Gigabit Fiber Can Add $326B to US GDP

Bandwidth Is All About Efficiency and Productivity

FIBER BROADBAND ASSOCIATION
RVA LLC
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When fiber leads, the future follows.

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I. OVERVIEW

Many have heard the argument that "symmetrical Gigabit bandwidth is mostly just marketing hype... there are very few, if any, applications that require a Gigabit today". It is true that most online applications will at least work at a minimum level with less bandwidth. Applications simply being functional misses the real point, however! The question is how effectively and how efficiently applications will run:

o Effectiveness: The less bandwidth available, the less capable applications can be. (As an example, most video quality is automatically downgraded when less bandwidth is available – providing less resolution, fewer frame changes per second, and sometimes a smaller picture size.)

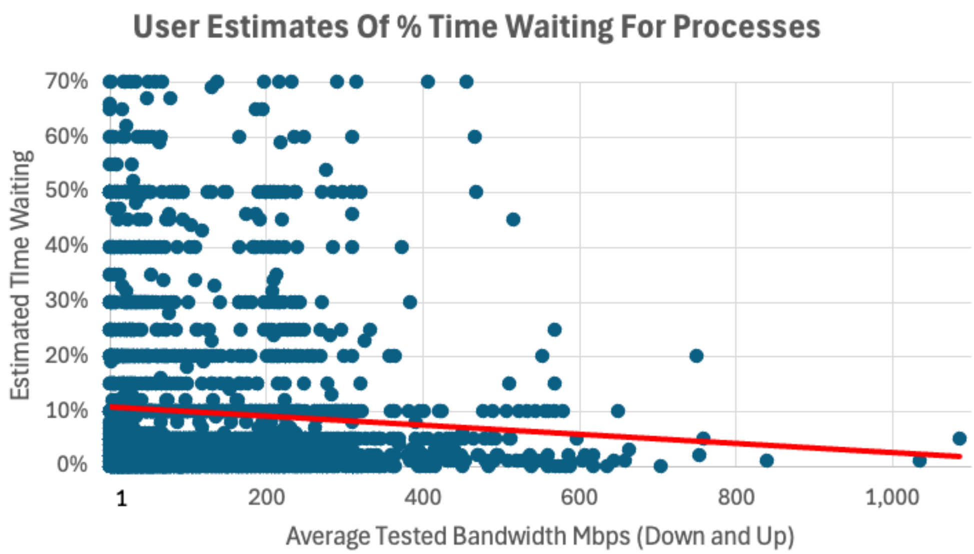
o Efficiency: The less bandwidth available, the more time it takes for interactive applications to process, and the more human time is wasted.

A new study demonstrates, via solid scientific evidence, that with higher bandwidth comes greater efficiency... and fewer wasted human hours. This time saved has real financial benefits – both to the individual and the country.

II. Past Studies: Perceptual Evidence Of The Bandwidth To Productivity Relationship

Since 2007, RVA has partnered with the Fiber Broadband Association (FBA) to conduct an annual survey among random samples of 3,500 North American consumers with various Internet delivery methods.

In recent years, consumers were asked to estimate how much time they felt was being wasted while waiting for applications to load or processes to complete ("gears turning"). The analysis of such consumer opinions compared to the actual tested consumer online bandwidth, using common linear correlation, consistently shows that lower received bandwidth relates to higher perceived time wasted, though as might be expected for a perceptual question, there is considerable variance around the mean – with some users mentioning extremes such as 0% or 70%. Additionally, despite the clear relationship shown by the trendline, one could argue that such a perceptual methodology does not provide absolute proof of a bandwidth to time lost relationship, thus more scientific analysis is needed.



III. Scientific Evidence Of The Bandwidth To Productivity Relationship

New methodologies introduced to the FBA/ RVA survey in 2024, more directly measures the bandwidth to productivity relationship through regression analysis of the time taken to complete a speed test and this clearly shows a relationship.

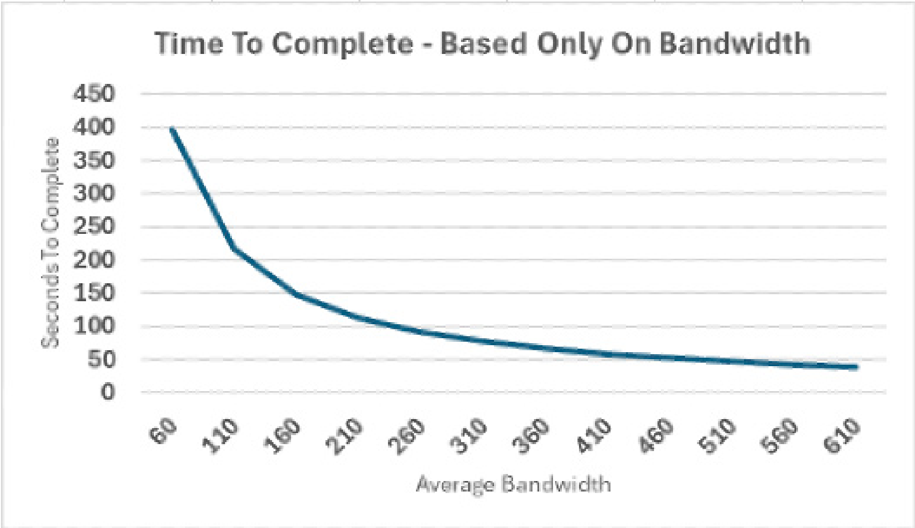
More importantly, there is a well-known formula to definitively measure the time it takes to transfer files based on file size and transfer bandwidth. This is as follows:

File Size in bytes / (Download Speed in bits / 8) = Time

Note: Since Mega bytes (MB) - used in measures of file size - is 8 times Mega bits (Mb) -used in measures of file transfer speed, the difference must be considered in the formula.

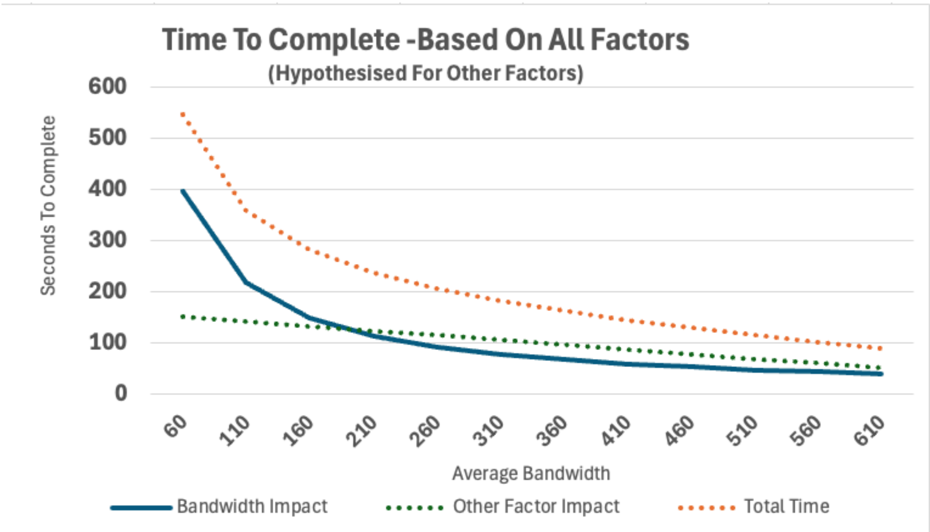
For simplicity, upload and download speeds are averaged together to create an index in the following chart. (See Appendix 1.)

This bandwidth to time calculation results in a downward sloping curve showing much less time lost waiting as bandwidth increases. Shown is a range between a 100/20 speed – or 60 Mbps average (considered a base user), and 700/500 speed or 600 on average (a real-world example of a symmetrical gigabit user with bandwidth constrained by Wi-Fi. Most gigabit users today are impacted by various constraints – especially in-home-Wi-Fi systems. See Appendix 2.)



It should be noted that there are many factors besides bandwidth that can influence the online process time for any application. At the end point, these factors include local device processing speed and limitations, software delays, user interruptions, and DNS resolution delays. Additional transmission factors include priorities placed on types of processes, and packet loss – often requiring retransmission. And, as will be seen, latency, the time it takes individual packets to move through the network, is certainly also important. Network queuing and buffer delays can be significant in this regard, influenced, in part, by time-of-day differences in traffic.

It is logical that the actual time to complete curve, including all factors, would be somewhat above the relationship shown, and it is further hypothesized that a chart showing all factors would have a somewhat less dramatic arc. While some of the other time delay factors do have correlation to bandwidth, the relationships seem to be more linear in nature. (For example, concerns such as latency, jitter, network routing, etc. are often lower with a better network that also has better bandwidth characteristics.)



However, only the calculated bandwidth data is used for this paper's analysis since there is not sufficient data available to reliably construct such a total time loss curve. With this data, the impact of bandwidth on human productivity can be analyzed further.

A. Do we have the time-loss measure amplitude correct for the base case?

Analyzing various data, human time loss was conservatively estimated as 11% (or 6.6 minutes) of an hour of interactive time online for the low-end 100/20 Mbps Internet base-case (60 Mbps average).

How can it be stipulated that 11% is a reasonable and conservative case? Two different methods were also used to calculate the base-case time-loss: 1) the percentage consumers estimated in the perceptual method (showing 11%); 2) a method developing the average file size transferred per hour, using Open Vault monthly user data – (showing 12%). (See Appendix 3)

The FBA/ RVA consumer broadband study indicates the average consumer spends about three hours of interactive time online per day (setting aside time watching streaming content or in video conferences where delays do not generally apply). Thus, the total time lost per day for an average 100/20 bandwidth user is 19.8 minutes.

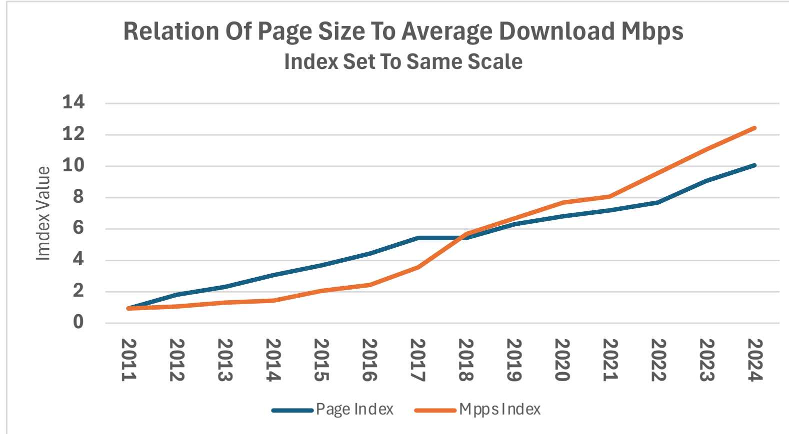
B. Has the range of useful bandwidth and the bandwidth efficiency curve always been the same?

The answer is clearly no. As throughput (bandwidth) to users increases, developers are enabled to improve user experience by increasing the file sizes of online activities without increasing the time spent on a given activity.

Historically, online providers curtailed their file sizes (and creativity) so online load times stayed at a level that most users could tolerate. Consider websites: As early as 1993, sources suggested website loads should be kept small in order for consumer loads to be under 9 seconds, with a best practice of 2.5 seconds, i.e. to avoid consumers giving up and leaving the website before it loaded. This same axiom continues to be stated today, with users increasingly likely to leave a website after 3 seconds. [1]

[1] https://www.pingdom.com/blog/page-load-time-vs-response-time-what-is-the-difference/

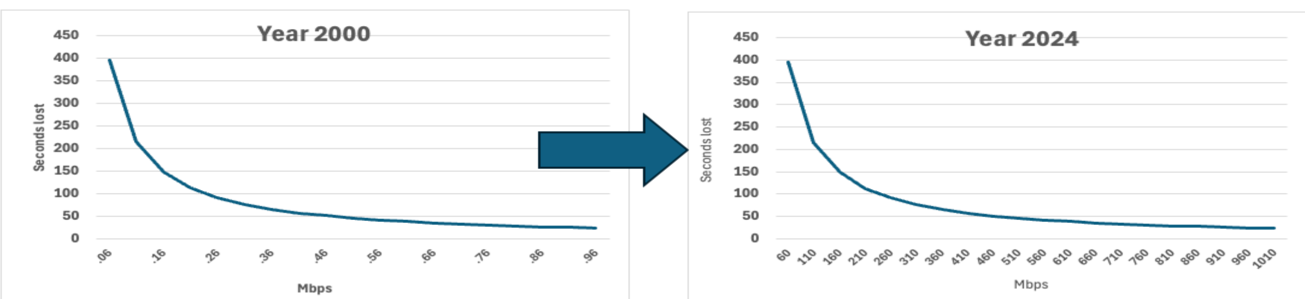
The increase of file size with throughput can be demonstrated by actual data. The average size of a website page has been increasing over time per HTTP Archive, relatively consistent with the average download speed consumers receive, per FBA / RVA.



As the throughput to consumers increased, websites have moved from text-only to limited media and then to richer media. (Only recently have some full screen video webpages appeared.)

The undisputable conclusion from the file size vs. throughput relationship is that the useful bandwidth range, and bandwidth efficiency curve is continuously shifting over time (to the right when shown graphically). Just before the FBA was founded in 2001, the useful bandwidth/efficiency curve would have stretched roughly from a low-end user at 56 Kbps (dial up) to a high-end user via 1 Mbps (DSL and cable modem). It has gradually increased 1000 times to a low-end user at 60 Mbps (100/20) stretching to a high-end user at 1 Gigabit.

Since 2000 The Internet Efficiency Curve Has Moved 1000X To The Right



One other note: those users who are still limited to very low bandwidth, such as 10/1 Mbps (5.5 average) broadband via poor DSL, wireless, or traditional satellite, are left behind, suffering more over time as their pipe size isn't increasing, yet the average bandwidth requirements of online activities is ever growing. For some in this group, the Internet is basically useless for anything beyond text messages. The introduction of low orbit satellites has been quite helpful for some in the category, with a throughput of about 70/2 Mbps (36 average), but there is no known roadmap for low orbit satellites to provide very high bandwidth in the future. [2]

[2] "Fiber to the Home vs. Emerging LEOS" https://fiberbroadband.org/wp-content/uploads/2023/03/Fiber-to-the-Home-vs-LEOs.pdf

However, getting fiber connections with their virually unlimited capacity to all Americans can enable the Internet efficiency curve to move to the right for all Americans for decades to come. [3]

IV. Impact Of Bandwidth Level On Productivity

As noted earlier, the RVA consumer study shows the average consumer spends about 3 hours in interactive time online per day as analyzed below:

The everyday online user conservatively experiences an average time wasted of 11%, or about 20 minutes per day in the base case of a 100/20 Mbps connection. Many consumers do not consciously think about their wasted online time because the delays come in many increments of seconds (2 seconds there, 10 seconds here, 30 seconds there...). In aggregate, however, the total is staggering!

Overall, the base case time loss equates to 120 human hours lost annually, or the equivalent of over 15 eight-hour workdays! But upgrading to 600 Mbps on average recovers 108 of these hours annually (or 13.5 workdays)!

Average User (3 hours Interactive	Wasted Mins Daily	Wasted Hrs Yearly	Saved Hrs Yearly Vs. Base
Base 60 Mbps Average (100/20 Mbps)	20	120	
600 Mbps Average (700/500)	2	12	108

Heavy interactive users at home, spending 7 hours of interactive online time per day, such as those working from home in addition to personal online time, waste 46 minutes per day in the base case, which equates to 281 hours annually, or the equivalent of nearly 35 eight-hour workdays! But upgrading to 600 Mbps real speed on average recovers 253 of these hours annually (or 32 eight-hour workdays annually)!

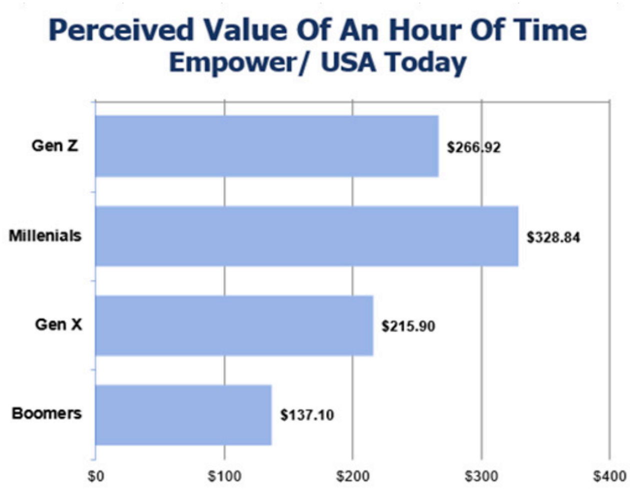
Average User (7 hours Interactive)	Wasted Mins Daily	Wasted Hrs Yearly	Saved Hrs Yearly Vs. Base
Base 60 Mbps Average (100/20 Mbps)	46	281	
600 Mbps Average (700/500)	5	28	253

V. Individuals Place A High Value On Lost Time

Most individuals perceive lost time as important, and place an economic value on their own time.

While this first example of time valuation may be on the high end, according to a May 2024 article in USA Today, quoting a survey of 2,200 adults by the financial planning firm Empower, the average adult values time at $240 dollars an hour. Millennials place the highest value on time based on the survey.

3 "Fiber Scalability and Longevity", Fiber Broadband Association Technology Committee, March 18, 2024. The theoretical capacity of a single full spectrum single-mode ITU-T G.652,D fiber is 600,000 Gbps



Another way of valuing time would be to use the average U.S. wage, which is currently about $35 per hour.

So then, how does wasted time on the Internet translate to dollars?

Using the Empower numbers, having 600 Mbps of average Internet throughput up and down, with associated time savings, is worth somewhere between $25,000 - $61,000 annually to each user.

The Value Of Hours Recovered at 600 Mbps	Average User (70 hrs. Recovered)	Heavy User (163 hrs. Recovered)
Time Valued At $240 per hr. (Empower survey 2024)	$25,988	$60,630
Time Valued at $35 hr (Average wage 2024)	$3,790	$8,842

Even using lower U.S. Census median income numbers as the standard, the worth of the 600 Mbps option is worth somewhere between $3,000 - $9,000 annually to each user.

VI. Governments Place A High Value On Lost Time

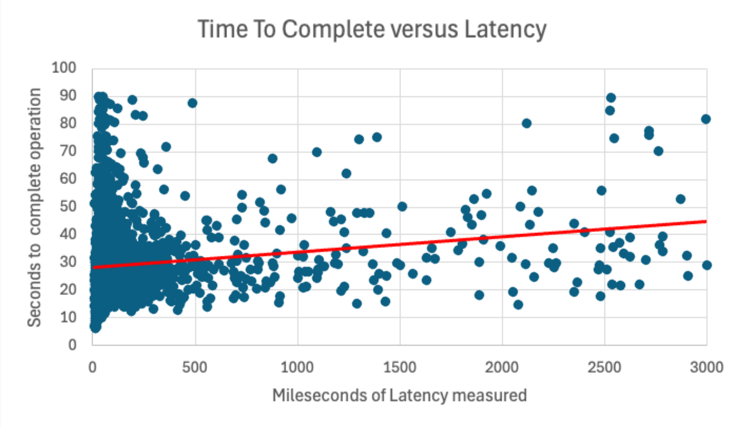
Most economists (public and private) believe productivity increase (more output per unit of time) is the primary way our economy and real wages per capita grow.

According to the current U.S. Bureau of Labor Statistics website, "Productivity growth is our opportunity to increase output without increasing inputs and incurring these costs... Productivity increases have enabled the U.S. business sector to produce nine times more goods and services since 1947 with a relatively small increase in hours worked."

Work from home accounts for about 24.5 % of all work conducted in the U.S. today based on RVA surveys. Moving home users from 100/20 Mbps to true Gigabit fiber would potentially add 1.2% or $326 Billion to Gross Domestic Product (GDP). (See Appendix 4.)

Governments, including the U.S. and Canada, are currently subsidizing Internet deployment, especially in low density areas. Thus, beyond the obvious argument that governments should only invest in Internet Infrastructure that will be viable for decades to come, immediate productivity improvement is another powerful reason governments should only invest in fiber Internet.

VII. And Bandwidth Isn't the Entire Productivity Advantage For Fiber



There is also a strong correlation between latency (a measurement of the time an individual packet of information takes to transmit back and forth and the time to process our example application (speed test process time). Based on the time to complete an online process in the FBA/RVA consumer study, the higher the latency, the more wasted time waiting for processes to finish.

Fiber has, by far, the lowest latency of all Internet methods. Using tested median latency (the measure most favorable to non-fiber methods), fiber has 37% better latency than cable, and 61% better than DSL and wireless, and 96% better than Geo Satellite. Switching to fiber will recover additional lost hours due to the higher latency of other methods.

Fiber also has greater uptime than other Internet methods, primarily because of fewer powered components in the network. (This means less time lost directly without any Internet, or having to switch to a wireless hotspot with lower productivity... and less time required dealing with customer service.)

VIII. Conclusions And Implications

An Internet provider promoting very high bandwidth, such as 1-10 Gigabit symmetrical with lower latency, is not just presenting marketing hype. A Gigabit or more of bandwidth can save significant valuable time for the individual, and can also contribute to increasing the overall Gross Domestic Product (GDP) of the U.S. and Canada.

Several key implications can be summarized:

1) Bandwidth need is always rapidly increasing, and constant improvement must be pursued

The public generally has difficulty imagining why more bandwidth might be needed in the future, but history shows every advance in the commonly available range of bandwidth enables more useful and exciting applications. In the 1990s, when the Internet was all about "kilobytes", "emails", and text-based "websites", very few had the vision of higher bandwidth and the potential future applications enabled. Fortunately, however, increased bandwidth was pursued – allowing the reality of "megabytes", "video conferences", "e-health", and "remote learning", which greatly helped the world survive the Pandemic of 2020.

2) Consumers should purchase the highest bandwidth delivery available to them whenever possible

The evidence shows the fastest Internet delivery available today should preferably be purchased over other Internet delivery options when possible – because of the value proposition. The best method is currently end-to-end fiber optic delivery. No other delivery method known to physics has as much current and future bandwidth advantage. (The second-best method is upgraded hybrid fiber cable, or HFC, with fiber deep into the network and DOCSIS 3.1 or DOCSIS 4.0 standards).

3) Consumers should strongly consider purchasing the highest speed tier available

The evidence also indicates the highest speed tier available from a fiber provider (usually 1-10 Gigabits symmetrical) should be purchased (if financially possible) instead of lower speed options ... even at a cost premium, because the time-based savings are usually far higher than the additional monthly cost.

4) Consumers and service providers should work to minimize restrictions within the home

Besides purchasing the highest bandwidth available, users should work to maximize processing speed in their devices as well as transmission efficiency within their own homes – using direct ethernet connections, or using advanced Wi-Fi mesh systems. (And if purchasing more than a Gigabit, the output of the router should be connected directly to the computer, if possible, to get the full benefit of such high speeds.) (See Appendix 2.)

5) Progress should begin now to move toward fiber to the room (FTTR)

Based on history, a 10 or 25 Gigabit online world will be here relatively soon – which basically demands a new infrastructure within buildings because Wi-FI systems require high frequencies to transmit over a Gigabit per second, and such frequencies cannot penetrate walls well. Therefore, home and commercial construction companies and service providers should also be moving now to extend fiber to each room in a building - starting with new construction.

6) Governments should demand the best possible transmission method for Internet investment programs

As the last 25 years have shown, the future of online technology moves very quickly. Barring some new breakthrough in physics, fiber is the only Internet delivery method that has a roadmap to very high future speeds. Further, getting more consumers on very high-speed fiber will increase Gross Domestic Product because of productivity improvement. Thus, governments should only subsidize fiber broadband for rural areas versus lower cost and less capable options, such as wireless delivery.

APPENDIX 1

An average of both uploading and downloading activity was used for simplicity in this analysis. Both have an important role to play in terms of time productivity.

While the average consumer uses download activities more than upload, during interactive online time, upload activities increase. Further, the potential time improvement is often higher on the upload side because of the common asymmetric nature of current bandwidth availability.

APPENDIX 2

Based on FBA/RVA research, few users with a Gigabit currently receive a full Gigabit symmetrical working speed. Many do receive a Gig when measured at the back side of the router, but there are a multitude of potential constrictions beyond that point. (It takes just one such bottleneck to restrict throughput.)

Wi-Fi is probably the most common restriction problem as noted widely in the literature, and as tested in the RVA/Consumer study, but there are many other potential choke points - some are listed below.

Network Transmission Constrictions
Distance/ location of server
Damaged ISP Fiber
Transit/ Middle Mile Capacity
Middleboxes
Throttling

In home Transmission Constrictions
Wi-Fi
Ethernet Cable type
Competing users

Device Constrictions
Memory
CPU size
NIC (Network Interface Card) restrictions
MTU (Maximum transfer units) settings

Speed tests themselves can also cause differences in reported results, based on the methodology used and the number and location of server test sites. See also, “Measuring Internet Speed: Current Challenges and Future Recommendations” (Feamster, Nick & Livingood, Jason December 1, 2020)

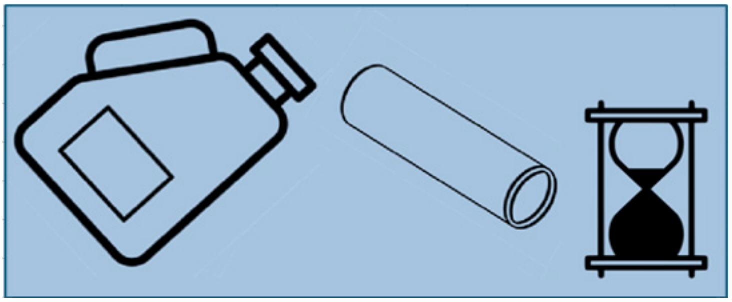
APPENDIX 3

The following methods were used to estimate time lost at the base level (100/20 Mbps or 60 Mbps average):

Method 1:

For this method, an average of consumer perceptions of time lost was used for a base user with 100/20 Mbps was used as noted previously (11%).

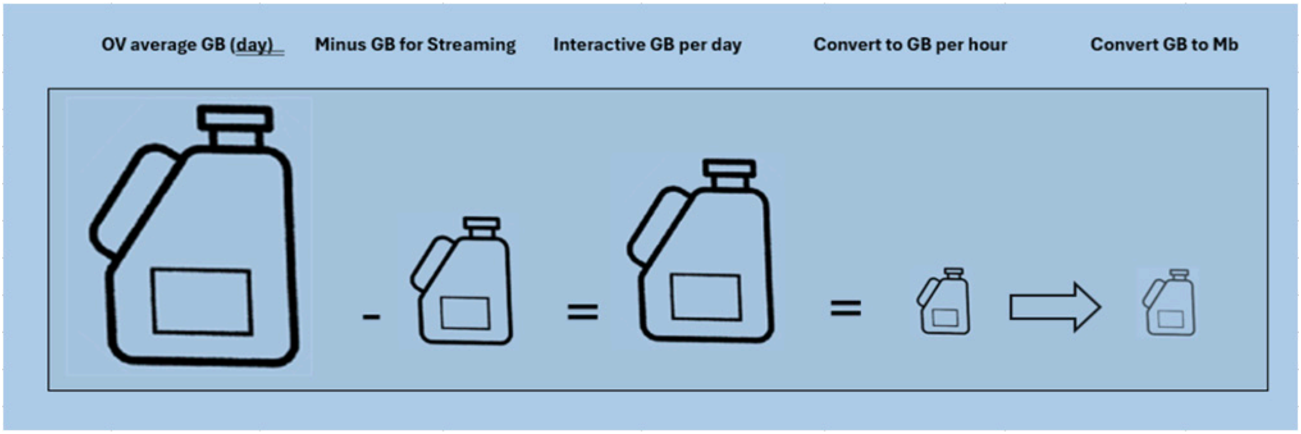
Method 2:



Average online waiting time for a base user = file size for an average consumer per hour divided by the pipe size for the base user

To determine the average file size per hour, this method utilized Open Vault's estimate of average data usage per month per user (Q4 2023), combined with information from the 2024 FBA/ RVA consumer study.

First the file size data from Open Vault was prepared for use in the analysis. After converting the Open Vault data to Gigabytes (GB) per day (by dividing by 30.4 days), the data was then converted for use in the analysis as shown. (The data must focus only on interactive online time per day and also has to be on the same scale as speed data – Mega rather then Giga, and on the same measurement system – bites rather than bytes.)



Estimates of GB used for 3 hours of streaming time and 0.7 hours of video conferencing time (based on the FBA/ RVA consumer surveys) were then subtracted. This data was then converted to hours assuming 3 hours of interactive time per the FBA/ RVA consumer survey.

The GB per hour was then converted to MB and then Mb to be equivalent to be on the same scale as the speed data. Then time waiting per day during interactive time was calculated by dividing the Mb balance by the Mb speed rates for a base user (100/20 Mbps).

As shown, the time waiting based only on bandwidth constraints was thus 7.2. minutes per hour – or 12% of interactive time lost. (That would sum to nearly 22 minutes of lost time per day.)

	OV: Usage Per Day		Less Non Interactive Online Time (3.7 hrs)			Interactive Online Time (3 hrs)					
	GB Monthly	GB Day (30.4 days)	Streaming GB (3 hours) (a)	2 Way Video GB (.7 Hours) (b)	Remaining GB	Convert to Hrs (/3 hrs per day)	Convert to MB (GB x 1000)	Convert to Mb (MB x8)	Mbps (Base user)	Secs Used Per Hr (File size/Mbps)	Added loss (1.3 X Transfer)
Download	600.90	19.77	6.90	0.70	12.17	4.06	4,055.5	32,444	100	324.4	
Upload	40.05	1.32	0.00	0.50	0.82	0.27	272.5	2,180	20	109.0	
Total Seconds										433.4	
Total Minutes										7.2	
% of hr.										12%	
	(a) 2.3GB per hour for streaming based on various services										
	(b) 1 GB Down and 7 GB upstream based on vatious sources										

APPENDIX 4

The increase in GDP moving from 100/20 Mbps bandwidth to Gigabit 700/600 bandwidth was determined as follows:

U.S. GDP EST 2024 (Billions)	$28,100	Billions
U.S. Work completed remotely	23.7%	Percentage
Hours of work in interactive online mode (4 of 8 hours)	50%	Percentage
Productivity improvement per hour during interactive hours (5.9 mins recovered per 60 mins)	9.8%	Percentage
Overall U.S. productivity improvement (percent working remotely x percent interactive x productivity improvement)	1.2%	Percentage
GDP increase in dollars (Billions) (GDP x productivity improvement)	$326	Billions