Perspectives from CENIC: Home Broadband Requirements
What is necessary for students (and families) during COVID-19 and beyond?

June 14, 2020

Executive summary

Why is CENIC concerned about home broadband?

If we have learned anything during this pandemic, it is that *access to broadband is now a social determinant of health, education, work, and economic security*.

In 2003, the State of California awarded a grant to CENIC to focus on speeding one-gigabit broadband to all Californians by 2010, or, in California shorthand, *One Gigabit or Bust*.[1] Seventeen years later, most of the 12,000 institutions that connect to CENIC have a achieved gigabit status -- with many school districts, libraries, and community colleges connected at 10 Gbps (and a few at 100 Gbps); almost all universities and medical centers at 100 Gbps (or multiple 100 Gbps), with some preparing to connect at 400 Gbps over next 12-36 months.

Twenty million Californians have access to CENIC, one of the most robust broadband research and education networks on the planet, from their schools, libraries, colleges, and universities. But not all CENIC members have gigabit access and many of those who do not have access are in communities where no one has broadband access: not from their homes and business, or from hospitals and clinics, or from their schools and libraries. CENIC long ago recognized that joining in partnership with communities, with business and government leaders, and with our private sector telecommunications partners, was the only way to ensure that broadband access would be the rising tide that lifts all boats.

Now we find ourselves in the midst of a pandemic, where our homes have become our schools, our workplaces, and our clinics via remote education, work, and telehealth, with access to broadband the lifeline that ensures continuity in all of these arenas.

What do we hope that our legislative and government agency leaders will consider?

As one of the leading economies in the world, California's actions should be shaped by what we might call *Gretzky's Law*: "I skate to where the puck is going to be, not to where it has been."

Standards for what constitutes broadband were not created for the historical moment that we find ourselves in, and they were not created for the myriad dependencies that we have on the Internet, across the many facets of our lives. Our great California historian, the late Kevin Starr, paraphrasing the philosopher Josiah Royce (another great Californian), noted that one of the sustained qualities of our State is the "hope of a great community -- a place, a society, in which the best possibilities of the American experiment can be struggled for and sometimes achieved." Broadband is now a stepping stone on this path toward a future of quality education, healthcare, and prosperity. It is now time to renew and redouble our efforts towards "*One Gigabit or Bust,*" this time for all Californians at home, as well as at school and work.

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[1] www.cetfund.org/files/Cenic_gigabit_or_Bust_Gartner_Full.pdf

How do we get from here to there?

1. Level the playing field, so that low income households can access the highest quality services available to them in their communities. To do this, subsidies are critical.

2. Acknowledge that bandwidth standards for rural and urban settings will be unequal for the foreseeable future, and the way towards sustainability and equity will be through unequal steps. Initial standards for and approaches to remote learning will be divergent and based on regional broadband capacities.

3. Understand that it isn't just bandwidth. When making investments in networks to the home, consider other critical factors beyond download speeds: upload, latency and packet loss, and data caps are all critical considerations.

4. Assert that the household is the denominator. We cannot simply talk about a single use (e.g., remote learning) in a home as the basis for a bandwidth standard. If we have learned anything during this COVID-19 experience, it is that concurrent use of the network -- several family members involved in different online pursuits simultaneously -- is the baseline for determining how much bandwidth is necessary.

5. Start from where we are right now, leveraging our existing installed telecommunications base, incenting the many leading telecommunications companies who build and operate these networks.

6. Build in accountability. Too frequently the network performance that households receive is (often considerably) less than what providers claim and/or advertise. Broadband initiatives need to be designed so that funders (and households) get what is being paid for. The testing and network instrumentation needed to provide these assurances are easy to do, but to date few regulatory or legislative bodies have had the will to make it a requirement for subsidies or other incentives.

What do we know about the current status of students in California?[2]

- Overall, one in four K-12 households in California do not have a desktop or laptop computer and a high-speed Internet connection. These households (25% of all households) were already significantly disadvantaged pre-COVID and will continue to be post-COVID; COVID only exacerbates and illuminates inequities. This represents about 870,000 families whose child or children are likely to fall behind in educational attainment during the COVID-19 crisis. If households with mobile broadband service are included, the share of households lacking resources for distance learning falls to 17%, which represents about 610,000 families.
- Only about half of the K-12 families in the bottom 20% of the income distribution have a desktop or laptop computer and subscribe to high-speed Internet. This compares to over 90% of families in the top income quintile.
- Households in coastal metro areas are generally better equipped than those in the rural communities of the Central Valley, Southeast and Northern California. However, large concentrations of under-resourced households exist within metro areas. As an example, the availability of an Internet-enabled PC at home for students in South Los Angeles is only slightly above that for students in Tulare County, which has the lowest availability rate in the state.

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[2] From the study, *COVID-19 and the Distance Learning Gap*, Professor Hernan Galperin, Director, Annenberg Research Network on International Communication, University of Southern California.

Are current benchmarks for what constitutes "broadband" adequate today?

In a word, "no." When creating standards for the requisite bandwidth for remote learning, it is essential to consider that all family members are impacted by stay-at-home orders, and thus our need to re-conceive of the home as a school or college, workplace, healthcare facility (for telehealth), library (for access to all media in digital form), and communications and entertainment hub, with several concurrent users who may be simultaneously using interactive applications.

In 2015, the Federal Communications Commission adopted a 25/3 Mbps benchmark,[3] capacity that would allow "basic or moderate use" in a household.[4] "Basic use" is defined as email, browsing, basic video, VoIP, and Internet radio for up to 4 users or devices at a time. "Moderate use" is defined as basic functions plus *one* high-demand application: streaming HD video, multiparty video conferencing, online gaming, telecommuting for up to three users (or devices) at a time. These benchmarks have remained unchanged since 2015. The FCC minimum threshold for "broadband" is 10/1 Mbps. The California Public Utilities Commission has a different benchmark of 6 Mbps/1.5 Mbps, which was later amended down to 6 Mbps/1 Mbps.[5]

These benchmarks are important as public policy measurers and, as such, because they shape decisions about how public funding is used to support federal and state broadband access, adoption, and subsidy programs for households.

Moreover, it is important to note that most discussions and subsequent definitions, as well as the way providers advertise their offerings, focus almost exclusively on download speeds. The assumption here is that the household is largely a consumer of content and, thus, what is most important is the speeds at which a consumer can access this content.[6] COVID-19 and stay-at-home orders have altered this situation dramatically, and these standards are inadequate to meet the critical needs of California's families for school, employment, and health care.

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[3] Mbps (Megabits per second) is the standard measure of broadband speed. It refers to the speed with which information packets are downloaded from, or uploaded to, the Internet.

[4] FCC Household Broadband Guide, 02/05/20.

[5] Assembly Bill No. 1665, Eduardo Garcia. Telecommunications: California Advanced Services Fund. Approved by Governor Brown, October 15, 2017. Filed with the Secretary of State, October 15, 2017.

[6] For organizations like CENIC – Research and Education Networks – the denominator is gigabit speeds (Gbps) rather than megabits (Mbps) for its members, whether they are schools, libraries, colleges, universities, health care organizations, or cultural and scientific organizations. Most of CENIC's 12,000 members connect at gigabit speeds or aspire to these speeds, and in these communities we are actively working towards this goal. As importantly, these organizations create, curate, and/or provide content to their constituents and, therefore, the upload speed is as important as the download speed and CENIC's requirement is for symmetrical connections – e.g., 1/1 Gbps, 10/10 Gbps, 100/100 Gbps, and so on.

What has changed with COVID-19 where bandwidth requirements are concerned?

1. Technical considerations:

Upload speeds matter. Interactive applications like video-conferencing, often with multiple participants; cloud-based applications where students are manipulating (in real time) documents or resources or scientific instruments; data-sharing applications where students are the source of data not just the passive recipient; educational simulations with students interacting with representations of real-world processes in a controlled environment -- all of these applications underscore that home broadband users ***produce*** content and ***interact*** with it and each other, and so upload speeds are a significant component in the broadband equation.

***Network latency matters*.** For our purposes, "latency" is defined by the time it takes for the data packet(s) triggered by a user's action (such as clicking on a link in a web browser) to travel across the network to their destination (such as a web server, in this case) combined with the time it takes for the resulting responses (data packets) to travel back. Latency is simply a measure of network delay (combining both directions is often referred to in networking terms as the round-trip delay). With time-sensitive streaming or interactive video, the higher the latency the worse the user experience.

In a multiple-participant Zoom classroom, for instance, low latency is essential. With high latency there are long pauses and overlapping noises or words, with speakers interrupting each other, unsure of when to stop or start speaking, resulting in an unsatisfactory, chaotic experience.

Latency is measured in milliseconds (ms) and there are a number of reasons it exists. It is something we can minimize, but not completely eliminate. While many application developers work toward ensuring that their applications are latency tolerant, assuming that users will be on a wide range of networks -- terrestrial, wireless, and satellite -- it is generally accepted that lower latency networks are preferable for the user's experience, with latencies <50 ms desirable (and lower latencies, even better).

Packet loss matters. On the Internet, small units of data called packets are sent and received. When one or more of these packets fails to reach its intended destination, this is called packet loss. Packet loss is often caused by network equipment dropping, mishandling, or the most common cause, discarding packets. With packet loss, a user might experience slow service, communications disruptions (frozen frames and stuttering behavior), and even total loss of network connectivity.[7]

[7] Experts differ on what acceptable packet loss is, but most agree that sustained packet loss over 2% is an indicator of problems. Most Internet protocols can correct for some packet loss, so problems are often invisible until that loss starts to approach 5% and higher and, at this level, the user experience is noticeably, and often significantly, degraded. Packet loss, like latency, is often a matter of "network hygiene," where network congestion, problems with network hardware such as misconfigurations, software bugs, overloaded devices, and security threats are present singularly or in some combination on a network.

Many experts agree that packet losses above 3% are problematic and the user experience is degraded.[8] The effects range for the inconvenience -- and for a student taking a test, the inequity -- of slowing down the application, through dropped connections, broken sessions, and lost work.

Data caps are a barrier. Data caps are a limit on the amount of data a user or household can use over an Internet connection. When the user hits that limit, Internet Service Providers have different responses, including charging overage fees, slowing data speeds and, even in some rarer cases, disconnecting a subscriber. Some plans are quite generous and either have no caps, or have caps from a paltry 40 GB to a generous 1 TB (or 1000 GB). The least expensive plans from some carriers also have the lowest data caps, thereby impacting low-income subscribers disproportionately. There are two prospective approaches -- a carrot or a stick: subsidies for low-income subscribers allowing bandwidth to be unfettered for remote learning and work; or removing those plans that have subsidies from any statewide systemic policy and funding initiatives.

2. Application requirements

Most current approaches to outlining the requirements for online activities focus on (a) download speeds for an application and (b) a single user. For instance, the FCC Broadband Speed Guide below, last updated February 2020, is based on running one application by one user at a time and notes "additional speed may enhance performance.[9]"

Minimum Download Speeds for Typical Activities

Activity	**Minimum Download Speeds (Mbps)**
General Browsing and Email	1 Mbps
Streaming Online Radio	Less than .5 Mbps
VoIP Calls	Less than .5 Mbps
On-line Learning	5-25 Mbps
Telecommuting	5-25 Mbps
File Downloading	10 Mbps
Social Media	1 Mbps
Streaming Standard Definition Video	3-4 Mbps
Streaming High Definition (HD) Video	5-8 Mbps
Streaming Ultra HD 4K Video	25 Mbps
Standard Personal Video Call (e.g., Skype)	1 Mbps
HD Personal Video Call (e.g., Skype)	1.5 Mbps
HD Video Teleconferencing	6 Mbps

[8] *Tutorial on Internet Monitoring & PingER at SLAC.* Authors: Less Cottrell, Warren Matthews, and Connie Logg, Created January 1996; last Update: December 1st, 2014. "More recently, we have refined the levels to 0-0.1% excellent, 0.1-1% = good, 1-2.5% = acceptable, 2.5-5% = poor, 5%-12% = very poor, and greater than 12% = bad. Changing the thresholds reflects changes in our emphasis, i.e. in 1995 we were primarily concerned with email and ftp. This quote from Vern Paxson sums up the main concern at the time: *Conventional wisdom among TCP researchers holds that a loss rate of 5% has a significant adverse effect on TCP performance, because it will greatly limit the size of the congestion window and hence the transfer rate, while 3% is often substantially less serious.* In other words, the complex behavior of the Internet results in a significant change when packet loss climbs above 3%".

[9] https://www.fcc.gov/reports-research/guides/broadband-speed-guide

Online Game Downloading	3 Mbps
Online Multiplayer	4 Mbps

Given the prevalence of interactive video in use by many schools, hospitals for a range of telehealth purposes, and in work-from-home, what follows is some application-specific data from providers of three of the most popular video applications:

Zoom: Bandwidth Requirements[10]

- 2.0 Mbps (up/down) for a single screen
- 800 Kbps/1.0 Mbps (up/down) for high quality video
- For gallery view and/or 720p HD video: 1.5 Mbps/1.5 Mbps (up/down)
- Receiving 1080p HD video requires 2.5 Mbps (up/down)
- Sending 1080p HD video requires 3.0 Mbps (up/down)
- 2.0 Mbps up 4.0 Mbps down for a dual screen
- 2.0 Mbps up 6.0 Mbps down for triple screen
- For screen sharing only: (150 – 300 Kbps up/down)
- For audio VoIP: 60-80 (Kbps up/down)

Google Hangouts: Bandwidth Requirements[11]

- Minimum bandwidth required[12]
  - Outbound: 300 Kbps
  - Inbound: 300 Kbps
- Ideal bandwidth for two-person video calls
  - Outbound 3.2 Mbps
  - Inbound: 2.6 Mbps
- Ideal bandwidth for group video calls
  - Outbound: 3.2 Mbps
  - Inbound (with 5 participants): 3.2 Mbps
  - Inbound (with 10+ participants): 4.0 Mpbs

Skype: Bandwidth Requirements[13]

Call type	Minimum download / upload speed	Recommended download / upload speed
Calling	30 Kbps / 30 Kbps	100 Kbps / 100 Kbps

[10] Source: Zoom https://support.zoom.us/hc/en-us/articles/204003179-System-Requirements-for-Zoom-Rooms and https://support.zoom.us/hc/en-us/articles/201362023-System-requirements-for-Windows-macOS-and-Linux

[11] Source: Google Hangouts support.google.com/meethardware/answer/4541234?hl=en
N.b. Hangouts changes how much bandwidth is needed based on the available network

[12] While meetings will operate with bandwidth speeds as low as 300 Kbps, video and audio quality might be poor.

[13] Source: Skype
support.zoom.us/hc/en-us/articles/201362023-System-requirements-for-Windows-macOS-and-Linux

Video calling / Screen sharing	128 Kbps / 128 Kbps	300 Kbps / 300 Kbps
Video calling (high-quality)	400 Kbps / 400 Kbps	500 Kbps / 500 Kbps
Video calling (HD)	1.2 Mbps / 1.2 Mbps	1.5 Mbps / 1.5 Mbps
Group video (3 people)	512 Kbps / 128 Kbps	2 Mbps / 512 Kbps
Group video (5 people)	2 Mbps / 128 Kbps	4 Mbps / 512 Kbps
Group video (7+ people)	4 Mbps / 128 Kbps	8 Mbps / 512 Kbps

Imagine a family of four with two K-12 students who are engaged in multiple online activities, while one parent is downloading files from the cloud for work while on a teleconference, and another parent, perhaps currently out of work, is looking online for employment, while pursuing a certificate program from a local university to advance his/her prospects. This could easily tally to 100 Mbps download capacity, with the interactivity necessary as well (and so a need for greater upload speeds), with upload speeds of 20-30/Mbps. For large file transfers and high-quality interaction from home, upload speeds that are symmetrical to the download speeds are highly desirable, with consumer-focused resources like Allconnect[14] suggesting symmetrical speeds of 40 Mbps for a single user. COVID-19 stay-at-home circumstances, with the prospect of a repeat in the fall/winter and potentially next spring, as well as the reshaping of education and the workplace, where new models of hybrid remote and in-school/workplace will likely characterize our future, have made previous benchmarks like the FCC's 25/3 Mbps an artifact of another, distant era.

3. Household composition matters

Many of our current conversations focus on one facet of the broadband divide: for instance, how much broadband capacity does a student need to conduct remote learning? But as we note above, remote learning in our current -- and likely, future -- circumstances does not occur in a vacuum, though there are providers who would argue that there is a particular bespoke technological approach that will solve the singular problem of K-12 remote learning. Given that lack of broadband access isolates not just a student, but the entire household, a focus on a singular solution for the student should only be part of any policy discussion or funding decision. Successful policy and funding decisions will focus on the household as the common denominator.

[14] www.allconnect.com

If the goal of new public policy and funding are to address broadband access and affordability among populations for whom access is either nonexistent, unaffordable, or both, then solutions need to focus on the family as the denominator. In so doing, there will likely need to be an acknowledgment that such support will enable the full panoply of applications that characterize the digital life of an analogous family with resources and access. Issues of affordability (and adoption) have been addressed persuasively and comprehensively by the California Emerging Technology Fund and others, so it will not be our focus here.

How have other states approached the issue of residential broadband?

California is somewhat aligned with four other states with our definition of 6/1 Mbps, though the standard in those states is higher at 10/1 Mbps, the FCC's starting point for "broadband." Twenty-eight states have definitions of 1.5 Mbps or less; eight states, 25/3 Mbps.[15] Only one state has higher and symmetrical bandwidths: Alabama, in its "Broadband Using Electric Easements Accessibility Act," states:

Broadband Services. The provision of connectivity to a high-speed, high-capacity transmission medium or to a technology supporting, in the provider-to-consumer (downstream) direction, a speed, in technical terms ("bandwidth"), with minimum download speeds of 25 Mbps and minimum upload speeds of 25 Mbps for either of the following: a. To provide access to the Internet. b. To provide computer processing, information sharing, information storage, information content, or protocol conversion, including any service application or information service over the electric delivery system of an electric provider, and includes any advanced communications capabilities that enable users to originate, send, and receive high-quality voice, data, graphics, video programming, and video communications using any technology including a broadband system.

Similar to California's numbers, Alabama has more than 840,000 persons, almost 20 percent of the state's population, with either no access or limited access to broadband Internet.[16]

Several states have aspirational language in statute or through state broadband office statements. Some examples:

Minnesota: *No later than 2026, all Minnesota businesses and homes have access to at least one provider of broadband, with download speeds of at least 100 Mbps and upload speeds of at least 20 Mbps.*[17]

New York: *The New NY Broadband Program seeks to drive statewide broadband access, at download speeds of 100 Mbps in most places and 25 Mbps in the most remote and rural areas.*[18]

Washington*: By 2028, all Washington businesses and residences have access to at least one provider of broadband with download speeds of at least 150 Mbps and upload speeds of at least 150 Mbps.*[19]

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[15] PEW Trusts State Broadband Policy Explorer https://www.pewtrusts.org/en/research-and-analysis/data-visualizations/2019/state-broadband-policy-explorer

[16] https://alabamaliving.coop/article/new-laws-to-help-electric-cooperatives-offer-broadband-service

[17] Minn. Stat. § 237.012

[18] https://nysbroadband.ny.gov/about

[19] Second Substitute Senate Bill 5511, Washington State 66th Legislature, 2019 Regular Session

Where are the examples, the most promising deployments, in California that may set the stage for the future?

Urban – Rural Divides

First, we must state that there is a bifurcation between the advanced approaches to current broadband deployments in dense urban areas (and adjacent communities) and those being deployed in sparsely populated rural communities in California, communities that often lack access to critical middle mile infrastructures.[20]

In our previous paper,[21] we focused on the cost of Fiber to the Home (FTTH) deployments in dense, low-income urban areas in California. The economics and technology of FTTH are designed for urban density and a rural adaptation would pose unique challenges in both arenas. While there are alternatives[22] to urban FTTH deployments being explored in rural areas, the fiber needs to cover great distances, as well as presume access to requisite middle mile and long-haul infrastructures, something we know is uneven in many of California's underserved communities. Distance makes the cost per home expensive and necessitates high subscriber "take rates" for such deployments to provide both incentive and a return on this investment.

There are, however, very promising efforts in fixed wireless deployments in rural communities that lack access to middle mile infrastructures, offering respectable download and upload speeds, and low latency. The best plans and, therefore the most compelling ones from a household point of view, would require subsidies to make them affordable to low-income, rural California households.

The Temporal Element

To reach low-income homes with affordable broadband, we need to turn to what is the best of breed in our already installed base, if we want to reach these households, by leveraging what exists, rather than what we hope will, eventually, be deployed. Otherwise, we risk part of a generation of students passing through our schools, along with their families, missing opportunities. While grand plans for massive fiber deployments are admirable aspirations, even if the funding appears from federal sources (along with state components) such projects take many years to plan, permit, build, and light -- and all of this needs to transpire before the first customer can avail themselves of this new service. The focus on the near-term and longer-term aspiration can co-exist, but there is an urgency now, given the need for continuity of education, health care, workforce, and economic security, to name, but a few fundamental societal needs.

Fortunately, for Californians, there are many pockets of leading-edge broadband efforts, both in urban and rural settings, led by a wide range of Internet Service Providers, large and small, incumbents, and newer entrants to the marketplace. The following examples are intended to be illustrative and not exhaustive.

Urban

In several urban communities, FTTH is available at symmetrical 1 Gbps (1000 Mbps) speeds, with plans starting at $40/month. For example, Sonic, with their "Gigabit Fiber" plan in many Bay Area counties

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[20] "Middle mile is a term most often referring to the network connection between the last mile and greater Internet. For instance, in a rural area, the middle mile would likely connect the town's network to a larger metropolitan area where it interconnects with major carriers." Community Networks: https://muninetworks.org/glossary#letterm

[21] CENIC & Private Sector Partners*: Fiber to the Home Estimates – 21 May 2020*

[22] https://www.isemag.com/2019/11/telecom-ftth-tap-network-architecture/

offers these speeds at this price. Other ISPs have similar gigabit offerings, some at higher price points, others with introductory rates that are at or near the $40/month. Most of these networks are low latency, have no data caps, and offer symmetrical gigabit services.

Frontier, with its Fios offering in California, has a 940/880 Mbps plan currently advertised at $74.99 where available, and with no data caps.[23] AT&T Fiber has a similar 940/880 Mbps plan at $49.99 a month, with no data caps. Both have lower bitrate offerings, e.g., 500/500 Mbps at lower monthly rates.

CenturyLink Internet, Cox Internet, Spectrum Internet, Suddenlink, Xfinity Internet all have 940 Mbps to 1 Gbps plans, with varying download speeds, some with monthly caps, some without, and at monthly rates that vary from $50 to $100, and most have lower bitrate plans, as well, at lower monthly rates.

It is also important to note some other extant technologies and those that are in the process of being deployed, in particular 4G and 5G technologies.

- 4G technologies (4G, 4G LTE, and 4G LTE-A). Depending on a variety of factors including your location, the network you are on and how busy it is, and the device you are using, 4G technologies can ***theoretically*** provide maximum download speeds of up to 1 Gbps and maximum upload speeds of up to 50 Mbps. Reported actual download speeds range from 10-50 Mbps and average upload speeds of 2-15 Mbps,[24] with latencies of circa 50 ms.[25]

- 5G technologies, once fully deployed, promise much faster download and upload speeds, with much lower latency.

Rural

The largest California recipient of the Connect America Fund Phase II (CAF II) is GeoLinks, who will offer rural residents speeds of 100/20 Mbps, with 40ms latency, with no data caps at $106/month. While these speeds are lower than what is available in urban communities, for many in rural communities, who have had little or no broadband service, and where there is little or no terrestrial infrastructure, this residential service is a game changer. Moreover, there are 80,000 households that are adjacent to communities where these CAFF II deployments are either in process or planned, so there is potential to leverage some of these deployments.

For low-income households, as noted before, for students studying remotely, or adults working from home, state or federal subsidies will be a necessary component of access. There are other, similarly, remarkable and heroic broadband efforts underway in pockets of rural California, and within reach of rural households, though none on the scale of GeoLinks CAF II project.[26] Many need additional access to

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[23] https://www.verizon.com/home/fios-fastest-internet/

[24] See www.digitaltrends.com/mobile/5g-vs-4g/ and www.lifewire.com/how-fast-is-4g-wireless-service-577566 Carriers also provide some of this data, for example www.verizon.com/articles/4g-lte-speeds-vs-your-home-network/

[25] datamakespossible.westerndigital.com/5g-vs-4g-side-by-side-comparison/ and www.statista.com/statistics/818205/4g-and-3g-network-latency-in-the-united-states-2017-by-provider/

[26] To view the GeoLinks (aka "California Internet, L.P.") project, see the FCC's map of Connect America Fund Phase II: Auction 903 Results at https://www.fcc.gov/reports-research/maps/caf2-auction903-results/

fiber middle mile and backhaul to urban Internet centers. This topic has been an area of on-going conversation and public policy efforts.

Another useful framework for evaluating rural infrastructure projects is the Federal Communications Commission's Rural Digital Opportunity Fund (RDOF).[27]

RDOF Technology-Neutral Service Tiers

Performance Tier	Speed	Usage Allowance
Minimum	≥ 25/3 Mbps	≥ 250 GB or U.S. average, whichever is higher
Baseline	≥ 50/5 Mbps	≥ 250 GB or U.S. median, whichever is higher
Above Baseline	≥ 100/20 Mbps	≥ 2 TB
Gigabit	≥ 1 Gbps/500 Mbps	≥ 2 TB

"Above Baseline" and "Gigabit" performance tiers would enable the multiplicative impact, on both downloads and uploads, of concurrent videoconference use in family congregate situations. These performance tiers are identical to those in the recent CAF II auction.[28]

For performance at or below the minimum, it should be noted that no vendors are actively selling equipment that supports such a low standard as 25/3 Mbps, or anything similar to the outdated, but still current, FCC national standard. For locations that are not yet served or that haven't been refreshed in decades, any new standard should necessarily be much higher. This is explicit in the RDOF standards above. Moreover, recognizing that for places that are not well served, it will be another long cycle before broadband to these communities is revisited and refreshed. That implies a higher standard, even the highest, is appropriate. In urban areas, this means fiber deployments. In a number of rural areas, particularly in the extreme geographies of the West, wireless may make sense, but it is essential that there is extra effort to get the towers and backhaul prioritized to sustain radio technology upgrades.

[27] https://www.fcc.gov/auction/904/factsheet
[28] https://www.fcc.gov/auction/904/factsheet

Satellite Internet constellations, referred to as low-Earth orbit (LEO) satellites, are designed to provide low latency Internet to homes, businesses, and enterprises. According to one of the companies, service will begin sometime in 2020.[29] Where this service will be initially available and the cost for consumers are unknown, as are the precise bandwidths available and the latency of the service.

Conclusion: Policy and funding considerations

1. ***Subsidies are critical.*** In order to reach low-income homes with high-quality broadband access essential for equally high-quality learning applications, subsidies to defray monthly recurring costs for households are an important consideration, with rural monthly subsidies necessarily higher than those for urban households.
2. ***Bandwidth standards for rural and urban settings will be unequal for the foreseeable future.*** What is currently possible in urban and rural communities is divergent. Consider separate standards and aspirational goals for each, which means that standards for remote learning will be divergent as well (as well as standards for other engagements from home).
    a. For ***urban areas***, there are multiple deployments of fiber, some to the home/premise (apartments), some interconnect with older technologies – to DSL, twisted pair cable, coaxial cable, etc. Leverage the installed base where possible, creating incentives for FTTH deployments. Aspire to ***1 Gbps symmetrical*** services to every home, with no data caps.
    b. For ***rural areas***, with low population densities, and little or no terrestrial infrastructure, look to the standard of ***100/20 Mbps***, low latency and packet loss, with no data caps. This aligns with the FCC's "above baseline" service tier and is a step on the way toward the "gigabit" tier.
3. ***It isn't just bandwidth***. When making investments in networks to the home, consider other critical factors beyond download speeds: upload, latency and packet loss, and data caps.
4. ***The household is the denominator***. We cannot simply talk about a single use (e.g., remote learning) in a home as the basis for a bandwidth standard. If we have learned anything during this COVID-19 experience, it is that concurrent use of the network -- several family members involved in different online pursuits simultaneously -- is the baseline for determining how much bandwidth is necessary.
5. ***Begin with what we have***. Consider ways to leverage the existing installed telecommunications base (or funded projects in construction and deployment) in each region throughout the state. Bandwidth to the home will likely shape the kinds of remote learning applications possible for a given school district or districts, for colleges, and for other home applications (telehealth, work-from-home).
6. ***Build in accountability.*** Ensure we get what we are paying for. Require independent network performance testing.

June 14, 2020

Louis Fox
President & CEO, CENIC

[29] www.starlink.com and spacenews.com/spacex-plans-to-start-offering-starlink-broadband-services-in-2020/