Written Testimony of

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Chairwoman Phillips-Hill and Minority Chair Steve Santarsiero, thank you for this opportunity to discuss the current state of broadband connectivity across the Commonwealth of Pennsylvania.

Over the past half-decade, my research team has collected over 25 million broadband speed tests from across the state, and the results of this overwhelming compendium of data document that our state faces a dire crisis that is undermining our economy, our educational system, our health care, our access to media and information, and the availability of untold additional resources that broadband connectivity makes possible. To be clear, the very foundations of our 21st Century social lives and economic livelihoods are being undermined by digital divides that are not just substantial, but growing.

Almost exactly thirty five years ago -- on September 26, 1994 -- Verizon PA submitted a "Modified Network Modernization Plan" to the State of Pennsylvania to address multiple deficiencies identified by the Public Utilities Commision in its proposed network rollout. This plan contained a profoundly forward-looking commitment:

> "Bell commits to deploy the technologies necessary to provide universal broadband availability in 2015. In order to meet this commitment, Bell plans to deploy a broadband network using fiber optics or other comparable technology that is capable of supporting services requiring bandwidth of ***at least 45 megabits per second or its equivalent***."[1]

In return, Verizon received substantial tax breaks and "rate flexibility" (the ability to charge customers more), which resulted in higher costs for PA residents -- extra funds that would ensure universal broadband connectivity by the end of 2015 at speeds exceeding the Federal Communications Commission's (FCC) current definition for broadband connectivity.

[1] As per the order adopted by the PA Public Utilites Commission on March 28, 2002. Available online at: hsttp://www.puc.state.pa.us/PcDocs/330586.doc.

While it is difficult to determine just how much money Pennsylvania residents have already paid for this roll-out, the consumer watchdog group, Teletruth, has conducted a number of in-depth investigations looking at Verizon's SEC filings, tax documents, and other records and what they've found is fairly astounding. As Teletruth's founder, Bruce Kushnick, stated in June 2015, over the course of the first decade of Verizon's "rate flexibility" PA residents invested heavily in broadband buildout:

> "...by the end of 2003, Verizon had collected almost $4 billion — approximately $1,135 per household, from excess phone rates and tax perks, paid by customers for a fiber optic upgrade that never happened."[2]

In 2004, after a decade of increased costs to PA residents under this rate flexibility plan, the Pennsylvania law was changed to *lower* the universal service speed to 1.5Mbps. And, over the next decade, tax subsidies and rate flexibility continued to provide substantial income streams in return for a universal service mandate. How much has PA already spent? The numbers are difficult to come by, but Teletruth has numerous SEC documents underscoring just how substantial these investments were:

> "We estimate that by the end of 2014, Verizon PA overcharged customers about $18 billion for a fiber optic future they never got."[3]

To this day, Verizon claims, "Verizon met its Chapter 30 obligations to deliver broadband to 100% of its Pennsylvania service territory by the end of 2015."[4]

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[2] Available online at: https://www.huffpost.com/entry/verizon-pennsylvanias-com_b_7532008
[3] Ibid.
[4] Available from: https://www.verizon.com/about/sites/default/files/pa_hsi.pdf

A Brief history of mapping efforts

Early mapping efforts

In 2007, the Broadband Data Improvement Act was introduced by Senator Daniel Inouye, and was passed into law in October 2008.[5] Section 106 of this act created a grant program under the Department of Commerce, "for the development and implementation of statewide initiatives to identify and track the availability and adoption of broadband services within each State."[6]

The American Recovery and Reinvestment Act of 2009 operationalized this mapping mandate under the Broadband Technology Opportunity Program (BTOP), enabling hundreds of millions of dollars to be distributed to states by the National Telecommunications and Information Administration (NTIA) for the purposes of broadband mapping. As a cornerstone of this effort, the NTIA was mandated to create and release a "National Broadband Inventory Map" by February 17, 2011. Roughly $350 million in tax payer dollars was spent on this effort. As I publicly stated at the time, "...with a few vital improvements, the map could easily become an exemplar of government data transparency as well as an incredibly useful tool for US residents and policymakers. But without these improvements, the National Broadband Map runs the risk of becoming a $350 million boondoggle—a map to nowhere filled with inaccurate and useless information."[7]

While input from broadband mapping experts was requested, it was roundly ignored, leading to a hodge-podge of different methodologies, ad-hoc mapping efforts, and one-offs among many states that did little to systematically document on-the-ground broadband speeds, service-level realities, and pricing structures. Meanwhile, over the past decade -- but especially over the

[5] Text of the Broadband Data Improvement Act is available here: https://www.govtrack.us/congress/bills/110/s1492/text
[6] Ibid.
[7] https://arstechnica.com/tech-policy/2011/06/national-broadband-map-a-350-million-boondoggle/

half-decade that the FCC has publicly released their national broadband map -- the United States has been systematically releasing national broadband maps that, as our research documents, have become *less* accurate and precise over time.

In 2010, the Federal Communications Commission developed the country's first "National Broadband Plan"[8] which, among other recommendations, pointed out:

> "other countries have expanded their broadband data compilation and dissemination efforts to provide more information to policy-makers and consumers. These efforts include collecting and publishing richer information about the extent of broadband deployment, utilization and pricing through broadband mapping, usage surveys, pricing portals and broadband quality of service measurements." [pg. 335]

To date, the United States has not integrated these recommendations into its broadband mapping efforts; and the most recent, August 1, 2019 FCC Notice of Proposed Rulemaking[9] still fails to incorporate broadband pricing and other improvements that the FCC itself has been identifying as essential for the better part of a decade.

Today's FCC mapping

Currently, the FCC collects self-reported broadband speed and availability data directly from Internet Service Providers (ISPs) via a mandated reporting process whereby ISP's file what's known as "Form 477" twice a year. The instructions for these forms allow ISPs to declare an entire census block as "served" if only a single house in that geographic area is served; but also enable ISP's to declare an area served if they *could* provide service without "an extraordinary commitment of resources."[10] The national broadband map essentially visualizes the aggregated information collected via Form 477; however, given these instructions, both the self-reported data, and the National Broadband Map derived from these data, by definition, overstate

[8] See: https://transition.fcc.gov/national-broadband-plan/national-broadband-plan.pdf
[9] See: https://docs.fcc.gov/public/attachments/DOC-358832A1.pdf
[10] See: https://transition.fcc.gov/form477/477inst.pdf, page 17.

broadband availability across the United States. The FCC has also been increasing the delay between data collection and public disclosure -- to the point that as of today, September 23, 2019, the last broadband service data available via the National Broadband Map dates from December 2017 -- over 18 months ago.

In addition to advertised speeds, ISPs also report the type of technology used to deliver service (e.g., satellite, cable, fiber), and the speed of the service(s) available for any particular geographic area. However, because there is no independent verification of these self-reported data, fairly egregious overstatements by ISPs have become commonplace. As just one example, upon reviewing the official data disclosed by the FCC, consumer watchdog group, Free Press found a fairly egregious error directly impacting the Commonwealth of Pennsylvania. According to Free Press's ex parte with the FCC:

> "Barrier Communications Corporation (d/b/a BarrierFree), claimed deployment of fiber-to-the-home ("FTTH") and fixed wireless services (each at downstream/upstream speeds of 940 Mbps/880 Mbps) to Census block containing nearly 62 million persons...We further examined the underlying Form 477 data and discovered that BarrierFree appears to have simply submitted as its coverage area a list of every single Census block in each of eight states in which it claimed service: CT, DC, MD, NJ, NY, PA, RI, and VA."

The FCC's Form 477 vetting process, if it exists at all, thus failed to identify this overstatement, and it took an outside group to point out that 100% coverage of 8 states with gigabit fiber-to-the-home service seemed odd. Only after Free Press went public with this information did the FCC agree to correct its database, and they issued a corrected dataset in May 2019 (for the December 2017 data set). How many additional, though individually less egregious overstatements, are contained within the FCC's data remains unknown, nor has the FCC ever audited its own data to look for additional, obvious errors.

As a part of our broadband mapping effort, our research team collected 11,000,000 speed tests from across Pennsylvania in 2018. By comparing these "actual" broadband speeds with claimed availability data (the FCC's Form 477 data), we were able to look, not only at raw broadband speeds from across the Commonwealth, but also at differentials between what ISPs stated was available and what ISP customers were actually receiving.

Economic impact of broadband

Internet access is a crucially important resource -- underpinning access to telemedicine, streaming media, thousands of useful services and applications, as well as job search and entrepreneurial activities. Put simply, without broadband, individuals, households, and entire communities are put at a direct disadvantage. How detrimental is the digital divide?

According to the National Bureau of Economic Research, broadband connectivity supplies roughly $2,000/year in economic value.[11] This $2,000 per household isn't just a result of increased training and job opportunities, but also cheaper flights and less expensive diapers, better medical information and access to untold online resources. Thus, for any community without broadband connectivity, they are hemorrhaging thousands of dollars every year from their local economy *for every* household that remains on the wrong side of the digital divide.

Housing value and broadband

Even beyond this yearly cost, there's the impact of lack of broadband on the most important asset most families have: their home. In May 2019, researchers Steven Deller and Brian Whitacre released a study on 887 rural communities looking at the impact of broadband connectivity on home value.[12] Among their many interesting findings, one, in particular, stood out to the authors:

[11] See: http://www.nber.org/papers/w21321.pdf
[12] See: https://blogs.extension.wisc.edu/cced/files/2019/07/Deller-Whitacre-2019.pdf

> "The more interesting result, however, is the impact of broadband access on housing values and here we find strong consistent positive relationships: higher access to broadband, regardless of the specific estimator used, has a positive impact on remote rural housing values." (Pg. 15).

According to Deller and Whitacre, these results translated to fairly extensive increases, "a 10% increase in coverage of at least 0.2Mbps results in the median house value increasing by $661" -- which means that for an unserved community, increasing even baseline coverage to a majority of local households may have an impact of thousands of dollars *per house* within that local community.

The authors helped drive home why this phenomenon was so powerful in their July 2019 blog post, "Broadband Availability Raises Market Value of Rural Houses," "Every semester that I teach my rural economic development class at Oklahoma State University, I ask how many students would move to an area without broadband access. Zero hands go up." And on the upside, for many of the most rural Counties struggling to identify revenue sources to offer and improve basic services, Deller and Whitacre state explicitly, "We estimate that annual property tax collections could increase from $25,000 – $65,000 in these counties, which could be significant for rural areas that often struggle to fund local services."

Business relocation & sustainability

The National Federation of Independent Business (NFIB) the lack of broadband access, especially in rural areas, is harming start-ups and small business prospects. Accordingly, NFIB has been calling for immediate intervention with a failure to act resulting in some fairly harmful outcomes:

> "Worrying about access to high-speed internet isn't something most city-dwellers think about. But for business owners in rural communities, it has become an issue they can't ignore. As more industries and day-to-day operations rely on fast and reliable

> connectivity, areas that lack the essential tool are increasingly left in the dust...National providers focus their lines on large towns and major highways, leaving local providers to pick up the slack—typically at high costs with extensive red tape."[13]

For far too many communities, this means that economic activity is being actively depressed -- not only are their businesses at a competitive disadvantage due to lack of broadband, but new businesses are moving away (and entrepreneurs doing likewise), due to slow or non-existent connectivity.

The current state of affairs is untenable…

In September 2018, the Pew Research Center found that 24% of rural Americans state that access to high-speed broadband is a "major problem," with an additional 34% stating that lack of connectivity is "a minor problem." Put another way, only 4-in-10 say access to broadband is "not a problem" in their communities.[14] This reality is, simply put, a serious problem.

So what's been happening?

Over the past 15 years, home broadband use has greatly increased in just the past decade-and-a-half:

- In 2003, roughly 20% of urban residents and 10% of rural homes used broadband.
- In 2018, 67% of urban residents and 58% of rural homes use broadband.

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[13] See: https://www.nfib.com/content/resources/start-a-business/absence-of-high-speed-internet-in-rural-areas-hurts-business-growth/

[14] http://www.pewresearch.org/fact-tank/2018/09/10/about-a-quarter-of-rural-americans-say-access-to-high-speed-internet-is-a-major-problem

But if you look closer at the data, a highly problematic trajectory begins to emerge. According to Pew's own data, in 2013, 70% of urban residents and 60% of rural homes were broadband users. So has broadband utilization flatlined and/or is it actually shrinking[15]?

The implications are profound: for half-a-decade, home broadband hasn't meaningfully grown. Within urban environments, it's quite likely that cord-cutters are swapping from home broadband to mobile connectivity -- in essence, dropping their cable line for a sole reliance on LTE or 4G connectivity; but in much of rural America, most residents don't have that option.

Taken together, this likely means that the broadband divide between rural and urban is growing, but is being hidden by the methodologies used to report data to the FCC, and from official missives about the state of broadband connectivity across the United States. And, when we connected an in-depth study of broadband connectivity across Pennsylvania, this phenomenon is exactly what our research team found.

The economic take-home message:

In 2015, the US Census Bureau reported that rural Pennsylvania had 1.35 million households. According to the FCC's highly optimistic estimates, roughly 40% of those households (or 540,000) do not have broadband connectivity. Just taking into account the economic value those 540,000 households represent at the National Bureau of Economic Research's level of $2000/year, the lack of broadband is costing Pennsylvania over $1 billion a year.

Together with the $18 billion in overcharges and tax subsidies already paid to Verizon and other ISPs by PA residents for universal broadband services that have still not been implemented, the lack of universal broadband connectivity has already cost the state well over $25 billion.

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[15] See: http://www.pewinternet.org/fact-sheet/internet-broadband

Our team and partners

Given the stark importance of garnering a more accurate picture of the true state of broadband adoption across Pennsylvania in order to develop interventions that would ensure universal broadband access, the Center for Rural Pennsylvania hired a national consortium of broadband mapping experts to develop a new state-wide broadband map. This team drew expertise from a number of well-established organizations, including:

Measurement Lab

M-Lab was founded in 2009 by New America's Open Technology Institute, the PlanetLab Consortium, Google, and a diverse group of academic researchers. M-Lab is an open source project with contributors from civil society organizations, educational institutions, and private sector companies dedicated to:

- Providing an open, verifiable measurement platform for global network performance
- Hosting the largest open Internet performance dataset on the planet
- Creating visualizations and tools to help people make sense of Internet performance

What is M-Lab's mission?

M-Lab aims to advance Internet research by empowering consumers with useful information about their Internet performance. By providing free, open Internet measurement data, researchers, regulators, advocacy groups, and the general public can get a better sense of how the Internet is working for them, and how to maintain and improve it for the future.

Why Measurement Lab?

Real science requires verifiable processes, and M-Lab welcomes scientific collaboration and scrutiny. This is why all of the data collected by M-Lab's global measurement platform is openly available, and all of the measurement tools hosted by M-Lab are open source. Anyone with the time and skill can review and improve the underlying methodologies and assumptions on which M-Lab's platform, tools, and data rely. Transparency and review are key to good science, and good science is key to good measurement.

An Open Platform for Researchers

M-Lab assists scientific research by providing widely distributed servers and ample connectivity for researchers' use. Each researcher-developed test is allocated dedicated resources on the M-Lab platform to facilitate accurate measurements. Server-side tools are openly licensed and operated, allowing third parties to develop their own client-side measurement software.

Better Open Data for Everyone

All data collected via M-Lab are made available to the public. M-Lab's historical data archive provides a common pool of historical network measurement information that anyone may use, and is a data source enabling consumers, operators, regulators, researchers, and civil society to understand the state and quality of the Internet.

The Open Technology Institute

OTI works at the intersection of technology and policy to ensure that every community has equitable access to digital technology and its benefits. We promote universal access to communications technologies that are both open and secure, using a multidisciplinary approach that brings together advocates, researchers, organizers, and innovators.

OTI's current focus areas include surveillance, privacy and security, net neutrality, broadband access, and consumer privacy. OTI conducts data-driven research, develops policy and

regulatory reforms, and builds real-world pilot projects to impact both public policy and physical communications infrastructure that people interact with every day.

The Open Technology Institute supports free expression and open technologies at home and around the world, and is committed to supporting engaged, self-sufficient communities by promoting safe and affordable access to connectivity. We view technology not as an end in and of itself, but a means.

Institute for Local Self-Reliance

The Institute for Local Self-Reliance challenges concentrated economic and political power, and instead champions an approach in which ownership is broadly distributed, institutions are humanly scaled, and decision-making is accountable to communities.

We believe that economic systems should embody democratic values, and that democracy can thrive only when economic power is widely dispersed. We believe that communities are healthiest when they possess the authority, capacity, and responsibility to chart their own course. We call this vision local self-reliance.

ILSR's initiatives work toward this vision in different sectors:

- Our Community Broadband Networks program fosters the creation of high-quality, locally accountable broadband networks;
- Our Community-Scaled Economy program counters monopolies and champions independent business and local banking;
- Our Energy Democracy program works to expand clean, dispersed energy generation and increase local ownership;
- And our Waste to Wealth and Composting for Community programs develop neighborhood-led recycling, reuse, and composting enterprises.

Across all of our initiatives, we're fighting unfettered corporate control in all its forms, from giant tech platforms to monopoly utilities, Wall Street banks to garbage incinerators. We're

showing how public policy currently favors bigness and perpetuates inequality, and what people can do to change the rules.

- **In-Depth Analysis —** We combine journalism and data analysis to produce influential reports, high-profile articles in national outlets, and compelling presentations. Reporters rely on our research to inform their stories and allies use it to guide their strategies.
- **Policy Solutions** — We identify, develop, and promote policies at the local, state, and federal levels that reverse economic consolidation and create conditions in which locally accountable models can succeed.
- **Grassroots Assistance —** We work with citizens, activists, and policymakers to answer hundreds of technical assistance requests each year, run workshops, produce podcasts, and create popular education tools that support campaigns.
- **Partnering with Others —** We build coalitions and work closely with allies, from entrepreneurs to city planners, retail workers to engineers, neighborhood groups to national advocacy organizations, and many more.

ILSR was founded in 1974. Our 20-person staff works across the country. We have offices in Minneapolis, Minn.; Portland, Maine; and Washington, D.C.

Schools, Health and Libraries Broadband Coalition

The SHLB Coalition is a nonprofit, 501(c)(3) advocacy organization that supports open, affordable, high-capacity broadband connections for anchor institutions and their surrounding communities. The SHLB Coalition is based in Washington, DC and has a diverse membership of commercial and non-commercial organizations that support our Mission from across the United States. We receive financial support from membership dues, from our conferences and events, and from the Bill & Melinda Gates Foundation and the John S. and James L. Knight Foundation.

The Coalition was first formed in 2009 as a short-term project to support the Broadband Technology Opportunities Program (BTOP) funded by the federal American Recovery and

Reinvestment Act. We also engaged with the Federal Communications Commission (FCC) in helping to shape the National Broadband Plan, the E-rate program and the Connect America Fund in 2010-2011. Because of our policy impact, the growth of our membership and success of our conferences, we decided in 2012 to become a permanent institution. We named a formal Board of Directors and incorporated in D.C. in 2012 and received 501(c)(3) approval from the IRS.

On the policy front, we actively promote a variety of federal initiatives to support broadband for anchor institutions. We work with the FCC to promote capital investment in E-rate reform, and we submitted a study estimating the costs of deploying fiber to the remaining unconnected schools and libraries. We are also involved in the Rural Health Care Program, which promotes greater deployment and use of telemedicine networks in remote areas.

The SHLB Coalition is one of the fastest growing broadband associations. We are increasing our membership, expanding our policy initiatives, hosting more events, expanding our community of supporters, and increasing our impact on policy-makers and communities across the country. We seek to cross traditional boundaries, encouraging conversation and cooperation across multiple sectors to seek practical, "win-win" solutions to the needs of anchor institutions and their communities for broadband services. We welcome your support!

X-Lab

The X-Lab is a future-focused think tank at Penn State University responding to the significant technology policy challenges facing society. X-Lab is composed of a consortium of technologists, developers, policy experts, innovators, business leaders, academics, entrepreneurs, researchers and futurists working to ensure that citizens don’t need to choose between fundamental rights and equitable access to technological resources. X-Lab studies the implications of disruptive eventualities in sectors such as AI-driven manufacturing, telecommunications, consumer protections, privacy and civil liberty, and smart infrastructure. By bringing together experts from across the technological, political and scientific spectrums, X-Lab empowers leaders with the expertise to make better-informed decisions.

Methodology & Results

We believe that empirical documentation is essential for informed decision-making. To that end, we collected over 11 million broadband speed tests from across PA in 2018, and, added to our historical archive, have access to over 25 million speed tests spanning the past half-decade. Utilizing these tests, we've mapped actual broadband speeds across various areas of the state (from counties and zip codes to state and national legislative districts) and developed the most comprehensive mapping of broadband connectivity ever undertaken in the State of Pennsylvania.

As part of our efforts to improve both documentation and forward iterative improvements to our methodology, 100% of our data, methodologies, and findings are freely and publicly accessible. Our hope is to help spur additional research and inquiry, not just across the Commonwealth, but also nationally (and beyond).

Peer reviewed, open architecture, open source, and open data

The research team leveraged M-LAB's broadband measurement platform and the Network Diagnostic Tool (NDT) to collect longitudinal, open data sets of internet speeds. M-Lab was built as an open, distributed server platform that hosts a diverse set of active measurement tools. Using tests hosted by M-Lab, the research team created a website application for Pennsylvania residents, that allows end users to run the NDT tests to measure the speed and quality of their internet service.

The research team also piloted a program to collect the latitude and longitude of testers (who actively consented to providing their exact location), using HTML5 (technology used to build websites) geolocation function.[16] Combining existing measurements from M-Lab[17] with this

16 Pennsylvania Broadband Mapping Initiative. (n.d.). Retrieved from https://pa.broadbandtest.us/

17 M-Lab already has a historic archive of over 15 million broadband speed tests from the years 2009 through 2017, and regularly received over 20,000 tests per month from Pennsylvania residents prior to this study.Lab. (n.d.). Retrieved from https://measurementlab.net/privacy Retrieved from https://measurementlab.net/privacy

additional data, the team aggregated and mapped the measurement data to a geographic area of interest (e.g., census tract, state legislator or congressional district, or neighborhood boundary) documenting the speeds local residents experienced over time, and comparing areas across the state.

The project's goal was to comprehensively map the availability of fixed broadband services throughout rural areas of the Commonwealth of Pennsylvania. By partnering with a number of media outlets, building partnerships with corporate, non-profit, and government partners, and leveraging Center for Rural Pennsylvania contacts across the state, the project was able to easily surpass its initial goals for data collection and ended up collecting over 11 million tests from Pennsylvania in 2018. In addition, the online system used for this initiative continues to collect data from across the Commonwealth and continues to enable anyone with a broadband connection to conduct a literally "one click" test to measure their broadband speed.

Prior to our study, M-Lab already had a historic archive of 15,121,002 million broadband speed tests from the years 2009 through 2017. During this time, M-Lab regularly received over 20,000 tests per month from Pennsylvania residents.[18] During 2018, the research team collected an additional 11,082,742 tests; the research platform developed will continue to collect broadband speed data from Pennsylvania into 2019 (and beyond), and these data will be made freely and publicly available. Adding the 11 million tests from 2018 to the historic archive of 15 million provided the research team with roughly 25 million broadband tests in Pennsylvania for analyses.

3 mapping layers

While the report includes baseline maps in the report's electronic appendices, these maps integrate multiple layers (such as county, senate and house districts), and the project's online mapping portal (see: http://broadbandtest.us) allows for comparisons of key metrics, enabling thousands of additional maps to be generated. As a part of the current analyses, the project team also provided a discussion of a variety of policy options that have been used to better meet the

18 Lab. (n.d.). Retrieved from https://measurementlab.net/privacy Retrieved from https://measurementlab.net/privacy

broadband needs of local residents, providing policy-makers with a set of options to improve the broadband availability in those areas where adequate broadband facilities and services do not yet exist.

Official/claimed/advertised speeds/availability

The 2019 report "Broadband Availability and Access in Rural Pennsylvania" [appended to this testimony] provides an exploratory analyses that shows where claimed and measured broadband access speeds differ; documents speed differentials between rural and urban constituencies; shows changes in these measures over time; characterizes communities with lower levels of broadband access; and identifies successful interventions that would generalize to Pennsylvanian communities and provide access to fixed wireline 25/3 Mbps connectivity.

We developed hundreds of maps showing the differences between the FCC map data and the M-Lab map data. Many counties experience much slower measured speed than that claimed by the FCC maps. This research project provides an exploratory analyses that shows where claimed and measured broadband access speeds differ; documents speed differentials between rural and urban constituencies; shows changes in these measures over time; characterizes communities with lower levels of broadband access; and identifies successful interventions that would generalize to Pennsylvanian communities and provide access to fixed wireline 25/3 Mbps connectivity.

In order to map areas where there is little to no actual broadband availability, the team cross-referenced claimed service provision areas against M-Lab's NDT data set of broadband speed tests conducted by end users. While these two measures may sometimes agree, these particular addresses have been spot-checked in areas where particular service tiers are claimed to exist, but where speed test data indicates that they may not (e.g., due to the type of infrastructure available, distance from cable head-ends, etc.). This method has enabled us to document the state of 25/3 Mbps service provision in rural Pennsylvania from January 1, 2018 through December 31, 2018, as measured via the M-Lab platform using the NDT test, and compare it with the

advertised state of broadband service in the FCC's Form 477 data that is self-reported by Internet Service Providers.

Verified speeds/availability

NDT is a speed and diagnostic test that reports actual upload and download speeds and as well as a number of other variables to help diagnose potential speed limitations. Of particular note, the NDT test provided by M-Lab is a single-stream performance test that measures a connection's "bulk transport" capacity as defined in the Internet Engineering Task Force's RFC 3148 [a formal document from the IETF] to an off-net location (e.g., one not on an Internet Service Provider's own network). This is important because it is much more representative of the genuine Internet performance users will experience during regular use, measuring actual bandwidth to a different point on the Internet beyond the initial connection to a customer's ISP, rather than just the speed from the user to the ISP's servers. Other multi-stream tests sometimes report different results and are different from NDT, choosing to focus on "aggregate capacity," or the total maximal throughput on that providers own network.

For this report, since the latest available Form 477 data of advertised available speeds is being used, which is for Q3-4 2017 and contrasting that with actual measurements from 2018, one would expect that advertised speeds from 2017 would be less than actual speeds from 2018. However, this is not the case, especially for rural communities; distressingly, it has been found that advertised speeds from 2017 are often substantially greater than the measured speeds from M-Lab tests that people in Pennsylvania ran in 2018.

M-Lab servers reside outside of ISPs' networks and inside Internet exchange points (IXPs). ISP networks connect to the Internet itself, and where Internet content typically is hosted, which means that NDT data can be very useful in measuring the consumer experience of accessing content anywhere on the Internet. The raw metrics collected by running an NDT test enable the calculation of upload and download speed, latency, and round-trip time. There is no universally

agreed upon way to assess broadband speed, and the FCC itself does not provide a universal standard for measuring speeds to accompany its published definitions of broadband.

However, M-Lab uses a scientifically standardized measurement suite designed by and for the network research community. The NDT speed test has been rigorously peer-reviewed, implements standards developed by Internet researchers, and is a 100% open source testing suite, which has enabled top researchers to review the code and ensures maximum transparency of the testing protocol as well as replicability of results. Combined with the research team's focus on measuring connectivity speeds that mirror the everyday user experience (i.e., a connection to the global Internet, not just the speed within a customers local ISP), the connectivity speed reported by NDT provides results that align with best practices within the scientific and network research community, the standards of the Internet community concerning connection capacity, and the everyday lived experiences of ISPs' customers.

Discrepancies between the two measures

By combining 2018 data with a historical archive of an additional 15,121,002 tests from Pennsylvania residents, the research team identified that since 2014, the discrepancy between ISP's self-reported broadband availability in the FCC's broadband maps and the speed test results collected via the M-Lab platform has grown substantially in rural areas, a trajectory not mirrored in urban areas; which may indicate systematic and growing *overstatement* of broadband service availability in rural communities.

Conclusion

This initial assessment of the state of broadband connectivity across Pennsylvania points to a major crisis that is particularly hard-hitting for rural residents. According to the best available econometric analyses, a lack of broadband connectivity has a direct economic cost of over $1 billion/year to households across the Commonwealth, and that is quite likely a conservative

estimate. In addition, the costs to businesses, and the detrimental impacts on home prices and tax collections, add substantially to the opportunity costs of doing nothing.

Looking to the future, those proposing interventions to ensure universal broadband connectivity would be wise to likewise investigate these opportunity costs as investments in this critical infrastructure is quite likely to (more than) pay for itself.