MIDDLE-MILE NETWORKS CAPACITY REQUIREMENTS FOR FIXED BROADBAND

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EXECUTIVE SUMMARY

Access to high-quality broadband has been historically limited in rural areas, as it is difficult for incumbent providers to build a profitable business case for fiber deployment where populations are sparse. Approximately 10% of U.S. households, mostly in rural communities, do not have broadband service, defined as 25 Mb/s or greater Internet connectivity. Yet, people living in these areas would also welcome the opportunity to work from home; they shop, consume entertainment, and access advanced education services and critical healthcare data online. The COVID-19 pandemic has only accelerated these trends: elevating high-speed reliable broadband from an optional service to an essential one, just like water or electricity.

The FCC Rural Digital Opportunity Fund and other public incentive programs have provided funding for service providers, utility co-ops, and municipalities to build out modern broadband networks to serve underserved rural communities. Many of these communities have been dependent on low-bandwidth copper-based DSL or geostationary satellite services and are eager to move to high-performance fiber-based services. Internet connectivity with nominal capacities in the range of hundreds of Mbps to a couple of Gbps is quickly becoming the reference for most households, the basic standard required to support their traffic demand. Entertainment has shifted from satellite TV to streaming video services such as Netflix, Amazon, Disney+, and YouTube on HD and 4K TVs. Devices such as smartphones and tablets also need scalable broadband to operate effectively in homes in rural communities. **As service providers build out rural networks, an important consideration is the bandwidth required in the Middle Mile to aggregate all the last-mile traffic to the core and internet providers.**

Growth in last-mile bandwidth is primarily being driven by video applications such as Zoom video calls for consumers and Work @ Home, streaming of video content at 720p, 1080p, and 4K, cloud gaming, as well

KEY FINDINGS

Rural broadband networks need to support increasing traffic and bandwidth:

- Average household bandwidth of 13 Mbps in 2021
- Average household bandwidth of 20.1 Mbps in 2025
- Rural area served with an average of 20,000 households
- Service providers' penetration rate growing from 25% to 60%
- This drives the requirement for a 200 Gbps by 2022 and 400 Gbps middle-mile ring by 2025

as social networking, web-browsing, and data downloads. ACG Research has developed a detailed traffic model projecting household network bandwidth growth from 2021 to 2025. We project that average household data rates in the peak hour will grow from 13 Mbps in 2021 to 20.1 Mbps in 2025. Our model considers application bandwidth, device penetration, and concurrency factors. From a middle-mile perspective, this drives the requirement for 200 Gbps rings by Year 2 (2022) and 400 Gbps rings by Year 4 (assuming peak traffic runs to 75% of overall capacity) in a typical rural area deployment (supporting around 20,000 households). It is critical that service providers plan their network architecture to allow for bandwidth growth in middle-mile rings to support NX 100GE capacity.

Middle-mile networks are typically fiber rings that aggregate the traffic from central offices or utility substations that connect customers in rural areas. We estimate a typical middle-mile ring will cover approximately 20,000 households. We assume that many households will switch from satellite and other low-quality services to new high-speed broadband networks. In our model we assume that a rural service provider will achieve a penetration rate of 25% of households in 2021 and 60% of households in 2025. Using our traffic model and these penetration assumptions we project the need for a single 100GE middle-mile ring in 2021 with growth to support 400 Gbps in 2025. Therefore, rural broadband service providers need to invest in a dedicated middle-mile network that can scale for N x 100GE.

Introduction

Consumers in the rural market have recognized since the pandemic struck in 2020 that scalable broadband service is not a nice to have service but an essential service, like electricity. Broadband has been essential for both work from home, learning from home; but also for streaming video entertainment provided by devices such as smart TVs, Apple TV, Roku, Amazon Fire TV. Broadband use also extends to a diverse mix of network connected devices: laptops, smartphones, tablets, gaming consoles, and smart TVs. The increased versatility and use of broadband are driving tremendous growth in rural internet traffic.

These new residential bandwidth growth and usage patterns have different effects on service providers' last-mile and middle-mile networks. Household fixed broadband and video services must provide adequate bandwidth to support the simultaneous use of connected devices for the entire household. The role of the middle-mile network is to aggregate the individual bandwidth requirements of households in a rural area where 20,000 households is considered an average for the US market. Here the growth in video traffic and gaming has the potential to drive massive increases in the required rural bandwidth capacity of the rural network. Similar traffic volume hikes are not expected to impact the long-haul network as severely. Rural network operators and content providers are dispersing caches, cloud data centers, and video serving offices down to and within middle-mile areas to reduce costly long-haul traffic requirements.

Methodology

The purpose of the residential broadband projection is to predict capacity requirements for the middle-mile network. The total bandwidth demand requirement in the middle mile reflects the effect of statistical multiplexing traffic from 20,000 households, which is the average number of subscribers for service providers, utility co-ops, and municipalities in rural markets. Because this projection is built bottom-up from individual devices and applications running within each household, two levels of averaging are employed to calculate bandwidth requirements that reflect the effects of statistical multiplexing:

1. Average bandwidth usage is calculated for all households within the rural area. This includes those households that do not use broadband services.
2. Average bandwidth usage during the 7 p.m. to 11 p.m. peak period is calculated. This can be calculated by using a concurrency rate, where concurrency rate is defined to be the hours of use during the peak period divided by the number of hours in the peak period. Average peak-period bandwidth is equal to the concurrency rate multiplied by the bandwidth required by the active application.

Total household fixed bandwidth demand is driven by the following application categories: video entertainment, web browsing, productivity, e-commerce, gaming, data transfer/downloads, and communications. Broadband bandwidth requirements are then classified by the type of device used to access the service. PCs, smartphone, and tablet usage is restricted to fixed access over the broadband connection as these devices typically use a Wi-Fi router to access the fixed broadband service. Smartphone and tablet broadband access via mobile data services is excluded from the analysis. Video includes HD and 4K TVs with streaming video services accessed via Roku, Amazon Fire TV, Apple TV, and Google Chromecast devices, among others. Future technologies include 8K TV.

The total bandwidth requirement is calculated for each device and application combination. It is then averaged for the peak usage period by applying concurrency rates. These individual bandwidth contributions are totaled to produce the average per household requirement.

Application-Specific Bandwidth Requirements

Each broadband application has a unique bandwidth requirement that depends on its function. For example, Twitter requires 50 Kbps whereas a Netflix HD movie viewed on a laptop/HD TV requires 6.7 Mbps.

Figure 1 presents 9 classes of broadband applications and provides examples of some of the most popular applications.

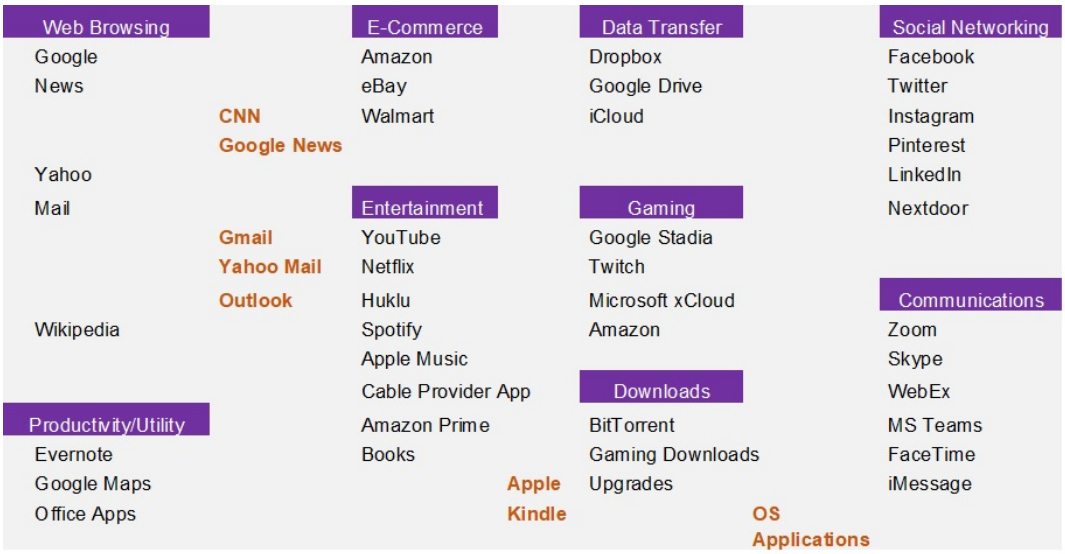

Figure 1. Popular Applications for PC/Laptop

In general, text and fixed image applications, such as Wikipedia and eBay, have the lowest bandwidth requirements; big, high-resolution videos, downloads, and data transfer applications, such as Netflix, Amazon Prime Video, cloud gaming, Dropbox, and application upgrades, have the largest bandwidth requirements.

Applications: PC, Smartphone, Tablet	Average Data Rate (Mbps)	Weights	Use-Case Growth Rates
Video Calls (Zoom, FaceTime)	1.5	15%	5%
Video Streaming 720p	1.6	5%	0%
Video Streaming 1080p	6.7	15%	2%
Cloud Gaming 720p	1.6	15%	10%
Cloud Gaming 1080p	6.7	2%	2%
Social Networking	0.2	23%	0%
Downloads	2.0	5%	0%
Web Browsing	3.0	20%	0%

Table 1. Bandwidth Requirements

Table 1 shows the bandwidth requirements, weights, and growth rates for application categories. The values are weighted to reflect the relative hours of use of each application. Video entertainment has substantially higher bandwidth requirements than the other categories and is projected to further increase its total bandwidth share. Today, Netflix, Disney+, Amazon Prime, and YouTube are the leading online video services.

Device Penetration

Figure 2 projects household device penetration for rural areas.

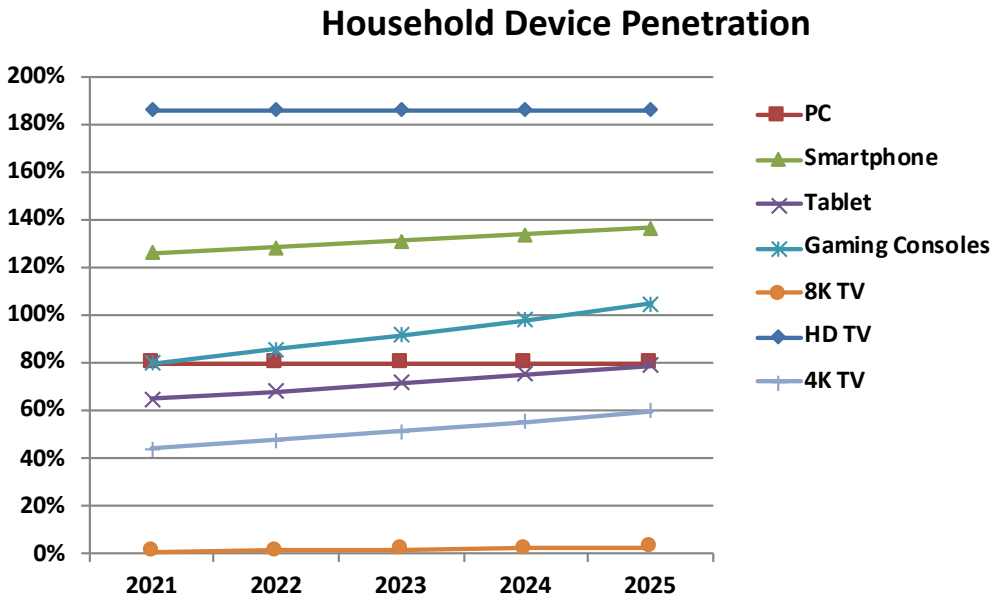

Figure 2. Household Penetration of Devices

In rural areas we expect smart phones and HD TV to have the highest penetration followed by gaming consoles. Video and gaming on both TVs (HD and 4K) and smart phones are key drivers of bandwidth growth. Although future 8K TVs will have very large bandwidth requirements (100 Mbps), the penetration and availability of 8K content will be low through 2025.

Concurrency

Measuring the bandwidth requirement on the middle-mile network requires consideration of the concurrency[1] factor. Additional usage hours during the busy period will boost the middle-mile network bandwidth requirement.

Table 2 shows the concurrency factors for all device types and subscription video on demand services.

[1] See the methodology section for a definition of concurrency and a discussion of its importance in measuring bandwidth requirements of rural networks.

Device Category	Total Daily Use Time (Mins)	% Of Total Use during Prime Time	Daily Use during Primetime (Mins)	Concurrency
PC	90.0	50%	45.0	19%
Smartphone	234.0	50%	117.0	49%
Tablet	120.0	50%	60.0	25%
Gaming Consoles	180.0	50%	90.0	38%
8K TV	10.0	80%	8.0	3%
HD TV (VOD)	202.0	80%	161.6	67%
4K TV	50.0	80%	40.0	17%

Table 2. Concurrency Factors

As expected, concurrency is highest for TV viewing and smart phones during the peak period (7–11 p.m.).

Household Bandwidth Usage

The average rural household data rate during the busy period is the main component of the middle-mile bandwidth requirement. The average household data rate is depicted in Figure 3. It is a combination of application bandwidth requirements, device penetration rates, and busy period concurrency.

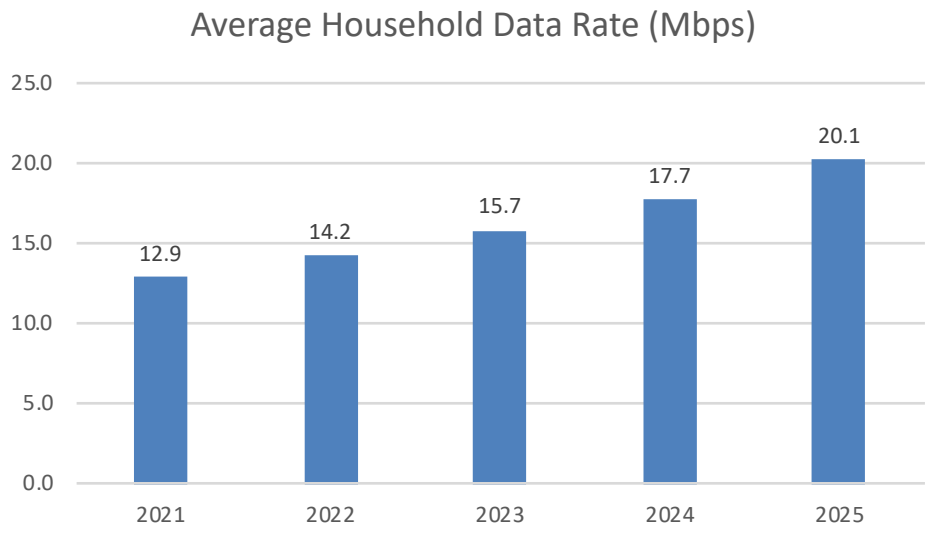

Figure 3. Average Rural Household Data Rate

Network Implications

The growth in the average household busy period traffic is driving the need for middle-mile bandwidth in rural networks. Figure 4 depicts a middle-mile ring architecture in a rural network. Typically, a single ring will serve a rural area with approximately 20,000 households. Given that there are limited alternatives for broadband connectivity in rural areas, the penetration rates for rural service providers will be high. The assumptions for penetration rates and the number of subscribers served in the middle-mile ring are presented in Table 3 and the bandwidth requirements in the middle mile ring are presented in Table 4. The bottom line is that rural middle-mile rings will need to support beyond 200 Gbps throughput in the near term. Our projections show that ring bandwidths of 400 Gbps will be required in 2025 as a result of traffic growth and household penetration rates.

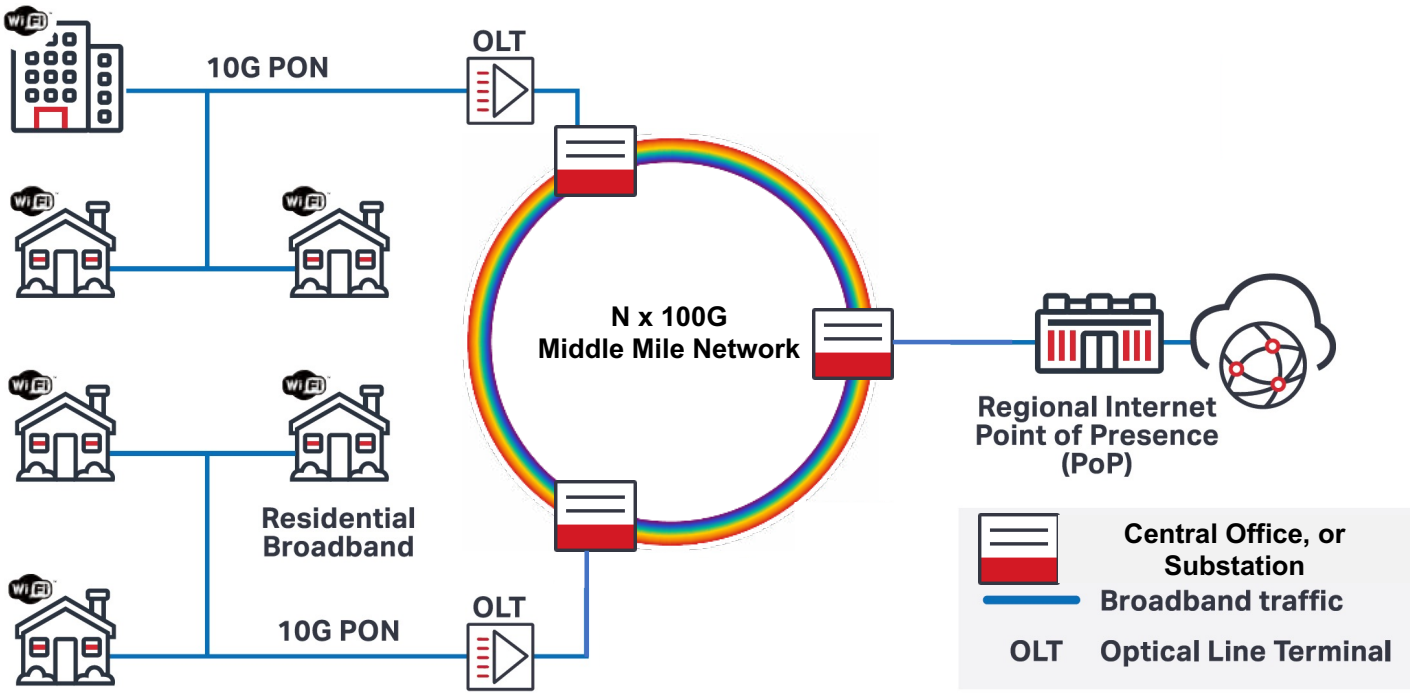

Figure 4. Middle-Mile Network Architecture

	2021	2022	2023	2024	2025
Rural BB Penetration Rate (%)	25%	35%	45%	55%	60%
Number of BB Households Served	5,000	7,000	9,000	11,000	12,000

Table 3. Growth of Broadband Households Served

	2021	2022	2023	2024	2025	CAGR
Average Household Data Rate (Mbps)	12.9	14.2	15.7	17.7	20.1	12%
Aggregate Middle-Mile BW (Gbps)	64	99	142	195	241	39%
Required Middle-Mile Capacity (Gbps)	100	100	200	300	400	32%

Table 4. Middle Mile Network Capacity Requirements

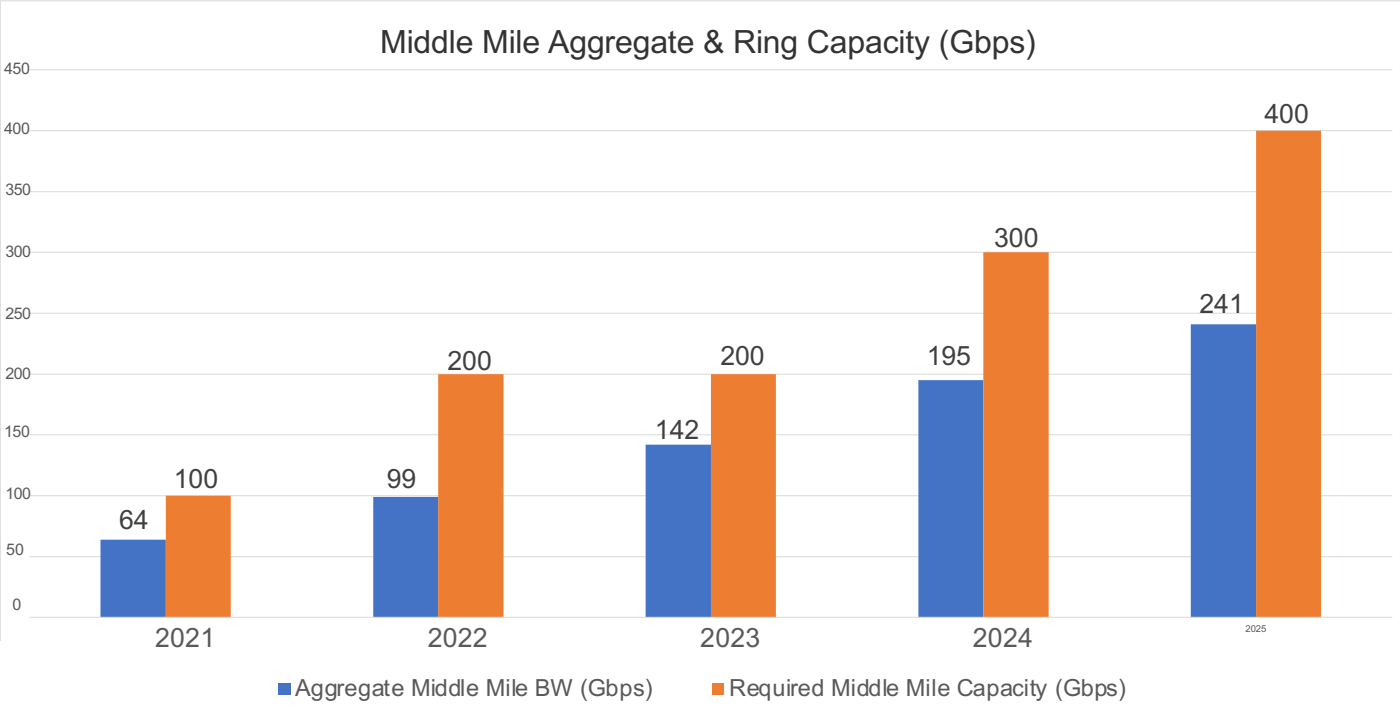

Figure 5. Middle-Mile Network Capacity Requirements

CONCLUSION

As service providers and utilities build out rural broadband networks, an important consideration is the network capacity required in middle-mile rings as the number of subscribers grows and as network traffic continues to increase. ACG has built a detailed traffic model that accounts for network traffic driven by bandwidth-intensive applications. Our model accounts for device penetration, application data rates, concurrency, and traffic growth. We project that average rural traffic per household during the busy period will grow from 13 Mbps in 2021 to 20.1 Mbps in 2025. This drives the requirement for 200 Gbps middle-mile rings by Year 2 (2022) and 400 Gbps middle-mile rings by Year 4. It is critical that service providers plan their network architecture to allow for bandwidth growth in middle-mile rings to support higher capacities.

This discussion is particularly critical. Because of the tight timelines for network expansion, many network operators are still replicating past architectures and platform choices that may prove incompatible with the demand evolution. As they deploy aggregation platforms that do not easily scale beyond 100 Gbps, they must replace these platforms at much shorter intervals or are forced to make substantial additional investments, such as adding a new layer of platforms, as the traffic demand grows.

A solid forecast of the evolution of broadband traffic demand per household can help in planning new broadband network builds. With a greater understanding of future network requirements, we expect service providers will be able to select the best architectures and platforms to support their business growth and ultimately maximize the return on their investments.

This paper is a collaborative project between Ciena and ACG Research.

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