Download Speed, by Technology and Data Source (Mbps)



probability (e.g., 95%) over a set time period (e.g., one hour) that includes peak usage times; [33] and

- Actual speeds and performance tested against a given set of standard protocols and applications.[34]

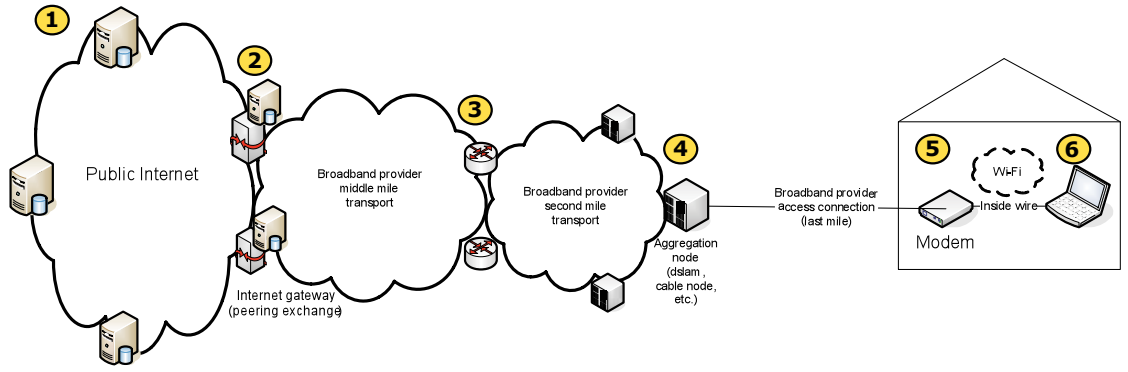
Precisely defined performance metrics will help promote clarity and transparency and drive stakeholder agreement. The FCC's current initiative to measure and report on *actual* speeds is an example of a process that can be used to develop useful performance metrics and measurements.[35]

In the absence of such a publicly established metric, and because data on actual speeds are not currently available,[36] the NBP relies on data that are currently available: actual speeds experienced by consumers as measured by third-party vendors Akamai and comScore, with some caveats.[37] Both data sets track speeds from the user's device (point 6 in Exhibit 16) to the nearest Akamai server, typically near a provider's peering point (near point 2 in Exhibit 16). As mentioned in the NBP, this fails to control for potential speed and performance degradation along many parts of the network – between the Akamai server and the ISP's network, through the ISP's controlled network (points 2-5) and finally within the user's home devices or through home Wi-Fi networks (points 5-6).[38] The actual speed referenced in this paper is therefore similar to what a user experiences to an Akamai server, while *actual* speeds as defined for the National Broadband Availability Target would refer to the services purchased from an ISP along the network they control (points 2-5) according to a FCC standard.

Per data from Akamai and comScore, U.S. consumers experienced an average (mean) of 4 Mbps of actual speed from their residential broadband connections in first half of 2009, with a median speed of 3 Mbps. This indicates consumers actually experience speeds that are roughly 50% of advertised tiers – and this gap is apparent across broadband technologies (*see* Exhibit 17).[39]

Finally, while 50% of consumers purchased broadband connections that enabled 3 Mbps or more of actual download speed in first half of 2009, consumers select varying levels of service. Almost 90% of U.S. consumers purchased broadband connections that provided more than 1 Mbps of actual download speed. A small subset (6%) of users purchased broadband with actual download speeds greater than 10 Mbps (*see* Exhibit 18).[40]

Exhibit 16:
Different Points in an Internet Network



DEFINITIONS

1. **Public Internet content:** Public Internet content that is hosted by multiple service providers, content providers and other entities in a geographically diverse (worldwide) manner
2. **Internet gateway:** Closest peering point between broadband provider and public Internet for a given consumer connection
3. **Link between second mile and middle mile:** Broadband provider managed interconnection between middle and last mile
4. **Aggregation node:** First aggregation point for broadband provider (e.g. DSLAM, cable node, satellite, etc.)
5. **Modem:** Customer premise equipment (CPE) typically managed by a broadband provider as the last connection point to the managed network (e.g. DSL modem, cable modem, satellite modem, optical networking terminal (ONT), etc.)
6. **Consumer device:** Consumer device connected to modem through internal wire or Wi-Fi (home networking), including hardware and software used to access the Internet and process content (customer-managed)

Exhibit 17:
Average (Mean) and Median Actual Download Speeds, Overall and By Technology (Mbps)

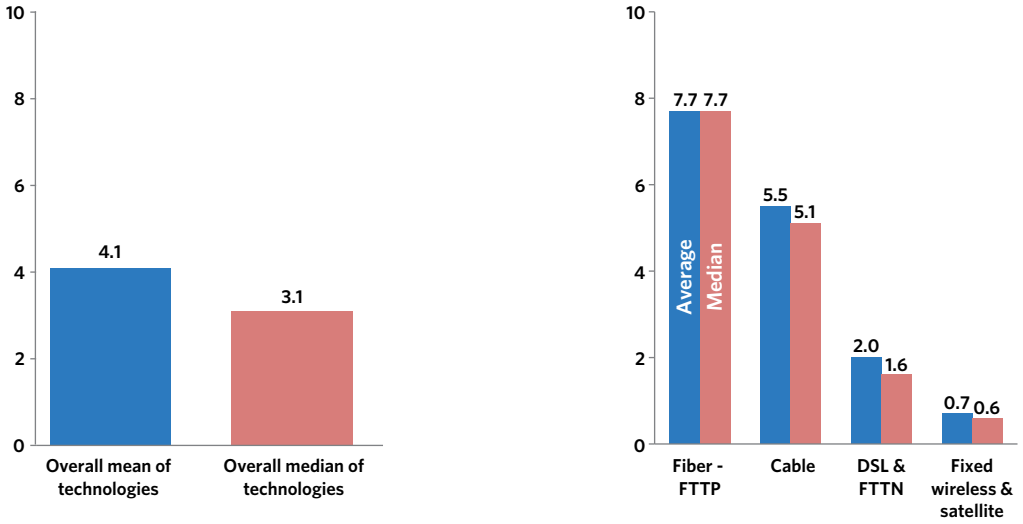
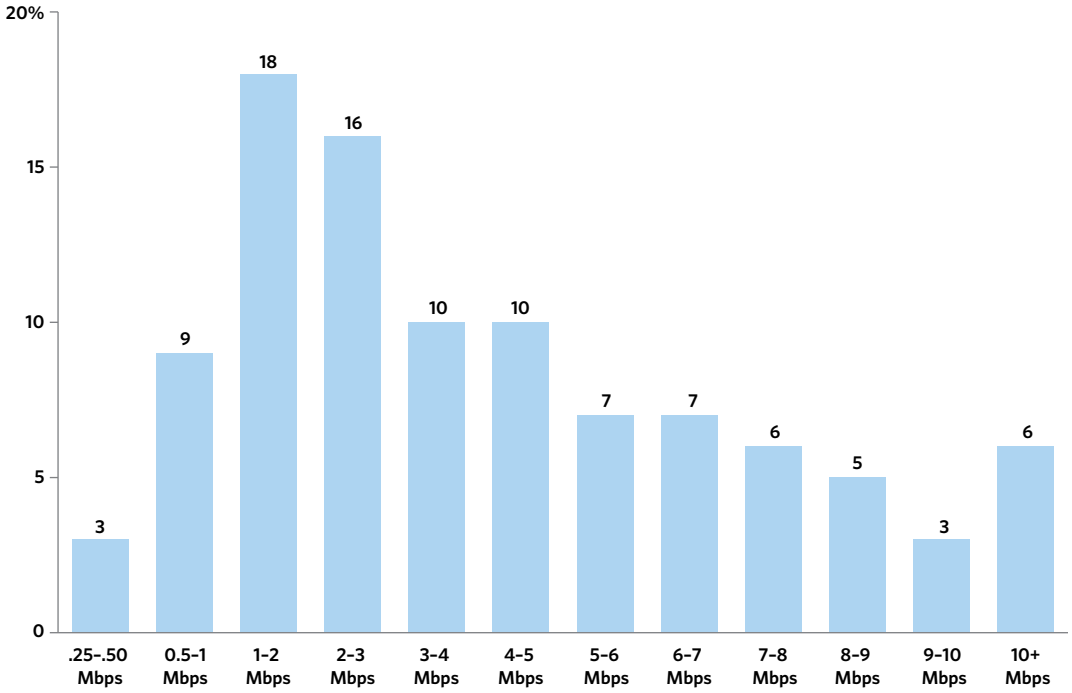


Exhibit 18:
Distribution of Users by Actual Download Speed, Mbps



III. SETTING THE NATIONAL BROADBAND AVAILABILITY TARGET

The NBP was written to address a broad Congressional mandate, including an analysis of "the most effective and efficient mechanisms for ensuring broadband access by all people of the United States."[41] The NBP notes that fulfilling this mandate calls for "filling the troubling gaps we face in the deployment of broadband networks."[42] Filling those gaps, however, requires first quantifying them, understanding the number of Americans who lack access to any broadband capability, and estimating the cost associated with making broadband universally available.

The first step in such analyses is establishing what it means to have access to "broadband." As discussed above, a broadband connection can be described by reference to a number of characteristics, including upload speeds, download speeds, availability, latency and jitter. Although all of these characteristics are important to the end-user experience, measuring the broadband availability gap is best accomplished by utilizing download and upload speeds—the most widely used and identifiable characteristics. The NBP therefore relies on a National Broadband Availability Target defined in terms of quantified download and upload speeds, with qualitative reference to a QOS consistent with the delivery of voice and video applications.

Because the Target serves as an input to calculating the broadband availability gap, it must be forward-looking (i.e., account for the evolution of demand). Thus, the Target was established based on several factors. The first factor, building on consumer-use patterns described above, is the bandwidth required for a **basket of applications** that enables a baseline "broadband" experience. The second, related factor is **today's typical use**, forecast to account for changes in use going forward. Finally, these two approaches are triangulated with **consumer purchasing patterns**.

Basket of Applications. There is no standard Internet user—each person on the Internet makes use of different applications to access the content, applications and services that matter most to him or her. However, expectations for a "broadband" experience are often like the basket of applications described in the full media use profile.[43] Those applications, including the ability to send and receive high-quality voice, data, graphics and video telecommunications, are beyond the capabilities of dial-up Internet connections. This set of applications also aligns with the Congressional view of broadband-related applications.[44] The *actual* (as opposed to advertised) bandwidth required for this type of use is approximately 4 Mbps downstream and 1 Mbps upstream, with acceptable quality of service.

Today's Typical Use. For a typical broadband user today, the vast majority of data use relates to e-mail and Web traffic. In other words, the typical consumer fits the emerging multimedia or utility use profile. While the utility use profile captures the basic e-mail and Web browsing activity of many Americans, video and interactive applications are increasingly common and have been cited in the public record as part of a typical broadband experience.[45] The bandwidth associated with the less data-intensive applications that are part of the utility and emerging-multimedia use cases is roughly 1 Mbps downstream and 250 kbps upstream.

Usage evolves over time, and sufficient speeds today will not necessarily be sufficient speeds tomorrow. In particular, today's utility users will likely migrate to emerging-multimedia applications; and today's emerging-multimedia users will seek full media capabilities. Thus, the bandwidth required for the emerging-multimedia use profile is unlikely to be sufficient indefinitely. At the same time, Internet-access technologies evolve alongside consumer use: only 15 years ago, the primary technology for accessing the Internet was the 14 kbps dial-up modem.

While it is unclear how use patterns will change, historical growth rates suggest that an actual speed target of 4 Mbps downstream (and 1 Mbps upstream) will provide sufficient bandwidth for a substantial majority of the current broadband subscriber population for a substantial—but not indefinite—period of time. Using the historical 20% annual growth in advertised subscription speeds as a proxy for the evolution of speeds required to run end-user applications, it would take approximately eight years for the 1 Mbps downstream requirement of the utility and emerging multimedia use profiles to grow to match today's 4 Mbps requirement for the full-media use profile. As noted, however, data suggest that people do not generally use the full capacity of their broadband connections, so growth in actual demand could be less than 20%. Applications may also become more efficient in their bandwidth demands, for example as video compression technologies improve.

Consumer Purchasing Patterns. The 4 Mbps download speed corresponds to the current, median actual speed of subscriptions—applying the annual growth rate to the first-half 2009 data suggests median actual speeds will reach the 4 Mbps level in 2010. This suggests that a typical user sees value in having capabilities that align with the full-media use profile regardless of their current use profile.

Thus the 4 Mbps download, 1 Mbps upload Target is forward-looking, taking into account forecasts of future usage,

along with current usage and historical increases in broadband speeds. It represents a speed significantly higher than what the typical residential customer consumes today (approximately 1 Mbps downstream and 250 kbps upstream), and a speed sufficient to stream high quality video from commonly used websites and services. This Target is intended to be a minimum level of service; it is not a limit on what speeds can be deployed. It also represents a higher universal target than many countries around the world, as noted in Chapter 8 of the Plan.[46]

If new applications drive demand for higher-speed connections, improvements in compression technology reduce the need for bandwidth or consumer habits shift significantly, the existing Target may cease to reflect the needs of the public. This scenario highlights the importance of revisiting the Target periodically with fresh analyses of both new and existing trends. Only through this process can the Commission ensure that the evolution of a National Broadband Availability Target keeps up with the evolving needs of all Americans.

Primary contributors to this Technical Paper: Peter Bowen and Shawn Hoy.

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APPENDIX 1: MOBILE BROADBAND PERFORMANCE

Ten years ago, fixed broadband was rare in most consumers' homes; but today almost two-thirds of U.S. consumers have purchased fixed broadband services. Less than 5 years ago, mobile broadband was similarly nascent, but the growth of smartphones and mobile computing devices such as netbooks, as detailed in Chapter 3 of the National Broadband Plan, has spurred mobile broadband's rapid growth. The short treatment below highlights several features of mobile broadband, including speeds and usage, and to supplement the discussions on Spectrum from Chapter 5 of the National Broadband Plan and in technical papers released in support of the Plan. It is not intended to be an exhaustive overview of the wireless space. *Fixed* wireless connections are not treated in this discussion of mobile broadband. Therefore, where the discussion below refers to fixed broadband, it implies wireline broadband service only.

Differences between mobile and fixed broadband performance

It is important to note several key distinctions between mobile and fixed broadband services. Fixed services are delivered to a set location (e.g., a house or a business). Key performance characteristics include advertised speed, actual speed and quality of service (QOS). Mobile services, in contrast, are connected to a mobile device, e.g., a laptop that travels with a person, a smartphone that is always on or an e-book reader. While key performance characteristics for mobile broadband include advertised speeds, actual speeds and QOS as with fixed broadband services, there are also additional performance metrics that are critical to consumers.

First, mobile connection quality will vary based on the location of the receiving device in reference to the transmitting device, which is often a cellular tower. If the receiving device (and the person using it) is behind a wall, blocked by terrain or otherwise has an impaired connection with the tower, the mobile broadband service will be degraded or not available. Second, the performance of the broadband connection degrades over distance to the tower, even with a clear line of sight. Performance at the edge of a tower's coverage is not equal to performance close to the tower. Finally, cellular signals are shared by many users—the more simultaneous usage, the lower the potential performance of any one connection. One analyst notes that cell towers average 1,000 users in "regular" periods of use, and if all 1,000 users accessed the network at the same time and with the same demand, performance would degrade appropriately.[47] This is a difficulty shared with fixed networks, but the scarcity of spectrum and the variability of receiver location—users can change position or move in and out of coverage areas constantly—make speed and performance measurements far more complex than in a fixed environment.

With these caveats in mind, this paper details mobile broadband speeds and performance, and consumer usage of these services.

Mobile broadband speeds and performance

Similar to the trend in fixed broadband, consumers have migrated to faster speeds for their mobile broadband connections with the adoption of new technology. Second-generation (2G and 2.5G) wireless digital technologies have average advertised download speeds that range up to 200 Kbps and can support basic voice, text and low-speed data. In 2010, however, third-generation (3G and 3.5G) wireless technologies are considered the standard for mobile broadband, as roughly 60% of U.S. land mass and 98% of the U.S. population is covered by 3G technologies.[48] 3G technologies have average advertised downloads speeds of .4–1.5 Mbps, with "peak" download speeds of 3–7 Mbps. It is important to note that "peak" rates often assume a single user close to a cell tower, and so for the reasons described above are less helpful to consumers in real-world situations. Advertised average 3G speeds continue to increase with new roll-outs such as the upgrade to HSPA standards. Deployment has started for fourth generation (4G) technologies such as WiMAX and Long Term Evolution (LTE), which have begun to be deployed with average speeds of 3–6 Mbps and 5–12 Mbps respectively, with peaks of 10–25 Mbps and 40–50 Mbps respectively.[49]

Similar to fixed broadband, the actual speeds that consumers experience with mobile broadband can be significantly lower than the advertised speeds. One study finds that actual speeds can be a quarter of the speeds advertised.[50]

Like 3G technologies, actual 4G download speeds over a given time period will likely vary from advertised averages and peaks, but further testing and real-world deployment will be needed to accurately assess 4G performance. As with all wireless technologies, spectrum allocation and usage will play a significant role in the eventual speeds and performance consumers' experience.[51] Today's typical speeds for mobile broadband mimic the speeds of fixed connections 5–10 years ago.[52] Although predictions are uncertain, mobile broadband speeds may follow a similar growth rate as seen in fixed broadband, as consumers continue to upgrade.

Finally, it is important to note that for all mobile technologies, speed and performance measurements are only valid when a wireless connection can be accessed. "Dead zones" and loss of signal can reduce wireless effectiveness, and analysts estimate

an available and reliable connection, even in urban areas, may only be accessed 80–95% of the time.[53]

Mobile broadband usage and consumer profiles

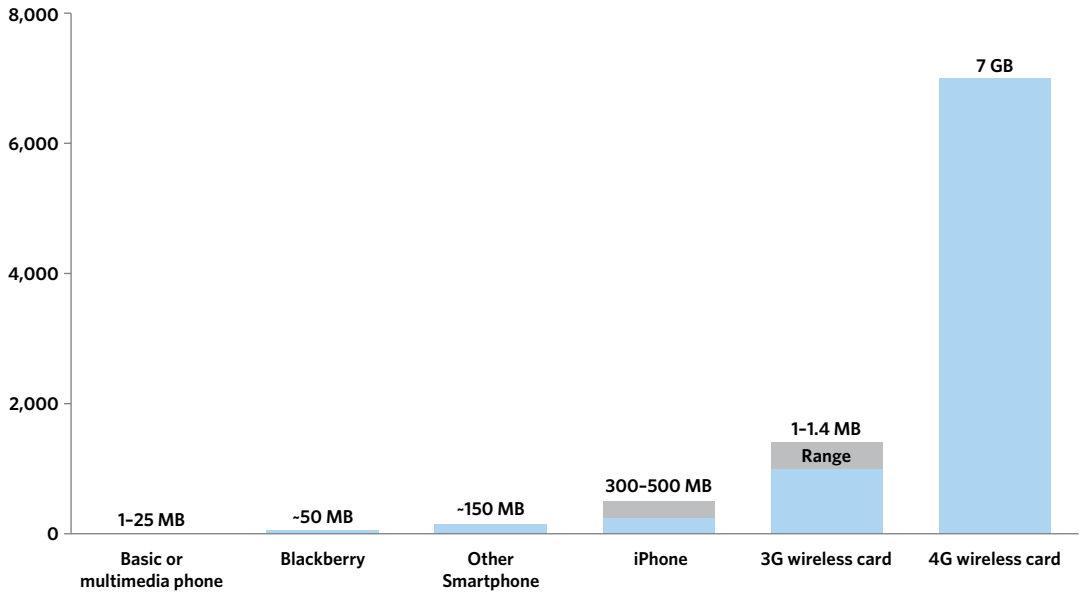
As of late 2009, the average mobile broadband user who owns a large-screen smartphone spent 38 minutes per day online via a mobile connection, which is over half the time that the average broadband consumer spends online at home via a fixed connection.[54] While mobile broadband is in many ways a nascent market, it is experiencing rapid growth with usage patterns becoming somewhat more similar to those for fixed broadband as technological capabilities better reflect user demands.

Consumers engage in significantly different patterns of use based on the phone or device they use to connect to mobile broadband. While basic multimedia phones have limited internet data usage of 1–25 MB/month, smartphone data usage averages 50–150 MB/month, and large-screen smartphones can push this data usage above 300 MB/month. Wireless cards in laptops, netbooks and other mobile devices drive even higher figures, in some cases mimicking fixed broadband. 3G wireless cards have average usage of 1–1.4 GB/ month—similar to the median fixed broadband user—while Clearwire reports that average usage for its 4G wireless card service is roughly 7 GB/ month—almost as high as the average fixed broadband user (*see* Exhibit 19).[55]

The fast pace of smartphone penetration is documented in Chapter 3 of the Plan.[56] Due to the high per-device usage rates of 3G and 4G wireless cards, these connections account for the majority of mobile data usage today. Wireless cards account for 75% of all mobile data consumption, while phones and wireless-enabled devices comprise only 25%.[57] Going forward, smartphones and wireless cards are expected to see 30–40% growth rates on a per-device basis as consumers continue to take advantage of new innovation and investment in mobile broadband and devices.[58]

Overall, mobile data usage is projected to grow at very high rates. Data usage more than doubled from 2008 to 2009, and projections estimate that growth may continue at 40–100% a year through 2015.[59] This pattern is similar to fixed broadband and mobile voice growth in the mid- and late 1990s, and while it is too early to see if mobile broadband usage will taper off, the historical experience of fixed broadband would imply that high growth could continue for some time.[60] While growth is high, overall mobile broadband traffic is a very small subset of total IP traffic. Today mobile broadband makes up less than 0.5% of all IP traffic, and even at the highest estimated growth rates, mobile would still comprise less than 5–10% of total traffic in 2015.[61] Finally, similar to fixed broadband, mobile broadband has a small percentage of users that consume a significant amount of data.[62]

Exhibit 19:
Monthly Data Usage (MB) by Type of Device using Mobile Broadband (2009)



APPENDIX 2: DETAILED BACKUP DATA ON EVOLUTION OF FIXED INTERNET ACCESS TECHNOLOGIES AND DOWNLOAD SPEEDS OVER TIME, INCLUDING SOURCES

Leichtman research aggregating provider figures for cable and telco. (on file with the Commission). Roughly 5–10% of overall Leichtman figures are business. Figures used were estimates for year-end and have been used to triangulate additional data such as Pew and FCC Form 477.

Pew Internet surveys 2000-2009; for 2009 survey, see John Horrigan, "Home Broadband 2009," Pew Internet & American Life Project, http://www.pewInternet.org/Reports/2009/10-Home-Broadband-Adoption-2009.aspx. For 2008, highlighting results to 2002, see John Horrigan, "Home Broadband 2008" http://www.pewinternet.org/~/media//Files/Reports/2008/PIP_Broadband_2008.pdf. Data provided in excel file directly to author from John Horrigan (on file with the Commission). Surveys used longitudinally with similar questions for comparison. For question on dial-up vs. broadband, "Does the computer you use at home connect to the Internet through a dial-up telephone line, or do you have some other type of connection, such as a DSL-enabled phone line, a cable TV modem, a wireless connection, or a T-1 or fiber optic connection?" (June 2000, Dec 2001, Dec 2002, Nov 2003, Feb 2004, Jan 2005, Dec 2005, Dec 2006, Dec 2007, Dec 2008, Aug 2009) and for question on what type of broadband, "What is your type of broadband connection— among those with broadband Internet connections at home?" (Oct 2002, Nov 2003, Jan 2005, Dec 2005, Feb 2007, May 2008); Horrigan, Broadband Adoption and Use in America at 1. As surveys were conducted in varying months in different years, data used has been from months that most closely approximated year-end figures.

	1994	1997	2000	2003	2006	2009	CAGR 94-09	CAGR 97-09	CAGR 00-09
US Households (HH millions):	**97**	**101**	**105**	**111**	**114**	**118**			
% with dial-up	7%	26%	38%	35%	15%	7%			
% with BB	0%	0%	4%	19%	45%	65%			
% with internet access	7%	26%	42%	54%	60%	72%			
Dial-up mix									
<56K	90%	60%	40%	20%	5%	5%			
56K	10%	40%	60%	80%	95%	95%			
Broadband mix									
Cable		65%	64%	62%	56%	53%			
DSL		30%	31%	34%	40%	37%			
Fix Wls/ Sat		3%	3%	3%	3%	3%			
Fiber*		0%	0%	0%	0%	5%			
Other		*2%*	*2%*	*1%*	*1%*	*1%*			
By technology (HH millions)									
Dial up <56K	6	16	16	8	1	0			
Dial-up 56K	1	11	24	31	16	8			
Cable	-	0	3	13	29	41			
DSL	-	0	1	7	21	28			
Fix Wls/ Sat	-	0	0	1	2	2			
Fiber*	-	-	-	-	-	4			
Other	-	*0*	*0*	*0*	*1*	*1*			
Internet (HH millions):	**7**	**26**	**44**	**60**	**69**	**85**			
Dial-up (HH millions):	**7**	**26**	**40**	**39**	**17**	**8**			
Broadband (HH millions):	**-**	**0**	**5**	**21**	**51**	**77**			
Median speeds deployed by technology (kbps)									
Dial up <56K	10	20	28	33	33	33			
Dial-up 56K	56	56	56	56	56	56			
Cable	-	1,000	2,000	3,000	6,000	10,000		**21%**	**20%**
DSL	-	384	768	1,500	1,500	3,000		**19%**	**16%**
Fix Wls/ Sat	-	200	200	500	1,000	1,200		**16%**	**22%**
Fiber*	-	-	-	-	5,000	10,000			
Other	-	*200*	*200*	*200*	*200*	*400*			
Median speeds deployed overall (kbps)									
Internet access speeds :	**14**	**40**	**200**	**900**	**3,000**	**6,300**	**50%**	**52%**	**47%**
Broadband speeds:		**800**	**1,500**	**2,400**	**4,000**	**7,000**	**N/A**	**20%**	**18%**

Sources: FCC Form 477 data (as of December 2008) (on file with the Commission)

U.S. Census Bureau, Census Bureau Reports on Residential Vacancies and Homeownership (press release), Feb. 2, 2010, at 3 tbl. 3, http://www.census.gov/hhes/www/ housing/hvs/qtr409/files/q409press.pdf (Census Bureau, Residential Vacancies and Homeownership) (118 M households in America).

Morgan Stanley Cable/Satellite at 10 (showing detailed breakdown of households and U.S. Internet access 1994–2009 and projections to 2016).

Website Optimization, "US Broadband Penetration Grows to 48.6%—Broadband Households at 38%—June 2004 Bandwidth Report," citing to Nielsen/NetRatings figures for 2004, http://www.websiteoptimization.com/bw/0406//. Key data: in May 2004, 42.53% of users accessed the Internet using 56kbps modems, 6.52% with 28/33.3kbps, and 2.34% with 14.4kbps modems; 51.39% of users are on dial-up (implying that 83% of dial-up users utilized 56 kbps modems). In 1999 (figure 1), dial-up was 95% of total connections—by technology, 14.4kbps modems represented 8% of Internet connections (10% of dial-up), 28/33kbps represented 52% (55% of dial-up), 56kbps represented 33% (35% of dial-up). By the end of 2002, 27% of U.S. households had broadband connections.

Robert Poe, Telecom Asia, "Satellite broadband's latest trick", April 2005, accessible at http://findarticles.com/p/articles/mi_m0FGI/is_4_16/ai_n13803354/. Key data: 840,000 global satellite subscribers in 2004.

Jeff Pelline, CNET news, Oct 1996, "Vendors push plain old ISDN", at http://news.cnet.com/Vendors-push-plain-old-ISDN/2100-1023_3-248424.html. Key data: 28.8 kbps is the "standard" modem of 1996.

Jim Davis, CNET news, Oct 1996, "56-kbps modems top study", Jupiter Communications, at http://news.cnet.com/56-kbps-modems-top-study/2100-1001_3-238991.html. Key data: estimates 56 kbps modems will control 50% of Internet access by 1998, 65% by 2000.

Steven E. Brier, "Downtime: Cable Modems: For a Few, Real Speed", May 1998, accessible at http://www.nytimes.com/1998/05/21/technology/downtime-cable-modems-for-a-few-real-speed.html?pagewanted=1. Key data: Cable modems delivers 8-10x the speed of ISDN (or roughly 800–1,200 kbps in 1998); in May 1998 there were roughly 250–275K cable modems.

Dr. Steve O'Neil, Bandwidth and Security, Feb 2001, accessible at http://www.accessmylibrary.com/coms2/summary_0286-701963_ITM (login required). Key data: in 2000, 75% of Internet users are on dial-up; the article also notes that "Cable typically provides bandwidth of up to 3Mb/s downstream and 50[sim]200kp/s upstream."

Angela Navarrette, "What will the Internet of the future be like?", February 1999 accessible at http://www.cnn.com/TECH/computing/9902/03/futurenet.idg/. Key data: In 1999 "[c]urrent cable connections can manage speeds up to 3 mbps, and that's likely to still be the case three years from now. Most DSL implementations run between 256 kbps and 1.5 mbps—and analysts say that's what most users will get for the next three years as well." Also notes that DSL speeds of 1 Mbps are the next big thing.

Hughes Press release, "Pioneering an Industry: Hughes Recognized by Frost & Sullivan for Satellite Broadband Leadership in North America," available at http://www.hughes.com/HNS%20Library%20Press%20Release/09-01-09_Pioneering_an_Industry_Hughes_Recognized_by_Frost_and_Sullivan_for_Satellite_Broadband_Leadership_in_North_America.pdf. Key data: Hughes had 470,000 subscribers in 2Q 2008.

Matthew Fordahl, The AP, "Comcast targets broadband 'abusers'" available at http://www.usatoday.com/tech/news/2004-01-30-broadband-flap_x.htm. Key data: Cable providers have doubled advertised speeds to 3 Mbps in 2004.

IDC, U.S. Broadband Services 2008-2012 Forecast, at page 3 (on file with the commission). Key data: "As of the end of 2007, the typical cable modem offering featured downstream bandwidth of 6Mbps... with the average DSL data rate at 3Mbps..."

Cisco, Government Affairs, "Facts & Stats – Broadband" accessible at http://www.cisco.com/warp/public/779/govtaff/factsNStats/FactsNstats.html. Key data: 37 million Americans were online end at the end of 1998 versus 19 million online in mid-1997; only 90K Americans had Internet access in early 1993; in 1998, 28% of Americans were online; as of October 1998, 1M Americans had broadband connections; in July of 1999, 1.6 million people had broadband access with speeds near or above 1.5Mbps [advertised]; DSL shipments in 1998 were estimated to be 350K units; 1.3 million DSL connections were projected by the end of 1999.

APPENDIX 3: DETAIL ON QOS AND THE IMPACT OF CONTENT DELIVERY NETWORKS (CDN'S) ON SPEED

Availability refers to the amount of time that the network is functioning, stable and able to provide connectivity between a computer and a desired application. This is usually expressed as a percentile such as "the network is available 99.9% of the time in a given month," or "the network is designed for 99.9% availability." This means that the network is functioning and stable for all but 43 minutes of the entire month. Networks designed for "high availability" are more costly than lower availability networks since redundant elements are required. Telcordia and ADTRAN for example have recommended that consumer fixed broadband should carry 99% availability.[63]

Packet loss is a measure of the number of packets that are lost in transmission from one device to another. Broadband communications networks today are nearly all IP based, in which computers communicate with one another by sending small bits of information, known as "packets," between them. Network operators must design networks with little packet loss to ensure that the user's application information is not lost. This is usually expressed as a percentage, such as "packet loss between device A and device B is designed for less than 1%."

Latency is a measure of the amount of time (usually measured in milliseconds) it takes for data packets to travel from one computer to another application or computer across a network. Latency can help describe a measure of "distance" between hosts on a network. For example, a reasonable roundtrip latency measurement between a pair of hosts from east coast to west coast may be roughly 90 milliseconds, whereas the latency between Atlanta and Philadelphia is closer to 20 milliseconds.

Other Quality of Service metrics may also become relevant with future applications and usage of the Internet.

Content Delivery Networks (CDNs) are designed and deployed for the purpose of optimizing the end user Internet experience by storing and sourcing "popular" content closer (by way of physical distance as well as fewer network elements) to end users. By sourcing this content administratively "closer," performance is improved by reducing possible sources of network degradation such as packet loss (fewer network elements with packet buffers), packet jitter (less network connections between fewer elements), and latency (packets between the CDN servers and users have shorter distances to travel). For example, even though the content from CNN.com may actually be sourced from a physical server in Atlanta, GA, a broadband provider in California may license a "copy" of that content from CNN and install it in a server in Los Angeles, such that the broadband provider's users in CA can experience CNN.com sourced from the server in L.A. instead of Atlanta. This reduces the overall propagation of packets for a given Web session, keeps the packets for a given user's Web session completely "on-net" for a broadband provider and improves the utilization of the backbone network while providing better quality for the end user.

However, these content source endpoints are changing in somewhat unpredictable and dynamic ways because not all content is subject to CDN distribution. Moreover, while the main "news" content of a Web page may be sourced from a local CDN server, other content on the page (such as ads and less popular content) may be sourced from an "off net" server. The non-local content is likely sourced outside of the broadband provider's network within the domain of the public Internet. In this case, the provider will send a user's content request through a public Internet Gateway (possibly through one or more ISPs) until the source is reached and the connection is established between source (off-net content server) and destination (end-user's PC).

Measuring the actual speed between the modem and the service provider's Internet gateway measures the worst case scenario network flow for broadband providers' span of control. For content that is accessed via CDN within a providers' network, the performance would likely exceed the measured value.

APPENDIX 4: SOURCES OF ADVERTISED AND ACTUAL SPEEDS

Organisation for Economic Co-Operation and Development (OECD)

The OECD cites average US advertised speeds at 9.6 Mbps, based on a simple weighting of all broadband plans available in the market (regardless of market share).[64] Data is submitted by individual countries, providing longitudinal comparison over time but creating significant caveats in the data themselves. This data provides an additional triangulation point but should be approached cautiously.

FCC Form 477

Form 477 data are collected from facilities-based broadband service providers every six months based on a schedule of upload and download speed tiers. The download speed tiers, which start at greater than 200 kbps, are:

- Greater than 200 kbps and less than 768 kbps
- 768 kbps to less than 1.5 Mbps
- 1.5 Mbps to less than 3 Mbps
- 5 Mbps to less than 6 Mbps
- 6 Mbps to less than 10 Mbps
- 10 Mbps to less than 25 Mbps
- 25 Mbps to 100 Mbps
- Greater than or equal to 100 Mbps

While these tiers are an improvement over past data collection, the wide ranges make 477 data most useful in the aggregate. The chart below shows the "ranges" of advertised speeds by technology (excluding mobile wireless technology). By taking the midpoint of speed tiers and then weight-averaging them by number of machines, the figure of 6.7 Mbps average download advertised speed is found. Taking the "bottom" speeds of each tier or the "top" speeds would give a range of 4.4-9.0 Mbps for overall average advertised speeds in December of 2008.

Ongoing data refinement and better data collection is likely to help improve 477 data going forward. For now, it provides a helpful additional input to validating other data sets.

comScore

comScore created a custom database drawn from their own internal opt-in panel, representing a cross-section of the U.S Internet population through 200,000 machines with data drawn from the first half (1H) of 2009, January to June. Data collection is done through a multi-step process:

1. The ISP is identified through an IP-reverse-lookup.
2. Speed tests are scheduled with a goal of one read every 24 hours that a machine is connected to the Internet.
3. The measurement is taken during a time when the machine has an active connection and the network stack indicates that the machine is idle.
4. comScore performs the standard speed test from Reston and Chicago datacenters (the exact location for each test is random depending on timing and server availability). For markets that are geographically distant from these data centers, latency issues can occur where the observed speeds will be slower than actual speeds. For these markets, comScore utilizes Akamai local data centers to perform the speed reads, thus limiting the latency to normal local traffic expectations. The logic and file size specifications of the speed test remain unchanged regardless of the data center where the test originates

Four key data components are collected for a single speed test: (i.) download speed (ii.) upload speed (iii.) IP address of the machine and (iv.) time stamp of the speed read (adjusted for time zone).

Form 477 data	All Broadband	Fiber (FTTP)	Cable	DSL & FTTN	Sat. and Fxd Wls
Average at bottom speeds	4.4	8.2	6.1	1.7	0.8
Average of mid-point of speeds	**6.7**	**13.9**	**9.2**	**2.5**	**1.3**
Average at top speeds	9.0	19.6	12.2	3.3	1.8

Download Speed Testing Methodology

A single speed test measurement of download speed consists of at most four steps, depending on the type of connection for the panelist's machine:

1. An HTTP request is conducted with no payload beyond the standard request/response headers to measure round trip time and control for latency
2. A 20KB file is sent to test if the machine is a narrow band or broadband machine -- if the speed is less than 80 kilobits per second, suggesting a narrow band connection, then no further testing is performed and the value for this preliminary test is registered as the speed test value.
2. If the speed for this preliminary test is greater than 80 kilobits per second, suggesting a broadband connection, a 512 kilobyte file is downloaded. If the speed for this second tier test registers less than 500 kbps, then no further testing is performed and the value for this second tier test is registered as the speed test value.
4. If the speed for this second tier test is greater than 500 kbps, a larger file will be downloaded based on the table below. The value for this third tier test is registered as the speed test value and counts the bytes downloaded, using that data to calculate the speed in Megabytes per second.

Speed Range Detected (rounded to the nearest 100 Kilobit)	File Size (bytes)
500 kbps-1 Mbps	1,048,576
1.1 Mbps-2 Mbps	2,097,152
2.1 Mbps-3 Mbps	3,145,728
3.1 Mbps-4 Mbps	4,194,304
4.1 Mbps-5 Mbps	5,242,880
5.1 Mbps-6 Mbps	6,291,456
6.1 Mbps-7 Mbps	7,340,032
7.1 Mbps-8 Mbps	8,388,608
8.1 Mbps-10 Mbps	9,437,184
>10 Mbps	15,728,640

Speed Tier Reporting

Speed tier calculation is used to identify the advertised tier of service to which each machine subscribes. Speed tier bucketing is based on a combination of ISP service, ISP's offered tiers of speed, and each machine's maximum observed speed. comScore calculates the subscribed speed tier for all machines where the Internet connection is made through one of the top 50 broadband ISPs in the U.S. Each machine is bucketed into a speed tier based on its maximum observed speed with 10% overage allowed for tiering purposes. For instance, an ISP offers advertised download tiers of 3 Mbps and 6 Mbps. If a machine's maximum observed speed is 3.25 Mbps, comScore will assign that machine to the 3 Mbps tier, while a machine with a maximum observed speed of 3.35 Mbps will be assigned to the 6 Mbps tier. Certain outliers are excluded: only speed reads within 6 standard deviations of the group average are used.

There is an exception to the tiering methodology outlined above when the ISP offers PowerBoost (Comcast, Cox, Time Warner Cable). PowerBoost technology gives machines bursts of speed when there is network availability, far above the advertised tier of service. In these instances, comScore buckets machine based on maximum observed speed versus the reported maximum speed of PowerBoost for tiers (e.g., Comcast 12Mbps service allows for speeds up to 15Mbps with PowerBoost).

FCC further considerations

The trade-off made in applying this methodology is that subscribed speed tiers are inferred from observed speeds, rather than known directly (from, say, subscribers' bills). For example, some machines in the data were tested more than 100 times: if any one speed read was more than 10% above the actual subscribed tier, the machine would be wrongly identified as subscribing to a higher speed tier. Alternately, if the maximum measured speed was substantially lower than the actual subscribed tier, that machine could be wrongly identified as subscribing to a lower speed tier. Both could bias the advertised tier upward or downward.

While acknowledging that comScore already excludes certain outliers, there was concern that the maximum observed speed exceeded 200% of the average observed speed for approximately 19% of machines. OBI then asked comScore to attempt to identify actual subscribed speeds listed on subscribers' bills by reviewing machines' screenshots as the Internet subscriber made an online bill payment. Although comScore was only able to identify subscriber bills for a small subset of machines, all machines in this small sample had actual subscribed speeds that matched the calculated subscribed speeds —including one machine where the maximum observed speed was more than 250% above the average observed speed. While OBI would ideally like to examine many more bills, this outcome was positive.

comScore's speed tests were single-threaded TCP tests. Typically, in early 2009, Web browsers downloaded data via a single thread per HTTP request, unless the application was specifically designed for multi-thread. As noted, 80% of all data transferred by the *median* broadband user is from standard Web browsing which typically (at the time) used single thread, although more advanced browsers and applications are moving to multi-thread. P2P applications such as BitTorrent use up to four-threads in their TCP protocols.

comScore speed data is used by many commercial providers today—five out of the top ten U.S. ISPs have used comScore data in advertising claims involving speed.

Shane Greenstein & Ryan McDevitt[65]

Another source for advertised speed tiers is Point Topic data from the Greenstein and McDevitt paper. In Tables 3a and 3b in its appendix, this paper lists average and median prices for cable and DSL service in America, based on a sample of 1500 service contracts offered by cable providers from 2004–2009. While these prices are reflective of overall market offers, they are not weighted for actual "take rates" by consumers, i.e., the market share of various offers (as noted on page 3 of the paper). For this reason, the data must be approached cautiously, although it still helps to inform our overall national view. In addition to noting cable advertised speeds (average of 9.3 Mbps, median of 8 Mbps in 2009 offers) and DSL advertised speeds (average of 3.6 Mbps, median of 3 Mbps in 2009 offers) the data offer a view of speed evolution over time—spanning 13–23% for different technologies. Again, this data must be approached cautiously but supports other data on advertised speeds and growth.

Greenstein & McDevitt Data (kbps)	2004	2005	2006	2007	2008	2009	Growth
Cable mean	3,341	4,119	5,230	7,030	8,574	9,343	23%
Cable median	3,000	4,000	5,000	6,000	8,000	8,000	22%
DSL mean	1,960	1,922	2,540	3,015	3,479	3,616	13%
DSL median	1,500	1,500	1,500	3,000	3,000	3,000	15%

APPENDIX 5: COMMENTS ON THE RECORD IN REGARD TO THE "DEFINITION OF BROADBAND"

The table below lists submitted speeds for purposes of the "Definition of Broadband" as discussed in Public Notice #1. While many commenters also submitted comments on additional performance metrics such as latency, jitter, etc, this comparison is focused on download and upload speeds. Some commenters also noted separate speeds for other purposes, such as Qwest, which noted that "the Commission should establish a minimum threshold in the range of 7 to 10 Mbps [advertised] as the threshold that must be met for a service to quality for any new subsidy funding [USF]."

While many comments provided guidance on whether metrics were referring to actual or advertised speeds, many did not. The table below has made a best attempt to correctly assign figures. For comparisons, the highlighted columns show what each submission would be if advertised speeds that commenters submitted were normalized to be equivalent to 50% of actual speeds (as per comScore) or 100%, as some parties have suggested. Finally, while most submissions reference what speeds are necessary for baseline Broadband today (2009/2010) and include a process for updating these speeds over a 1–5 year period, others have only included projections based on other targets—adjustments are noted.[66]

The chart below shows that comments on the "Definition of Broadband" submitted to the Commission have an "average" actual download speed of 2–2.5 Mbps and a "median" actual download speed of 0.5–0.8 Mbps for the year 2009. For upload speeds, the respective figures are 0.65–0.7 Mbps and 0.2–0.25 Mbps.

Baseline "Definition of Broadband" speeds (translated into actual speeds)

**Note: For purposes of comparison, advertised speeds have been translated into "actual" speeds at both 50% (comScore) and 100% ratios*

	DOWNLOAD SPEEDS SUGGESTED				UPLOAD SPEEDS SUGGESTED			
Company/ Organization	**Advertised Speed**	**Actual Speed**	**Implied Actual Speed (50%)**	**Implied Actual Speed (100%)**	**Advertised Speed**	**Actual Speed**	**Implied Actual Speed (50%)**	**Implied Actual Speed (100%)**
Adtran		0.70	0.70	0.70		0.20	0.20	0.20
Apple (fixed wireless)	10.00		5.00	10.00				
CenturyLink		0.77	0.77	0.77		0.30	0.30	0.30
Clearwire		3.00	3.00	3.00		0.77	0.77	0.77
Comcast "Current Gen"	0.60		0.30	0.60	0.50		0.25	0.38
Covad		10.00	10.00	10.00		2.00	2.00	2.00
CWA #1		1.50	1.50	1.50		1.50	1.50	1.50
CWA #2		10.00	10.00	10.00		1.00	1.00	1.00
Echostar	0.76		0.38	0.76	0.26		0.13	0.19
Expand networks	0.26		0.13	0.26	0.26		0.13	0.19
Free Press		5.00	5.00	5.00		5.00	5.00	5.00
FTTH Council "minimum"	0.77		0.38	0.77	0.38		0.19	0.29
FTTH Council "Average"	9.10		4.55	9.10	1.70		0.85	1.28
Hughes/ WildBlue	0.76		0.38	0.76	0.26		0.13	0.19
Microsoft		4.00	4.00	4.00		1.00	1.00	1.00
National Rural Telco coop		1.00	1.00	1.00				
Native Pub Media/ NCAI		1.50	1.50	1.50		1.50	1.50	1.50
Nebraska Rural Ind. Telcos	0.77		0.38	0.77	0.20		0.10	0.15
NCTA	0.77		0.38	0.77	0.20		0.10	0.15
OPASTCO	0.77		0.38	0.77	0.20		0.10	0.15
Qwest	0.77		0.38	0.77	0.20		0.10	0.15
Rural Cell. Ass. (unserved)	0.20		0.10	0.20	0.20		0.10	0.15
Rural Cell. Ass. (underserved)	1.00		0.50	1.00	0.20		0.10	0.15
Trace Center (Disabilities)		0.50	0.50	0.50		0.50	0.50	0.50
Time Warner Cable	0.76		0.38	0.76	0.20		0.10	0.15
Utopian		1.54	1.54	1.54		0.26	0.26	0.26
Verizon Short-term	0.76		0.38	0.76	0.20		0.10	0.15
Windstream	0.76		0.38	0.76	0.20		0.10	0.15
Median PN comment:	**0.76**	**1.52**	**0.50**	**0.77**	**0.20**	**1.00**	**0.20**	**0.23**
Average PN comment:	**1.80**	**3.29**	**1.92**	**2.44**	**0.34**	**1.27**	**0.64**	**0.69**

**Notes: Not all submissions included in chart, especially if speed recommendation unclear; Excludes any speeds for "anchor institutions" or mobile broadband comments*

ENDNOTES

[1] This paper focuses on fixed broadband connections – terrestrial or satellite, wired or wireless – but not on mobile broadband. Appendix 1 discusses the performance of mobile networks.

[2] This paper does not "define" broadband, as discussed in comments and replies to Public Notice #1 -- *Comment Sought on Defining "Broadband"—NBP Public Notice #1*, GN Docket Nos. 09-47, 09-51, 09-137, Public Notice, 24 FCC Rcd 10897 (WCB 2009) (*NBP PN #1*). *See* Appendix 5 for a summary of replies regarding speed and the "Definition of Broadband" as discussed in *NBP PN #1*.

[3] FCC, Broadband Service Capability Survey, (2009) (FCC, CONSUMER SURVEY) (Question 15 analysis) *available at* http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-296444A1.pdf. Data on hours spent online come from multiple sources, triangulated for a best-fit line. Data sources: Pew Internet Project: Internet tracking report. "More online, doing more" Feb 18, 2001 (citing that an average American spends 4 hours online a week or roughly 16 hours per month) accessible at http://www.pewInternet.org/~/media//Files/Reports/2001/PIP_Changing_Population.pdf.pdf; Nielsen/NetRatings for 2000 reported 14.9 hours per month in December, 16.5 hours per month in November, 17.5 hours per month in September; Nielsen, A2/M2 Three Screen Report, "Television , Internet and mobile usage in the US" for 2004-2009 (quarterly updates) (showing 21, 22, 23, 26, 27 and 29 hours online a month from 2004–2009 respectively) (corroborated by Nielsen data on file with Commission); Occupational Outlook Quarterly, Winter 2000-2001 (BLS), "Internet Use: Here, There and Everywhere", accessible at http://www.bls.gov/opub/ooq/2000/Winter/art04.pdf at 41 (page 2 of supplement) (average user was online 15 hours per year in 1995—1.3 hours per month—and 160 hours per year, or 13.3 hours per month in 1999). Nielsen/ Net Rankings—November 16, 1999 press release (Business Wire) http://www.allbusiness.com/retail/retailers-book-music-hobby-stores-toy-game/6732462-1.html (showing 8 hours, 13 minutes per month average in October 1999).

[4] Nielsen Three Screen Report 3Q 2009.

[5] comScore database. These data only include hours online spent in a web browser. Therefore, time using non-web-based e-mail applications, *e.g.*, Microsoft Outlook, and other non-web-based applications such as P2P file sharing are not included. This is consistent with historical tracking of time online. In addition, data are for residential connections and do not include business use, which can vary significantly by individual.

[6] Morgan Stanley Cable/Satellite at 9 and Exhibit 3 (median usage is roughly 2 GB/month, and average usage is roughly 14 GB/month); Cisco Systems, Inc., *US Visual Networking Index*, June 9, 2009, ("Cisco VNI 2009") (excel file downloadable for reference), http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-481360.pdf (in 2009 each Internet connection generated roughly 11 GB/month of traffic but only 6 GB/month of traffic per Internet user due to connection sharing). Comcast has seen median usage of 2-4 GB/month as of December 2009 (*see* Comcast.net at http://security.comcast.net/get-help/faq-full.aspx?guid=00a2862a-33e2-474f-8d1f-c6dcc5ef02a9#usage). *See also* MINTS (Minnesota Internet Traffic Studies), University of Minnesota, http://www.dtc.umn.edu/mints/home.php (last visited Dec. 22, 2009) (MINTS data) (average of 10 GB/month for US consumers in 2009; updated data on file with the commission shows average of 11 GB/month with ending usage at roughly 13-14 GB/month for 2009); Mike Dano, "Cox details LTE tests, but highlights limitations," February 18, 2010 (Cox's wired Internet subscribers average 8 GB per month of data use), http://www.fiercewireless.com/story/cox-details-lte-tests-highlights-limitations/2010-02-18.

[7] comScore database. It is important to note that for most fixed broadband plans, there are few "hard cap" limits on usage. Several providers tell customers that above a certain level (typically 50-250 GB/month in 2009) they will first warn and then may remove users from their network after providing warning. As an example of metering initiatives, Comcast has recently trialed a "usage" meter (*see* http://blog.comcast.com/2009/12/comcast-data-usage-meter-launches.html).

[8] comScore database; ADTRAN White Paper 2 at 6. Sandvine, "2009 Global Broadband Phenomena" at 1, 7 (Sandvine Global Phenomena), accessible at: http://www.sandvine.co.uk/downloads/documents/2009%20Global%20Broadband%20Phenomena%20-%20Executive%20Summary.pdf; Cisco VNI 2009; David Needle, "Why Comcast's CEO Is Bullish on Net Video," accessible at http://www.Internetnews.com/bus-news/article.php/3844726/Why+Comcasts+CEO+is+Bullish+on+Net+Video.htm (last accessed March 18, 2010); Douglas Williams, Forrester Research Inc., "Use-Based Broadband Access, Oct 15 2008 at 2 (courtesy of Forrester Research, Inc.).

[9] MINTS data (noting that "[i]n the United States, there was a brief period of 'Internet traffic doubling every 100 days' back in 1995–96, but already by 1997 growth subsided towards an approximate doubling every year and more recently even that growth rate has declined"). Andrew Odlyzko, who runs the MINTS website and has focused on data growth over time, concludes that Internet traffic growth started tailing off in 2002 and 2003 and was likely down to 60% per year by 2007, before reaching 50-60% in 2008 and 40-50% in 2009. While global growth rates have historically been higher than U.S. growth rates due to more rapid increases in penetration abroad, Odlyzko notes that this is likely no longer the case (updated information from Professor Andrew Odlyzko, University of Minnesota, on file with the Commission).

[10] Note that this range is slightly higher than the range on page 16, Chapter 3 of the National Broadband Plan due to updated information from several sources. MINTS data (recent MINTS updates note: "[m]anual analysis of other sites, together with some confidential discussions with service providers, and many reports, . . . lead[s] to a conclusion that [global] wireline Internet traffic growth, while still vigorous, has slowed, from the previous 50-60% per year pace, down to about 40-50 Odlyzko notes that annual U.S. per-user growth rates are likely 30-35% for bandwidth, with a factor of 1.5 between upper and lower bounds, which on a 95% confidence interval puts growth at 29-39% (updated information from Professor Andrew Odlyzko, University of Minnesota, on file with the Commission). *See also* Cisco VNI at 4 (projected growth rates); Comcast, WC Docket No. 07-52, Feb 12, 2008 at 13, footnote 31 (Comcast noted 40% annual growth rate); C. Labovitz, *et al.*, ATLAS Internet Observatory 2009 Annual Report, presentation at 2009 NANOG (slide presentation) (at page 29) accessible at: http://www.nanog.org/meetings/nanog47/presentations/Monday/Labovitz_ObserveReport_N47_Mon.pdf; (various estimates of worldwide growth —Observatory: 45%; ISP Survey: 35-45%; Cisco 50%; MINTS 50-60%); Letter from Craig Mundie, Chief Research & Strategy Officer, et al., Microsoft Corp., to Marlene H. Dortch, Secretary, FCC, GN Docket Nos. 09-47, 09-51, 09-137 (Sept. 22, 2009) at 3 (Microsoft Ex Parte).

[11] comScore database; this correlation holds true for both average and median comparisons; dial-up is included in Exhibit 6 but not in average and median figures shown in Exhibit 3.

[12] Horrigan, *Broadband Adoption and Use in America at 16.*

[13] comScore database.

[14] Internet users typically use e-mail services provided by third parties, but broadband providers may also offer e-mail services. comScore data shows that of the total time spent online engaging with e-mail content, just 5% is spent with ISP-based e-mail (e.g., mail.comcast.net). Letter from Ellen Satterwhite, Policy Analyst, Omnibus Broadband Initiative to Marlene H. Dortch, Secretary, FCC, GN Docket No. 09-51 (May. 20, 2010), attachment.

[15] John B. Horrigan, Pew Internet & American Life Project, "The Mobile Difference" (2009). http://www.pewinternet.org/~/media//Files/Reports/2009/The_Mobile_Difference.pdf. For details on how the typology was built, see http://www.pewInternet.org/Reports/2009/5-The-Mobile-Difference--Typology/2-Introduction/2-Building-the-Typology.aspx?r=1. For details on the specific breakdown of buckets and four categories, see http://www.pewinternet.org/Reports/2009/5-The-Mobile-Difference--Typology/1-Summary-of-Findings/Overview.aspx?r=1. Additionally, comScore and other usage data were overlaid through FCC analysis to refine use profiles further. Original Pew data focused on all Americans, including non-adopters of Internet and dial-up users. These figures have been refined to focus only on broadband consumers. In addition, these profiles are based in part on consumer survey data—any reference to mobile data usage is in that context and is not meant to be a complete treatment of mobile wireless data usage.

[16] For SD video requirements for some commonly used online video services, see, for example, Hulu, "Technical Issues," accessible at http://www.hulu.com/support/technical_faq (recommending a downstream

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bandwidth of 1,000 Kbps for the smoothest playback on high resolution streams); CNET TV, "CNET TV now in High Definition," accessible at http://cnettv.cnet.com/9755-18593_53-6915430-1.html (recommending 1.5 Mbps minimum downstream speed for 480p (SD) videos and 2.5 Mbps minimum downstream speed for 720p HD videos); VIVA PBS, "VIVA PBS Streaming Video FAQ," accessible at http://sites.google.com/site/vivapbsstreamingvideofaq/ (offering 800 Kbps stream and 300 Kbps stream); YouTube, "Getting Started: System Requirements," accessible at http://www.google.com/support/youtube/bin/answer.py?hl=en&answer=78358 (requiring a broadband connection with 500+ Kbps).

17 ADTRAN White Paper at 2; Telcordia Comments in re *NBP PN #1* filed Aug. 31, 2009.

18 The "basket of applications" approach builds on numerous public record comments to this effect (*see, e.g.*, comments from Sprint Nextel in re *NBP PN #1* at 2 and at FCC public meetings/ workshops; AT&T comments in re *NBP PN #1* at 4-5; Kodiak comments in re *NBP PN #1* at 4).

19 comScore database. Similar to overall data usage, this imbalance in types of applications creating data usage is due to the extreme data intensity of P2P applications and video applications.

20 Cisco VNI 2009 at 1.

21 However, e-mail and browsing are only a small part of the *average* consumer's data usage, since video and peer-to-peer (P2P) applications compose over 80% of all data, driven largely by the highest-volume users (*see* comScore database). Similar to overall data usage, this imbalance in types of applications creating data usage is due to the extreme data intensity of P2P applications and video applications.

22 John Horrigan, *Broadband Adoption and Use in America at 1 (OBI Working Paper No. 1, 2010) (Horrigan, Broadband Adoption and Use in America). See also* Appendix 2 for more detail and sources on the evolution of Internet speeds. Note that data limitations make median purchased advertised speeds the only comparable metric available for the 15-year period. "Fiber" may include both Fiber-to-the-Node (FTTN) such as AT&T's U-verse service, and Fiber-to-the-Premise (FTTP), because consumers are asked to identify their connections type in Pew surveys and other sources. We have attempted to cross-reference this data with industry announced figures wherever possible, but in survey and market research context "Fiber" can include both FTTN and FTTP.

23 *See* Appendix 2 for further detail and sources.

24 *See* Appendix 2 for further detail and sources.

25 ADTRAN White Paper 2 "Defining Broadband Speeds: Deriving Required Capacity in Access Networks," at 14-15, GN Docket 09-51 (Jan. 4, 2010) ("ADTRAN White Paper 2"); Letter from Thomas Cohen, Counsel, FTTH Council to Marlene H. Dortch, Secretary, FCC, GN Docket No. 09-51 (Dec. 14, 2009) at 12 (showing graph of median downstream throughput growth over time); Shane Greenstein & Ryan McDevitt, *Evidence of a Modest Price Decline in US Broadband Services* 1 (CSIO, Working Paper No. 0102, 2010) at tables 3a and 3b (Greenstein & McDevitt, *Evidence of a Modest Price Decline*), *available at* http://www.wcas.northwestern.edu/csio/Papers/2010/CSIO-WP-0102.pdf (using Point Topic data from 2004–2009 shows similar trends with Cable mean/median growth of 22–23% and DSL mean/median growth of 13–15%); *see also* Appendix 4; Jeffrey Lindsay, Bernstein Research, "Weekend Media Blast: How ya gonna keep 'em down on the farm after they've seen Paree?" at 2. (Oct 16, 2009) (Courtesy of Bernstein Research); Microsoft Ex Parte at 3.

26 *See* Appendix 2 for detailed sources.

27 *See* Appendix 4 for detail on data and sources. The OECD notes US speeds average advertised download speeds of 9.6 Mbps for 2008, based on a simple weighting of all broadband plans available in the market (regardless of market share). FCC data from December 2008 using Form 477 found an average of mid-points of tiers of 6.7 Mbps, with a range of 4.4–9.2 Mbps. comScore data found an average of 8.0 Mbps and a median of 7.0 Mbps for Jan–Jun 2009.

28 *See* Appendix 4 for detail on data and sources. Note that data from Greenstein & McDevitt are only available for Cable and DSL offers. FTTP and FTTN are different technologies that often are both referred to as "Fiber" in surveys, marketing materials, and market research. FTTP technology involves running fiber optic cable to a user's premise, typically connecting to an Optical Network Terminal (ONT) unit. FTTN technology involves running fiber optic cable to the "node" of a region or neighborhood and then running traditional copper DSL service from the node to the premise. Data on speeds in the National Broadband Plan (Chapter 3) showed these together, but for purposes of this paper, they have been separated and FTTN is included with DSL figures. However, it is likely that survey and market research sources use these terms interchangeably, and where this is likely the case, it has been noted in sources and descriptions.

29 This speed represents the theoretical maximum that a provider can deliver between the modem (more technically the network interface unit, or NIU) located at the end-user's premises and the service provider Internet gateway that is the shortest administrative distance from that NIU (points 2-5 in Exhibit 16). Some providers provide more detailed "page 2" disclosures on this speed. For instance, AT&T notes in its "about" section that "[b]roadband access is provided in speed tiers of: (1) 200 kbps to 768 kbps downstream (not available for AT&T U-verse High Speed Internet service), (2) 769 kbps to 1.5 Mbps downstream; (3) 1.56 Mbps to 3.0 Mbps downstream; (4) 3.1 Mbps to 6.0 Mbps downstream; (5) 6.1 Mbps to 10.0 Mbps (available only with AT&T U-verse High Speed Internet service); and (6) 10.1 Mbps to 18 Mbps downstream (available only with AT&T U-verse High Speed Internet service) (collectively 'Service Capability Speeds')." However, in "page 1" marketing materials, advertised tiers of "up to" 768 kbps, 1.5 Mbps, 3.0 Mbps, 6.0 Mbps, 10 Mbps, and 18 Mbps are the only metrics shown. *See* http://www.att.net/csbellsouth/s/s.dll?spage=cg/legal/att.htm&leg=tos

30 *See* Appendix 3 for more detail on QOS and the impact of Content Delivery Networks (CDNs).

31 Verizon Comments in re *NBP PN #24* (*Comment Sought on Broadband Measurement and Consumer Transparency of Fixed Residential and Small Business Services in the United States—NBP Public Notice #24*, GN Docket Nos. 09-47, 09-51, 09-137, Public Notice, 24 FCC Rcd 14120 (WCB Nov. 24, 2009) ("*NBP PN #24*")), filed Dec. 14, 2009, at 14; SamKnows Comments in re *NBP PN #24*, filed Dec. 16, 2009, at 5; Epitiro comments in re *NBP PN #24*, filed Dec. 14, 2009, at 7–14; NCTA Comments in re *NBP PN #24*, filed Dec. 14, 2009, at 9; Time Warner Cable Comments in re *NBP PN #24*, filed Dec. 14, 2009, at 5–6.

32 Sandvine Comments in re *NBP PN #24*, filed Dec. 14, 2009, at 5–6.

33 Epitiro Comments in re *NBP PN #24*, filed Dec. 14, 2009; SamKnows Comments in re *NBP PN #24*, filed Dec. 16, 2009; NAF Comments in re NBP PN #24, filed Dec. 14, 2009.

34 Verizon Comments in re *NBP PN #24*, filed Dec. 14, 2009, at 15 ("tests conducted using representative Internet file sizes").

35 In April 2010, the FCC announced a partnership with a third-party measurement company to test actual consumer broadband speeds, in order to inform FCC and other government consumer disclosure initiatives, and to make data publicly available for better understanding of broadband speed and performance.

36 In the Omnibus Broadband Initiative's ("OBI") September 2009 Commission presentation, where comScore data was presented (since updated), OBI asked for better provider data to refine this analysis. To date, however, comScore and Akamai data remain the best available to the Commission, due to a lack of response from providers. Recent Commission actions to contract with a third-party measurement company are aimed at creating more detailed data on actual speeds.

37 comScore, Inc., Jan.–June 2009 Consumer Usage database (sampling 200,000 machines for user Web surfing habits) (on file with the Commission) ("comScore database"); s*ee* Appendix 4 on details of comScore approach and methodology.

38 The effect of home networks and devices is unclear today. Various analyses by the FCC have not been able to clearly isolate this effect. Analysis of comScore equipment did not show statistical variance in speeds over a controlled small sample set; however, data from SpeedTest showed an average 30% degradation in speeds due to home wireless network routers. The upcoming Third Party Measurement initiative described in Chapter 4 of the National Broadband Plan will provide useful clarity on this topic. comScore database. Speedtest database 2006-2009 (on file with the Commission).

39 Note that these figures are a different presentation of the same data from the National Broadband Plan, Chapter 3, Page 21 which states "[w]hile median actual download

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speeds for fiber and cable are 5–6 Mbps, median actual download speeds for DSL are 1.5–2.0 Mbps, and under 1 Mbps for satellite." Data has been re-cut to look at fiber only as FTTP and include FTTN in DSL figures. comScore database. Akamai, The State of the Internet, 3rd Quarter 2009, accessible at http://www.akamai.com/stateoftheInternet/ (registration required) (U.S. average download speed of 3.9 Mbps); Akamai publishes this report quarterly, showing download speeds over the Akamai network.

40 comScore database.

41 American Recovery and Reinvestment Act of 2009, Pub. L. No. 111-5, § 6001(k)(2)(D), 123 Stat. 115, 516 (2009) (Recovery Act).

42 Federal Communications Commission, Connecting America: The National Broadband Plan 19 (2010) ("*National Broadband Plan*"), http://www.broadband.gov/plan/.

43 The "basket of applications" approach builds on numerous public record comments to this effect. *See, e.g.*, comments from Sprint Nextel in re: PN #1 at 2 and FCC public meetings/ workshops; AT&T comments in re PN#1 at 4-5; Kodiak in re PN #1 at 4.

44 *See, e.g.*, 47 U.S.C. § 1302(b) (defining "advanced telecommunications capability"—a term the Commission uses synonymously with "broadband"—as enabling "users to originate and receive high-quality voice, data, graphics, and video").

45 *See, e.g.,* Sprint Nextel comments in re NBP PN #1 at 2 and FCC public meetings/ workshops; AT&T comments in re PN#1 at 4–5; Kodiak in re PN #1 at 4.

46 *National Broadband Plan* 135

47 Glen Campbell *et. al.*, "Mobile data: Traffic jam ahead?", February 2, 2010 at 12 (courtesy of Bank of America/ Merrill Lynch) (BofA Mobile)

48 *See* Chapter 3, National Broadband Plan at 22.

49 Mike Dano, "Cox details LTE tests, but highlights limitations", February 18, 2010 accessible at: http://www.fiercewireless.com/story/cox-details-lte-tests-highlights-limitations/2010-02-18 (Fierce article); Atkinson & Schultz, Broadband in america at 24, 66; Verizon Network Facts, accessible at http://aboutus.vzw.com/bestnetwork/network_facts.html; Richard Bennett, ITIF, "Going Mobile: Technology and Policy Issues in the Mobile Internet", March 2010 at 17 available at http://www.itif.org/files/100302_GoingMobile.pdf; Steve Smith, Coda Research Consultancy, "US Mobile Traffic Forecasts: 2009-2015", at 6 (2009) (unpublished manuscript, on file with the FCC) (Coda US Mobile); Suzanne Choney, msnbc.com "Getting up to speed with 4G", March 22, 2010 accessible at http://www.msnbc.msn.com/id/35950008/ns/technology_and_science-wireless/

50 Akamai State of the Internet Q3 2009 at 3 (speeds of 700-750 kbps); Coda US Mobile at 23 ("American consumers receive on average about a quarter of advertised download speeds"; actual download speeds of 800-950 kbps and upload speeds of 375-660 kbps); Chetan Sharma *et. al.*, "State of the (mobile) Broadband Nation", at 9-10 (2009) (Chetan State of Mobile) (actual speeds of 245-645 kbps); comScore database.

51 *See also* Chapter 5 of the National Broadband Plan and Omnibus broadband initiative, mobile broadband spectrum forecast (OBI, mobile broadband spectrum forecast), 2010

52 A common cite is to "Edholm's law" that notes (in 2004) how mobile access speeds will march in lockstep upward. *See* Steven Cherry, IEEE, Edholm's Law of Bandwidth (2004) available at http://spectrum.ieee.org/telecom/wireless/edholms-law-of-bandwidth. The 2004 projection was that 3G would deliver 1 Mbps download speeds in 5 years.

53 Reliability is described as the percentage of all completed one-minute performance tests in which the service was available, uninterrupted and faster that dial-up. *See* Mary Meeker et al., Morgan Stanley Research, The Mobile Internet Report 1(2009) available at http://www.morganstanley.com/institutional/techresearch/pdfs/mobile_internet_report.pdf) (Morgan Stanley mobile report). Availability is described as the ability to access a wireless signal with data transfer. *See* Chetan State of Mobile at 8.

54 Sarah Reedy, "Video skyrockets in Bytemobile's first analytics report," Nov 2009 accessible at http://connectedplanetonline.com/3g4g/news/bytemobile-video-analytics-111909/

55 Jason Armstrong, "Wireless data growth set to exceed, invest along the food chain," Goldman Sachs, March 21, 2010 at 11 (courtesy of Goldman Sachs) (Goldman Wireless) (1 MB/month for feature phone, 25 MB for multimedia phone, 200 MB for smartphone, 1,400 MB for 3G data card, 7,000 MB for 4G data card); BofA Mobile; Validas database on data usage by type of (courtesy of Validas) (Non-smartphone 25 MB, Blackberry 54 MB, Other smartphone 100 MB, iPhone 273 MB, Aircard 1,400 MB); Fierce article (more than 500 MB for iPhone); Morgan Stanley mobile report at 104; Cisco Mobile VNI database (on file with the Commission) (database in excel detailed assumptions of 2009 Cisco Mobile VNI database, showing 3G handset at 30 MB usage, mobile broadband handset at 65 MB usage, portable data card at 873 MB usage and fixed supplement at 5.5 GB usage for 2009). These figures are before voice traffic data usage, which is estimated to generate 1MB of data for roughly 10 minutes of calling (although this varies from 3.5-15 minutes, and does not take into account the loss of spectral efficiency due to quality of service considerations for voice). 4G technologies, such as LTE, should reduce this loss in efficiency.

56 *See* Chapter 3 of the National Broadband Plan.

57 Glen Campbell, "Mobile data traffic jam: Update", BofA/ Merrill Lynch, March 23, 2010 at 1 (courtesy of BofA/ Merrill Lynch) (BofA mobile updated) ("implying that smartphones and data cards are responsible for 25% and 75% of total traffic, respectively"); Cisco mobile VNI.

58 BofA mobile updated at 1; Goldman Wireless at 1, 12.

59 Cisco VNI at 1; BofA mobile updated at 1; Coda US Mobile at 25; Goldman Wireless at 1.

60 For more on projected growth rates and spectrum supply and demand, *see* OBI, mobile broadband spectrum forecast

61 Goldman Wireless at 7.

62 Various data sources report similar figures to fixed broadband. For instance, AT&T reports that the top 3% of iPhone users consume 40% of all data. See Peter Svenson, Associated Press, "AT&T: Tighter control of cell data usage ahead" Dec. 9, 2009 available at http://www.msnbc.msn.com/id/34345712/ns/technology_and_science-tech_and_gadgets/

63 Telcordia Comments in re *NBP PN #1* at 22 filed Aug. 31, 2009; ADTRAN White Paper 2 at 14-15.

64 Organisation for Economic Co-Operation and Development (OECD), http://www.oecd.org/document/54/0,3343,en_2649_34225_38690102_1_1_1_1,00.html, accessing excel file 5. Services and Speeds, 5a. Average advertised download speeds, by country (Sept. 2008).

65 Shane Greenstein & Ryan McDevitt, Evidence of a Modest Price Decline in US Broadband Services 1 (CSIO, Working Paper No. 0102, 2010) at Tables 3a and 3b.

66 All comments filed in response to *NBP PN #1*: ADTRAN at 7; Trace Center (Disabilities) at 2-3; Utopian at 1; Verizon at 4; Windstream at 10; Expand Networks at 3; Hughes/WildBlue at 3; Rural Cellular Association at 6; Apple in summary and at 10; CWA at 3 (conflicting comments, both included); CenturyLink at 2; Free Press at 3; TWC at 4; Comcast at 8; NCTA at 2; Clearwire at 4; Covad at 3; Echostar at 1; OPASTCO in summary (iii); Qwest at 2; Native Public Media/ National Congress of American Indians at 9; National Rural Telecommunications Cooperative at 2; Nebraska Rural Independent Telephone Companies at 16; Fiber-to-the-Home (FTTH) Council at intro. *Also see* Microsoft Ex Parte at 9.