Bandwidth Requirements for eLearning

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EXECUTIVE SUMMARY

The COVID 19 pandemic has turned homes into remote classrooms connected via the internet to teachers and learning resources. Known as eLearning, internet-enabled remote learning requires sufficient network resources to support and never impede a student's learning experience. The goal of this research effort was to quantify the minimum bandwidth required to support students using the most popular online education platforms for remote learning.

NetForecast determined that an internet connection supplying 9 Mbps downstream and 5 Mbps upstream is sufficient to support a single student, and 11 Mbps downstream and 5 Mbps upstream is sufficient to support up to three students—assuming no other household internet use such as adults working from home. Our determination was based on analysis of nearly 7,000 hours of usage data collected from eLearning students ranging from elementary school through college in 23 households from January through April 2021.

It is important to note that additional household usage may increase peak usage above the recommended connection speeds.

For additional information on video conferencing bandwidth requirements, see our recently published report: *Internet Connection Requirements for Effective Video Conferencing to Support Work from Home and eLearning*.

USAGE DATA COLLECTION & ANALYSIS

The NetForecast eLearning bandwidth requirements study used two usage data collection methods based on whether students were using their own or school-supplied computers. For students using school-supplied computers dedicated exclusively to eLearning, NetForecast deployed wireless routers equipped with NetForecast-proprietary UMap® usage measurement software. For students with home-supplied computers used for other activities in addition to eLearning, participants downloaded NetForecast-proprietary "Observer" usage counting software that students manually activated at the start and deactivated at the end of each learning session.

Fourteen households used UMap routers to measure data usage, and students in 10 households used the Observer application. One household had both.

UMap routers measured usage associated with each connected device once every 15 seconds around the clock. UMap measurements were associated with device MAC address (a hardware identification number uniquely identifying a device on a network). Data was collected from some households with multiple students to study total usage during simultaneous eLearning sessions.

NetForecast's Windows-based Observer application was used to measure eLearning usage for students using computers not exclusively dedicated to eLearning. The Observer application allowed NetForecast to differentiate eLearning from other online activities. At the start of each eLearning session students identified the eLearning program they were using and manually started measuring usage. At the end of the session, they were to stop the program. The program also enabled them to enter notes about their eLearning activities and the quality of their experience during the session.

Connected devices included Windows, Chromebook, and Apple computers. Internet connection speeds ranged from DSL to 1 Gbps, provided by seven different ISPs. Households were tracked to ensure adequate data was collected during the measurement period.

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The usage each minute is the sum of the individual student minutes for each household. This means that usage peaks occurring in the same minute are fully accounted for in the multi-user results. We only included minutes that exceeded a minimum usage of 500 Kbps downstream or 50 Kbps upstream. This data was averaged, and 95th percentile values were calculated based in the variance in the data. The 95th percentile values reflect the maximum bandwidth each student can generally be expected to use.

ELEARNING NETWORK RESOURCE USAGE RESULTS

Most eLearning activity in participating households occurred between the hours of 8 AM and 10 PM local time, with the highest bandwidth usage in the morning (see Figure 1). The data reflect the expected usage pattern for eLearning students.

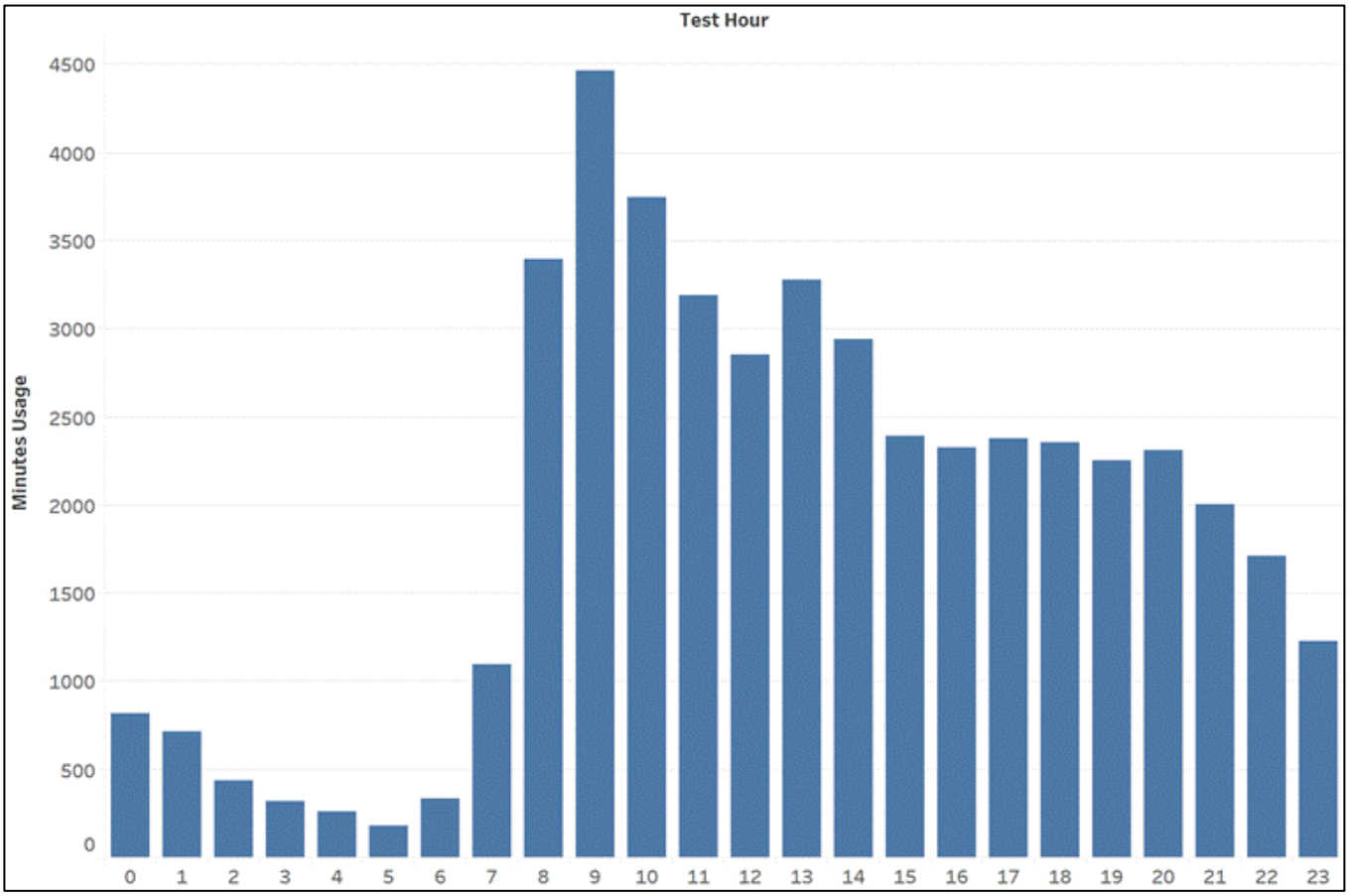

Figure 1 – eLearning Usage Distribution During the School Day

eLearning Bandwidth Consumption per Household

NetForecast UMap routers measured usage for school-supplied electronic devices dedicated to eLearning in 14 households. Figure 2 shows an example of daily downstream and upstream usage from 8 AM to 10 PM by a single student from Monday, March 29th through Sunday, April 4th. The measurements reflect the fact that the student was in a "hybrid" learning situation—physically attending classes on Mondays and Tuesdays, and learning from home Wednesdays through Fridays. During the days when the student was physically in class, eLearning traffic occurred after school hours—and on days when the student was learning from home, activity was dispersed throughout the day. Weekend usage counts were negligible.

Despite the apparent consistency of usage in Figure 1, the following two figures show that examining the data in detail exposes usage variability across hours. For internet planning purposes, usage averages are not as useful as understanding usage peaks. Notably, however, the data for multi-student households show the peaks generated by individual students rarely coincided.

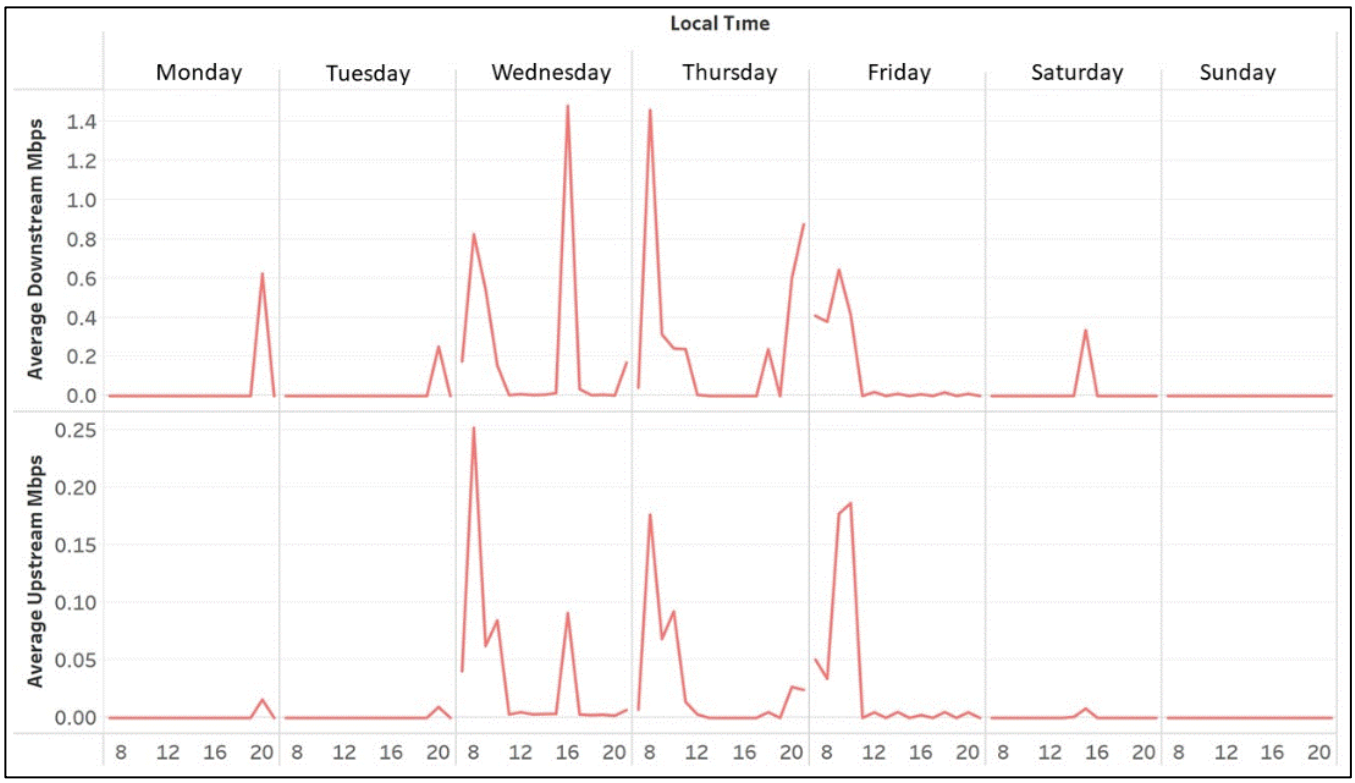

Figure 2 – Example of Usage by a Single "Hybrid" Student (8 AM to 10 PM)

NetForecast measured multi-student usage by totaling one-minute average usage for each student within the household during the same minute. Figure 3 shows an example of daily downstream and upstream bandwidth usage for three students sharing an internet connection. The graph shows that usage peaks tend not to occur at the same time.

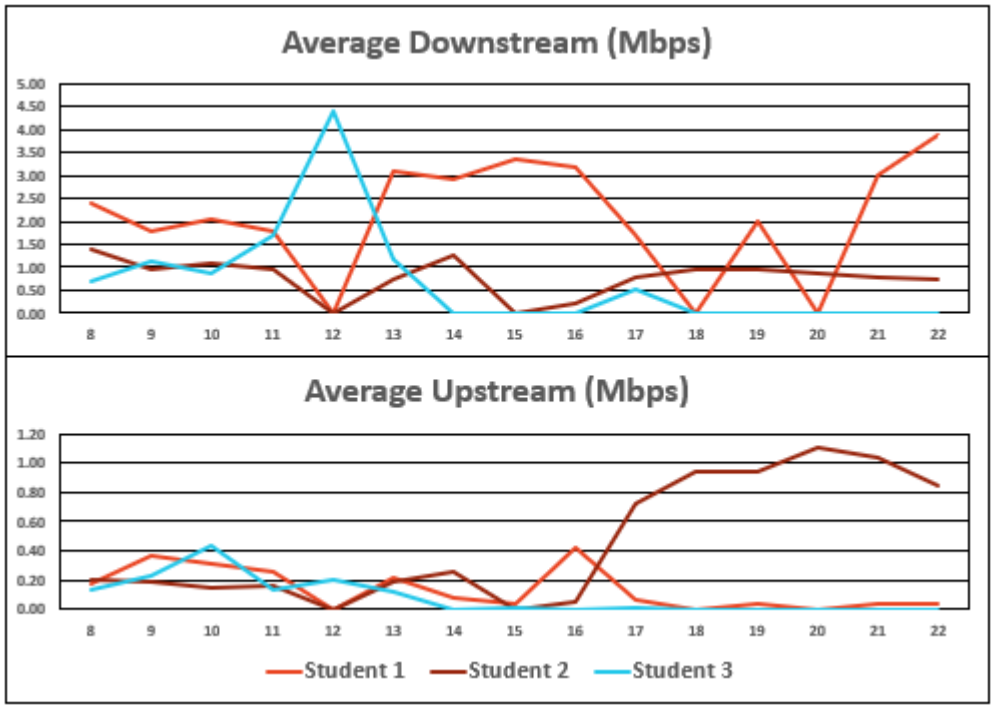

Figure 3 – Example Daily Usage in a Household with 3 Students

Figure 4 summarizes the average and 95th percentile downstream and upstream usage values for households with one, two, and three online students. As mentioned earlier, the critical 95th percentile result drives our recommendation. Internet connections provisioning 9 Mbps down and 5 Mbps up should be sufficient to support one student, and 11 Mbps down and 5 Mbps up should adequately support up to three students. If usage modestly exceeds those values, adaptive bitrate technologies are designed deliver acceptable video resolution and audio fidelity for videoconferencing applications.

Students per Router	Downstream		Upstream	
	Measured Average (Mbps)	Measured 95th Percentile (Mbps)	Measured Average (Mbps)	Measured 95th Percentile (Mbps)
1	1.69	8.41	0.63	4.85
2	3.88	10.60	0.71	4.93
3	4.21	10.93	0.73	4.95

Figure 4 – Measured eLearning Bandwidth Consumption

Bandwidth Consumption for Popular eLearning Applications

For students using their own computers in 10 households, NetForecast gathered and analyzed data regarding the bandwidth consumed by the most commonly used eLearning applications: Zoom, Google Meet, Blackboard, and Schoology. The measurement data summarized in Figure 5 show that Blackboard consumed the most downstream bandwidth, Google Meet consumed the most upstream bandwidth, and Schoology consumed the least bandwidth in both directions.

Zoom was the most commonly used eLearning application within the participating households, and accounted for most of the recorded hours. NetForecast found that average upstream bandwidth usage for each application was less than anticipated, and parents informed us that this is likely due to students not activating their cameras during group learning sessions. We also found that average downstream usage was higher than anticipated. This phenomenon, which is also reflected in the 95th percentile trends, is likely due to teachers relying on multimedia to keep students engaged, and therefore generating more usage than a typical work-at-home business meeting.

eLearning Application	Downstream		Upstream	
	Measured Average (Mbps)	Measured 95th Percentile (Mbps)	Measured Average (Mbps)	Measured 95th Percentile (Mbps)
Blackboard	2.34	8.53	0.45	1.33
Google Meet	2.22	5.62	0.14	1.39
Zoom	1.73	6.17	0.31	1.06
Schoology	1.66	3.38	0.09	0.18

Figure 5 – Bandwidth Consumption by eLearning Application

RECOMMENDATION

Based on based on analysis of nearly 7,000 hours of usage data collected from eLearning students ranging from elementary school through college in 23 households from January through April 2021, NetForecast recommends an internet connection with at least 9 Mbps downstream and 5 Mbps upstream to support a single eLearning student, and 11 Mbps downstream and 5 Mbps upstream to support up to three students. This recommendation does not include consumption contributed by other household members or traffic sources.

ABOUT THE AUTHORS

Alan Jones is Director of Software Development for NetForecast. He has led teams developing products and internal infrastructure for some of the world's largest telecom companies. After eight years designing and testing cellular handsets, he spent over a decade working on test systems for mobile networks. He currently works with mobile and cloud-based product development.

Rebecca Wetzel is the President of NetForecast, and an internet industry veteran. She helped realize the commercialization of the internet in its early days, and worked to design and market some of the internet's first value-added services. She has spent much of her career launching and guiding network technology startups and working as an internet industry analyst.

Forrest Workman is an analyst and project manager who brings over 35 years of results-driven engineering experience and software management to NetForecast. He has a strong background in systems and business analysis, engineering management, problem resolution, leadership, and project management. He has worked in diverse fields, including aerospace, massively multiplayer online games, casino gaming, and network performance and analysis.