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Rural Broadband and the Unrecovered Cost of Streaming Video Entertainment

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Rural Broadband and the Unrecovered Cost of Streaming Video Entertainment

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ITS Gotenberg June 2021¹

Introduction

Over the past 15 years, the business of internet content delivery has changed substantially. The major impetus for the change has been growth of streaming video entertainment services for movies, TV, music, and games.² This has resulted in rapidly increasing demands on broadband infrastructure and data transport costs, without a corresponding increase in broadband provider revenue. Indeed, end user broadband prices have fallen between 28-43 percent in the US in the last five years from increased wireless competition, even though broadband speeds and capacity have increased.³

The broadband access market (especially in the USA) is characterized by flat or so-called “all-you-can-eat” and uniform pricing in which there is one price for an advertised speed for an entire country or region. The advertised level of speed is only a very limited proxy for the cost of providing the product, but it is the differentiator that is expected by the market, and it does enable a degree of price discrimination based on customers' willingness to pay. The high fixed costs of a broadband access network means that providers must carefully manage prices to be able to generate sufficient revenue from a given area subject to a set of advertised prices.

Uniform rates apply over vast areas (e.g. the western United States) although the cost of serving these locations vary widely, both in terms of fixed and variable costs. Uniform (over service area) prices have an advantage in marketing and most customers prefer flat prices because it avoids unpredictable expenditures. The latter effect has been well documented for voice telephony in the past. Broadband providers attempt to choose prices and service areas to ensure that overall revenue exceeds cost by a sufficient margin, or at least to cover costs.

This means that some premises (even in urban areas) have their service priced at below cost but can receive broadband access at the advertised flat and uniform (over service area) prices because service in the area makes financial sense to the broadband provider. The provider only needs average revenue to

¹ This project is undertaken as post-doctoral research to investigate network policy questions on wireline broadband networks. While significant aggregate sector data is available at the national and international level, there is limited academic investigation of cost recovery at the firm level, particularly in the rural US setting. In this case, the authors requested data from the broadband providers to study. US government agencies may have more detailed data, but it is not necessarily publicly available. This paper represents a modest, preliminary effort and recommends further research.

² “Cisco Annual Internet Report – Cisco Annual Internet Report (2018–2023) White Paper,” Cisco, March 9, 2020, <https://www.cisco.com/c/en/us/solutions/collateral/executive-perspectives/annual-internet-report/white-paper-c11-741490.html>.

³ “2020 Broadband Pricing Index Report,” USTelecom (blog), 2020, <https://www.ustelecom.org/research/2020-broadband-pricing-index-report/>.

exceed average cost, after all. Large firms like AT&T and Comcast can make this model work in many areas they serve and are furthermore can absorb fluctuations in cost because of massive averaging effects.

Evidently, there are areas in any country that cannot be served by the large providers using this specific flat and uniform (over service area) pricing system and these (mainly rural) areas are the subject of this paper. The academic literature is clear on tariff diversity being a key to expanding broadband penetration (Haucap et al. 2016). The approach of serving these areas using a similar model of flat and uniform (over service area) pricing by small companies is inherently fraught with difficulty because of the issues of size and demand and our research finds that rural broadband providers (RBPs) are under increasing pressure, mainly due to high volumes of traffic generated by the five Big Streamers.

The fact that the large national broadband providers can discover flat and uniform (over service area) prices to enable this business model does not immediately imply that an appropriate solution of the same kind exists for RBPs. Even in the national market, the system is under some pressure as evinced by AT&T's recent introduction of a 1.2 terabyte per connection cap on monthly data traffic, together with a flat and uniform national price of \$30 per month for lifting the cap. Problems with flat-rate access have been well documented by Howell (2010). Flat rates imply directly that low-volume users subsidize high-volume users. Furthermore, late adopters tend to be low-volume users and/or have low willingness to pay for the service. In rural areas, the distribution of potential customer on the two-dimensional axes of willingness-to-pay and volume of use may be very different from that in other areas. If there are many potential low-volume users with a relatively high willingness to pay, flat and uniform (over service area) prices will be feasible.

Howell's research documents that late adopters and low-volume users prefer a two-part tariff, based on an access price and a volumetric price. The introduction of a two-part tariff in a market will attract some users from the flat tariff in addition to adding new customers. It will therefore necessarily reduce the extent to which low-volume users subsidize high-volume users and is therefore not simply an add-on to a market with flat and uniform (over service area) prices.

Our observation in this research is that RBPs are having a great deal of difficulty managing revenues in the face of exploding video streaming traffic which this paper documents extensively. The pricing issues mentioned here almost certainly all play a role but further research into this is called for as well as possibly the construction of appropriate models of consumer behavior. A conclusive demonstration that RBPs might not be able to find a flat and uniform (over service area) pricing structure under which revenues in the medium term outpace costs is the subject of future research.

Using the example of three RBPs who have shared some cost and data traffic data with us, we illustrate that the cost challenges are driven overwhelmingly by online streaming services for which the providers charge amounts that are comparable to what the RBP fees for broadband access are. This is traffic for which the RBPs incur substantial costs but which they are unable to monetize.

The current federal programs to support rural connectivity do not necessarily address the underlying problem when they are also flat and uniform (over service area). That is, subsidies that are based on an underlying pricing model that might not be workable in the context of rural broadband, is unlikely to address the problem in a cost-effective way in the medium term. In fact, flat and uniform subsidies might aggravate the problem for RBPs as research suggests that lower income is associated with higher

average content consumption (Boik et al. 2019). Although RBPs require the federal subsidy to provide the service, this research suggests that the subsidy in the present form (flat and uniform) might be increasing the number of high-volume users and thereby contributing in part to the problem.

However, broadband internet is increasingly recognized as an essential service to which everyone must have access.⁴ The COVID pandemic has underscored the importance of broadband networks to enable people to work, learn and access healthcare from home. The “digital divide” describes demographic and geographic gaps in broadband service. The FCC data shows that 22% of rural Americans, about 13 million people, lack high speed wireline internet of 25/3 Mbps or higher.⁵⁶ This persistent problem is related in part to US policy and regulation which is essentially governed by the Telecommunications Act of 1996 which conceptualizes the then fledgling commercial internet with traditional telecom network considerations. Today’s data-centric broadband networks are vastly more complex than a traditional time division multiplexing telephony system but still regulated under an obsolete model. This policy stagnation has unwittingly inhibited the development of pricing and business models which would improve the provision of fiber and other wireline networks in rural areas.

The rural broadband providers in this study are in four distinct rural regions of the United States, have an average of 20,000 customers each, and have network footprint roughly 3000 square miles. The preliminary results show that current broadband prices are approximately \$50 per month per subscriber which covers the last mile cost of the network and operating costs, but not the capital cost of the middle mile, a separate cost which scales in equipment requirements as traffic increases. Separately, the Big Streamers earn about \$25 per month per subscriber, an amount which is already half the price of broadband and is likely to increase.

The big streaming services by Netflix, YouTube, Amazon Prime, Disney+, and Microsoft comprise 75% of total network traffic on the four rural broadband networks and require an additional cost of \$11.65 per month in capital costs, which is presently absorbed by the broadband providers. Note that this cost is almost all equipment cost. Overall, the analysis shows that 77–94 percent of total network costs is related to streaming video entertainment. This amounted to \$100-180 of unrecovered costs per subscriber annually. Given the popularity and growth of video streaming entertainment, the middle mile cost is expected to double in 3-4 years, while the number of subscribers is expected to stay constant. The increase in unrecovered cost to enable some 30 percent growth (or 30,000TB) will grow to \$25.04 per subscriber or \$81,953,409 in total for the four providers.

As the paper shows, the video streaming entertainment providers do not engage with rural broadband providers to find equitable means to recover to middle or last mile network costs. Netflix and YouTube

⁴ “USTelecom Broadband Investment Forum,” *USTelecom* (blog), accessed December 8, 2020, <https://www.ustelecom.org/event/ustelecom-broadband-investment-forum/>.

⁵ “REPORT AND ORDER, FURTHER NOTICE OF PROPOSED RULEMAKING, AND ORDER ON RECONSIDERATION” (FCC, December 13, 2018), <https://docs.fcc.gov/public/attachments/FCC-18-176A1.pdf>. This is based on Staff analysis of FCC Form 477 Data, as of June 30, 2017, and FCC population estimates, as of June 30, 2017.

These estimates may overstate or understate the estimate of Americans with access to fixed advanced telecommunications services. See Federal Communications Commission, Staff Block Estimates, <https://www.fcc.gov/reports-research/data/staff-block-estimates> (Staff Analysis of FCC Form 477 Data)

⁶ “2020 BROADBAND DEPLOYMENT REPORT” (FCC, April 24, 2020), <https://docs.fcc.gov/public/attachments/FCC-20-50A1.pdf>.

offer caching services to the rural broadband providers, but these are exclusionary to the proprietary services of the platforms and entail additional costs for rural broadband providers to participate.

The situation represents a classic free rider problem in which beneficiaries of quasi-public goods do not necessarily pay for them (Baumol 1952). Despite the salience of the larger “digital inclusion” and “broadband equity” agenda which seeks to reduce the cost burden on the end user and expand access (Rhinesmith 2016), Big Streamers have succeeded to evade participation in cost recovery. If anything, the policy debate frequently favors that Big Streamers do not participate financially in middle and last mile network costs, an atavism that contradicts business model development in other industries.

The effort to understand the characteristics of internet traffic and its equitable cost sharing is like the movement in clean energy. For decades, consumers were unaware of the carbon impact of the energy they consumed. Education helped drive a revolution in accounting so that consumers became aware of the impacts of different energy sources, demanded cleaner alternatives, and forced companies to be more transparent. When consumers stream video entertainment, they are not aware of its cost burden on the network, nor can they control their consumption or demand more efficient delivery. Making the traffic elements more transparent can force those improvements on the part of the Big Streamers.

The four rural broadband providers report repeated attempts to address this issue with the Big Streamers and to find a collaborative solution for all parties have gone nowhere. Separately the authors of this paper attempted to obtain feedback on this analysis from the Big Streamers; only Microsoft responded. A Microsoft representative explained that there are parts of the country where connectivity is a challenge, and that there is no ideal solution to the middle mile shortfall. She referred to Microsoft’s Air Band Initiative which uses TV white spaces, the unused broadcasting frequencies between television channels, to transmit data.⁷ Microsoft admits that the TV white spaces initiative, however innovative, is not a one-size fits all solution. Moreover, this technology does not address the middle mile shortfalls in existing fiber to the home networks described in this study. Note that Microsoft has a variety of streaming services, not all are for entertainment.

Rural broadband providers generally operate at close to breakeven with little to no profit margin. This contrasts with the double-digit profit margins of the Big Streamers. As such, the paper sheds light on network investment shortfalls in rural areas. Many broadband providers simply do not deploy because of a lack of business model with equitable cost recovery. Understandably consumers are frustrated because they want broadband, however they are not necessarily willing to pay \$200 per month or more for it, which is what it costs to build and run a fiber network to a home in a rural area. Moreover, there is little policy discussion about the need to incorporate the Big Streamers in business model development.

The paper observes that entertainment choices, which have a high private value, are discretionary and may vary significantly by the individual subscriber. This suggests that flexible pricing should be deployed to recover costs from the relevant parties producing and consuming the entertainment. This contrasts with applications for work, school and healthcare which have a higher social value than entertainment and place lower resource demands on the network. The paper also reviews other research on the evolution of the internet’s typology which has changed significantly from 1995 to today, notably with

⁷ Charlotte Edmond. “Airband: The initiative to bring the internet to everyone.” Microsoft. September 1, 2020. <https://news.microsoft.com/on-the-issues/2020/09/01/airband-initiative-rural-broadband-digital-divide/>

the consolidation of regional and local access providers and the effective elimination of earlier exchange layers which have been subsumed into the video streaming providers networks.

The paper describes the components of the rural broadband networks, policy background for their evolution, an overview of providers, and the financial calculations of cost recovery. In addition to public information, the data studied includes a series of reports from the rural broadband providers. This data has limitations including the use of different enterprise traffic measurement tools. Naturally, a study done with a common set of measurement tools is preferred. This suggests that a follow-up study with a larger sample of rural broadband providers and common measurement tools would further refine the analysis. The paper contributes to the broadband policy literature and suggests further research, ideally by the Federal Communications Commission (FCC) which likely has access to the relevant information. The issue will likely be of increasing importance as the FCC has just finalized the Rural Digital Opportunity Fund Phase I auction (Auction 904) in which 180 bidders won \$9.2 billion over 10 years. These funds have no provisions for the middle mile, only the last mile.

The Components of the Rural Broadband Network

A rural broadband network internet consists of three components: (1) point of presence or PoP, (2) Middle Mile, and (3) Last Mile.

Point of Presence (PoP)

The **PoP** is where the Rural Broadband Provider interconnects with the Internet and other online networks. These PoPs have multiple Internet Exchange Points (IXP) and peering points.

A content delivery network (CDN) can be described as a parallel PoP. A CDN is a geographically distributed network of proxy servers and data centers designed to improve the performance and availability of data and service. Most streaming video entertainment is processed by a CDN. If a broadband provider has a presence in the CDN they may pay for a port, otherwise they “pay” for this through the arrangement with middle mile provider or IXC (inter exchange carrier). CDNs and interconnection points are typically located near major cities and at great distance to rural America.

Google and Netflix own some of the largest networks, followed by Facebook and Akamai (which is not dedicated to a specific service).⁸ Early on, Akamai’s key customers were Google and Netflix, but these two companies decided to build their own CDNs to reduce their data transportation costs and exert greater control of their traffic. A network map from Akamai shows that it has dozens of locations across the US, primarily situated to speed video to cities.⁹ Large parts of the mid-west, south and west US have no Akamai servers.

Middle Mile

In the **Middle Mile** enables transport and transmission of data communication from the central office, cable headend or wireless switching station to an Internet Point of Present. It encompasses Wide Area Network (WAN)/data storage center costs, access, transit, domain name registration, web hosting, email

⁸ Labovitz, Craig, “Internet Traffic 2009-2019 Craig Labovit,” 2019, https://storage.googleapis.com/site-media-prod/documents/20190610_Labovitz_Internet_Traffic_2009-2019_v1.pdf.

⁹ “Media Delivery Network Map | Akamai,” accessed January 5, 2021, <https://www.akamai.com/uk/en/resources/visualizing-akamai/media-delivery-map.jsp>.

services, spam filters, co-location fees, and intermediary transit to carrier “hotels.” In addition there can be significant and costly maintenance on the equipment in the Middle mile.

Some rural broadband providers may have a central office in the middle mile, but others do not. In either case, there are significant costs to maintain a central office, data center, headend, or switching station (in telecom networks, the telephone exchange provides access to the local loop) with a set of equipment including backhaul network equipment, servers, routers, network switches, multiplexers, and other enterprise equipment. The costs of this mile are ongoing and scale with the level of traffic. As internet traffic increases every year, the cost is part of the network increases and may be the costliest component for many rural broadband providers. A typical Middle Mile cost is the purchase of a circuit to facilitate connection to the PoP. As the amount of data grows for customers, the bigger the circuit (or the greater the capacity) needed reach the PoP to exchange traffic. Some rural providers deploy a core network or backbone, an additional network layer in between the middle and the last mile. They may operate a series of central offices connected with a core network. The core network facilitates the connection across a greater geographic distance common in rural settings and is helpful to improve performance.

Last Mile

The **Last Mile** is a figurative term which refers to the last leg of the network, or the final physical portion of the network from the Middle Mile to the end user. The Last Mile includes the routing of network facilities from the demand location to the central office. It also includes switching and transmission equipment, cable/wire, maintenance, and power costs.

It may be more or less than a mile and likely the network that the end users observe. Notably last mile networks can contain remote cabinets, but it may not. This depends on network architecture and distance from the central office in an exchange.

Depending on the layout and design of the rural broadband network, the costs can also increase with required equipment. For the Rural Broadband Provider, the many so-called last mile costs are generally fixed and upfront for a given set of premises, for example the trenching cost to lay the fiber and the rights of way from the municipality. However, some costs are ongoing like facility maintenance, locates, upgrade of electronics, and so on.

Because the bandwidth of fiber is vast, increases in video traffic can be accommodated within the fiber optic wires themselves and does not greatly increase cost, other than some minor marginal costs for power. Rather the increase of streaming video traffic burdens the *electronics within the Middle Mile* at the interface with the Point of Presence (or in running multiple central offices with a core network). Note that the FCC’s Universal Service Fund (USF) generally covers last mile costs, leaving the Middle Mile and other costs unrecovered. Depending on the design of their network, costs can be observed in the last mile, core network, and in the middle mile in which the amount and cost of circuits will vary with capacity.

Netflix and Google's Caching Services

Netflix offers rural broadband providers the opportunity to participate in their caching services OpenConnect¹⁰ and Google with CDN Interconnect¹¹, an offer for storage equipment and servers near or within the rural broadband network. These companies do not offer an opportunity to participate to every rural broadband owner – only when the network meets certain streaming capacity thresholds. When Google and Netflix deploy these proprietary caching servers and services, they only enable the proprietary content from Google and Netflix respectively; these cannot be purposed for content from other providers.

Most, not all, of the streaming service providers use adaptive bit rate technology to adjust content quality to the end-to-end connection's capacity. However, the caching server brings the content closer to the consumer and allows for a better customer experience. The caching server is not necessarily responsible for the adaptive bit rate. Users experience this as videos they access may first appear fuzzy but quickly clear up. The adaptive technology quickly finds the best capacity available on the broadband connection to ensure the high-quality rendering for the video, though it puts stress on the local network's core and last mile. Netflix uses this to ensure a good customer experience, but also to maintain an advantage over competitors. The higher the capacity on the broadband connection the higher quality (and higher capacity) video product available for viewing. A closer source is going to mitigate delays, packet loss, jitter, etc. all of this can negatively impact the video product. Shorter distances are better.

The caching servers do not however remove all the upstream data requirements for the broadband provider. Consider Netflix's OpenConnect program which places content delivery devices at an IXP or in the rural broadband provider itself. In the case of an IXP, an ISP will still be responsible for the high volume of traffic between its network and the IXP.¹² In order to join the Open Connect program, the rural broadband provider must guarantee the availability of the following before Netflix will plan an Open Connect Appliance (OCA) near the rural broadband provider's network:

1. 5.0 GBPS (gigabits per second) of peak Netflix traffic per deployment site;
2. 1.2 GBPS inbound traffic for 12 hours per day to the device;
3. peering with Netflix at a Netflix point of presence (PoP) if possible; and
4. designation of six distinct partner roles at the rural broadband provider.

This means that the rural broadband provider must guarantee 51,840 gigabits of incoming data per day from Netflix to deliver an unknown amount of traffic to its subscribers. Assuming 3 hours at peak traffic of 5 GBPS (the minimum Netflix requirement being in terms of peak traffic) and the rest of the day at an average of 2 GBPS, the rural broadband provider will deliver 205,200 gigabits of Netflix content to its end-users. This data traffic strategy reduces some, but not all, of the cost of downloading the streaming

¹⁰ "Netflix | Open Connect," accessed December 8, 2020, <https://openconnect.netflix.com/en/>.

¹¹ "CDN Interconnect Overview," Google Cloud, accessed December 8, 2020, <https://cloud.google.com/network-connectivity/docs/cdn-interconnect?hl=da>.

¹² "Requirements for Deploying Embedded Appliances," Netflix Open Connect Partner Portal, accessed December 8, 2020, <https://openconnect.zendesk.com/hc/en-us/articles/360034538352-Requirements-for-deploying-embedded-appliances>.

traffic. While Netflix markets the service as a net benefit to broadband providers, it entails a net cost to the rural broadband provider compared to the counterfactual in which Netflix did not exist.

Our observation of traffic on one of the RBPs confirms this. It uses a Netflix Open Connect device to cache traffic. In June 2020 it reported 187 terabytes of incoming Netflix caching server traffic and 1,590 terabytes of outgoing traffic – a saving of 88 percent off the incoming core internet traffic ('first mile') that would be observed if it had not been using a cache. Caching makes sense, but the relative savings from caching are not all that large since it still must provision its own middle-mile and last-mile infrastructure to distribute that traffic to its subscribers. Because of the lower subscriber density in rural areas, the cost of this will be larger than it would be for an urban broadband provider. Although this is one of the larger of the RBPs in the study, the savings from having the Netflix caching infrastructure is significant only at the level of connection to the core network.

The cost of caching content itself or of operating a CDN or providing caching services could therefore be much higher (per paying customer) for a small rural provider in a sparsely populated area than for a larger provider in an urban area. This is part of the additional required cost of providing urban-equivalent internet access to rural areas. Furthermore, certain non-subscription streaming content such as advertising supported YouTube video is nearly impossible to cache¹³ by the broadband provider as the material is broken up into segments interrupted by ads targeted at the viewer.

When content providers participate in provisioning content delivery networks (CDNs), these networks place content in special servers that are located closer to consumers and allow ISPs to direct content to their subscribers at a lower cost, perhaps through hosting a CDN node or connecting to one at an IXP. This creates a *download offset* factor for content on the CDN which means that the ISP often needs to pay only once for upstream data traffic if a piece of content is requested multiple times by its subscribers. However, taking on a CDN adds additional cost through administering the connection and/or hosting the servers and in general administration of the relationship.

Streaming video entertainment makes operational demands on rural broadband providers by requiring the stepwise upgrading of infrastructure to cope with higher peak demand and incremental costs incurred by the higher volume of traffic over time. The investments required to accommodate the additional streaming content are substantial, and rural broadband providers have limited ways of recouping the increased cost of provisioning the network from subscribers. Large urban broadband providers can either negotiate effective revenue sharing agreements with the content providers through bundling agreements (Comcast offering Netflix as part of a cable subscription package or charging for "internet connections" for example) or launch their own streaming services of their own or acquire content providers, as AT&T did with DirectTV and WarnerMedia for example. Rural broadband providers have no such scale and therefore no such options.

For example, in 2014, Netflix reached an agreement with Comcast and other large broadband providers the transit of Netflix traffic that is presumed to have involved Netflix paying the large broadband providers who own the internet backbone (Lyons 2014). Two years later, the two companies entered into a new

¹³ Caching and Video | NetEqualizer News Blog <https://netequalizernews.com/category/topics/caching-and-video/>

agreement that involved bundling of their media products.¹⁴ Rural broadband providers do not have the scale, resources, or negotiation power to reach such agreements. The bargaining power is weighted in favor of the Big Streamers, with a single actor driving 15 percent or more of the rural broadband provider's traffic, as is the case for Netflix on EATEL. By contrast, rural broadband providers account for only a scintilla of traffic on the Big Streamers' networks.

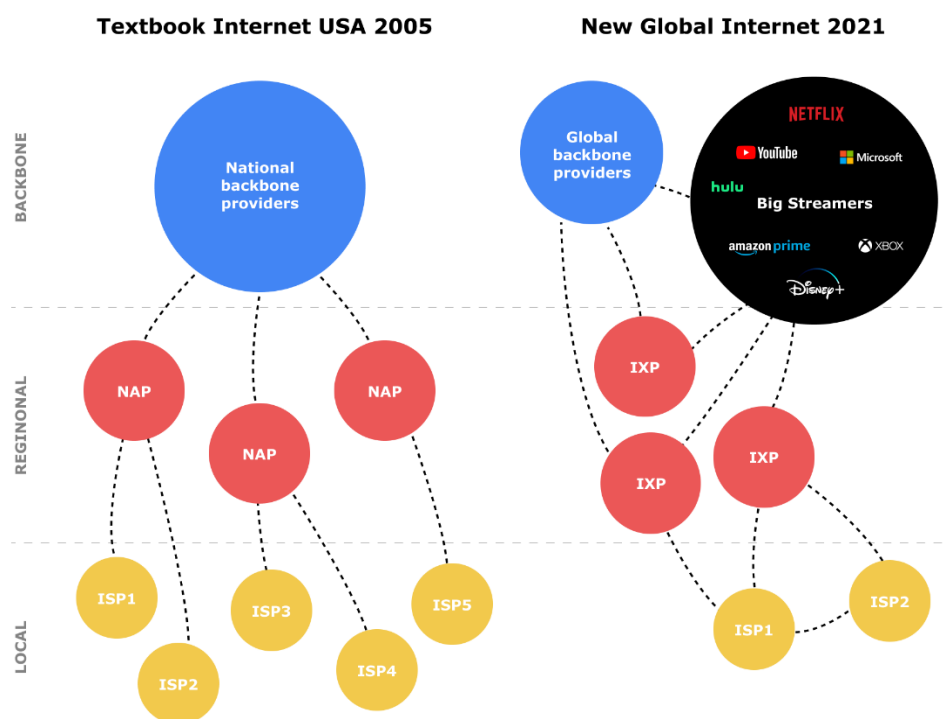
Historically internet subscribers would connect through internet service providers (ISPs) that would in turn connect to higher-tier internet access providers, often at an internet exchange point (IXP). Even though much of the content was already provided by the large firms that are still dominant today, the video entertainment companies used to distribute their content through first-tier internet providers which connected among themselves and with lower-tier providers.

Today the Big Streamers run their CDNs through which the bulk of the data received by consumers is delivered over most, but not all, of the internet. The CDNs form a kind of parallel network to the original internet and have reduced the importance of small and mid-tier internet providers. Rural broadband providers now need to connect not only to several higher-level providers but likely to a CDN. This has changed the economics of end-user internet content delivery, and in most countries, led to the disappearance of "mom and pop" rural broadband providers, putting "greater pressure on small access providers to get streams to their rural customers."¹⁵

The evolution is diagrammed below.

¹⁴ Trefis Team, "What Does The Deal With Netflix Mean For Comcast?," Forbes, accessed December 8, 2020, <https://www.forbes.com/sites/greatspeculations/2016/07/11/why-netflix-deal-matters-for-comcast/>.

¹⁵ Joon Ian Wong, "The Internet Has Been Quietly Rewired, and Video Is the Reason Why," Quartz, accessed December 8, 2020, <https://qz.com/742474/how-streaming-video-changed-the-shape-of-the-internet/>.



Adapted from Israel and Bensen, 2012. Clark 2021

While large broadband providers in urban areas can absorb the operational expenses of contracting with CDNs, rural broadband providers have little to none of such opportunities. Furthermore, the volume of traffic from the Big Streamers also requires the regular upgrading of network equipment inside the core network as well as last-mile connections to homes. In rural areas, these upgrades can be significantly more expensive than in urban areas because the increased cost cannot necessarily be borne reasonably by a small, static customer base. The rural consumer connection has a higher cost to set up in the first place even if the connection is subsidized by local, state, or federal funds. However, this is insufficient to amortize the expensive middle mile upgrades required on a regular basis, and we believe that RBPs have far fewer options in a world of flat and uniform (over service area) pricing to select a customer base that allows their average revenue to exceed their average cost.

Academic and Policy Background on Cost Recovery

Historical pricing for telecommunications and broadband

The historical pricing of telecommunications included three components.

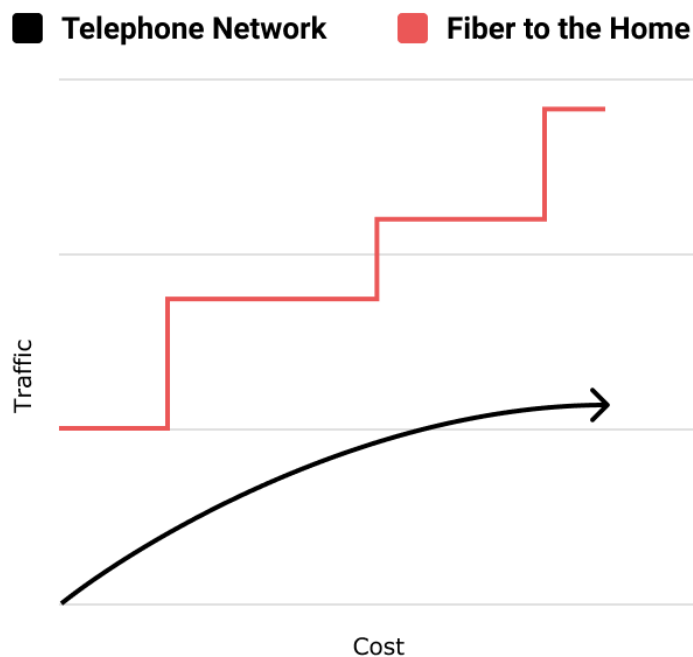
1. **Origination:** The dial tone service connected the call from the originating customer's equipment to a telephone company's central office or exchange. Note that with cellular mobile service, there are no dial tones, so this function has been rationalized into the network design.
2. **Transmission:** the transportation of the signal (the call) to another telephone company office near the recipient of the call.

3. Termination: completing the call from the receiving company central office to the receiving subscriber's equipment.

These elements reflected the design of the network and its flexibility to interoperate with other networks. Notably in the early days of telephone, there were many phone companies. Having discrete pricing allowed multiple networks to flourish and interoperate because they were able to recover costs.

Investment models

Traditional legacy services like telephony offered a scalable investment model in which incremental cost is covered by the addition of one or a few services on a single network. Next generation networks enable a multitude of services have a different cost structure, requiring stepwise investment. The USF established in 1996-97 was predicated on a model of traditional legacy networks and focused on last mile provision; it did not anticipate the growth of video or the need to build out, operate and maintain the middle mile. The following diagram illustrates the scalability of a legacy network like the telephone versus next generation investment required to facilitate fiber to the home broadband which not only requires a greater overall investment per subscriber, but investments are made in increments as traffic increases.



In 2020, video accounted for 75 percent of all downstream internet traffic, but the internet was neither designed for this reality, nor are the USF funds available to support it in a sufficient, predictable, and equitable manner. To properly fund the cost of the network, it is necessary to identify and allocate the costs associated with certain services. This can be quite complex as different services will make heterogeneous demands on peak and average capacity of the network. Legacy telephone networks are like a postal service that delivers only letters to normal mailboxes: more letters require only incremental increases in system capacity and very little new infrastructure. Next generation broadband networks, on

the other hand, are like a delivery service for online shopping, while they can deliver almost anything at any time, demand changes quickly and requires significant investment in different vehicles, distribution centers, sorting facilities, and the like.

Two-sided markets

Markets can encourage the development with flexible investment models. Indeed, that there is a persistent digital divide reflects that markets have not been allowed to work to recover costs. Tirole and Rochet presented the concept of two-sided markets in 2003 (Rochet & Tirole 2003). Tirole subsequently won the 2014 Swedish Royal Bank Prize in Economic Sciences in Memory of Alfred Nobel, being one of the youngest awardees in history.¹⁶ Broadband, like other communication networks for radio, TV, and print is a two-sided market. The broadband provider is situated in the middle with end users on the one side and content providers on the other. The notion of two-sided markets suggest that the intermediary wants to get both sides of the market “on board” and that there is an incentive to price efficiently.

Two-sided markets also help explain how participation by advertisers and content providers drove the expansion of the media industries in the US. One of the key benefits of this model is that viewers didn't need to bear all the costs themselves; it was shared by the market participants on the other side of platform, namely advertisers who funded radio and television programs, so consumers didn't have to pay out of pocket for the use of the media platform. When subscribing to newspaper and magazines, people have availed themselves to a variety of models whether by subscription, advertising-subsidized, publisher-underwritten, or a combination thereof.

Indeed, consumers are well-aware of advertising-supported and “freemium” online services, but oddly such developments were restricted for the underlying broadband service itself. This is likely the result of a concerted historical effort by Big Streamers to reject transparent and open two-sided markets outright as it obliges them to pay for the traffic they send into networks. Netflix, for example, has reportedly reached deals with large broadband providers (Wang and Ma 2020) but offers only standard OCA appliances to qualifying smaller ISPs. It is important to note that the Big Streamers also have a flat and uniform (over service area) pricing model so many of their users will tend to be high-volume consumers.

Netflix offers a streaming video service that consumes significant network capacity and frequently impinges on other, non-Netflix users' ability to enjoy the network.¹⁷ Rural broadband providers need to provision additional capacity to deliver Netflix. Because the Netflix subscribers are a strict subset of any one network's user base, the rural broadband provider believes Netflix has the social obligation to participate in the cost of delivering the service, so it does not have to impose the cost across all its subscribers, especially those that do not desire Netflix. The Netflix perspective is that the broadband providers' choice of technology is its responsibility, and it is incumbent on the broadband provider to deliver Netflix data regardless of the cost. Netflix's desired outcome is for the broadband provider to

¹⁶ “The Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel 2014,” NobelPrize.org, accessed December 8, 2020, <https://www.nobelprize.org/prizes/economic-sciences/2014/tirole/facts/>.

¹⁷ “Study Reveals Causes of Core Internet Congestion – Netflix, Comcast to Discuss at DC Net Neutrality Event 6/18 | MIT CSAIL,” MIT, June 15, 2014, <https://www.csail.mit.edu/news/study-reveals-causes-core-internet-congestion-netflix-comcast-discuss-dc-net-neutrality-event>.

invest in excess network capacity and raise its subscription price on all network users, rather than any distribution cost be borne by Netflix and/or its subscribers.

In other instances, a content provider may want to subsidize the delivery of its content to maximize viewing. A health care provider would be willing to subsidize the cost of broadband subscriptions to its members to encourage adoption of preventative telehealth care and monitoring tools. The cost of avoiding an adverse health event is well worth a small portion of the end user's monthly broadband subscription fee. The health care consumer benefits with better health outcome and the health care provider reduces costs.

The focus on supporting the requirements for video has been driven in large part by the high private value placed on streaming video. It is almost certainly the case that video is the internet's "killer app" – the one thing for which consumers are likely to pay the most. But the social value of online video is likely small relative to work, education, and healthcare – and these other applications likely have very different technical requirements. Thus, the goal of provisioning ubiquitous high-speed internet access is at odds with provisioning ubiquitous access to important online educational, health care, employment, and government service resources. In a world of unconstrained resources, we would of course have unlimited bandwidth connectivity that supported universal access to these socially valuable resources. But in a world of constrained resources, we face a tradeoff between the rate of provisioning networks that support the most resource-intensive and highest private-value services and the rate of provisioning more modest networks that support the most socially valuable services, but that may not support the highest private-value services (Hurwitz and Layton 2015).

Overview of the Big Streamers

The following section provides a review of publicly available information for the Big Streamers.

	Market capitalization (billions)	Annual revenue (billions)
Netflix	\$230	\$26
Alphabet	\$1190	\$185
Disney+/Hulu	\$315	\$59
Amazon	\$1590	\$385
Microsoft	\$1620	\$149

Source: Google Finance, December 2020, world-wide users

	Paying US Subscribers (millions)	Global Subscribers (millions)
Netflix ¹⁸	73.08	200
YouTube TV ¹⁹	2	30
Disney+/Hulu ²⁰	36.6	137
Amazon ²¹	56	150
Microsoft Xbox	Not available	90

Netflix

From a DVD by mail company, Netflix has transformed itself to a behemoth through the global reach and quality of broadband networks. In 2019, it earned over \$20 billion, and its market capitalization is \$217 billion.²² Netflix revenue for the quarter ending September 30, 2020 was \$6.436B, a 22.7% increase year-over-year.²³ At this pace, Netflix will likely reach \$24 billion in revenue for 2020. Netflix describes itself as the world's leading Internet television network in nearly 50 countries with access to an ever-expanding library of TV shows and movies, including original programming, documentaries, and feature films. Through broadband, the company offers its customers, the ability to watch as subscribers want, anytime, anywhere, on nearly any Internet-connected screen. Netflix accounts for a staggering one-third of the world's streaming content and has 200 million subscribers,²⁴ more than any cable provider in the world, 6 times more subscribers than Comcast, and 7700 times more than Nex-Tech.

¹⁸ "Netflix Subscribers Count in the U.S.," Statista, accessed January 25, 2021,

<https://www.statista.com/statistics/250937/quarterly-number-of-netflix-streaming-subscribers-in-the-us/>.

¹⁹ Todd Spangler and Todd Spangler, "YouTube Tops 20 Million Paying Subscribers, YouTube TV Has Over 2 Million Customers," *Variety* (blog), February 3, 2020, <https://variety.com/2020/digital/news/youtube-tops-20-million-paying-subscribers-youtube-tv-has-over-2-million-customers-1203491228/>.

²⁰ "Hulu: Number of Paying Subscribers by Quarter U.S. 2019-2020," Statista, accessed January 25, 2021, <https://www.statista.com/statistics/258014/number-of-hulus-paying-subscribers/>.

²¹ "Amazon Prime Video Statistics and Facts," *Market.Us* (blog), accessed January 25, 2021, <https://market.us/statistics/online-video-and-streaming-sites/amazon-prime-video/>.

²² "Netflix Revenue 2006-2020 | NFLX," accessed December 8, 2020, <https://www.macrotrends.net/stocks/charts/NFLX/netflix/revenue>.

²³ Ibid

²⁴ <https://www.lightreading.com/cablevideo/netflix-blows-by-200-million-subs-worldwide>

Netflix offers its customers a tiered pricing structure of Basic, Standard and Premium, in which it charges more depending on the number of devices on which the subscriber views Netflix as well as the quality of the picture provided.²⁵ Note that Netflix engages in price discrimination with a variety of tiers and add on services, e.g. first time user pricing, heavy user pricing, and the ability to watch multiple screens. Netflix also leverages its global dominance to win pay windows for competitors' content in addition to leveraging the most popular TV shows underwritten by the world's public broadcasters.²⁶

Alphabet's YouTube

Alphabet Inc., market cap \$1.2 trillion, is the multinational conglomerate containing Google and its subsidiaries. Its 2019 revenue was roughly \$162 billion. Google is the single most visited website in the world, and its flagships products are the leaders globally, e.g., Search, YouTube, Maps, Android operating system, Chrome web browser, and the Chrome operating system.

Google operates business lines using personal information including online advertising, search engines, cloud computing, software, and internet access with businesses such as Google Fiber, Google Fi, and Google Station. Among its 200 apps are Blogger, Docs, Sheets, Slides and Gmail, Calendar, Drive for cloud storage; Translate, and Photos. It also has some popular connected devices. YouTube is a leading Alphabet application. It is on track to earn more than \$6 billion in advertising revenue for 2020. YouTube Premium is an ad-free version of YouTube, which is offered to US subscribers for \$12 per month. YouTube Premium has over 20 million subscribers globally.²⁷

Amazon Prime

Amazon, \$1.6 billion market cap, bills itself as the "Earth's most customer-centric company, where customers can find and discover anything they might want to buy online, and endeavors to offer its customers the lowest possible prices." It earned \$281 billion in 2019. It has three dozen different business. In addition to its flagship ecommerce platform and Amazon Web Services for enterprise IT, Amazon Prime, a subscription service which offers digital content including games, books, music, movies, and on-demand video. Prime is expected to earn Amazon \$3.6 billion in 2020.²⁸

Microsoft

Microsoft is a leading platform company with a market cap of \$1.6 trillion with expected 2020 revenue of \$143 billion. In addition to its enterprise software platforms, it operates Xbox, the video game platform. Xbox and other Microsoft-supported games have exploded 30 percent over the last year with

²⁵ "Plans and Pricing," Help Center, accessed December 8, 2020, <https://help.netflix.com/en/node/24926>.

²⁶ Roslyn Layton, "Netflix's Exclusive Deal For Denmark's Borgen Could Upset International Sharing Agreements With Broadcasters," *Forbes*, June 30, 2020, <https://www.forbes.com/sites/roslynlayton/2020/06/30/netflix-exclusive-deal-for-denmarks-borgen-could-upset-international-sharing-agreements-with-broadcasters/>.

²⁷ Micah Singleton, "YouTube Premium and Music Now Have More Than 20M Subscribers," *Billboard*, April 2, 2020, <https://www.billboard.com/articles/business/digital-and-mobile/8550124/youtube-premium-music-20-million-subscribers/>.

²⁸ "Amazon Prime Video Statistics and Facts," *Market.Uz* (blog), accessed December 8, 2020, <https://market.us/statistics/online-video-and-streaming-sites/amazon-prime-video/>.

users topping 90 million in 2020,²⁹ and revenue exceeding 10 billion annually.³⁰ Note that Microsoft has a variety of services that use streaming. While Xbox may be used for entertainment, other Microsoft streaming services, like Teams, are different social purposes.

Disney+/Hulu

Launched just a year ago, Disney+ already has some 75 million users globally. Part of the Walt Disney Company, Disney+ distributes films and television from Disney Studios, Pixar, Marvel, Star Wars, National Geographic, and others. Hulu is an online video entertainment provider owned by the Walt Disney Company with ownership shares from NBCUniversal and Comcast. Hulu has some 36 million users and \$2 billion in revenue.

Overview of Rural Broadband Cost Recovery Calculation

This study focuses on four rural broadband providers (78,167 subscribers in total) and considers the rapid increase in peak and average traffic on their networks and associated costs driven by the Big Streamers. It estimates the revenue this generates for the content providers and extrapolate the costs to the broadband providers to reflect on whether it will remain feasible for rural broadband providers to continue providing free delivery service of content, considering flat USF payments which only cover the last mile and a limited ability in the rural market to absorb price increases.

The calculation below includes a series of steps based upon information from the four rural broadband providers. It calculates the revenue from residential customers for broadband, the cost of delivering online video entertainment, the growth of online video entertainment, the revenue generated on these rural networks by the streaming video entertainment providers, and the rural broadband providers' unrecovered cost of the middle mile that is required to deliver the Big Streamers' traffic to end users in rural areas.

The Rural Broadband Providers (RBPs)

The companies in the study are independent firms in distinct rural areas. Over the years, they have upgraded their infrastructure to build fiber networks, many to the end users' premises. Chickasaw Telephone Company was founded in 1909 to provide telephone service in a rural area south of Oklahoma City. Together with BrightNet³¹ and its other affiliates, the company provides fiber optic connectivity to homes and businesses throughout Oklahoma and parts of Texas and Kansas. For 85 years, EATEL has served Ascension and Livingston Parishes, an area in between Baton Rouge and New Orleans. Its current offerings include internet, TV, phone, and home security. Nex-Tech serves 45 communities between Kansas City and Denver with fiber optic enabled internet, TV, phone, and IT solutions, as well as cellular wireless services. Located north of Bloomington, Indiana, Smithville

²⁹ "Xbox Live MAU 2020," Statista, accessed December 8, 2020, <https://www.statista.com/statistics/531063/xbox-live-mau-number/>.

³⁰ Matt Brown, "Xbox Q4 Revenue Surges 64% Driven by Record Engagement amid Pandemic," Windows Central, July 22, 2020, <https://www.windowscentral.com/xbox-microsoft-q4-2020-earnings-gaming>.

³¹ "Brightnet Oklahoma | Chickasaw Holding Company," accessed December 8, 2020, <http://69.8.3.49/our-affiliates/brightnet-oklahoma>.

Communications provides a range of connectivity services to homes and business on its fiber optic network. Following is a summary of the providers, their geographic footprint, and subscribers.

	Footprint (square miles)	Subscribers
Chickasaw Telephone Company (Sulphur, OK)	617	3621
EATEL (Gonzales, LA)	506	28,046
Nex-Tech (Lenora, KS)	10,000	25,500
Smithville Communications (Ellettsville, IN)	782	21,000
Average	2976	19,542

The average of the four providers produces a footprint of 2,976 sq. miles and 19,542 subscribers. Such a region is comparable to half the size of Connecticut. However, the same area in Connecticut has as many as 650,000 households or 30 times as many customers. This demo-geographic inequality underscores the fundamental economic challenge of serving rural areas, as there are fewer households across which to cover the costs of building and maintaining a network. It is for these structural reasons that the US Congress developed the USF program to support the provision of advanced telecommunications and information services to rural areas. However, when USF was set up, it was not expected that video would be the prevailing internet application. The original internet “killer app” was email. Had it been known that streaming video would become the application which consumed the most bandwidth, it is likely policymakers would have chosen different funding models.

Step 1. Calculate the expected annual subscriber revenue of the rural broadband providers

Expected pro forma subscription revenue for the providers was calculated based on pricing information from Nex-Tech, Smithville, and Chickasaw. EATEL data was not available. Unless otherwise noted, original data traffic, price and cost information was provided by the broadband providers.

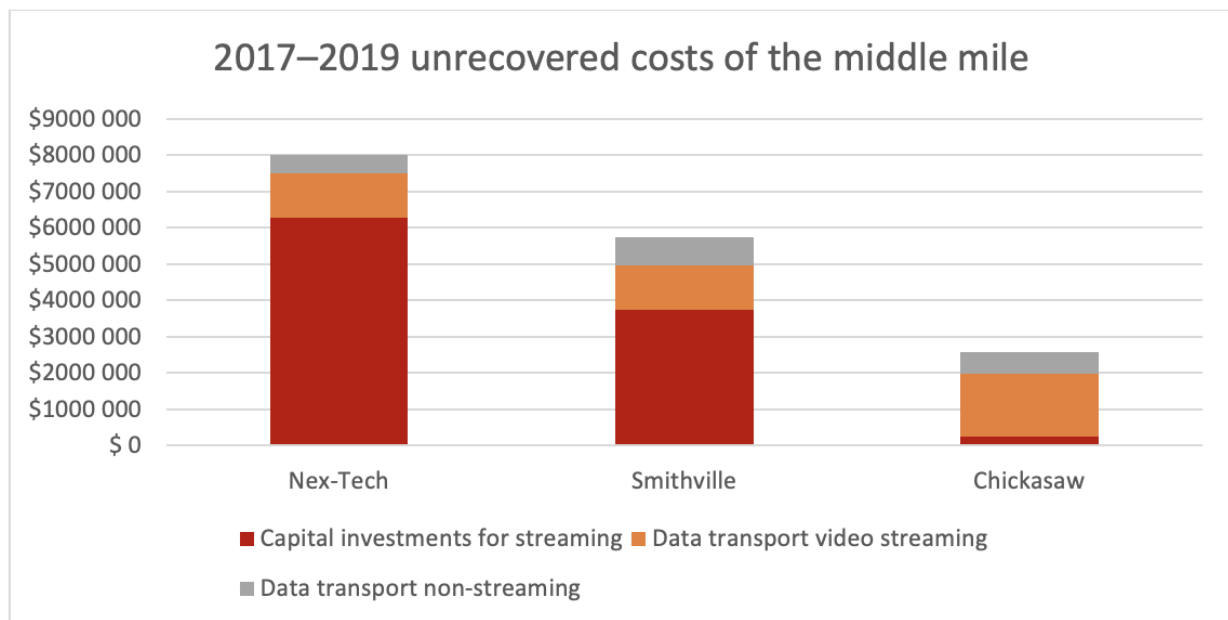
Pro forma annual revenue based on current prices, 2020				
Rural Broadband Provider	Subscribers	Monthly broadband price (\$)	Revenue per month (\$)	Revenue per year (\$)
Nex-Tech	25,500	45.95	1,171,725	14,060,700
Smithville	21,000	50.00	1,050,000	12,600,000
Chickasaw	3,621	48.00	173,808	2,085,696

Step 2. Examine the broadband network cost of the Big Streamers

The companies provided the following data for a three-year period 2017-2019. These costs include capital investment in equipment as well as variable costs to deliver the streaming video entertainment. Note that this capital investment is expected to last for three to five years to accommodate the expected increase in traffic growth, and in certain cases, could include some last mile costs.

Rural Broadband Provider Middle Mile Network Costs 2017-2019 (\$)	Nex-Tech	Smithville	Chickasaw
Non-streaming network cost	519,588	752,400	581,250
Streaming video entertainment cost	1,212,372	1,227,600	1,743,750
Capital investment streaming video entertainment cost	6,280,000	3,750,000	245,000
Total for 3 years	8,011,960	5,730,000	2,570,000
Average for 1 Year	2,670,653	1,910,000	856,667
Subscribers	25,500	21,000	3,621
Annual Cost Per Subscriber	104.73	90.95	236.58
Monthly Cost Per Subscriber	8.73	7.58	19.72
Streaming Video Entertainment Portion Only	7,492,372	4,977,600	1,988,750
1 Year	2,497,457	1,659,200	662,917
Annual Cost Per Subscriber	97.94	79.01	183.08
Monthly Cost Per Subscriber	8.16	6.58	15.26
Total costs related to streaming video entertainment	94%	87%	77%

The key takeaways are that for the period 2017-2019, 77-94 percent of middle mile, network costs were related to streaming video entertainment. This amounted to \$100-180 per subscriber annually. Going forward, however, these costs are expected to increase with the growth in video traffic.



In addition, broadband providers must pay for the upgrades for other network services. Internet access infrastructure is shared, and deployment accounts for:

- peak usage requirement per connection; and
- maximum total simultaneous requirement of all downstream connections.

This determines the internet access network topology in terms of both line capacity and the requirements of intermediate hardware such as routers, cards, and switches. Streaming video entertainment increases both peak usage per connection as customers might be sent very high-definition video to devices capable of handling the high-quality video experience as well as increasing overall simultaneous use as households consume more streaming media for extended periods of time. This situation has shown to be especially true since the Covid-19 lockdowns commenced.

Step 3. Describe the growth in online video entertainment on rural broadband networks

Each of the companies provided traffic information for their networks which is summarized here. The trends observed with the three companies are consistent with larger internet trends described by Cisco, Sandvine³², and others for internet traffic to US households.

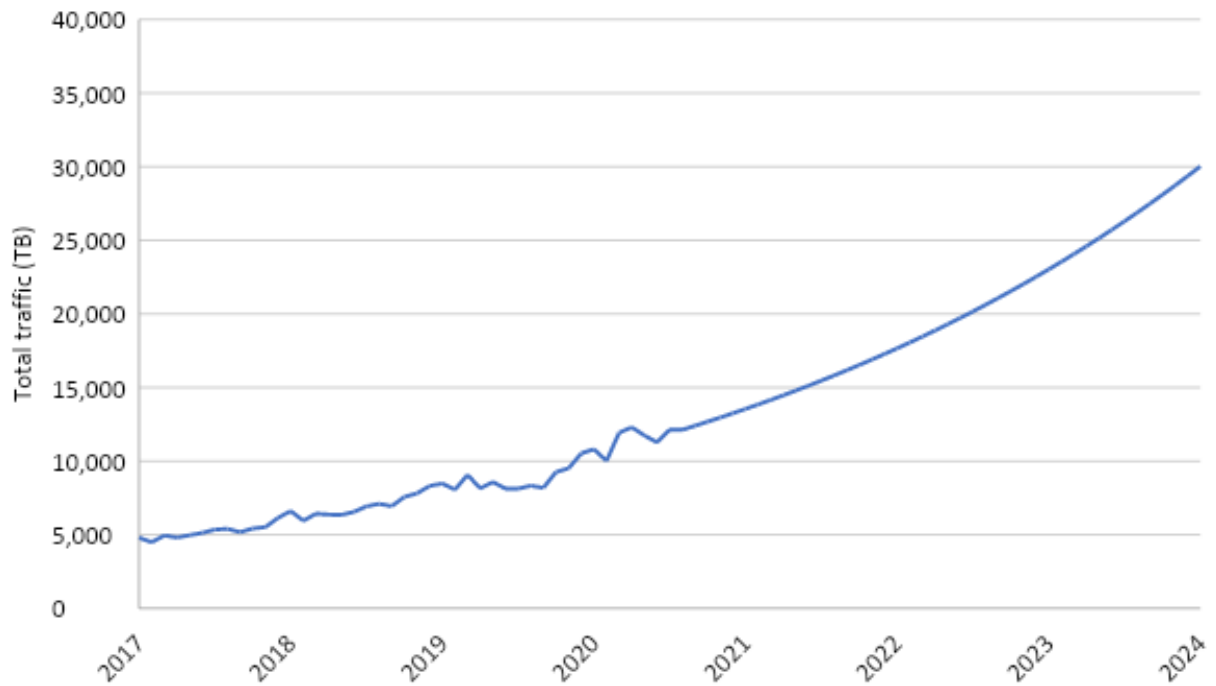
3.1 Nex-Tech Traffic Increase

Nex-Tech experienced an explosive growth in total traffic from the Big Streamers as measured in terabytes equal to about 30 percent per year. The data was collected by Nex-Tech using NetFlow Analyzer and Arbor Networks Software tools.

Traffic growth on ISP Nex-Tech since 2017			
	Download	Upload	Total
Average monthly growth (compounded)	2.18%	2.98%	2.23%
Average annual growth	29.53%	42.31%	30.37%

The growth of 30 percent was projected for four years into the future yielding more than 30,000 TB per month by 2024. Although the cost of data transport is decreasing (in general), the traffic is growing at a much faster rate, and this growth in traffic requires further capital investment in the middle mile. The following chart illustrates the past and projected traffic growth of the Big Streamers on Nex-tech.

³² Sandvine Internet Phenomena. Continuous reporting on upload and download traffic for 10+ years. Shows traffic inequalities and disproportions related to predominance of key video entertainment providers: Sandvine, "Global Internet Phenomena," accessed January 5, 2021, <https://www.sandvine.com/phenomena>.



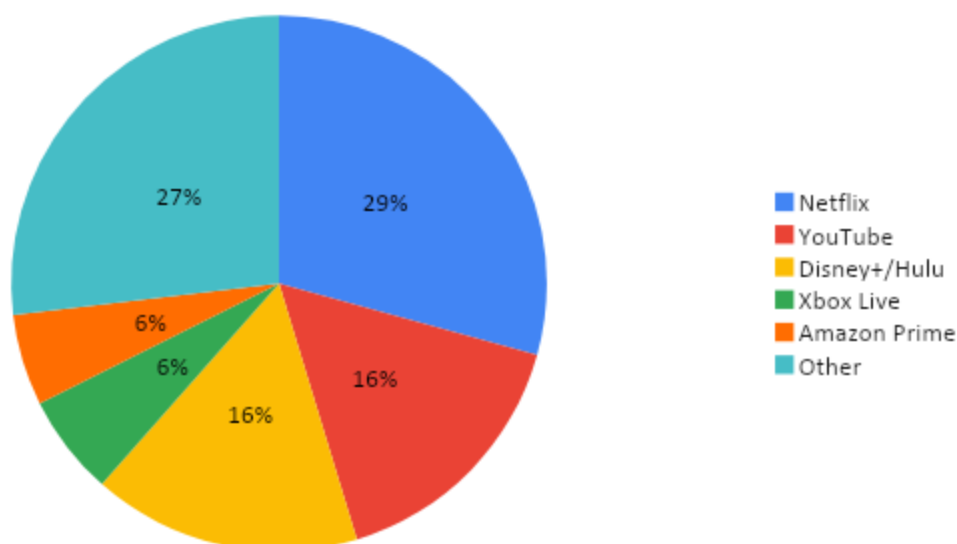
3.2 Smithville Video Traffic Share

Smithville does not have the same analytical tools as Nex-Tech and thus provided insight into the share of traffic by source rather than its total streaming video entertainment volume. The leading sources of traffic were Netflix, YouTube, Xbox Live, Disney+/Hulu, and Amazon Prime. The streams from these Big Streamers consumers 73 percent of Smithville’s network’s peak capacity, leaving scant resources for all other applications. Note that traffic congestion becomes an operational concern when a network reaches 80-85 percent of peak capacity (Bauer et al. 2009).

Peak capacity on Smithville from top content providers	
Netflix	29.30%
Disney+/Hulu	16.20%
Google/YouTube	16.00%
Xbox	6.10%
Amazon Prime	5.50%
Other	26.90%

The share of peak traffic is illustrated in the following graphic. Seventy-three percent of peak traffic is generated by the five services in the table above, with the largest single share from Netflix. The example is instructive as both peak and total (equivalently, average) traffic impact on the cost for the RBP to provide the service.

Share of peak capacity on ISP Smithville



3.3 EATEL Video Traffic Share

EATEL offered similar data to Smithville using the Kentik tool but provided the average rather than peak traffic numbers. The top five content providers are responsible for 44.5% of average traffic here. Even though EATEL's subscriber revenues and costs were not used in the remainder of the estimate, their traffic numbers confirm the overwhelming contribution to traffic by the top five online video entertainment providers.

Average traffic on EATEL from the Big Streamers	
Netflix	15.44%
Alphabet	13.42%
Disney+/Hulu	9.27%
Amazon	3.53%
Xbox Live	2.84%

This study focuses on the major streaming video providers, but other services are significant. On some networks at various times, other service could comprise between 1-3 percent of total traffic. These include PlayStation, DirecTV, Facebook Video, Apple Software Updates, Twitch, Sling, Chrome Update, TikTok, and TubiTV.

Step 4. Calculate Revenue Earned by the Big Streamers

Online video entertainment providers earn significant monthly revenue from their services, as the following table shows. Revenue per customer reflects the price of the streaming video entertainment service divided by the average number of subscriptions per US household. This reflects that in a specific

household there may be several contract subscriptions and even more than one subscription to the same content service if it is something that members of the household use on individual devices. It is furthermore a conservative estimate as the average number of subscriptions per broadband household (and possibly, per rural household) will be higher than that for all households.

Note that this table only reflects customer fees. The Big Streamers also earn significant additional revenues, for example YouTube also earns advertising revenue from its ads; Amazon earns revenues from advertising.

Average Big Streamer revenue per rural broadband subscriber per month				
	Monthly price of video entertainment service (\$)	Average customers per connection/household	Revenue per customer	Estimated number of customers
Netflix	12.99	0.66	8.57	33,080
Amazon Prime Video	12.99	0.50	6.50	25,061
Hulu	11.99	0.27	3.24	13,533
Xbox Live	4.99	0.41	2.05	20,550
Disney+	6.99	0.26	1.82	13,031
YouTube Premium	11.99	0.18	2.16	9,022
Total for top six services			\$24.34	114,276
Note: This calculation does not include revenue from any advertising; total number of customers may exceed ISP subscribers since customers subscribe to multiple streaming videos services.				

Recall that among the four rural broadband companies, we have a total of 78,167 subscribers (including EATEL) Each month, the five streaming video entertainment providers earn some \$25 in revenue from each household, or \$292 annually per household. There are some 110 million households in the US and the average number of content provider customers per rural broadband provider subscription is calculated by dividing the total reported number of US customers of each content provider by the total number of US households. The revenue of the five streaming video entertainment providers is then calculated for the customer base of the four rural broadband providers.

Top five content providers (annual)	
Revenue per RBP subscriber	\$292.08
ISP additional cost attributed to content	\$69.05
Top five content providers (annual)	
Revenue for four RBPs	\$22,831,017.36
ISP estimated addition cost	\$5,397,431.35

Step 5. Calculate Unrecovered Cost

The escalating cost of provisioning data and upgrading network infrastructure to accommodate rapidly growing traffic from the Big Streamers in high-cost locations has a dramatic impact on the viability of rural broadband providers. Our estimates of the growth in unrecovered cost were informed by the following observations.

1. Nex-Tech reports over 5% average per annum growth in middle-mile costs due to the increase in traffic over the period 2017 to 2019.
2. Another rural service provider recently had to spend nearly \$800,000 on the upgrade of its core ring from 10 to 200 GBPS.
3. Rural broadband providers typically must deploy middle-mile infrastructure over much greater distances than suburban or urban providers.
4. Make-ready costs per customer for unserved areas are higher for providers that have lower take-up per mile of buildout due to low population density.

Costs due to greater traffic (peak as well as average) arise mainly from first mile and middle-mile operations. In both, capital outlays are incurred and for the former there are additional costs for data transport.

Consider the estimated monthly cost of carrying the Big Streamers' traffic. In the most optimistic assumption of traffic levelling off after 2020 and existing infrastructure investments being sufficient to absorb this traffic (future scenario 1), the average monthly cost per subscriber for carrying this content, declines from \$11.65 in 2020 to \$7.09 in 2024. This is regarded as a quite unlikely scenario since the growing quality and quantity of available devices suggest that demand for even higher resolution video is set to be very robust.

Monthly cost of providing streaming video – future scenario 1 (flattened use and data transport cost, capital investment tapering off)					
	2020	2021	2022	2023	2024
Data transport	\$7.09	\$7.09	\$7.09	\$7.09	\$7.09
New capital investment	\$4.56	\$2.28	\$1.14	\$-	\$-
Total	\$11.65	\$9.37	\$8.23	\$7.09	\$7.09
Source: average of three RBPs based on their own internal data					

However, if we assume that traffic keeps growing by 30% per year and (conservatively) that the new capital investment stays flat while data traffic costs escalate (future scenario 2), the monthly cost of provisioning streaming video rises from \$11.65 per subscriber (\$17.47 per consuming subscriber if not including low-consumption households) to \$25.04 per month by 2024 (amounting to \$37.56 per heavily using subscriber) which translates to annual expenditure for accommodating streaming video of \$23,487,620 for the four RBPs.

Monthly cost of providing streaming video – future scenario 2 (use continues to grow, data transport cost flat, continued capital investment)					
	2020	2021	2022	2023	2024
Data transport	\$7.09	\$9.24	\$12.05	\$15.71	\$20.48
New capital investment	\$4.56	\$4.56	\$4.56	\$4.56	\$4.56
Total	\$11.65	\$13.80	\$16.61	\$20.27	\$25.04
Source: average of three RBPs based on their own internal data					

The table above does not reflect the pessimistic scenario, but a more realistic assumption would be, as confirmed by one of the RBPs that data transport cost (not volume) grows by around 10 percent per annum (future scenario 3). This would cause, still with flat capital investment, cost per subscriber to the RBP of streaming video grow to over \$15 per month by 2024 as shown in the following table.

Monthly cost of providing streaming video – future scenario 3 (use continues to grow, data transport cost declines, continued capital investment)					
	2020	2021	2022	2023	2024
Data transport	\$7.09	\$7.85	\$8.69	\$9.62	\$10.64
New capital investment	\$4.56	\$4.56	\$4.56	\$4.56	\$4.56
Total	\$11.65	\$12.41	\$13.25	\$14.18	\$15.20
Source: average of three RBPs based on their own internal data					

Cisco forecasts the ratio of peak to average traffic to nearly double³³ in the next few years. There is a possibility that, together with increasing total traffic, this will require even greater new capital investment than assumed in either of the three tables above, possible pushing the monthly cost to almost to \$30 per subscriber per month or \$28,140,120 per annum for the four RBPs.

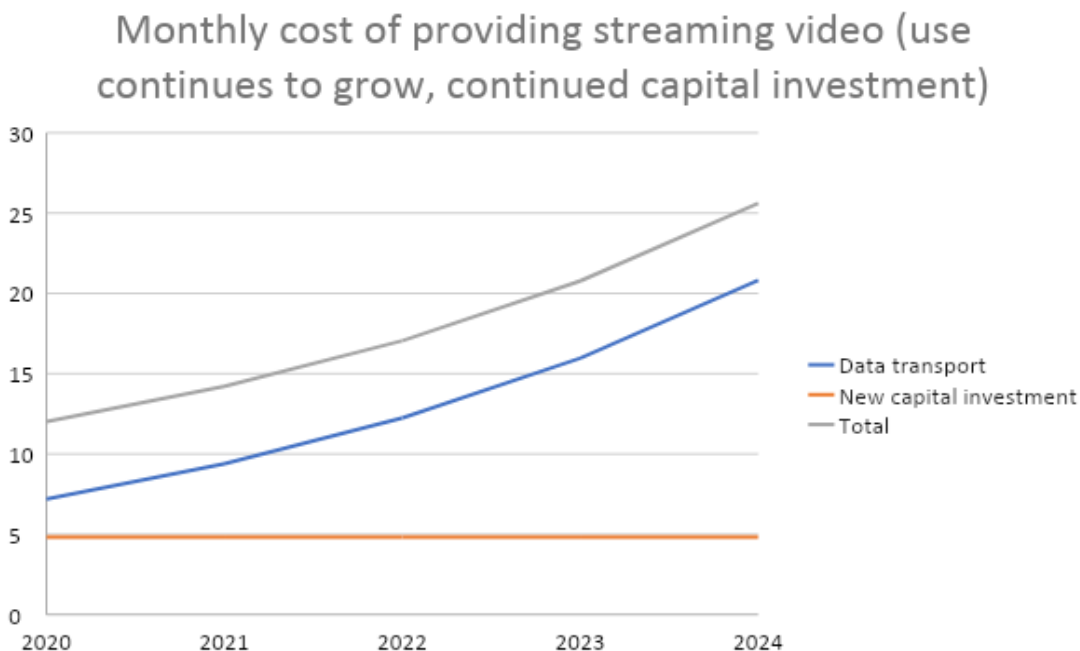
Big Streamers Revenue Could Exceed the Price of Broadband

Unlike the price of broadband, which has been decreasing per megabit, the price of content has been increasing. Because of rural broadband providers' investment in networks, Big Streamers have been able to increase their revenues from zero to \$25 per month per subscriber, an amount which is already half the price of broadband and likely to increase. Upwards of 90 percent of rural broadband providers' investment cost is associated with facilitating the Big Streamers' traffic. The Big Streamers benefit from this investment, but they do not contribute to its cost recovery. Moreover, they resist efforts to find a means of equitable cost recovery. As explained in the Introduction, RBPs likely have far greater difficulty

³³ Colin Dixon, "Video Bandwidth Growth Defined by UHD, Cord Cutting," *NScreenMedia* (blog), December 3, 2018, <https://nscreenmedia.com/video-bandwidth-growth-cisco-vni-2018/>.

(even in the presence of subsidies) to find a flat and uniform (over service area) price for a specific level of service (25/3 megabits per second, for example) which renders their average revenue greater than their average cost. Simply increasing the price is not necessarily sufficient as a drop-off in customers substantially increases the already considerably higher average cost per end-user. If a given level of price (including subsidy) and fixed level of traffic makes it possible to operate profitably in an area, there is no guarantee that it will remain possible to do so with higher levels of traffic.

In future scenario 3 (discussed above), it is assumed that new capital investment is flat, but data transport costs continue to grow.



The major cost driver for RBPs is to provision for streaming video, and this cost is projected to amount to close to 50 percent of their total revenue within a few years. The Big Streamers generate enormous revenues from rural broadband subscribers while most of the costs are absorbed by the RBPs. Middle-mile network upgrades and data transport costs are required for the fraction of broadband subscribers that are (heavy) users of streaming video services, and it is unfair to pass this cost on to the entire market through substantial increases in the broadband subscription fees. Furthermore, price increases of this magnitude are likely to be unsupportable in the rural markets served by the RBPs.

The following table summarizes the key metrics for rural broadband providers.

Key metrics for Rural Broadband Providers	
Share of total data transport cost due to streaming	62%
Share of peak capacity provisioning due to top 5 streaming	73%
Share of average capacity provisioning due to top 5 streaming	45%
Annual data traffic growth	30%
Unrecovered cost per subscription (2020, all video streaming)	\$11.65
Unrecovered cost per subscription (2024, conservative estimate)	\$15.20
Unrecovered cost per subscription (2024, high estimate)	\$25.04
Average price of broadband connection	\$47.79
Average additional cost to provide for top 5 streaming	\$6.98
Top 5 content provider revenue per subscription	\$24.34

The following section discusses categories of policy solution to address the inequalities.

Policy Solutions

This paper has described the challenge to recover middle mile and core network costs to facilitate traffic from the Big Streamers on four rural broadband networks. Given that they cannot recover costs and their attempts to negotiate with the streaming video entertainment providers have failed, rural broadband providers could stop – or significantly reduce – middle mile and core network investments. The rural broadband providers can communicate the situation to their customers, noting that they don't want increase prices to pay for ever-increasing capacity, the cost of which cannot be shared equitably with the Big Streamers.

The practice of two-sided markets suggests that the situation can be resolved by engagement from both sides, for example the Big Streamers contribute, and the End Users contribute. It may also be the case that the government contributes. In long term scenarios, the architecture of the internet itself evolves and reshuffles existing market arrangements. For example, had the internet been designed with the current streaming video entertainment use case in mind, it could make delivery more efficient and cost effective.³⁴ In any event, this is not a near-term solution. Moreover, optimizing the internet for the Big

³⁴ Lehr, William and Sicker, Douglas, Would You Like Your Internet With or Without Video? (August 1, 2016). TPRC 44: The 44th Research Conference on Communication, Information and Internet Policy 2016, Available at SSRN: <https://ssrn.com/abstract=2757374> or <http://dx.doi.org/10.2139/ssrn.2757374>

Streamers could preclude the engineering requirements needed for so-called “smart” solutions for cities, transportation, energy, so on.³⁵

Big Streamers Pay

Following two-sided market and internet peering norms, the Big Streamers and Rural Broadband providers would negotiate a fee to send traffic into the rural broadband providers’ networks. Fees could be based upon agreed thresholds and could reflect periods of peak usage and other appropriate metrics. This fee is like the postage that Netflix used to pay to the US Postal Service when it sent DVDs by mail.

Such fees are pro-consumer in that end users are not forced to pay middle mile upgrades to facilitate streaming video entertainment, particularly for those who don’t subscribe to streaming video entertainment. Moreover, this incentivizes Big Streamer to invest in video compression technologies and other solutions to reduce the traffic burden on networks and thus reduce distribution fees.

Big Streamers will likely challenge rural broadband providers’ efforts to bring transparency to network traffic cost increases. They are likely to say that they could not handle the administrative requirements of paying invoices from rural broadband providers, when in fact the Big Streamers already manage payments and contracts with hundreds of millions of customers globally.

This solution may require government oversight to ensure good faith negotiation. This concept is rooted in the notion of “implied covenant of good faith and fair dealing,” which arose as a means to address abuse in 19th century contract negotiation by industrial robber barons. The comparison is apt today as the Big Streamers have far greater global market power than any 19th century oil company, railroad, or factory. Government oversight may be needed to overcome Big Streamers’ refusal to negotiate or their use of delay or distraction tactics.³⁶ Alternatively, the government could set the compensation fee.

Indeed, Big Streamers discussed in this paper, Alphabet (Google) and Amazon Prime have come under antitrust scrutiny in the US and abroad (Microsoft faced antitrust scrutiny in its early life). Netflix has faced regulatory censure in many countries for its business model and operations which challenges local laws for content development and distribution. In effect, the goal of the Big Streamers is to minimize, if not avoid, any traffic delivery costs. Over time, this ability to reduce their costs has strengthened their profitability and indirectly increased their market power.⁴⁴

Another option would be to incorporate the Big Streamers into the Universal Service Fund, a classic example of Pigouvian government intervention to address market failure. A usage fee would be collected from the largest video entertainment streaming providers⁴⁰ and then distributed by the FCC and/or Universal Service Administration Company to all cost recovery participants. However, there are foundational challenges in the Universal Service Fund today, which may be exacerbated with the expansion of the program.

³⁵ Lehr, William and Clark, David D. and Bauer, Steven and Claffy, KC C., Regulation When Platforms Are Layered (July 26, 2019). TPRC47: The 47th Research Conference on Communication, Information and Internet Policy 2019, Available at SSRN: <https://ssrn.com/abstract=3427499>

³⁶ Katie Shonk. “How to Negotiate in Good Faith: To negotiate in good faith, parties must desire to reach agreement and commit to meeting deal terms. Here’s how to identify “false negotiators” and others who violate good faith.” Harvard Law Review. January 6, 2020. <https://www.pon.harvard.edu/daily/business-negotiations/negotiate-good-faith/>

Admittedly the Big Streamers may have difficulty to figure out how to negotiate with RBPs. They may be challenged on whether and how to increase their prices, for example a price for rural users versus one for urban. It is likely that the Big Streamers will likely challenge these efforts to bring transparency to network traffic and equitable cost recovery. Ideally market actors should be able to resolve the issue without government intervention, but almost two decades of experience have shown that Big Streamers will avoid participating in middle mile and core network costs unless forced by government.

End Users Pay

To date, rural broadband providers have managed the issue through end user pricing.³⁷ This is not optimal, as increasing the rate of flat fees across the board forces low volume users to pay even more (and possibly drop their broadband service) while high volume users pay less, relative to what they use. Big Streamers oppose increases on end user broadband prices because it reduces the amount of money that end users can pay for big streaming subscriptions. Under current circumstances end users do not know that video streaming traffic is different and places disproportionate demands on the networks. Under flat pricing, users cannot control the delivery costs of video streaming data.

Rural broadband providers could implement usage-based pricing on its customers. End users would purchase fixed fee broadband services and overages would be charged at pre-determined rates. To create transparency, rural broadband providers should call the overage fee a “Big Streamer Delivery Charge.” Consumers will then have timely, relevant information and can determine how to optimize their budget.

To date, Big Streamers have squeezed both sides of the market by supporting campaigns and organizations which claim that the price of broadband is too high³⁸ and in their refusal to negotiate with the rural broadband providers to find equitable cost arrangements. The effect of the former policy is to create pressure on the rural broadband providers to make network investments without increasing prices, thereby ensuring that more consumers dollars are reserved for add on entertainment services.

Taxpayers Pay

Failing a solution in the marketplace, forcing taxpayers to fix the problem is another, albeit suboptimal, solution. A recent paper describes using federal and state funding to build government-owned networks which are leased to private providers under the term “Open Access Middle Mile.”³⁹ The method encourages federal, state, and local actors to coordinate with large broadband users which need middle mile networks and find opportunities, particularly with government-owned utilities etc., to double-up to ensure greater use of the network.

This is an extension of municipally owned networks which have a mixed record of success (Yoo & Pfenninger 2017). Federal and state coffers are already strapped after years of deficit spending and the

³⁷ “Don’t Call Them Data Caps: A Deep Dive on Usage-Based Broadband Pricing,” *American Enterprise Institute – AEI* (blog), December 1, 2020, <https://www.aei.org/technology-and-innovation/dont-call-them-data-caps-a-deep-dive-on-usage-based-broadband-pricing/>.

³⁸ Becky Chao and Claire Park. “The Cost of Connectivity 2020.” New American Foundation. <https://www.newamerica.org/oti/reports/cost-connectivity-2020/>

³⁹ “If We Build It, Will They Come? Lessons from Open-Access, Middle-Mile Networks,” Benton Foundation, December 1, 2020, <https://www.benton.org/publications/middle-mile>.

ongoing financial crisis of the COVID-19 pandemic. Many consumers are hard-hit financially and are loath to support tax increases. Government-owned networks have difficulty to attract the people with skills to market, manage, and upgrade broadband networks. Moreover, the decisions of where to apply the funding is frequently politicized with grants being made to favored locations or regions. It is not clear how these locations would be selected and whether these middle mile networks would necessarily help rural broadband providers. Government-owned networks sound like a good solution on the surface have a practical impact of reducing private sector investment and competition.

The parties with the information about the cost are best positioned to find solutions. As such, it makes sense for the government to support a good faith negotiation between the Big Streamers and the rural broadband providers.

Conclusion

The paper described the challenge of provision of rural broadband provision by examining the economics of 4 fiber to the home networks in different parts of the US. It shows how streaming video entertainment is the largest and growing category of traffic and which puts unique demands on the network. The paper described the history, policy, and economics of traditional end user pricing models flat, and uniform (over service area) based on speed tiers, and their shortcomings to support continued investment. It introduced the notion of the Big Streamers, the five largest video streaming providers and their content distribution practices. The document also reviewed the components of a rural broadband network. It reviewed traffic data from the networks, calculated revenue and cost, defined amounts of overage, and projected future shortfalls. This analysis demonstrates that rural networks are heavily burdened by huge volumes of streaming content which is turned into revenue not by the broadband providers but by the Big Streamers.

The policy solutions section introduced the three types of response and their implications. The current model of flat and uniform (over service area) pricing (even with subsidy) is likely to become unsustainable for rural broadband provision. The paper contributes to the ongoing policy discussion of rural broadband and closing the digital divide.

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