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Broadband Access in City of Columbus, Ohio

Assessment and Strategies for Addressing the Broadband Gap

Commissioned By:
The Columbus Foundation

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1. Introduction and Scope

The internet has dramatically altered the ways in which people engage with the world around them, the way they communicate, learn, and access vital services and information on a daily basis. Over the past three decades, the speed and convenience in which individuals can exchange views, conduct business transactions, access healthcare and government services, and obtain other critical services has grown exponentially. For some the internet may feel like ever-present resource, but a surprising number of Americans still do not have fixed broadband internet access. A Pew Research study finds that 33 million Americans—10 percent of the population— still lacks adequate internet access. The latest Census Bureau American Community Survey finds many census tracts and entire counties with less than half the households having home internet access.

This report was generated within the context of a larger working group of concerned citizens and organizations in the City of Columbus looking to understand how to close the Digital Divide within their community. The Digital Divide is a larger and more varied topic than broadband access, involving factors across many domains including access to connectivity, devices, and literacy. Within the wider context of this group, this report focuses on providing data and analysis around the availability, differentiation, and lack of adoption of internet services by households in the City of Columbus, Ohio as a foundation upon which other policy and planning discussions may be framed. Specifically, we have been asked to present maps and visual information outlining the presence of broadband service within the City of Columbus, to identify or prioritize areas where there may be a need for increased access, and provide short and long-term recommendations for increasing access in these areas. We recognize that the City of Columbus is part of a larger context with Franklin County and also Ohio State, however the scope of our report was limited to City of Columbus.

AECOM began working on this analysis in May of 2020 and presented the findings of the report in June of 2020. This report is based on public datasets available online, information provided to us by the working group from May to June of 2020, and subscription databases to which AECOM maintains access as an infrastructure company. This research effort did not include access to proprietary information from service providers or in-person surveys in the neighborhoods involved. Public datasets forming the core of this evaluation included the FCC Form 477 Broadband Deployment data, the American Community Survey data, and documents provided by various team members in the working group.

AECOM has broken this report into three major components, an introduction to the topic of broadband and definition of terms, the evaluation of current internet service access and finally, the presentation of possible solutions based on precedent and industry best practices.

We encourage the working group to continue to propose efforts and pursue all means for addressing each element of the Digital Divide.

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2. Executive Summary

Through the course of our evaluation of current internet service access we learned that physical telecommunications infrastructure in Columbus is widely present across the city. Some datasets we analyzed indicated areas with gaps in coverage but in all cases our further exploration of these areas indicate these appear to be artifacts in the dataset, that there was more than one fixed broadband service provider option in those gap areas. More information on this is presented in the section Existing Broadband Service Provider Access. Our conclusion is that the condition driving lack of adoption of fixed broadband access in these areas is more complicated and diverse than simply lacking broadband infrastructure. The factors driving lack of adoption appear to be, in no order, economic factors, technical literacy, and personal choice. More on this is presented in the section titled Understanding the Broadband Gap.

This report therefore finds that the Broadband Gap in the City of Columbus is not the result of a gap in infrastructure and that any strategy for closing the Broadband Gap will have to be addressed with community planning, subsidies, and public private partnerships aimed at improving the economic model and lowering the cost barrier to home internet adoption. We have proposed a combination of short, medium, and long-term solutions.

Short term solutions require results before construction or infrastructure plans could be enacted. The fastest way to close the gap is to better utilize the infrastructure that is already in place with education and subsidy programs that allow more people to utilize existing fixed and mobile broadband infrastructure by lowering the barrier to adoption from an average of $50 per month to a more practical cost for households that are economically challenged. Options include additional education efforts around existing residential broadband service options and subsidy plans where communities may lack the digital literacy skills or access to evaluate options and leveraging bulk purchases for mobile hot spots and data plans.

Medium-term solutions include leveraging existing city and community buildings and network infrastructure to expand access to existing city and community provided Wi-Fi access points including expanding coverage at major parks, community centers, and pedestrian areas. Another medium-term solution involves extending city and community network infrastructure wirelessly further out into surrounding neighborhoods using managed wireless infrastructure such as wireless mesh solutions.

Long-term solutions will depend on budgeting, regulatory, and teaming opportunities. Best practice long-term solutions should consider the economic model or business case in addition to planning for best practice service speeds and reliability. Long term solutions should recognize the critical nature of the infrastructure and consider the speed and throughput requirements of residents being asked to work and learn from home for extended periods of time. In the longer term these will primarily center around opportunities for Public Private Partnerships leveraging existing public or municipal dark fiber and partnering with private service providers for last mile connectivity to the home.

Please refer to the full report for the background on understanding broadband terms and technologies, our findings on the state of internet access infrastructure in the City of Columbus, the nature of the Broadband Gap, and our recommendations with case studies.

3. Introduction to Broadband

In this report we present information on fixed broadband access. This discussion includes references to terms and definitions that benefit from some background. There are many reports and statistics on internet usage available in current publication from federal, local, and non-profit organizations, but one of the most helpful in understanding the fundamentals of residential broadband speeds is the FCC Broadband Speed Guide. This guide does a good job of introducing the basic concepts of internet service tiers and the proper evaluation of the recommended minimum connectivity for a household. In this document the FCC outlines several usage scenarios and categorizes them as Light Use, Moderate Use and High Use which, when combined with the number of users requiring concurrent internet access at a residence, corresponds to a recommended service tier. These service tiers are described as Basic, Medium, and Advanced. Charts from the FCC Household Broadband Guide are included in this report for reference. The full guide can be found at: https://www.fcc.gov/consumers/guides/household-broadband-guide.

It is important to address a common misunderstanding about the terminology used in broadband access networks. The terms bandwidth, throughput, and speed are often used interchangeably to describe how much data can be transmitted to or from an end user. But there are technical differences between these terms that should be understood. Although bandwidth is the most common term used in this context, when talking about that data transfer as a consumer, we are technically referring to **throughput,** not bandwidth. Throughput is a measure of how much data is transferred from source to destination. **Bandwidth** is a measure of how much data could be theoretically transferred from source to destination under ideal conditions. It is helpful to think of bandwidth as a multi-lane highway in which only a certain amount of traffic is passing through (throughput). A service provider may build a fiber network capable of very high bandwidth, however they do often throttle the traffic to achieve a lower throughput. **Throughput** measures speed while **bandwidth** is only indirectly related to speed. Therefore, it is appropriate to interchange the terms throughput and speed.

The data throughput requirements of various common internet and corporate applications is what forms the basis for the FCC speed tiers. As an example, streaming HD video is characterized as requiring 5 to 8 Megabits per second (Mbps) while streaming a podcast or online radio is characterized as requiring less than 0.5 Mbps. A list of throughput datapoints is presented below, including FCC established data points as well as throughput recommendations for some common consumer applications such as Zoom. Note that the FCC established datapoints only specify the download speeds but for interactive or collaborative applications such as video or audio conferencing, something of critical importance during a government mandated stay-at-home times such as we are experiencing currently with Covid-19, the upload capability is equally critical.

Application / Usage	Download (Mbps)	Upload (Mbps)
Typical Application Speeds (minimum sustained)		
Youtube HD video	5	0
Youtube UltraHD Video	20	0
Zoom Meeting - HD Group Calls	3	3
Audio Streaming	Less than 0.5	0
Web Conference Audio	Less than 0.5	1
FCC Datapoints from FCC Broadband Guidelines		
General Usage		
General Browsing and Email	1	(Not Given)
Streaming Online Radio	Less than 0.5	(Not Given)
VoIP Calls	Less than 0.5	(Not Given)
Student	5 to 25	(Not Given)
Telecommuting	5 to 25	(Not Given)
File Downloading	10	(Not Given)
Social Media	1	(Not Given)
Streaming Media		
Streaming Standard Definition Video	3 to 4	(Not Given)
Streaming High Definition (HD) Video	5 to 8	(Not Given)
Streaming Ultra HD 4K Video	25	(Not Given)
Video Conferencing		
Standard Personal Video Call (e.g., Skype)	1	(Not Given)
HD Personal Video Call (e.g., Skype)	1.5	(Not Given)
HD Video Teleconferencing	6	(Not Given)

Table 1: Broadband Access Requirements for Typical activities and Usage Profiles

The FCC maintains a definition of broadband which it refers to as a “Performance Benchmark for Fixed Service”. This definition is important due to its frequent usage in governance and regulatory work. The FCC has defined and updated their definition of Broadband several times. In 1996 the FCC definition of Broadband was 0.2 Megabits per Second (Mbps) download and 0.2 Mbps upload. This increased in 2010 to 4 Mbps download, 1 Mbps upload. In 2015 the FCC increased the benchmark of broadband to the now current 25 Mbps download and 3 Mbps upload or 25/3. This 25/3 definition was a major improvement but as this report shows, in the current stay-at-home situation and with new technologies that have become more prevalent since 2015, any plans for building out new infrastructure would be wise to target a higher standard or tier of service. Further information on the history of the FCC definition of Broadband can be found on the FCC website and in the article on Broadband Definition at BroadbandNow at: https://broadbandnow.com/report/fcc-broadband-definition/#:~:text=The%20official%20FCC%20broadband%20definition,Mbps%20download%2C%201%20Mbps%20upload.

The latest FCC report on Broadband Deployment, 2019 Broadband Deployment Report, discusses the introduction of other benchmarks such as latency, data caps or “allowances”, and pricing. Ultimately, the 2019 report dismisses inclusion of these additional metrics in the official benchmark as not affecting, “…the underlying determination of whether advanced telecommunications capability has been deployed…” and point to a lack of, “…reliable, comprehensive data sources…” for evaluating these other benchmarks. The latest FCC Broadband Progress Report is the 2020 report, however much of the discussion of benchmarks references the findings in the 2019 report. Online access to the all of the Broadband Progress Reports can be found at: https://www.fcc.gov/reports-research/reports/broadband-progress-reports

In a discussion of broadband definitions, marketing of broadband services, and evaluation of usage, it is important understand the value of these speeds over time. The perception of many subscribers is that these numbers are a promise or minimum speed, however they are typically a maximum speed enforced by the service provider, assuming best case conditions on the network, effectively, a maximum speed. Generally, speed requirements for specific applications are stated as the maximum or peak required and combining users does not simply result in the total sum of the peak application requirements. The nature of maximum versus sustained internet connection speeds and shifts in peak usage time is complicated but it is important to understand how these applications and their throughput requirements impact broadband infrastructure and service tier discussions. The question of what internet speeds should be considered for minimum functional access for a household depends on the way the throughput demand works in real world scenarios.

Peak Throughput:
Streaming media consists of "bursty" traffic with momentary peaks while video buffers. This "bursty" property of streaming media along with variable compression helps accommodate lower speed tiers. At some threshold however, lower speed will still result in stuttering or pauses for buffering. *Real time video* such as web conferencing exhibits more sustained, less "bursty" throughput and low speeds will result in lost video and audio.

Of importance is the fact that the maximum speeds referenced for each of the various applications in the table above is a peak number which occurs periodically and typically for a brief time. For example, an end user viewing a high-definition Youtube video will initially require a peak download rate between 12 and 25 Mbps depending on the network conditions at that time. However, assuming sufficient throughput, that peak exists in time for only a few seconds as the end user's browser queues up, or buffers, the video's initial content. The video may then consume perhaps 2 to 4 Mbps for 15 to 30 seconds before again bursting to a higher peak utilization for less than five seconds. This process continues for the duration of the video. If insufficient throughput is available for streaming video, the browser application will typically freeze the playback while it waits for the content to buffer and then continue from where it paused, resulting in pauses but no loss of information. Other examples of bursty throughput applications include web-browsing, email, and file transfers. With these non-live applications the network simply transfers data at peak available throughput until the information is full transferred. The user perceives this as extended load times.

A different and vital classification of internet application is real-time media. Real-time applications such as video conference calls and voice-over-IP have a sustained throughput requirement over the duration of the call with minimal fluctuation. For consumer live video or web conferencing this is between 1 and 3 Mbps for the duration of the call. This is because a live video call cannot buffer (or save in advance) more than 150 milliseconds of video and audio without losing synchronization with the other participants on the call. This illustrates a difference between live video, such as a video call, versus streamed video, such as a Youtube or Netflix show. For live video, a delay in transmitting the data may be allowed for a brief interval, however, if this persists the application will simply skip the information and process the remaining real-time audio and video, resulting in choppy video and lost audio.

Considering the bursty and constantly changing nature of application throughput requirements, service providers need not interpret the maximum speed metrics as a pervasive requirement. For example, combining the requirement for two simultaneous Youtube video streams is not so straight forward as adding together the two maximum speed requirements. Instead the downstream throughput demand is characterized in the figure below which depicts two simultaneous Youtube users each streaming a high definition video for one minute. The result is that two users with video streams requiring a burst of 20 Mbps do not result in infrastructure that requires 40 Mbps rather, the brief peaks rarely overlap and therefore the sustained demand is more often less than 4 Mbps per stream. In this example, an internet connection with 25 Mbps throughput would be sufficient to support both streams with no impact to buffering times. A 10 Mbps connection would result in more time at the peak as the lower throughput means that the peak period would be extended to account for the full buffering but would likely result in minimal disruptions. A 5 Mbps connection would likely suffer significant buffering and may prove unsustainable, requiring lower video quality to be served.

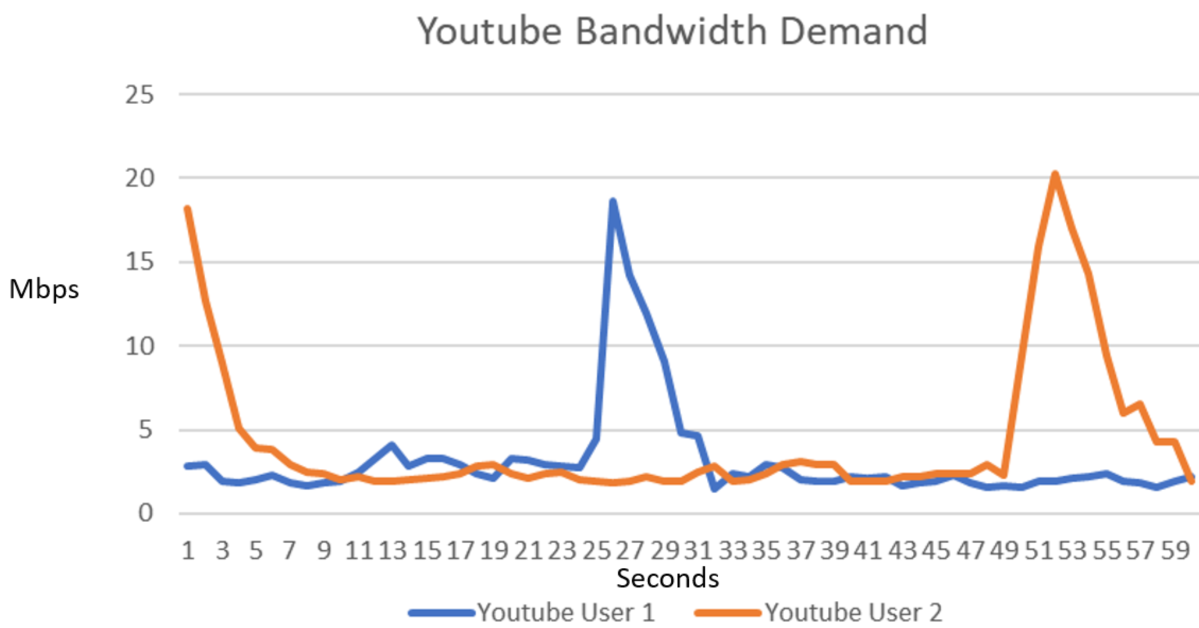


Figure 1: Bandwidth Consumption for Two Simultaneous Youtube users

Since Covid-19 there has been a renewed focus on Internet as a critical social and economic infrastructure element. Students rely on the internet to access school hosted educational materials while adults rely on the internet to work from home. The topic of securing functional access to the internet with enough throughput has become a critical infrastructure question for many communities as service providers have worked to keep up with the increased usage of communities and Cities who have suddenly shifted to working and studying from home.

Covid-19 Internet Speed Shift: During the Covid-19 stay-at-home period, large portions of America have been asked to remain at home, where possible using distance learning and telecommuting applications. This has resulted in a boom in video conferencing with many households having multiple work or school calls simultaneously. This resulted in an explosion in upload throughput unforeseen in the FCC 2015 Broadband Benchmark.

Given the number of things that have changed since the introduction of the 2015 FCC Broadband Benchmark, increased usage of two-way media, namely video conferencing, and increased simultaneous broadband usage, any community looking to ensure a functional level of broadband service would be advised to consider a modification to the 2015 FCC Broadband Benchmark.

Industry trends show an increased prevalence of video calls during the current stay-at-home period and anticipate a general shift to greater video conferencing usage in the near future including video calls for telemedicine, education, work, and other daily services. This increase in video calls means that while 25 Mbps download throughput may be sufficient, the average household will need greater upload throughput capacity during stay-at-home guidance or increased working from home periods, even if it is not a pervasive demand.

Proposed Bandwidth Benchmark: Keep the FCC 2015 25 Mbps download, modify the upload from 3 Mbps (a single video conference stream) to 15 Mbps (up to 4 simultaneous video conference streams)

Our analysis of the functional level of broadband service posits the following scenario for household broadband requirements: a household with four individuals requiring simultaneous participation in working or learning from home. Using the FCC's own suggested minimum download speeds, supplemented with specific application requirements for upload speeds, our recommendation is that **a functional definition for broadband access in 2020 should be based around 25 Mbps download and 15 Mbps upload, or 25/15**. This recommendation accounts for four simultaneous 3 Mbps uploads activities, such as video calls, while leaving some buffer for other tasks.

Our recommendation is that long-term residential broadband planning should account for the added upload demand necessary to accommodate multiple household residents on video conferences, telemedicine, and online learning with the expectation that these applications will continue to trend upwards. We also see a shift from High Definition to Ultrahigh Definition (UHD) video as well as more mobile devices and displays shift to the UHD standard for recording and playback of videos. The last major trend we include in our recommendation for long-term residential broadband throughput planning is the proliferation of Internet of Things and other connected devices that increasingly need to upload and download data to cloud services. Based on these trends, we recommend that projects targeting 2030 and beyond should consider higher minimum speeds tiers forming the basis of the Basic Broadband service, based at 100 Mbps downstream and 25 Mbps upstream. We encourage higher speed tiers to be considered for more advanced usage but view the 25/15 as a recommended new definition Basic Broadband for communities looking to address the topic of the Broadband gap in a post Covid-19 world. The following table presents this progression of historic, current, and recommended broadband definitions.

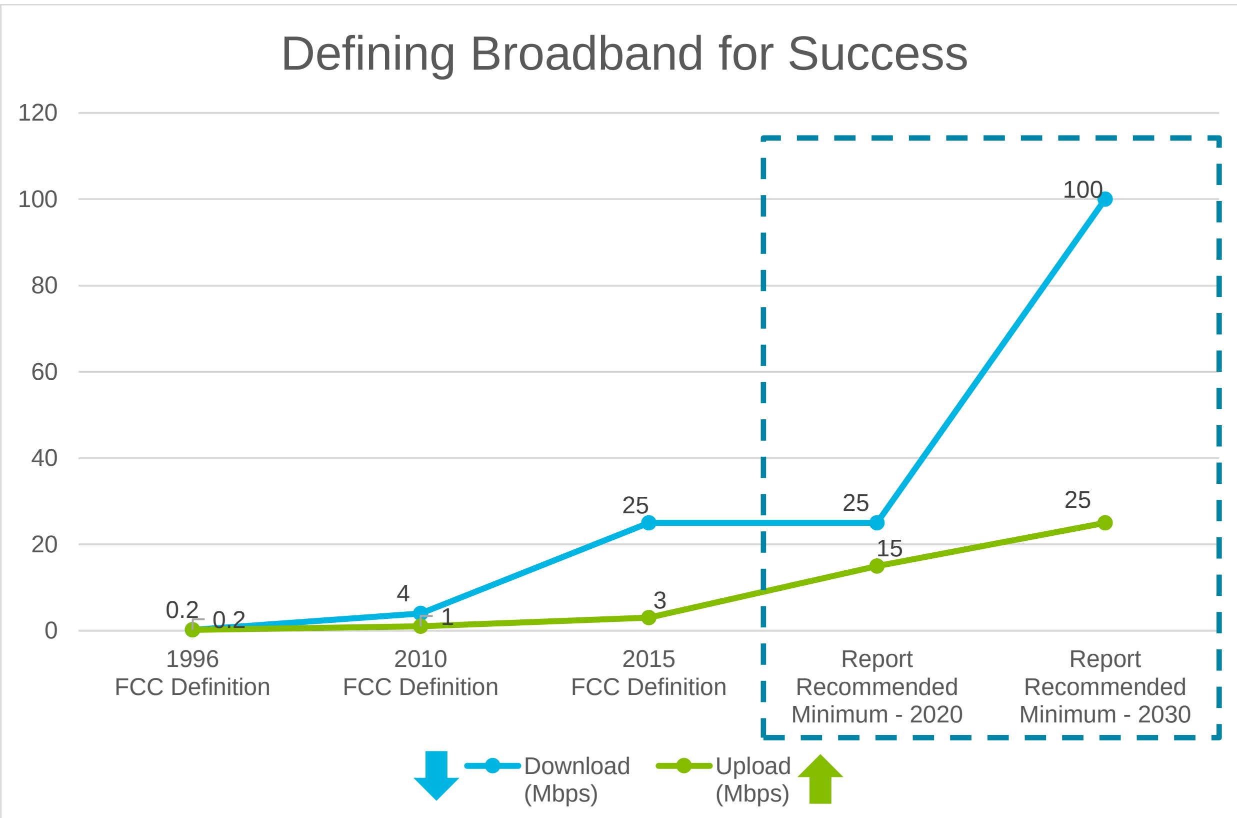


Figure 2: Historic, Current, and Recommended Broadband Definitions

4. Understanding the Broadband Gap

The presence of a significant portion of the population who lack internet access is common across the United States and is an issue being pursued at both the urban and rural level with different approaches.
Understanding the Broadband Gap involves two separate activities, **1) looking for areas lacking sufficient fixed broadband infrastructure** and 2) **looking for areas that have low adoption rates**. These are not necessarily the same locations.

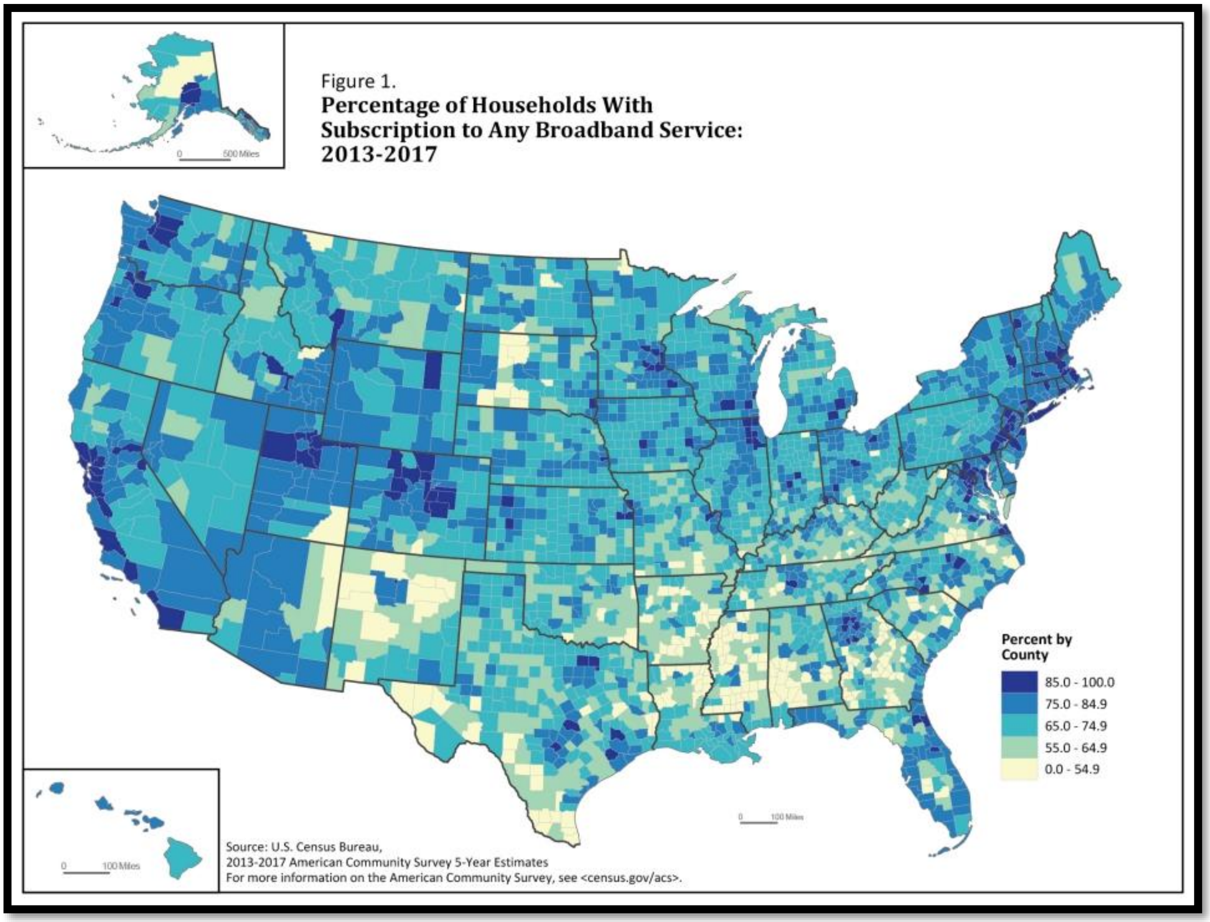


Figure 3: National Broadband Adoption, ACS 2013-2017

The most standardized datasets for this information are the FCC Form 477 Data and the American Community Survey, ACS, data. These are public, nationwide datasets organized by census tract and updated regularly. However, they each have their own shortcomings. The FCC Form 477 data is self-reported by service providers and this can result in reporting errors such as the April 2020 error identified where one service provider incorrectly reported service across census tracts nationwide. Known issues with the ACS dataset include questions about the phrasing of the questions asked and extrapolation from a limited sampling.

AT&T Form 477 Reporting Error
This error did not affect the City of Columbus study. Tracts affected in Ohio were: Athens (39009), Cuyahoga (39035), Erie (39043); Lucas (39095); Portage (39133); and Summit (39153).

The gap in access to internet service is very real. As an illustration of this gap, Columbus City Schools provided an overview of data summarizing those areas with the greatest number of households not accessing school online services such as Clever. In Figure 4 below, the darker purple areas are those with the highest number of students NOT accessing the system, in other words, the darker the purple, the worse the access. As this report demonstrates, these areas largely correspond to the areas with the least internet access as documented by the American Community Survey (ACS) data on internet access and subscriptions.

Identifying Areas of Need

One of the visualizations that most clearly shows the divide in accessing online services was provided by Columbus City Schools in the form of data on students not accessing Clever, the Columbus City Schools Single-Sign-On centralized learning resources portal. This information was provided as a data visualization in Figure 4 below showing areas with the highest concentration of “not accessing Clever” as the darkest purple areas. Note the correlation to the American Community Survey (ACS) data on poverty and ACS “No Internet Access” responses.

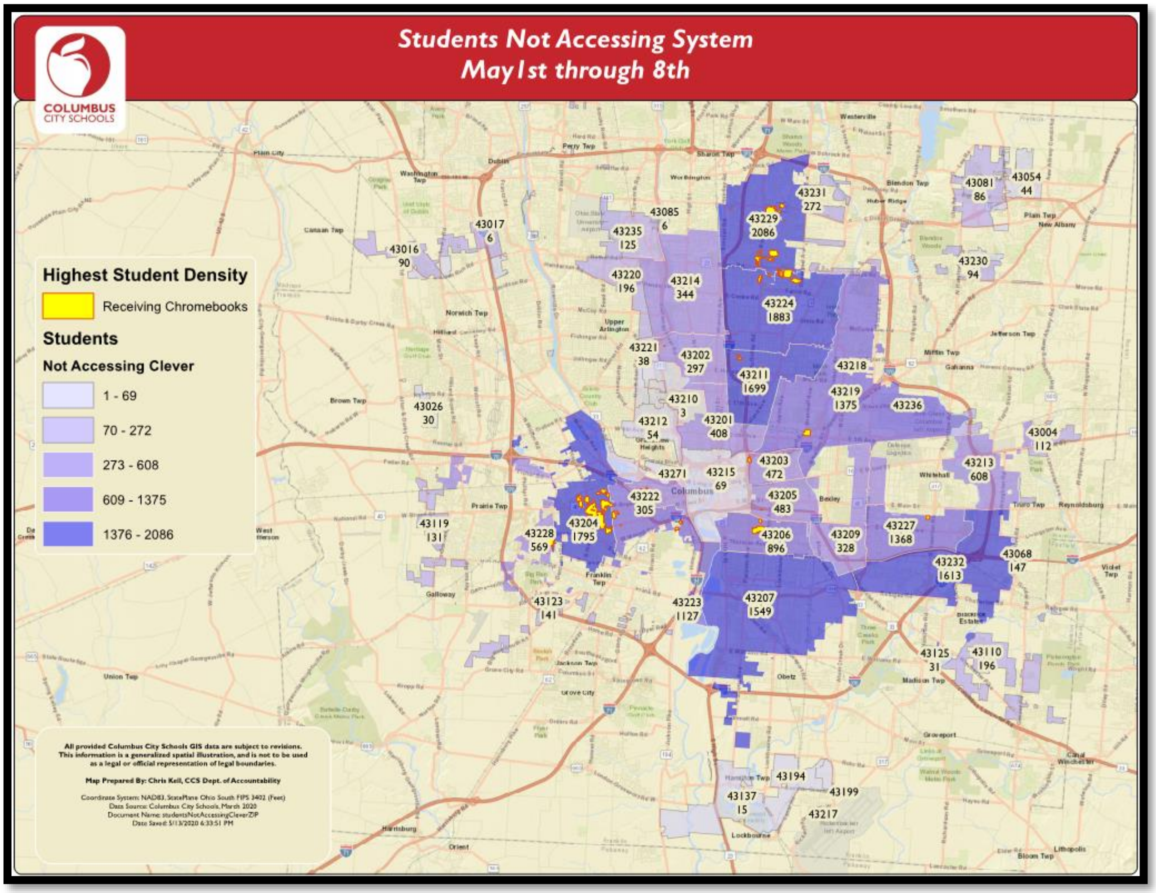


Figure 4: Student Participation in Remote Education

A nationwide survey performed every year, the American Community Survey includes data for all Census tracts nationally based on a smaller sampling with more detailed questions than the Census. The visualizations below are from this ACS data and show responses based on a 5-year average of ACS data from 2013 to 2017 with data extrapolated from samples of areas.

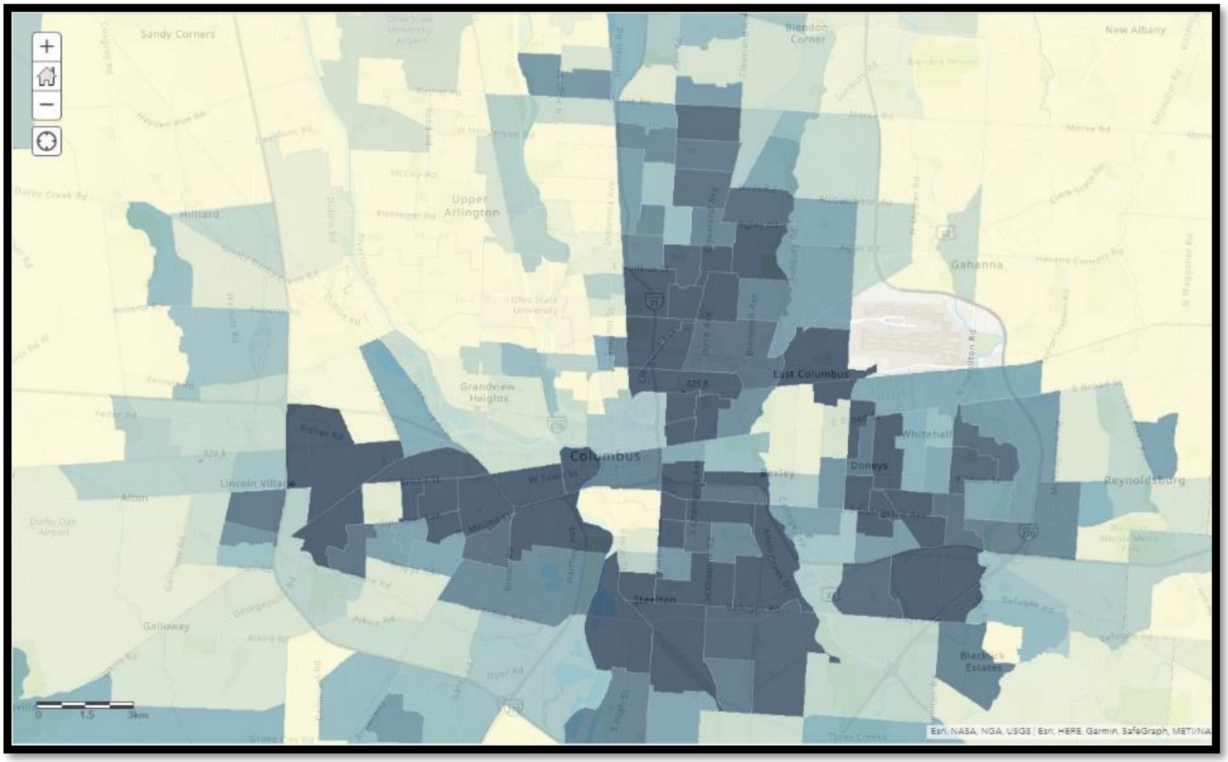


Figure 5: ACS No Internet Access Response, Census Tracks with <5% to >27%

By adjusting the visualization boundaries, an image of the census tracts indicated by the ACS data to have the highest number of responses for “No Internet Access” is returned. In this visualization, the minimum threshold was set at 29% and the upper end for differentiation at 50%.

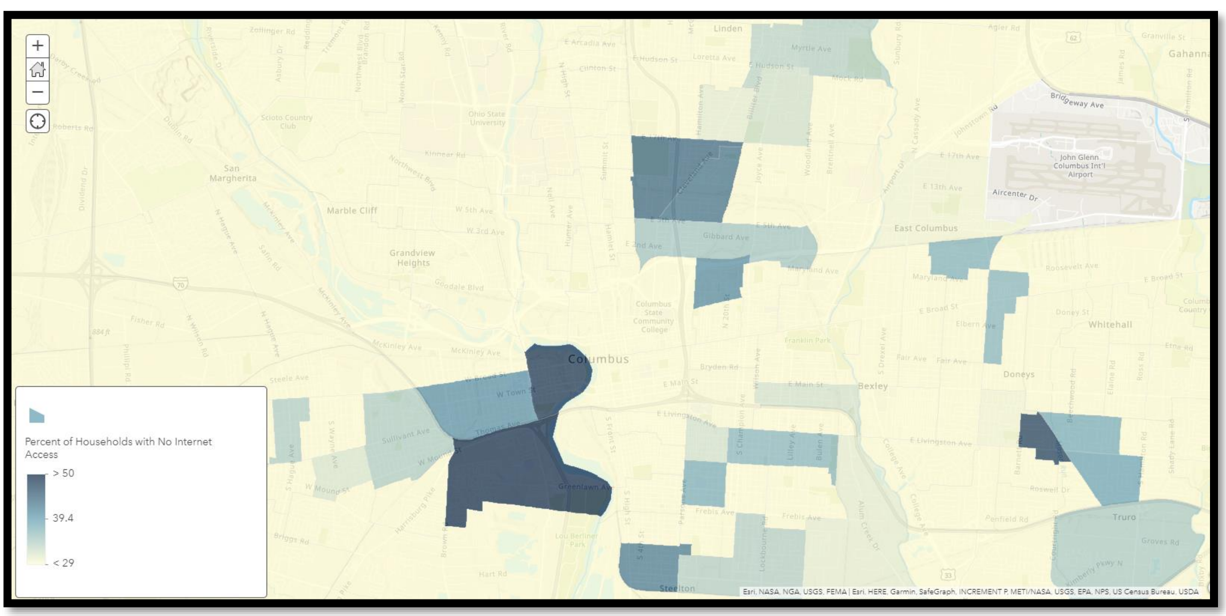


Figure 6: ACS No Internet Response, filtered for 30% or higher minimum

The data from these census tracts is summarized in the following table. This report makes no statement that 30% is the appropriate guideline for action but chose 30% as representing a focused list of the census tracts with the least internet adoption or access. The working group or readers of the report can create a similar list by adjusting the visualization options in the public ACS data live GIS visualizations linked in this report.

American Community Survey Data for Columbus Ohio: Census Tracts with > 30% Responding "No Internet Access"		
Census Tract	Number of Households Without Internet Access	% of Household Without Internet Access
51	438	57.6%
42	142	49.3%
93.31	289	48.1%
14	291	44.6%
15	316	43.6%
61	406	42.9%
29	462	41.5%
50	706	41.0%
93.23	580	38.9%
93.21	347	38.1%
56.20	348	37.9%
27.10	414	37.4%
27.30	388	37.0%
55	642	37.0%
23	175	35.2%
93.25	708	34.5%
49	672	34.4%
46.20	303	34.3%
87.20	469	34.0%
75.20	396	33.9%
9.20	243	33.5%
56.10	227	32.0%
75.11	257	32.0%
54.10	185	31.8%
48.20	291	31.5%
7.30	403	30.7%
87.30	194	30.6%

Table 2: Columbus census tracts with lowest internet access levels per the ACS data

For comparative purposes, the ACS dataset on Poverty by census tract is included here as well. Note the correlation between internet access, school online education system access, and poverty levels (darker shaded areas).

Figure 7: ACS Poverty Demographics, Census Tracks with <2% to >30%

Lack of internet access is a complicated situation but barriers to adoption largely come down to two main categories, the presence or availability of internet access and the affordability or terms of the subscription. This report was commissioned to evaluate the availability of internet service primarily, however in evaluating the data it became evident that the main barrier to accessing the internet was not a lack of infrastructure.

Cellular or Wired Internet?
ACS data shows a correlation between lack of wired internet access and usage of mobile data on a smartphone or tablet. The topic of cellular-only internet is addressed later in this report.

There are numerous sites dedicated to making the ACS data available to community organizations and government members. One location available to readers of this report at the time it was release is the following location.
http://columbus.maps.arcgis.com/apps/webappviewer/index.html?id=599e40323acc46d090eabe37a835c86d

Existing Broadband Service Provider Access

AECOM has analyzed the City of Columbus and surrounding service areas for multiple provider offerings. The research was conducted using a variety of sources such as service provider web pages, service provider external affairs contacts, FCC Form 477 registration databases, American Community Survey (ACS) data, subscription-based fiber and wireless database repositories, and organizations which are focused on the topic of broadband availability and digital inclusion. The following maps show the Service Provider reported data (FCC Form 477) for the City of Columbus across multiple speed tiers.

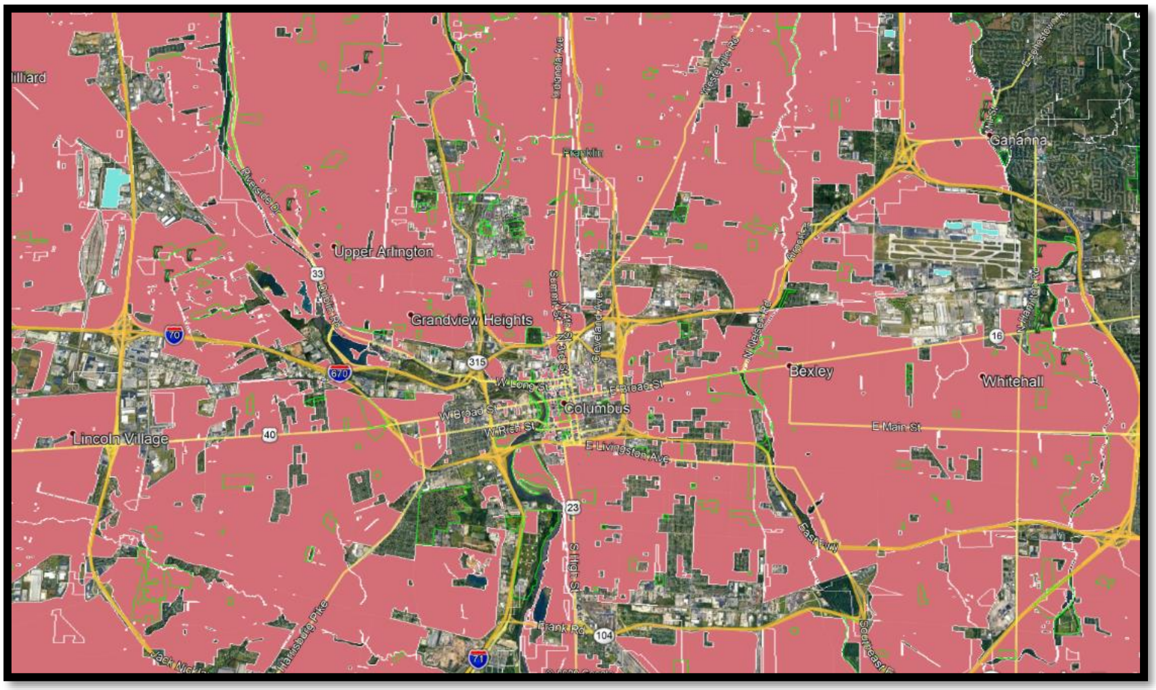


Figure 8: 10Mbps x 1 Mbps Service Availability based on FCC Form 477 Data

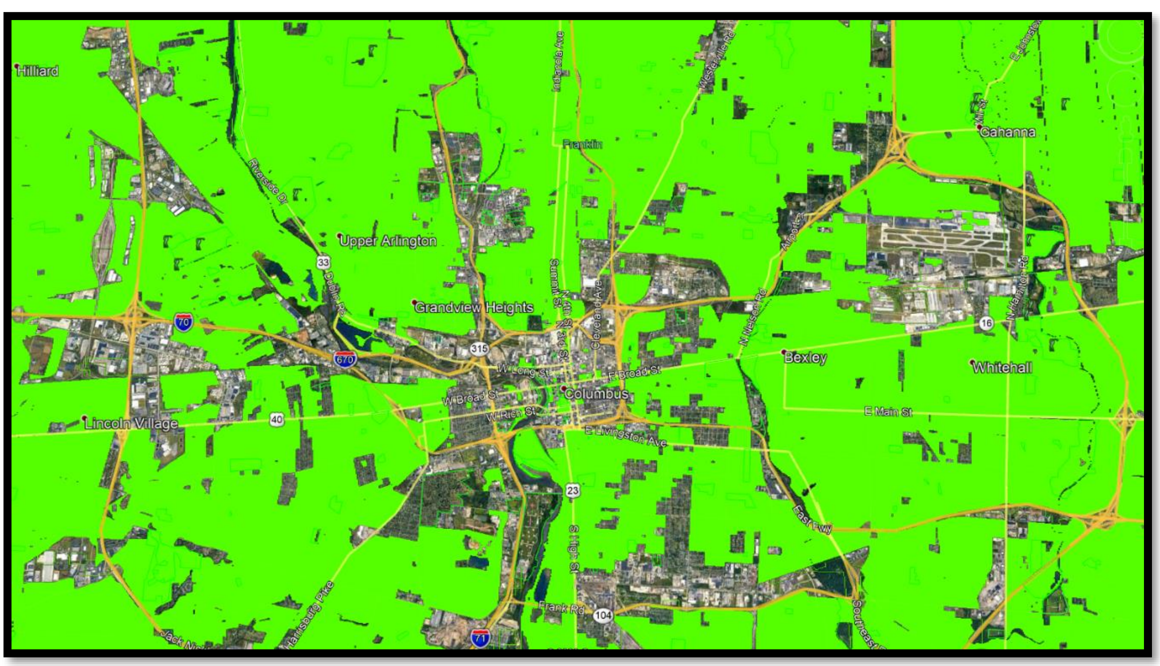


Figure 9: 25Mbps x 3 Mbps Availability based on FCC Form 477 Data

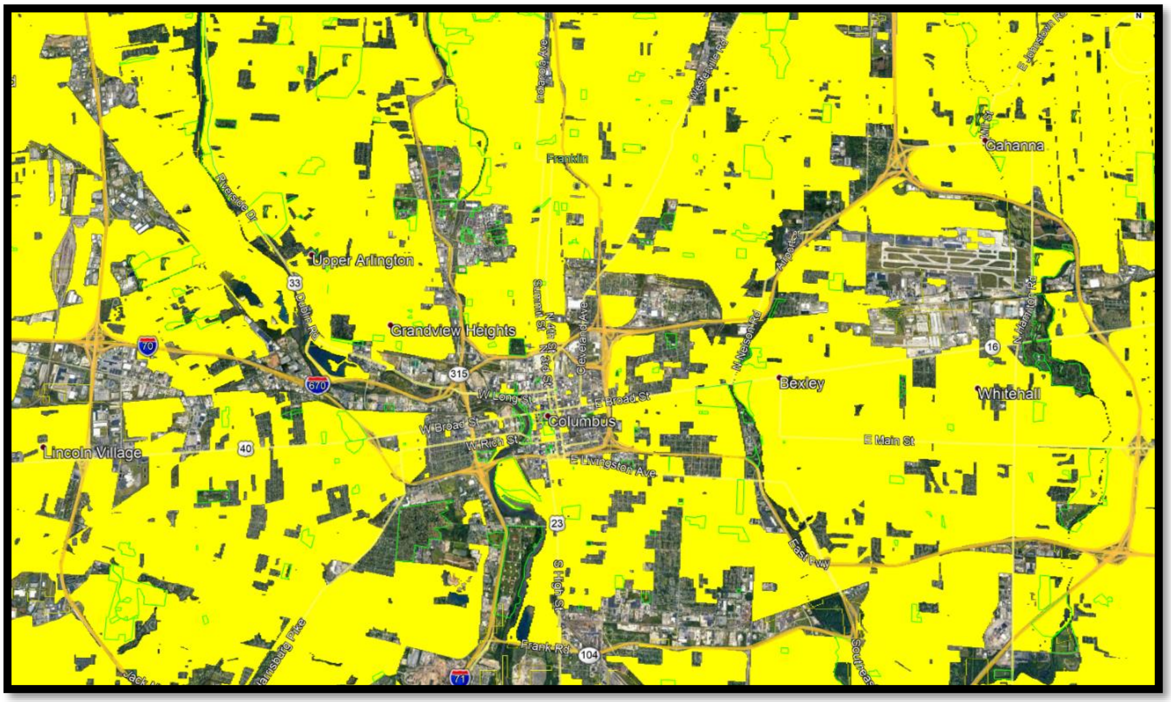


Figure 10: 50 Mbps x 5 Mbps Availability based on FCC Form 477 Data

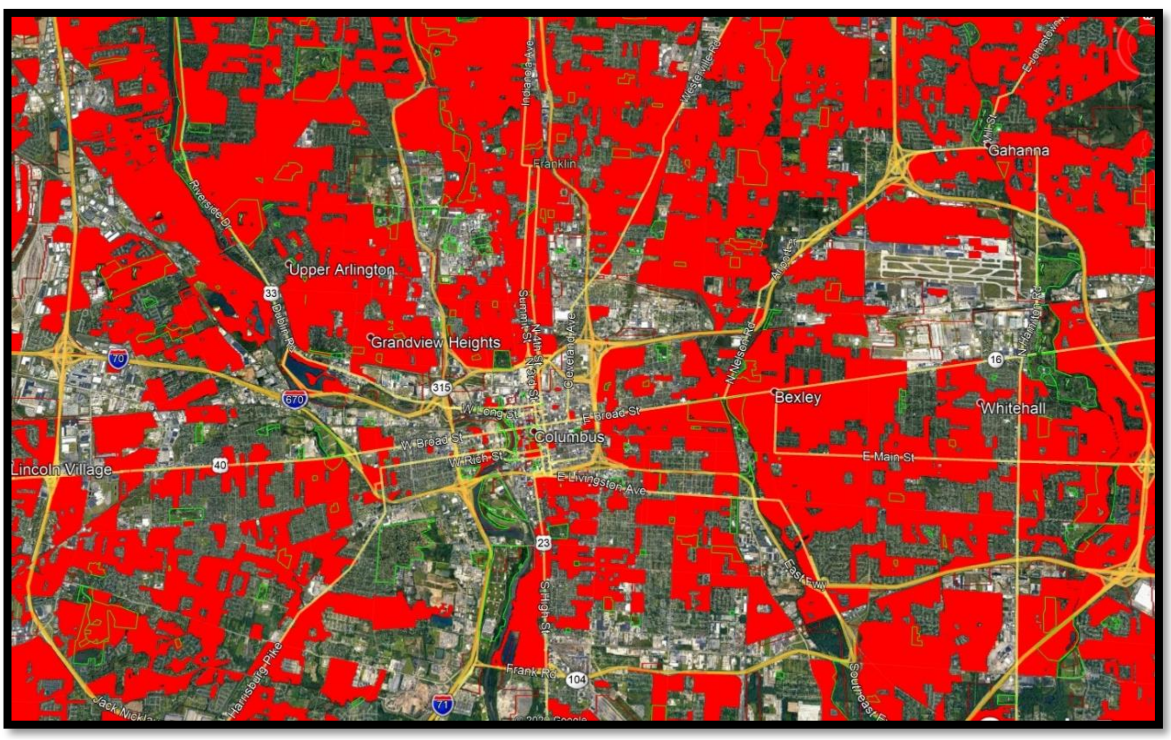


Figure 11: 100 Mbps x 10 Mbps Availability based on FCC Form 477 Data

As depicted in the coverage maps above, there appear to be significant gaps in broadband availability. These gaps are particularly worrisome given that some of them are found in economically challenged neighborhoods as established in ACS data and data provided by the Columbus City School District. However, as we began to validate the data, we found that each of these areas were in fact served by multiple providers and the speed tiers offered were comparable to other service provider areas in the city. For example, the zip code of 43223 has a particularly large gap as shown by the FCC data. As represented by the American Census Survey, the FCC 477 data, and the Columbus School system, this zip code is an area of concern with respect to K-12 remote learning attendance, economic status, and the number of households without a broadband subscription. Looking at AT&T's offering in this specific area reveals speeds only up to 5 Mbps with 1.5 Mbps being the typical offering at a price of $49.99 per month. Relative to the speed tiers and costs in other neighboring areas, this is an uncompetitive offering at the price for speed metric. However, there are some inaccuracies with that data as we find that access to an alternative broadband provider is not the issue as depicted in the figure below. By looking at other providers in these areas, we see more competitive price for speed offerings. This was typical of our findings in performing these spot checks, one service provider may have a non-competitive offering in an area, but others offered better price to speed, but the overall subscription cost remained high.

There are multiple areas within the city that have similar data discrepancies showing a lack of service or high speeds when in fact there are viable options for consumers. Another example is Zip Codes 43204 and 43207 which represented some of the highest rates of non-participation in online school activities. The figures below however reveal that the reason is not likely due to a lack of broadband services being available.

The methodology used to validate the FCC service provider data was to select specific areas within the top five zip codes of concern (prioritized based on poverty level, Census survey responses regarding internet subscriptions, and data obtained from Columbus City Schools. We then analyzed those areas for specific geographical barriers that might inhibit a service provider from investing in broadband infrastructure. These potential barriers include bridge spans, railroad tracks, rivers, and major roadways. These geographical features can complicate a broadband infrastructure buildout by requiring additional labor, materials, and administrative overhead such as seeking rights-of-way and other regulatory requirements. Household addresses which were adjacent to these elements were selected first and used to verify which of the service providers were able to provide internet services for that address. Additional addresses were selected along side streets and avenues that spanned the specific area with a focus on household addresses located on a corner as well as near the midspan of the roadway.

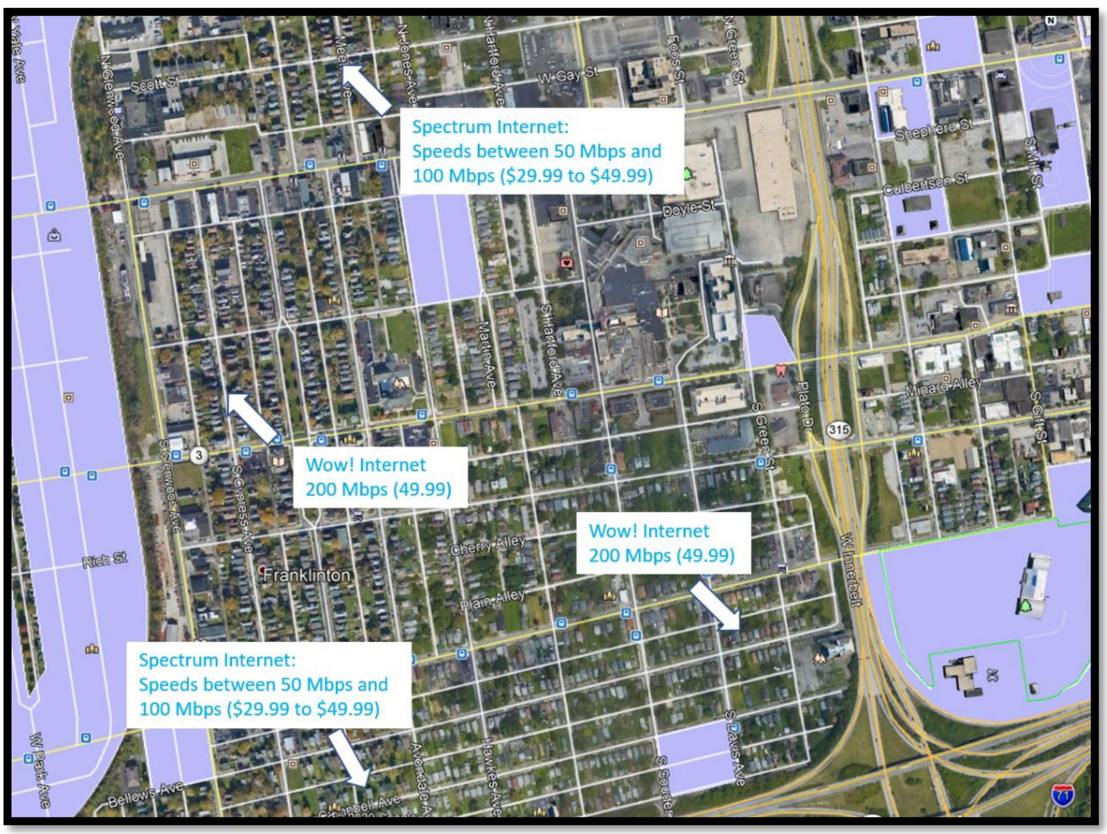


Figure 12: Service Availability Examples in Zip Code 43223

Figure 13: Service Availability Examples in Zip Code 43204

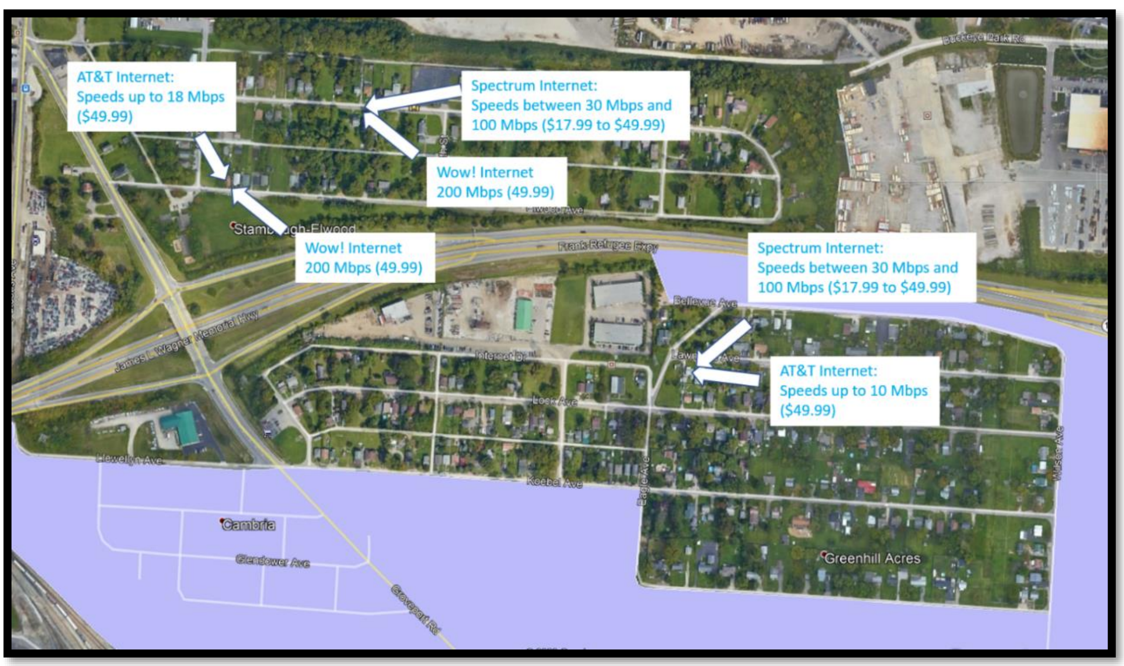


Figure 14: Service Availability Examples in Zip Code 43207

Most neighborhoods are served with at least 4 service providers with some areas having as many as 5. These areas are mostly found in the downtown and surrounding areas including Bexley, German Village, and Grandview Heights. The remaining areas in Columbus are served by at least 2 to 3 internet providers with cable and DSL services being the primary technology. The most prevalent service providers in Columbus are Charter Spectrum and AT&T who have the top two service areas as well as subscriber counts. The competitive footprint for service providers is detailed below by zip code:

Zip Code	AT&T	AT&T Fiber	Bresco Broadband	CenturyLink	Mediacom	Spectrum	Wow!
42223	100	x	50	x	x	940	50
43068	100	x	50	100	x	940	50
43201	100	1000	50	x	x	940	50
43203	100	1000	50	x	x	940	50
43204	100	x	50	x	x	940	50
43205	100	1000	50	x	x	940	50
43206	100	1000	50	x	x	940	50
43207	100	x	50		x	940	50
43211	100	1000	50	x	x	940	50
43213	100	1000	50	x	x	940	50
43219	100	1000	50	x	100	940	50
43222	100	x	50	x	x	940	50
43224	1000	1000	50	x	x	940	50
43228	100	x	50	x	x	940	50
43229	100	x	50	x	x	940	50
43231	100	1000	50	x	x	940	50
43232	100	1000	50	x	x	940	50

Table 3: Service Provider Max Speed* by Zip Code (source: broadbandnow.com)

* AECOM found that the maximum speed data was inaccurate in some cases. While the listed max speed may be available, that does not mean every address in that zip code can be served at that speed. For example, the service provider Wow! is able to provide up to 200 Mbps in some of these areas and AT&T's DSL service was often less than 100 Mbps.

Note that satellite-based internet service providers such as HughesNet and Viasat were excluded from this list due to insufficient upload speeds. As shown in the Introduction to Broadband section, upload speeds are critical for working from home and distance learning functions. In the future, the next generation of satellite offerings such as those being developed by Starlink, plan to offer gigabit service with a planned 30 to 50 millisecond latency which is an improvement over previous satellite-based services. The target audience for Starlink however are areas where no broadband or satellite service is available. Although the service is beginning beta testing this summer, it remains to be seen how quickly the service will be generally offered, what latency and throughput or speed will be, as well as what the price model will be.

Satellite Broadband:
Pro's: Limited Buildout costs
Cons: Lower upload speeds and higher latency
Next Gen: A new generation of Satellite internet services are in development and are aiming to address the digital divide topic, but initially aimed at areas remote from existing infrastructure. i.e. rural and under-developed areas.

AECOM concluded that even in economically challenged neighborhoods, one or more high speed internet providers is available for consumer internet services.

Additional resources for accessing and visualizing the FCC and the ACS data can be found at the locations below:
City of Columbus GIS:
http://columbus.maps.arcgis.com/apps/webappviewer/index.html?id=599e40323acc46d090eabe37a835c86d

Mapping Data Created by MORPC:
https://www.arcgis.com/home/webmap/viewer.html?webmap=dbe9615d3423404a87257577a3cfdfe8&extent=-83.206,39.86,-82.6989,40.0776

FCC Broadband Deployment web tool: https://go.usa.gov/xwpAj

https://broadbandmap.fcc.gov/#/area-summary?version=jun2019&type=nation&geoid=0&tech=acfosw&speed=25_3&vlat=39.99594817197561&vlon=-82.99799706212838&vzoom=10.380680405214546&scheme=ramp3

Existing Broadband Service Provider Pricing

The list of broadband service providers in the Columbus area is long. The large operators certainly have a considerable footprint throughout and there are quite a few mid-tier operators as well. However, the remaining list of operators do not represent a ubiquitous list of competing services in the region. In fact, the operating footprint of some of the smaller carriers is surprisingly small and often fractured. This is likely due to the presence (or lack thereof) of metro and long-haul fiber which is either owned by the service provider or leased. Such a factor, combined with the business requirements and demographic of potential subscribers in a given area, can often result in an erratic geographical footprint for services offered. In general, and throughout the country, service providers do their homework when pursuing a new broadband market area. Aside from typical consumer demographics such as median age, income, or the density of homes, the business model may be focused on underserved areas or existing markets that do not cater to business needs or offer fewer tiers of service. Other factors may include opportunistic synergies such as negotiating to install infrastructure for a greenfield development in exchange for franchise rights to the area. Other operators may simply plan on only providing internet services without the complexities of voice or video services which often increase the regulatory and licensing overhead for a broadband provider. These factors typically drive broadband providers across the nation to build a varied set of pricing options that fit the budget and requirements of the subscriber market.

For the Columbus area however, we find that the service provider offerings for internet-only service is quite generic in terms of options. While there are some lower speed tier options available in a specific area, the pricing is often not enticing enough for the average consumer to consider. We find it common that the service provider also imposes additional fees such as $10 per month equipment fees or onerous minimum contract terms of 2 years. There is often an introductory price which increases at the end of the minimum term. In most of these cases it would make sense for the consumer to purchase the higher-priced option as the lower-priced compromise offers less value. We found this lack of price differentiation to be the case throughout the Columbus area and is likely driven by a focus on higher-priced (and therefore more profitable) bundled packages. While bundling is a common practice in the service provider industry, tier flattening has a negative impact on those households with a limited budget or more narrow set of service requirements who cannot afford the higher tiered service

Tier Flattening
The notion of tier flattening is an important topic in discussions of Digital Divide as lack of differentiated service with lower speed tiers at lower costs can present barriers to adoption by lower income households. Further information on Tier Flattening can be found at the NDIA website:
https://www.digitalinclusion.org/blog/2018/07/31/tier-flattening/

Existing Wireless Service Availability

The Columbus region is well served by wireless service providers. AECOM has analyzed the region to expose any gaps in coverage and found no apparent deficiencies in both cellular tower siting or geographical anomalies that could impede a wireless provider's signal. The figure below provides actual antenna siting within the area and is inclusive of all wireless service provider's networks. AECOM performed map-based measurements in economically challenged areas where an interior antenna siting within a neighborhood was not available. In all cases, a perimeter antenna location was available in less than 3000 feet which is indicative of a wireless infrastructure that is serving a dense and healthy subscriber market.

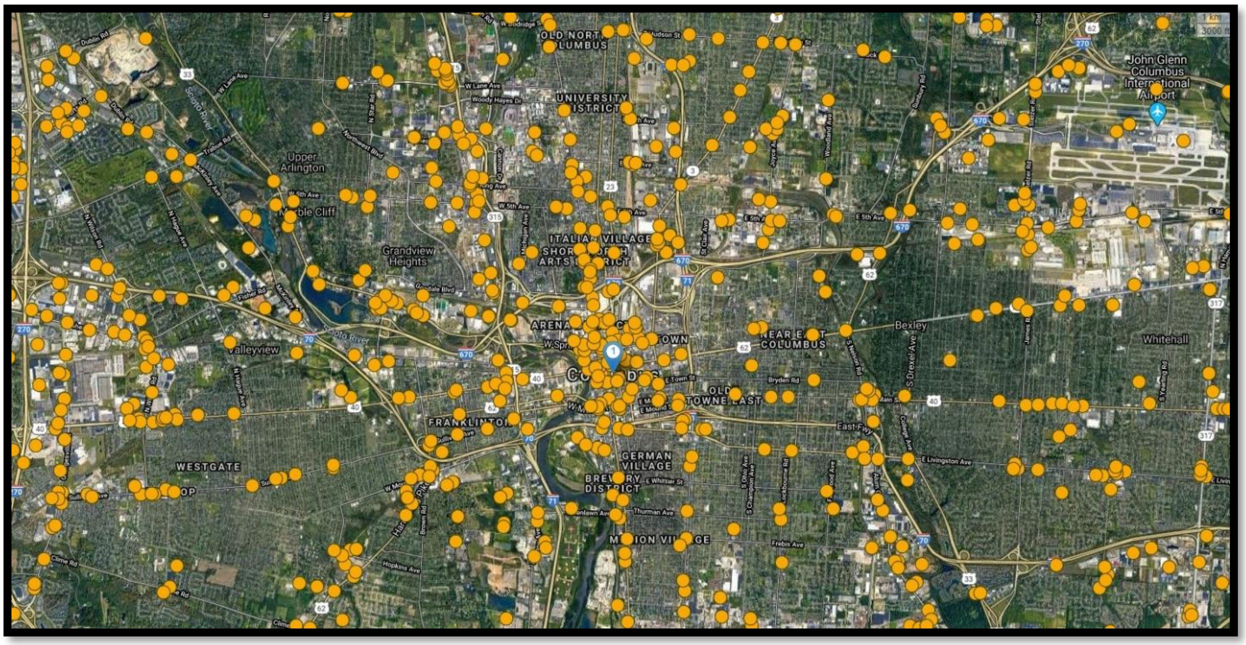


Figure 15: Cellular Antenna Siting

The primary wireless providers in the Columbus region are:

- AT&T LTE
- Sprint LTE
- T-Mobile LTE
- Verizon LTE

By utilizing one of these providers, a consumer can expect reliable coverage throughout the area. Other tertiary providers do provide services however they are likely utilizing infrastructure from one of the providers above. In general, no coverage gaps exist until 25 miles southeast of Columbus or 35 miles northeast of the city. It is important to note that coverage gaps can occur within a well-served area due to architectural and structural elements in buildings. The largest impedance to wireless signal propagation is what is known as low-e glass or low emissivity glass used in newer and refurbished buildings and homes. Low-e glass contains metallic coatings or is manufactured with a metallic film that blocks solar heat and therefore improves a home or commercial building's energy efficiency. Unfortunately, low-e glass effectively blocks electromagnetic (EM) radiation from penetrating the glass, thereby reducing the efficacy of wireless signals inside the building. In many cases a small cell signal booster or, in the case of larger commercial facilities, a distributed antenna system (DAS) can be deployed to remedy this problem.

The ACS data shows a correlation between low wired internet subscription areas and high mobile data only areas. This is in keeping with information provided by the working group that many households facing a financial barrier to wired internet have chosen to prioritize mobile data. During a time of stay-at-home orders such as much of the country is facing right now, this significantly disadvantages these households as data plans often come with data caps not designed with the needs of providing an entire households 24/7 data requirements.

However, deploying mobile data hotspots as stopgap coverage for households with no wired internet is an effective means of temporarily providing internet connectivity and is an approach being pursued by many government and charitable organizations with growing traction. The emergence of 5G may make this a more sustainable method of covering households especially where there is a lack of wired infrastructure. Further information on cellular data as residential broadband solution is provided in the technologies and recommendations section of this report.

5. Closing the Gap – Current Programs

A number or service providers, city government, and charitable organizations have existing programs in place or in development to bridge the cost and affordability gap. Additionally, many of the service providers have put temporary programs in place to address the unusual conditions of Covid-19. Below is a summary of some of these programs.

Subsidies Preceding Covid-19

There are several federal and service-provider programs focused on discounts and or subsidies for internet connectivity. The important consideration for all these programs is that unless a household has already enrolled in a low-income assistance program like public housing or SNAP, it is unlikely they will qualify for assistance paying for home Internet. However, many providers have plans geared towards low-income customers by pairing a discount with the service. Below are examples of those discounts which can be applied to a typical recurring fee of between $29.99 and $49.99 per month.

- AT&T – Up to 10 Mbps for $5/mo. or $10/mo.*
- Cox – Up to 15 Mbps for $9.95/mo.*
- Mediacom – Up to 10 Mbps for $9.95/mo.*
- Spectrum – Up to 30 Mbps for $14.99/mo.*
- Xfinity – Up to 15 Mbps for $9.95/mo.*

*Nearly all providers require installation fees and monthly equipment charges.

Broadband Relief for COVID-19 Impacts

The following is a synopsis of broadband service providers discounts and benefits related to the COVID-19 pandemic as well as benefits for economically disadvantaged households. There were additional COVID-19 financial relief programs available in the early spring of 2020 however the deadline for those registering with those programs has passed. The following is the state of Covid-19 relief programs as of June 2020. These existing plans may factor into or provide a model for future subsidies to lower the cost barrier to adoption.

AT&T

AT&T offers a program called “Access” which provides SNAP participants with 10 Mbps internet access at a $10 rate with no contract or installation fees. The discounted service will include a monthly data allowance of either 150GB, 300GB or 600GB data/mo. depending on the type and speed of service available (3 Mbps, 5 Mbps, and 10 Mbps respectively. After June 30th, 2020, if the monthly data plan allowance is exceeded, AT&T will automatically charge $10 for each 50GB of data usage in excess of the data plan, even if less than 50 gigabytes is used.

Through June 30, 2020, AT&T is offering several temporary relief terms for customers including:

- Will not terminate any postpaid wireless, home phone, or broadband residential or small business account
- Waive any late payment fees
- Waive domestic wireless overage charges
- Keep AT&T’s public Wi-Fi hotspots open for any American who needs them
- Households who participate in the National School Lunch Program and Head Start qualify for a $10 per month access fees for fixed and wireless internet access with unlimited usage.

- 90-Day free access to Cisco Webex meetings
- If activating a new wireless access plan,

For existing wireless hot spot subscribers, AT&T is automatically increasing mobile hotspot data by 15GB a month for each line on an unlimited plan that currently includes a monthly tethering allotment. This provides existing AT&T Unlimited Elite customers with 45GB a month of tethering per line. Eligible hotspot plans include:

- AT&T unlimited plans: AT&T Unlimited Elite, AT&T Unlimited Extra, AT&T Unlimited &More Premium, AT&T Unlimited Enhanced Plus, AT&T Unlimited Plus
- All AT&T Mobile Share® plans
- AT&T PREPAIDSM monthly plans: $75, $65, $50, and $35

Other programs offered by AT&T have either expired or are associated with first responders, employees, and military member serving aboard select U.S. Naval ships.

Charter Communications/Spectrum

Families without internet will be able to get the service at no cost for 60 days from Charter Communications/Spectrum. Charter will offer free Spectrum broadband and Wi-Fi access for 60 days to households with K-12 and/or college students who do not already have a Spectrum broadband subscription at any service level up to 100 Mbps. The service won't be free after 60 days. Customers will have to notify the company to cancel the service to avoid regular pricing. They also offer:

- A broadband Internet access connection, with 100Mbps or 200Mbps download speeds (based on market) and 10Mbps upload speeds, provisioned to the end-user (e.g. student, faculty, staff) and billed to the school or district to support mission-critical remote connections.
- $49.99/ month
- Wi-Fi - $6.99 / month
- No term requirement and no early termination fee on any end-user connection. It requires a minimum of 25 connections within 1 year
- A fully featured business-class modem and professional installation from one of our trained and certified technicians
- Fully outsourced business-class end-user support for questions and technical support, available to end-users 24/7/365

Spectrum also offers Spectrum Internet Assist which is a broadband program that delivers speeds of 30 Mbps for $17.99 per month including the modem.

Comcast/Xfinity

New customers will receive 60 days of complimentary Internet Essentials service, which is normally available to all qualified low-income households for $9.95/month. Additionally, for all new and existing Internet Essentials customers, the speed of the program’s Internet service was increased to 25 Mbps downstream and 3 Mbps upstream. That increase will go into effect for no additional fee and it will become the new base speed for the program going forward. The company also shared that it will not disconnect a customer’s internet service or assess late fees if they contact the company that they can’t pay their bills during this period.

Wow!

Wow! customers who are unable to pay for their service will not be discontinued. Scheduled rate increases are temporarily suspended.

6. Mobile vs Fixed Broadband

Pew Research Center Release the Mobile Technology and Home Broadband 2019 report, available here: https://www.pewresearch.org/internet/2019/06/13/mobile-technology-and-home-broadband-2019/
Based on a January 2019 survey, the data reveals 27 percent of adults reported not subscribing to home broadband, 45 percent of whom said that the reason for not doing so was that their smartphone did everything they needed. A variety of other reasons were provided, as shown in the following graphic:

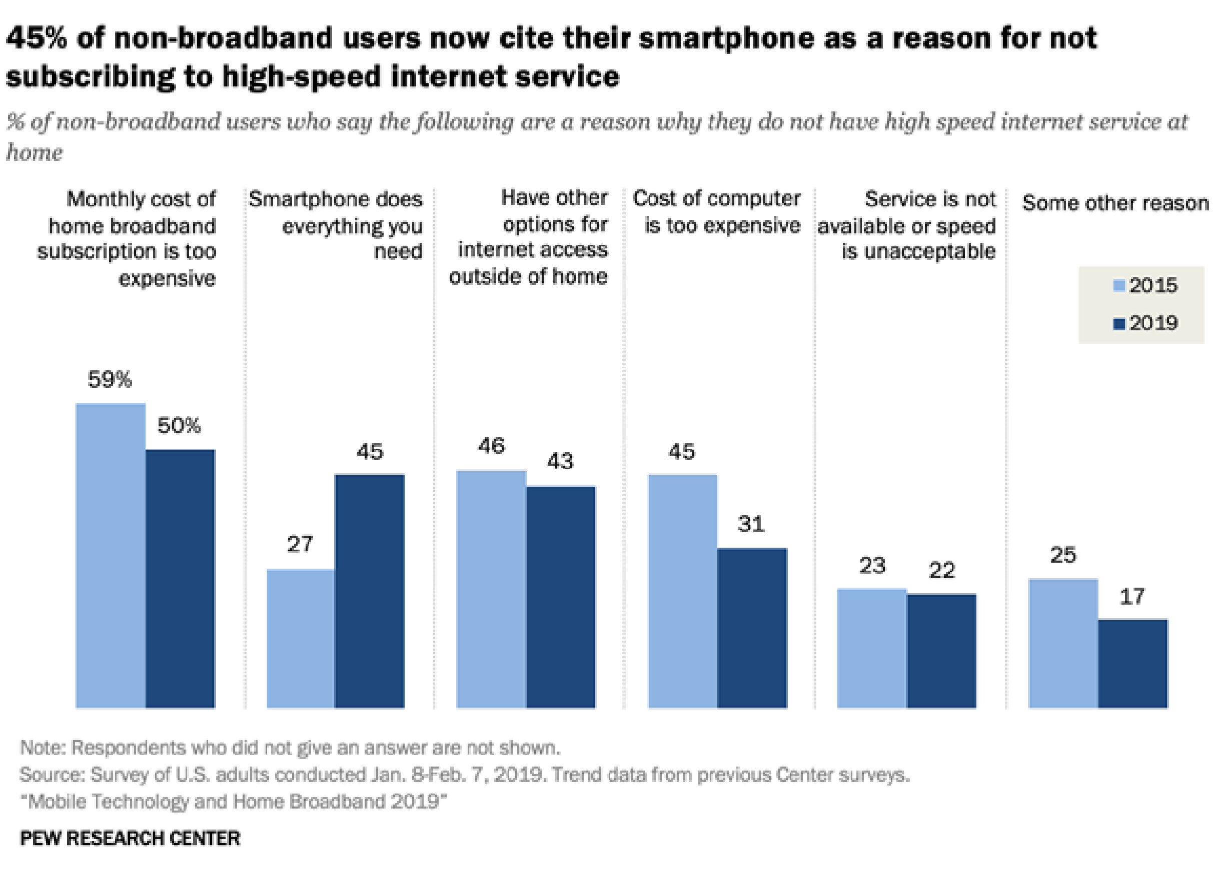


Figure 16: Reasons for Choosing Cellular Data Over Wired Broadband from Pew Mobile Technology and Home Broadband 2019 Report

That same study found that the growth in adults who opted for a smart phone vs. a wired broadband connection grew considerably between 2013 and 2019 as show in the graphic below:

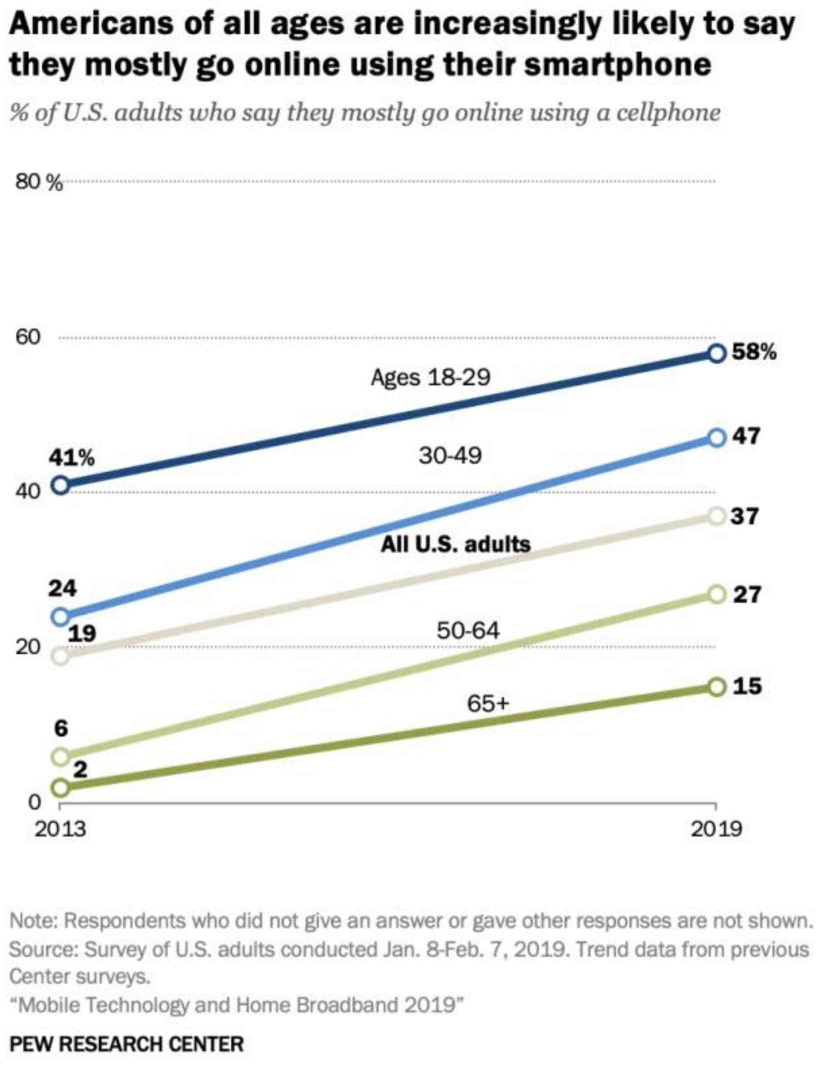


Figure 17: Demographics for Choosing Cellular Data Over Wired Broadband from Pew Mobile Technology and Home Broadband 2019 Report

This is a troubling set of statistics given the goal of improving broadband adoption amid the COVID-19 pandemic. Households that use a smartphone as their primary internet source are (whether the reason is personal preference or economic compromise) not properly prepared for providing adequate throughput for home-bound remote learning. While a smartphone can provide a hotspot Wi-Fi connection for other users, the speeds are not nearly as scalable when two or more users are simultaneously using the service. Given that the students will likely be engaging in video conference applications such as Zoom, there is the likelihood of insufficient throughput coupled with an increased need for monthly usage. This is an untenable situation for lower income households who cannot afford unlimited plans and especially unexpected charges for exceeding monthly data plan allocations. While some wireless service providers are offering unlimited plans and waiving of overage charges, these are currently temporary programs and should not be relied upon as an ongoing budgetary number.

Mobile Broadband at Home
The Covid-19 Stay-at-Home guidance has meant more people working and learning from home. Those who relied on a blend of mobile broadband and free WiFi have faced challenges with teleworking and distance education due to bandwidth sharing limitations and data plan caps and overage fees.

7. Technology for Broadband Access

The following technologies form the basis for any recommended solutions to bridging the broadband gap through infrastructure build out. This is an introduction to the technologies with more guidance on recommended solutions following.

Metro Fiber Deployments

Metro fiber refers to a portion of today's telecommunication networks that many consumers are unaware of. Upstream of the broadband access networks and corporate local area networks (LAN), is an ecosystem of fiber optic companies who employ sales teams, engineers, and technicians to provide wholesale access to fiber optic pathways within and around a given service area. These companies plan, install, lease, buy, and sell portions of their investment in fiber cabling to service providers, municipalities, government entities, and business customers. These fiber networks are expensive to deploy and therefore pricing for this type of "backbone" internet access is beyond the realm of consumer pricing structures. The higher cost is a function of the longer distances the fiber must be deployed through versus the "last mile" type of fiber deployment that is associated with broadband access networks.

Additionally, metro fiber networks are only deployed along paths which make economic sense for the company investing in it. The metro fiber deployment may follow major roads, rail tracks, be adjacent to municipal infrastructure such as water towers, schools, or libraries, and cross under bridges and overpasses. The routes the metro fiber provider chooses to deploy fiber in represent a mix of business and service provider locations as well as underdeveloped areas that are deemed to have a significant growth potential in the future. Metro fiber may pass through suburbs or dense multi-dwelling areas of a city however, this is usually for convenience in reaching the wholesale customers, and not with the intention of serving households directly.

Metropolitan fiber networks (sometimes referred to as "middle mile" networks) have continued to proliferate over the past three decades to the point where it is typically not difficult to locate a metro fiber service provider within a block or so from any urban street corner. These networks serve a variety of purposes including private corporate, municipal services, wholesale backhaul, internet peering, and disaster recovery applications. While the underlying technologies in a metro fiber network vary widely from provider to provider, the end result is scalable, secure, and reliable speeds without the need for constructing expensive fiber links between desired service areas.

Traditionally, these networks were composed of SONET rings that provided a vast array of network speeds using multiple wavelengths of light. SONET technologies can provide anywhere from 3 Mbps to 10 Gbps of throughput with the ability to go even faster for some network applications. SONET technologies still play an important role in the infrastructure of many telecommunications services. In the past 20 years however, the technology has shifted to a focus on Ethernet networks which can provide any number of throughput options with the ability to aggregate services up to hundreds of gigabits per second. Ethernet networks are more common in the endpoints that the backbone network serves and therefore simplifies the network end-to-end. Whatever the service requirement, metro fiber network providers typically offer 24/7/365 network operations centers (NOC) to support the monitoring and management of these mission critical networks.

For the purposes of this analysis consider that the presence of metro fiber in a given service area increases the likelihood of a relatively low-cost accessibility for wholesale, municipal, and enterprise grade connectivity to the internet or even other locations within a private or public organization. For example, if a subset of streets in a neighborhood lacks sufficient services from internet providers, the existing metro fiber footprint can be assessed to determine the most economical and convenient location to host a broadband access platform. That platform can then be leveraged to interconnect subscriber homes with wireless, fiber optic, or even a hybrid approach of fiber and copper cabling. While larger service providers typically deploy their own metro networks, smaller providers may opt to lease two or more fibers from a wholesale metro fiber operator and thereby avoid the considerable fiber deployment investment.

AECOM Technology Solutions Group has analyzed self-reported data from multiple metro fiber network operators in the Columbus area. This data depicts a robust delivery of fiber optic services throughout the city and surrounding areas. The following map provides a high-level snapshot of the existing fiber routes for each of the metro fiber service providers in the area. Note that some providers may have a significant fiber footprint just outside the Franklin County area but do not compete within the central Columbus area itself. Also, some providers have leveraged a specific fiber route through the city and deployed fiber simultaneously alongside competing providers to save on construction costs. Additional maps of each specific route that a metro fiber provider has deployed in is further detailed in Appendix A. At this time, AECOM makes no representation of pricing, availability, or applicability for these fiber service offerings

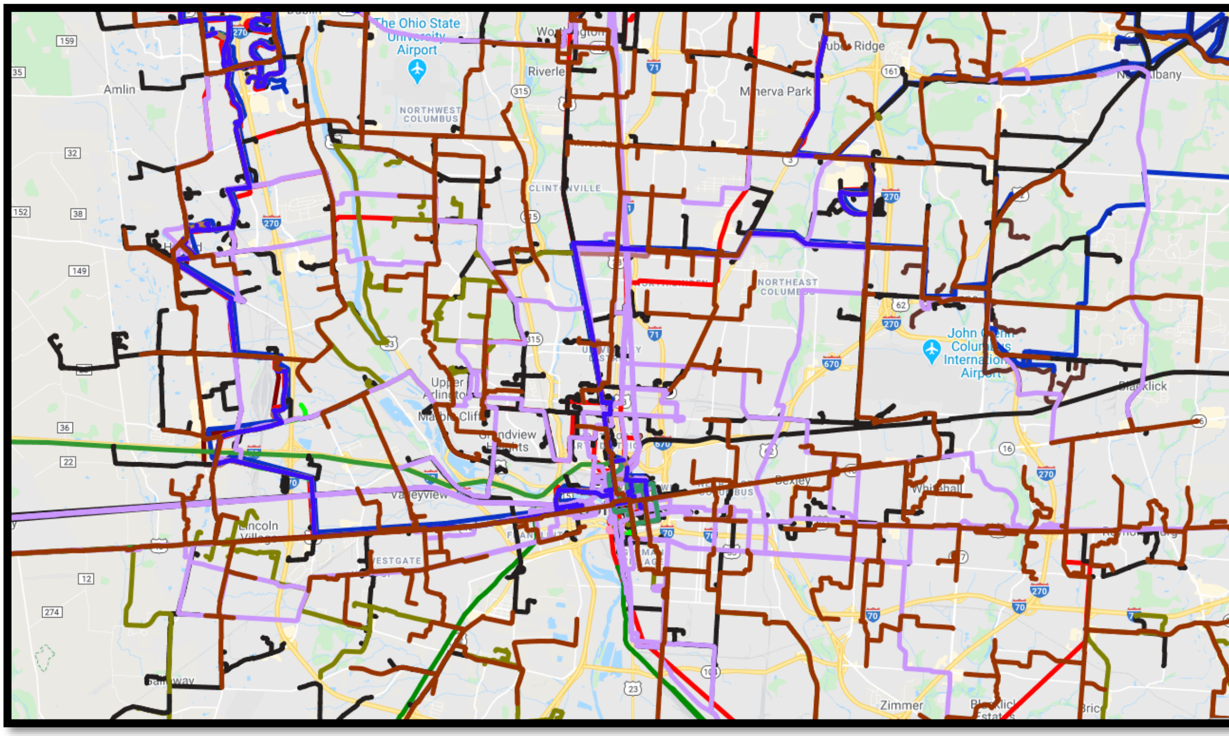


Figure 18: Aggregate of all Columbus Metro Fiber Providers

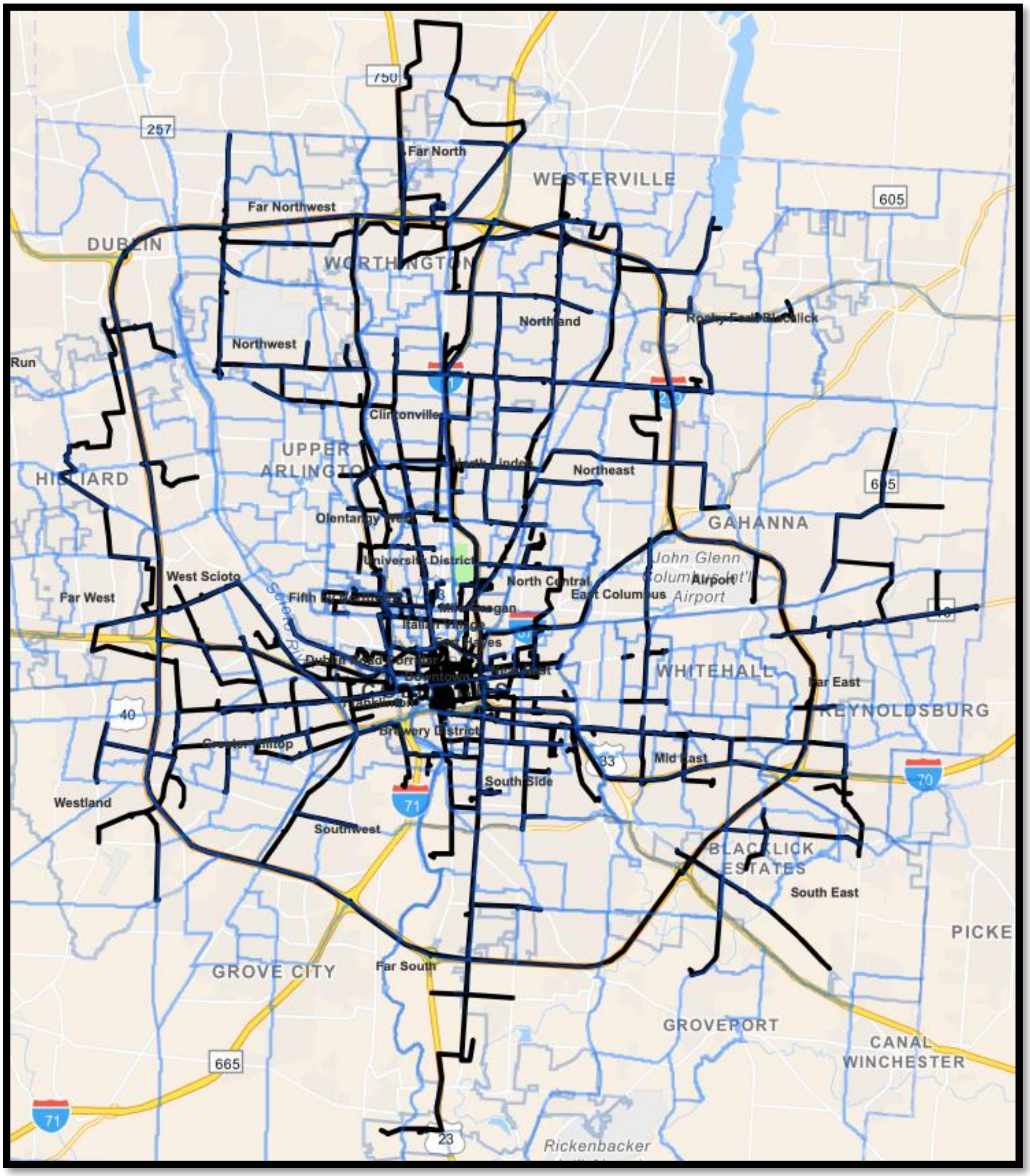


Figure 19: City of Columbus Fiber Network

The City of Columbus itself has deployed over 1000 miles of fiber optic cabling including 288 strand counts which is a considerable investment throughout the city. The network continues to grow today with a healthy $2M to $2.5M annual investment based on areas of need and growth projected by the City. The 100G network serves city facilities and transportation infrastructure and has a smaller portion reserved for commercial dark fiber network which is offered under indefeasible Right of Use (IRU) agreements. The City is currently exploring other options for use of the network and is amenable to discussions around how it could be leveraged to help address the digital gap in some areas of the city.

There are few areas within the City of Columbus where metro fiber does not exist. These diverse fiber deployments do not automatically translate into an opportunity for accessing broadband. They are however the means by which a broadband operator can access their own core network or perhaps interconnect with other networks. This interconnection point is called a peering network and they play an important role in how the internet operates as they route traffic between various cities and even countries on the globe. For broadband access delivery the metro fiber networks within the Columbus area indicate that there is a healthy competition for these core network offerings and therefore a diverse set of options for subtending to various broadband platforms in the region.

Wireless Mesh

Wireless mesh networks or wireless community networks have existed since the early 2000's. The technology itself serves a variety of business and organizational needs. While the technology is typically described as an ad-hoc cluster of nodes which communicate peer-to-peer, most mesh networks rely on static nodes which are connected to a high-speed broadband connection. Wireless mesh networks may consist of smart metering devices or field-deployed laptops sharing the same protocols and routing updates. In the context of a residential broadband service offering, wireless mesh networks can be a formalized offering from a small business provider or more commonly, they result from a collection of volunteers who organize within their community to deploy balcony or roof-mounted wireless nodes that collectively form a network. A set of internet exchange points (IXP) which peer with a traditional internet service provider is determined and placed in geographically dispersed positions to maximize the service area. As the number of nodes increases in a mesh network, so does the smaller number of IXP nodes. Within the residence, a router is deployed similar to traditional broadband networks so that a household can manage their own internal local area network.

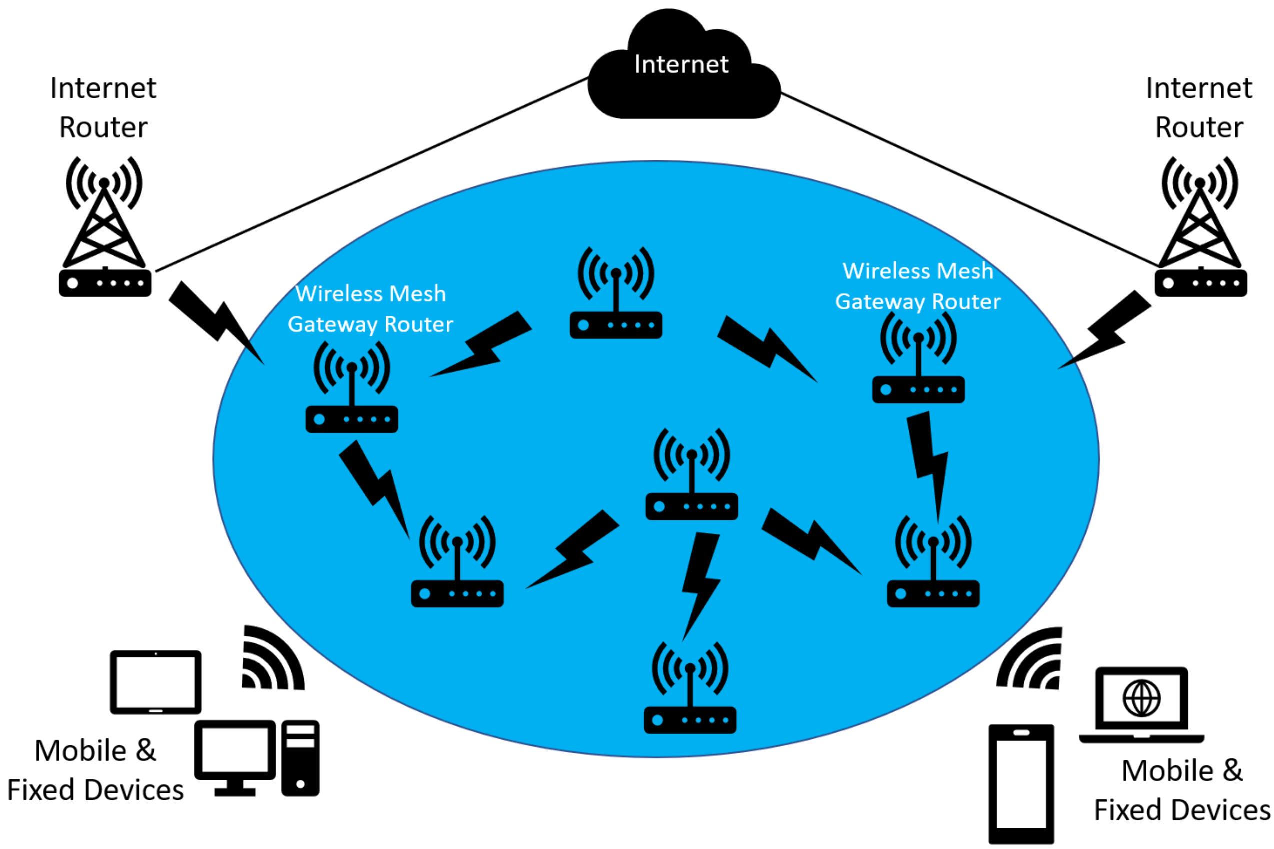


Figure 20: Wireless Mesh Network Diagram

The most significant advantage of wireless mesh networks is that the access portion of the network is simplified and there is no need to deploy any cabling infrastructure between homes. However, the wireless signals are vulnerable to weather related outages and individuals on the edge of a network may have fewer nodes with which to form an alternate path to the IXP nodes. Because many residential mesh networks are purpose-built to connect underserved neighborhoods, there is typically a very low or even no recurring cost per month. However, the upfront costs of the wireless

Wireless Mesh - Pros & Cons
Pro: Low Infrastructure, speed of deployment
Con: Weather, support/maintenance

equipment and installation may be considerable; ranging from $250 to $400 depending on the building type and difficulty in reaching a signal. Subsidized installation fees are available for some networks such as the large New York City Mesh network (NYCmesh.net).

Passive Optical Networks

Later in this report, AECOM will detail several short-term strategies for addressing the broadband access gap without the need to invest in an entirely new broadband access infrastructure. This section however will detail the broadband technologies to consider in addressing a longer-term solution where either a public/private partnership or collaboration with existing service providers is not successful.

To meet the demands of current and future applications, it is imperative that broadband access networks be able to provide the necessary throughput and do so with high reliability. AECOM asserts that optical fiber with the application of passive optical networks (PON) provides the ultimate solution for existing and future requirements. With optical fiber technologies, throughput demands are satisfied, bringing the communications infrastructure more powerful tools that can interface directly with homes, businesses, offices, community centers and government agencies. Optical fiber technology provides a higher capacity data transfer at speeds at any rate a consumer is willing to pay for including up to 10G PON, enabling the community or service provider to supply an ever expanding range of services and applications, such as High Definition TV (HDTV), Video on Demand (VoD) and high-speed data all while providing the capability of traditional voice connectivity.

Broadband access equipment providers are able to offer seamless delivery of converged services known as triple-play (voice, video, data) using Passive Optical Network (PON) technologies. A PON is made up of fiber optic cabling and passive splitters and couplers that distribute an optical signal through a branched “tree” topology to connectors that terminate each fiber segment. The passive (unpowered) fiber in the midspan of the network can span for 20 Km (12.5 miles) or more. This architecture is depicted in the figure below and details the speeds for Gigabit Passive Optical Networks (GPON) however other speeds are available including 10 Gbps PON referred to as XGS PON.

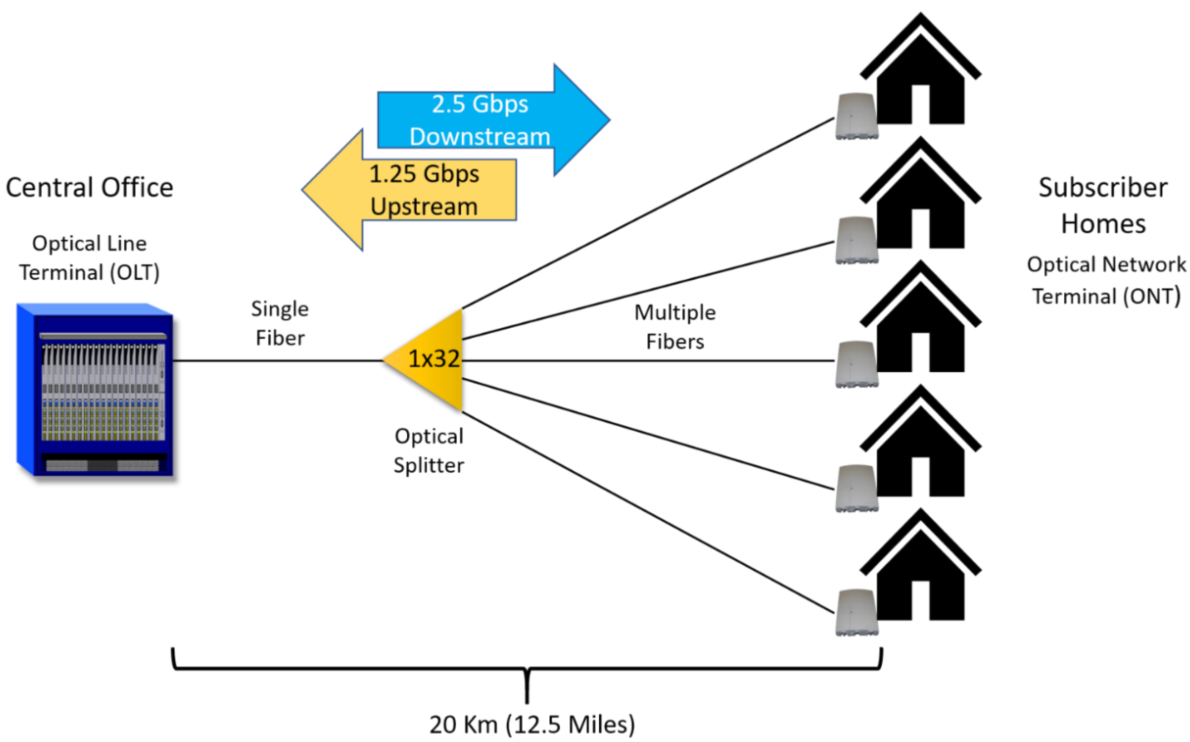


Figure 21: Gigabit Passive Optical Network Overview

PON technologies have become the defacto standard for broadband delivery and even as the market expands into the 5G wireless spectrum, PON will continue to serve as the backbone for those wireless backhaul and antenna installations. Examples of larger broadband access offerings based on PON technologies are:

- Frontier (formerly Verizon) FiOS
- AT&T Gigapower
- Google Fiber

The following is a partial list of advantages in using passive optical fiber systems:

- Higher Bandwidth Capacity
- Resistance to Outside Interference
- Longer Reach
- Lower Maintenance Costs
- Longer Life
- Better Reliability

Communities and service providers can offer a wide range of value-added services and ever-increasing speeds without the concern of the fiber infrastructure itself needing to be replaced in the future. PON technologies also require less power than legacy access technologies such as xDSL (a generic term for various generations of digital subscriber loop technologies using copper twisted pair cabling) and CATV systems. This is particularly true in the midspan of a PON deployment where no power is required at all. As PON technologies evolve, only the endpoints of the network need to be addressed and newer network elements can co-exist with prior equipment due to the ability to use different wavelengths of light on the same fiber infrastructure.

It is important to note that both xDSL and CATV systems can provide very high bandwidth services to subscribers. The technology has evolved to keep pace with demands however, there are compromises associated with this technology evolution. With xDSL for example, the local loop (the copper phone wire connecting houses to the service provider’s central office) must be in excellent condition to provide that maximum throughput. VDLS2 is the latest iteration of xDSL offerings and can provide up to 300 Mbps. This is only a best-case scenario however as the speed rapidly declines as the distance of the copper cable increases. After only a mere 1500 feet distance from the central office, the more realistic throughput for VDSL2 is closer to 100 Mbps. These are sometimes effective technologies for dense urban environments found in European countries, but not at all effective given the very different environment of sprawling suburbs frequently found throughout the U.S. CATV technologies which rely on DOCSIS infrastructure can also provide very high bandwidth services to the consumer. But they too suffer from compromise in terms of cost to deploy, power consumption, and the need to bond more coaxial cables to achieve speeds comparable to PON technologies.

Key Market Drivers for PON Deployments

There are two key market drivers that influence the direction of a PON deployment. They include competition and the evolution and advancement of broadband technologies over copper, fiber, and wireless infrastructures. How these drivers will affect the decision-making process in the early stages of building the ideal FTTX network cannot be overemphasized (Fiber to the X meaning fiber deployed to a home, business, curbside, or network node).

Competition – Today’s carriers are in an aggressive race to maintain and extend their customer base to secure the highest possible market share. The fact remains that those who provide a fiber infrastructure that reaches every user will ultimately win this race. Although broadband access delivered over a cable infrastructure can currently compete with fiber technologies in terms of bits-per-second, ultimately the complex mechanisms developed to improve cable modem throughput will not be able to contend with fiber optic technologies. Indeed, 10 Gbps PON technologies are being deployed today for business and 5G deployments. Furthermore, the standards bodies around PON technologies are already working on the next two generations of PON which include 25G and even 50G PON standards. It is unlikely that any investment in legacy broadband protocols using copper coaxial cables will result in a competitive technology race.

Incumbent local exchange carriers (ILECs) and multiple service operators (MSO'S) may deploy some combination of fiber and existing embedded copper infrastructure in a fiber-to-the-node (FTTN) or hybrid-fiber coax (HFC) distribution. Smaller service providers, however, must either enjoy a monopoly as the only infrastructure provider in a given area or be the first to deploy a PON system in their service areas to remain competitive among larger carriers. The bottom line is that those who do not make a move toward any PON architecture, particularly in greenfield situations, run the risk of being competitively obsolete. Competition is intense for providing the latest in triple play services and the continued existence of some service providers may very well depend on constructing the right PON network that best meets the demands of current and potential customers.

Business Case

Before engaging in a broadband access deployment, a service provider should have a comprehensive view of the proposed broadband network in terms of the value of existing infrastructure, what service bundles will be offered, which technologies will deliver those services, and how to configure the optical and copper portions of the network to best leverage bandwidth capabilities. Business case considerations include time-to-market criteria such as construction time frames, take rates (the percentage of homes or businesses who will subscribe to a service in a given area), and network reconfigurability issues. The Business case is where the balance between capital expenditures (CAPEX) and operational expenditures (OPEX) is determined. There are initial construction costs and costs incurred over the life of the network that, in total, drive the Total Cost of Ownership (TCO). As with any business enterprise, TCO is a key calculation in determining the long-term profitability of a broadband access network. Many carriers spend an inordinate amount of attention on the initial capital outlay, which is understandable given corporate mandates. However, the Infrastructure layer of the network has a useful life in the 15-25-year range. Spending more on CAPEX typically reduces OPEX over time. Important issues include not only the need for competitive analysis but an assessment of potential subscriber density, fiber and copper cabling component material lists, and other characteristics that determine whether additional CAPEX will save on OPEX as the network is installed and operations commence.

In general, the business case must be supported by a positive take rate. The take rate for a given area can range widely depending on competition and pricing however for most markets a minimum of a 35% take rate is required to achieve a positive TCO. Other factors influence take rates such as household demographics, cultural elements, and technical literacy. A better understanding of the reasons for low take rates and the price points necessary to drive high take rates in the most at need areas should be the subject of follow up research by the committee.

Take Rate & Pricing
Given the importance of Take Rate to the business case of any broadband access network, further work should be done in key Columbus communities to understand the price points required to drive adoption among key demographics. Additional research on what other factors are slowing adoption would be helpful including whether cultural and technical literacy

When considering a PON deployment it should be acknowledged that the subscriber household is not the only beneficiary of high-speed connectivity. A municipality for example can use a fiber over-build to connect its own municipal buildings, parks, and utility infrastructure to minimize existing leased network connectivity, centralize voice and data requirements, re-vitalize commercial zones, and simplify the overall operations and maintenance of complex municipal systems.

8. Strategies for Broadband Growth

Following our analysis of the existing broadband deployments and services as well as our review of the existing metro fiber deployments, we suggest the following options be considered as prioritized from Short Term to Longer Term projects.

- SHORT: Leverage existing wired and wireless infrastructure through continued Covid-19 internet access discounts and subsidized cellular data hotspot partnerships.
- MEDIUM: Augment existing infrastructure with fast to implement and agile deployments of wireless internet technologies such as community wireless mesh and additional community-based Wi-Fi access Points (WAPs).
- LONG TERM: Public Private partnership leveraging existing municipal or private metro fiber deployments to expedite and incentivize private partners to develop service offerings in underserved areas and providing lower price tier to those in need. Also, opportunities for Mesh W-Fi operated as an infrastructure by volunteers or charitable organizations.

Short Term / Immediate Solutions

Short-Term Option: Hotspots and Bulk Purchasing

The fastest way to make an impact is to leverage the robust existing infrastructure already available in the City of Columbus. Service providers and charitable organizations have already begun to put efforts in place as shown previously in this report by implementing subsidies and programs to deploy hotspots to those in need. By increasing funding and awareness of these programs, the number of households with access to internet could be expanded immediately. Any subscriptions for hotspot service should come with no data caps or at the very least, a significant data plan to prevent data cap overages which would cause further expense on the part of the subscriber. Information on some of these programs is available at the following Links:

- Columbus City Schools (https://www.ccsoh.us/Page/7661)
- PC's for People (https://www.pcsforpeople.org/)
- Mobile Beacon Bridging the Gap (BTG) (https://www.mobilebeacon.org/bridging-the-gap/)
- NE Ohio Model (not yet launched: https://www.wdbco.org/)

Some challenges associated with this approach of subsidizing or outright purchasing hotspot connectivity is the administrative overhead that may result. While it would be convenient for example to have a service provider reflect an agreed-upon discount or subsidy on a subscriber's wireless bill, it would require the service provider to change their billing systems. Unfortunately, changes in a provider's backend billing system are not frequently implemented. These billing systems are highly complex and tied to multiple operational systems and include regulatory checks and balances. A project which seeks to approach service providers with the need to reflect these lower rates in the billing system can expect a long turnaround time and perhaps an unwillingness on the service provider's part to proceed in that direction. Instead, it is advised that a project absorb this administrative overhead on the outset by paying for the service and equipment up front. Alternative approaches that seek to reimburse subscribers after incurred costs are likely not a tenable approach at scale as some households may not be able to absorb the upfront cost and wait for a subsequent reimbursement.

Medium Term Solutions

Temporary pricing plans and subsidized hotspots are a rapid mechanism to move the needle on internet access without waiting to fund or break ground on a new infrastructure buildout. However, these options should be viewed as short term, "triage" type solutions. Medium term solutions should provide a way for a community to connect without relying on subsidized plans or loaned equipment. The fastest way to do this is with deployments that minimize the required infrastructure build out. The two following solutions rely on a combination of taking advantage of existing internet locations at community centers as well as leveraging wireless technology for connectivity or backhaul.

Medium-Term Option: Municipal and Neighborhood Wi-Fi

Providing free Wi-Fi around public areas like libraries, parks, and shopping centers can allow students to do their homework close to home, or allow others to check their email, or even apply for a job. Wi-Fi can prove very beneficial by assisting citizens after storms or extended power outages. It can even have an economic effect as customers may spend more time in commercial shopping centers once Wi-Fi is introduced. Wi-Fi can also be used to communicate with citizens by populating the landing page of a Wi-Fi service with things like a calendar of city events, listings of local restaurants, and lists of things to do in the city.

Conceptually there is a framework for providing access to those without internet access already in place through the efforts of city organizations such as the Columbus Metropolitan Library which fills a vital role providing Wi-Fi to library patrons. Efforts like this can be extended past the bounds of the library building or other city property to include Wireless Access Points serving concentrically larger areas from points of existing internet access and infrastructure. There is existing precedent across America for Neighborhood and City scale Wi-Fi.

It may be helpful to prioritize areas that have the greatest need for connectivity and happen to overlap with the location of public facilities or parks that have existing internet access. These areas would offer the greatest impact with the least construction cost. Examples of these high priority areas could include:

- Neighborhood parks
- Athletic fields
- Community centers
- Commercial areas with heavy pedestrian traffic

Another potential target for reaching low-income households with a Wi-Fi solution is to deploy systems directly within public housing projects. This strategy represents a relatively low-cost solution within a higher density environment. A municipal or leased fiber connection could be leveraged as the backbone connection with a commercial or enterprise-class Wi-Fi deployment distributing the signals throughout the households. A wireless survey will need to be conducted to properly design the network and suitable locations for the core network equipment will need to be identified.

For other public areas, a single outdoor wireless access point can typically provide coverage for up to 50 to 75 devices and serve an area of roughly 300 feet from the antenna assuming a clear line of sight. If internet service is already present at the location, then the cost of providing and installing a single outdoor Wireless Access Point should be budgeted in the range of $3500 to $7000 depending on the solution and its capacity to scale. The cost per access point thereafter is dramatically reduced to roughly $1000 to $2000 per access point, depending on the local conditions such as mounting type, availability of network connections, and local power. Lower cost options are available however they will lack granularity of control, service metrics, and potentially may not provide as long of a service life as more robust solutions.

While AECOM believes a free Wi-Fi service will prove very beneficial, it is not suggested as a general strategy for bridging the digital divide. The need to travel from home in order to access the network or the potential of bad weather for outdoor venues is likely to reduce the efficacy of the Wi-Fi approach to broadband accessibility.

Medium-Term Option: Community Wireless Mesh

NYC Mesh provides a framework for what a community led mesh network effort could look like. An organization of citizens organized around a core team of technical leads and supported by community charitable organizations and or City resources following the below steps to pilot wireless mesh coverage:

1. Identify pilot hub locations in critical target areas. Pilot hub locations should meet the following criteria:
    a. close proximity to areas with poor broadband adoption

   b. have access to an outdoor elevated mounting location, ideally a roof on a building taller than average surrounding buildings

   c. have access to an existing high-speed internet connection

2. Identify pilot subscriber node locations. Neighborhood subscriber node locations should meet the following criteria:

   a. Have line of site to the pilot hub location

   b. Have access to the roof or subscriber node location

Following successful deployment of a small number of pilot hubs and nodes, expand the number of nodes and hubs, growing the mesh and providing additional Super Node locations where higher speed hubs can be located to continue growing the community wireless mesh throughput.

There are existing models for this community mesh approach including NYC Mesh that provide a framework for what a community led mesh network effort could look like. An organization of citizens organized around a core team of technical leads and supported by community charitable organizations and or City resources following the below steps to pilot wireless mesh coverage:

1. Identify pilot hub locations in critical target areas. Pilot hub locations should meet the following criteria:

   a. close proximity to areas with poor broadband adoption

   b. have access to an outdoor elevated mounting location, ideally a roof on a building taller than average surrounding buildings

   c. have access to an existing high-speed internet connection

2. Identify pilot subscriber node locations. Neighborhood subscriber node locations should meet the following criteria:

   a. Have line of site to the pilot hub location

   b. Have access to the roof or subscriber node location

Examples of other mesh network projects in the country include:

- Minneapolis wireless internet network: (http://www.minneapolismn.gov/wireless/)
- NYC Mesh (https://www.nycmesh.net/)
- Red Hook Wi-Fi (https://redhookwifi.org/)
- Personal Telco (https://en.wikipedia.org/wiki/Personal_Telco)
- Seattle Wireless (https://en.wikipedia.org/wiki/Seattle_Wireless)
- West Virginia Broadband (https://en.wikipedia.org/wiki/West_Virginia_Broadband)Long-term Solutions

Long Term Option: Public-Private Partnerships

The challenges facing Columbus in ensuring that affordable broadband access is available to everyone is certainly not new. Many communities across the country are engaging or seeking to solve similar issues where subsidized broadband access or other strategies have proven less successful. One approach that has worked for many organizations is a public-private partnership (PPP). A PPP is typically a collaboration between local governments and private sector businesses such as a broadband service provider, metro fiber provider, or both. There are three models for how a PPP is typically structured:

Private investment with public facilitation – This approach to a PPP is characterized by private enterprises making the primary investment on infrastructure with the public sector entity providing guidance on requirements, lessening administrative and bureaucratic burdens, and communication with homeowners.

Private execution with public funding – This model requires a substantial amount of public funding but allows for the private sector company to perform the infrastructure buildout directly. This approach lessens the logistical complexities of a deployment and is likely to be the most attractive to service providers.

Shared investment and risk – This model involves a more collaborative approach to PPP's as both the private sector company and the public sector organization negotiate mutually amenable terms for the various elements of the partnership including capital investments, operating costs, maintenance costs, and revenues.

Examples:

- City of Westminster, Maryland (http://www.bbpmag.com/MuniPortal/EditorsChoice/1115editorschoice.php)
- Bland County, Virginia (https://www.thecarrollnews.com/news/5975/carroll-expanding-broadband-service-in-county)
- Prince George Electric Cooperative, Prince George County, Maryland (https://www.ruralband.coop/)

An excellent resource for further study on this subject is a paper produced by the National Telecommunications & Information Administration (NTIA) can be accessed here: (https://broadbandusa.ntia.doc.gov/sites/default/files/resource-files/bbusa_effective_public_private_partnerships.pdf)

If a public-private-partnership strategy is pursued, an evaluation of which PPP structure to proceed with is required. AECOM recommends that an organization with sufficient funding and a desire to fast-track the effort pursue a shared investment and risk model. This will present the least risk for both parties and therefore promote an environment where the most rapid deployment could be achieved.

Long Term Option: PON Technologies

As stated previously, a PON deployment presents the most future-proof access mechanism for broadband services. According to BroadBandNow.com, there are currently almost 250 municipal broadband providers deploying fiber optic services in the U.S. This list grows longer if it includes municipalities which have some mix of network sharing and co-branding with other corporate entities. There are many architectural means to construct a PON network which allows for costs saving and flexibility in addressing right-of-way challenges. As mentioned previously, leveraging existing dark fiber networks will allow for the strategic placement of core network equipment (routers, switches, OLTs, etc.) where it makes the most sense. In general, the OLT must be placed within 20 Km of the area it serves. The 20 Km distance is linear feet of fiber, not simply a radius from the central office to the subscriber home. This distance can vary depending on the condition of the fiber and the likelihood of downstream fiber cuts and repairs. For example, an aerial fiber distribution (a deployment where much of the fiber is hung from telephone poles) that extends through neighborhoods with a high density of trees is more susceptible to weather related outages due to fallen trees. Over time the impact to a fiber network in this type of distribution is that multiple splices of a single fiber run (i.e., repairs) may result in a loss of optical power which exceeds the optical budget for reaching subscriber homes. Therefore, it is inadvisable to distribute a PON network close to its optical distance limitation in these conditions. A mostly underground fiber distribution, although initially more capital intensive than aerial distribution, results in a lower operational cost model and less impairments on the optical distribution network. It should be noted however that even in instances where a fiber network begins to suffer from optical budget issues, there are higher power optics that can be installed at the OLT to increase this distance by a few kilometers.

One of the largest capital expenditures for a PON deployment is what is known as the cost for "homes passed". This is simply the cost incurred for getting fiber from the service provider's central office to the roadway in front of each of the homes in a service area. It does not include the actual fiber drop to the home nor does it include the ONT which terminates the fiber at the subscriber's home. The cost factor of "homes passed" ranges widely across the U.S. The following list represents factors which can influence the cost of the "homes passed" metric:

- The type of fiber distribution (e.g., aerial vs. underground)
- The accessibility of dark fiber (metro fiber) networks (e.g., municipality owned vs. leased fiber)

- The availability of existing facilities to house the central office equipment (e.g., a core network deployed in an existing municipal IT equipment room vs. the need to construct a new facility to house the network equipment)
- The likelihood of administrative and/or regulatory overhead in obtaining the right-of-way for fiber deployments (e.g., a municipality that can waive some engineering reviews and/or fast-track an installation crew's permitting process)
- Fiber installation labor costs (e.g., union labor vs. non-union labor)

The cost in U.S. deployments may therefore range between $1300 and $3000 per home passed based on these and other regionally-specific factors. AECOM expects the cost within the Columbus City area to be just below the median of that range at about $1750 per home passed. This homes-passed figure takes into consideration the history of Columbus' municipal and community organization's willingness to collaborate on projects. It also assumes that the jurisdictions having authority over permitting and right-of-way decisions will have a vested interest in assisting the project. This rough-order-of-magnitude figure could be improved upon by establishing partnerships where stakeholders work together to reduce administrative burden and/or provide internal resources to offset costs. For example, a municipality that owns their own fiber network, provides detailed maps on its location, and clear specifications on the design and deployment methodologies to be used can dramatically lower installation costs for a subcontracted fiber installer. Alternatively, a subcontractor who needs to perform site surveys, write specifications, seek approval for designs, receive right-of-way agreements, and negotiate dark fiber connectivity for the core network, will need to pass these costs on to the service provider.

In addition to the cost of deploying a PON network near the subscriber homes is the individual cost of the subscriber connection. Although an attractive fiber offering in an area that was previously not competitive may produce a large initial onboarding of subscribers, the expectation should be an incremental take rate of subscribers over a period of years. As previously stated, a take rate of 35% is a minimum metric to budget for in a PON deployment. For each of those subscribers there will be a considerable cost to connect the subscriber to the existing PON fiber distribution. AECOM estimates the following rough order of magnitude for the subscriber home connections:

Table 4: ROM Cost for Subscriber Home Connection

Subscriber Home Connection Costs		
Pre-connectorized, direct-bury, fiber drop:	$	100.00
Network Interface Device (NID) and misc. materials	$	50.00
Optical Network Terminal*	$	120.00
Wi-Fi Broadband Router	$	110.00
Internal wiring materials	$	75.00
Labor	$	200.00
Total	**$**	**655.00**

*Optical Network Terminal providing Ethernet-only service

As noted above, the pricing reflects a deployment where the subscriber's network termination (ONT) provides a single Ethernet port for connection to a broadband router. This would provide an internet-only connection. Some deployment models may include an ONT with integrated Wi-Fi router and other services such as an RF Video TV connection and two plain old telephone (POTs) lines. The latter can greatly increase the cost of a PON deployment and will be accompanied by regulatory fees, licensing, and other administrative overhead costs. For the purposes of this report, it is expected that internet-only services are required, and any other subscription services would be the responsibility of the subscriber.

The final costs for deploying a PON broadband access system lie in the upstream core network itself. The complexities of how the access network integrates with the larger metro/service provider network can also vary widely. A leased circuit or fiber with enough capacity for 5000 homes for example may cost upwards of $3000 to $5000 per month depending on service level agreements and costs to interconnect to the internet in a given area. For the purposes of this report, we will focus only on the upfront costs associated with the OLT itself. The OLT cannot simply be priced at an initial cost. As the network grows, the quantity of modular optical cards within the OLT chassis will grow with it. We will therefore propose a density per optical card using GPON technology which is the most prevalent technology in the U.S. today. We will further assert that a management platform will be provided without a custom billing platform. That is, the subscribers will be managed using inventory capabilities of the management platform itself with no need for complex billing and integration into back end office systems. The following ROM pricing is an estimate of the central office costs associated with an initial deployment serving 5000 subscribers. It does not include other network costs for internet connectivity and/or facilities related costs (i.e., the central office construction itself, core routers, and firewalls which may already exist for other purposes).

Table 5: Central Office PON Equipment Costs (Initial 5K Subscribers)

Central Office Costs*	
Optical Line Terminal Chassis and Power Systems	$30,000
GPON Cards serving 5000 subscribers	$ 376,000.00
GPON management system	$ 60,000.00
Misc. Racks and interconnect components	$ 165,000.00
Licensing and Maintenance Support	$ 20,000.00
Labor	$ 100,000.00
Total	**$ 751,000.00**

* Does not include internet connectivity, core routers, firewalls, or leased metro fiber costs

As the PON network expands in the market, the initial investment in the management platform will not need to be incurred again. Labor costs are reduced as templates and other provisioning within the management system will have already been completed. The following is therefore representative of the costs associated with adding an additional 5000 subscribers to the existing PON network.

Table 6: Central Office PON Equipment Costs (Additional 5K Subscribers)

Additonal Central Office Costs (+5000 Subscribers)	
Optical Line Terminal Chassis and Power Systems	$30,000
GPON Cards serving 5000 subscribers	$ 376,000.00
Misc. Racks and interconnect components	$ 165,000.00
Licensing and Maintenance Support	$ 15,000.00
Labor	$ 55,000.00
Total	**$ 641,000.00**

In summary, by coupling the “homes-passed” factor with the per-subscriber and central office infrastructure, we arrive at the following ROM figure for this broadband access deployment.

Table 7: ROM Cost for 10K Subscriber PON Solution

PON Deployment for 10K Subscribers	
Central Office Equipment serving 10K Subscribers	$ 1,392,000.00
Cost to install infrastructure for 10K Homes Passed	$ 17,500,000.00
Cost per individual subscriber home	$ 6,550,000.00
Total	**$ 25,442,000**

Long Term Option: 5G Wireless Networks

The question of how rapidly 5G Networks will be deployed for general broadband service delivery is not currently clear. There has been much discussion and misunderstanding around the latest 5G wireless offerings and there are indeed significant rollouts of 5G infrastructure being deployed today. But much of this infrastructure will serve the 5G network in the future, and not necessarily within the next eighteen months.

The technology is poised to provide significant improvements in wireless throughput and enable an enhanced platform for the Internet of Things (IoT) and increased visibility on enterprise, government, and consumer-based devices and systems. It will likely be a significant option for consumer broadband access when it is fully implemented in service provider networks. But the arrival of a ubiquitous, always-on, ultra-fast wireless 5G network for broadband access will rely heavily on how quickly the market will demand 5G services for a very broad variety of services.

It is a change for the service provider industry in that there is now a business-to-business (B2B) market which is leading the move to this next generation of mobile technology. The delivery of 5G architectures will not only improve the way consumers access business and public platforms, but it will enhance the way businesses address vertical markets such as industrial automation, telemetry, transportation, and healthcare. This focus on the B2B market allows for new monetization models and a new set of revenue sources. This is all enabled by the increased connectivity and ease of integration for the thousands of electronic devices and systems we encounter every day in our personal and professional environments. And in an age when revenues from legacy telephone lines and even video distribution is rapidly declining, it is of paramount importance that service providers begin to roll out these services to maintain revenues and profits. The traditional consumer broadband access offering which bundles voice, video, and data is becoming less favorable to consumers as they continue to “cut the cord” for both video and voice services.

Service providers are therefore looking to expand their offerings to a new B2B market in addition to the healthy existing market of smart-phone subscribers. But a plan that assumes the ongoing 5G rollouts will adequately address the broadband access market in the near term, comes with the risk of it only addressing high-density and highly-profitable urban centers across the U.S. Less dense suburban areas may take longer to be addressed by wireless service providers.

5G technologies are characterized by the following attributes:

- 5G utilizes new spectrum from lower bands (600 MHz-3.5GHz) and high band (28GHz and above), that benefits from technologies like massive MIMO.
- While 5G antennas are lower powered than existing 3G, 4G, LTE networks, they can deliver much more throughput than these legacy networks, albeit with a need for more and smaller antennas.
- 5G uses NFV (Network Function Virtualization) and SDN (Software Defined Networking) technologies to increase flexibility in network deployment and operations.
- 5G uses techniques such as edge computing to deliver millisecond end-to-end connectivity.
- 5G is a new wireless network that can deliver required levels of performance for specific types of applications of services for market segments or enterprises such as industrial automation or real-time video streaming.
- 5G is a technology that can integrate with other licensed and unlicensed technologies, particularly in an enterprise environment.
- 5G will further drive the realization of fixed-mobile convergence. Convergence is both at the core / infrastructure layer with, for example, SDN and NFV delivering capabilities over both fixed and mobile networks, and the access network with 5G leveraging fiber in the access network.

5G Benefits & Drivers

- Higher Speed
- Greater Device Density
- Ultra-low delay
- Lower power

The precise role of the telecoms (5G) operator in each of the different use cases is still to emerge but it is a fair assumption that the commercialization of 5G in industry verticals will be the responsibility of existing telecom operators and enterprise IT departments.

Telecoms operators’ enterprise service revenues are currently dominated by the provision of public and private network connectivity. Enterprises also spend heavily on mobile communications. Operators are expanding into the ICT services business, but this still represents a relatively small proportion of total enterprise revenues. With the emergence of low-powered wireless access ((LPWA) technologies such as NB-IoT operators are stepping up their endeavors to expand into the IoT market but these currently represent just one per cent of mobile operator revenues globally.

Unlike previous generations of mobile technology – and more specifically 3G and 4G – building a business case on smartphones and assumptions around (mobile) ARPU (average revenue per user) uplift that can be generated may not be enough for 5G in the short- to medium term. This is because LTE and the planned performance improvements to LTE, will support the delivery of many of the services we see in today’s markets.

The role of the mobile operator in providing applications which, at some stage in the future, might embed 5G connectivity is also an issue. Many of the use cases that have been associated with 5G, for example in healthcare, or in robotics or drones, are only likely to materialize if mobile operators can find a way of inserting themselves in ecosystems where they have not traditionally had a role. And every sector has its own ecosystem with dedicated providers of services, solutions and connected devices.

The 5G market will undoubtedly impact the wireless market in new and significant ways. But for the purpose of addressing broadband access in the near term, it should be regarded as a burgeoning market and not necessarily a target for improving the economy or accessibility of broadband in the next 24 months.

Long-Term Option: Co-Op Broadband Networks

Increasingly, utility Co-Ops are looking to deliver broadband as an alternative to incumbent ISPs. Co-Ops are described as a non-profit business where the consumers of a utility (typically water, gas, or electric) work as a democratic collective to establish rates, determine which services to provide, and implement plans for expansion. Co-Ops are an excellent means to deploy broadband services because the utility companies that are often the core business can also choose to deploy fiber infrastructure along gas or water lines or through aerial telephone poles.

One Co-op network within Ohio that has started pilot projects for this approach is Consolidated Cooperative (https://www.consolidated.coop/) about 40 miles North of Columbus. They are targeting expansion in less populated and rural areas and offer both residential and business services.
https://muninetworks.org/content/consolidated-fiber-bring-high-speed-internet-access-rural-central-ohio

Monroe electric in Mississippi recently engaged a partner to begin a FTTH deployment in addition to tis electrical services (https://www.broadbandtechreport.com/fiber/article/14173685/ms-electric-coop-taps-conexon-for-ftth-buildout)

Case Studies & Precedent

There are many programs, projects, and organizations dedicated to addressing the Digital Divide in communities across the nation. Many of these programs address topics of computer literacy while others focus on improving access and affordability of broadband technologies. Over 300 municipalities in the U.S. have also helped to build out and support their own broadband access platforms to augment service areas.

This report attempts to provide context to this discussion that is relevant to the City of Columbus and does not duplicate the other research efforts of the working group. Following are examples of broadband access improvement projects across the United States.

Greenlight Community Broadband, Wilson, N.C. The city of Wilson began their push for improved broadband in 2008 and was highly successful in deploying high-speed and cost-effective services to rural consumers. (https://www.greenlightnc.com/services/packages-pricing/internet-broadband)

EPB, Chattanooga, TN. EPB is an electrical and telecommunications company owned by the City of Chattanooga. It was the first fiber optic city-wide network to deploy 10G services across its fiber network. The successful deployment has not only been responsible for an increase in municipal revenues but has been acclaimed as being directly responsible for attracting high-tech jobs and employers such as Volkswagen and Amazon. (https://epb.com/home-store/internet#support)

Additional case studies about successful broadband projects is available on the Institute for Local Self Reliance's website: (https://www.muninetworks.org/tags-3). The site also includes an interactive map of various deployments available here: (https://www.muninetworks.org/communitymap)

Case Study: DC Community Access Network (DC-CAN)

The DC Community Access Network (DC-CAN) is a publicly funded and managed broadband project which connects public institutions across Washington D.C. DC-CAN Provides affordable broadband access for schools, nonprofits, and community anchor institutions in economically disadvantaged areas. This investment in public infrastructure helped the city upgrade internet service in libraries, recreation centers, and senior centers that later served as digital literacy training sites. DC-CAN is a 100 Gbps network which also serves as a middle mile provider, offering local telecommunications companies wholesale services so they can provide low-cost broadband to District residents and businesses. Consumers wishing to participate in DC-CAN must be eligible for the Lifeline program or other public assistance programs such as the National School Lunch Program, housing assistance, Medicaid, SNAP, or SSI benefits. The cost for internet access starts at $9.95 per month and is in partnership with multiple service providers such as Comcast, RCN, Verizon, and the Wilderness Technology Alliance which provides refurbished laptops at $75 each.

At A Glance: DC-CAN

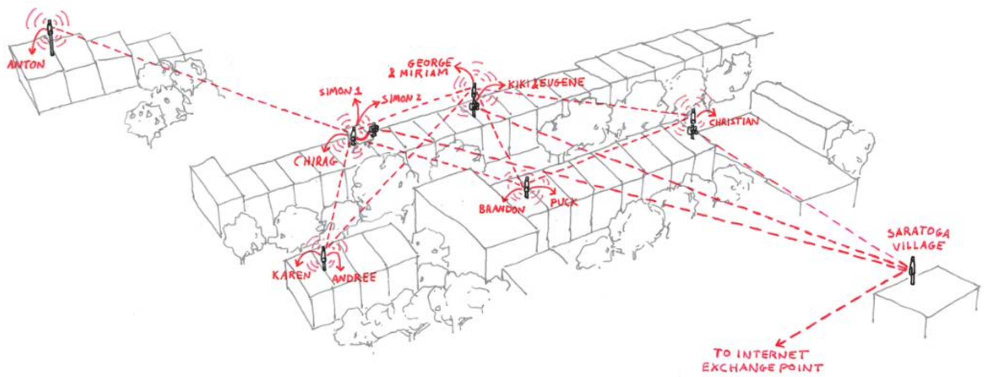
- **Location:** Washington, D.D.
- **Technology:**
- **Size:**
- **One Time Install Cost:**
- **Monthly Fee:**

https://connect.dc.gov/affordable-internet

Precedent: e-Vermont Community Broadband Project

The e-Vermont Community Broadband Project helped rural towns in 33 communities get connected to the Internet. e-Vermont worked locally to ensure the best use of online resources to strengthen economic development. It was funded through a federal program for Sustainable Broadband Adoption (SBA) and the matching support of local funders.
https://publicservice.vermont.gov/content/broadband-availability

Case Study: Community Mesh Precedent, NYC MESH



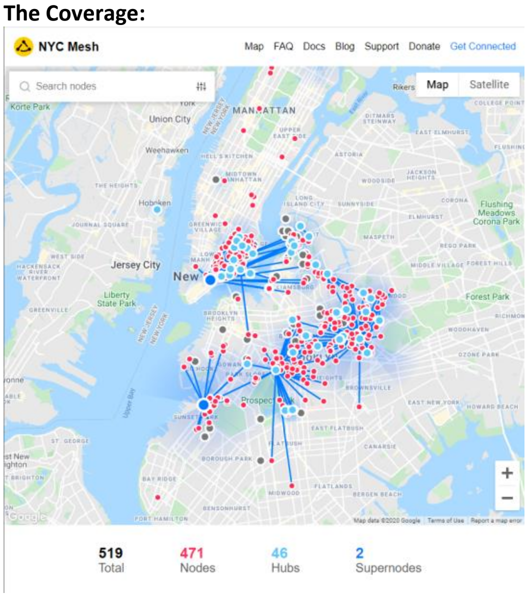
NYC Mesh is a community-owned network. This means that city residents take it upon themselves to maintain and grow the network. The basis for this solution is a hybrid approach consisting of super nodes, Hubs, and Rooftop or Neighborhood Nodes. A super node is one a point where the mesh network connects to or peer with an internet exchange. A Hub is a point where the neighborhood Nodes can aggregate and access the Super nodes.

Opportunity: The challenge for Community Wi-Fi and Mesh Networks is getting access to rooftops for mounting the radios and getting access to wired internet for super nodes. In the case of Columbus, any Community Wi-Fi or Mesh architecture would greatly benefit from organizations volunteering to host the super nodes and provide rooftop access for the radios. From there, the cost of the network is essentially the cost of the radios. The model used by NYC Mesh involves multiple options for connecting to the network including the most hands-off option based around having a volunteer come out to the site and installing a radio for the new subscriber for the cost of $290 including the ownership cost of the radio and the labor for the installation. Beyond this one-time cost to the subscriber (or a subsidizing agency), NYC Mesh asks for a monthly donation to help cover the work to maintain the mesh network. The NYC Mesh ask is a $20 monthly donation, although they will gladly accept larger donations to help offset the costs for other subscribers.

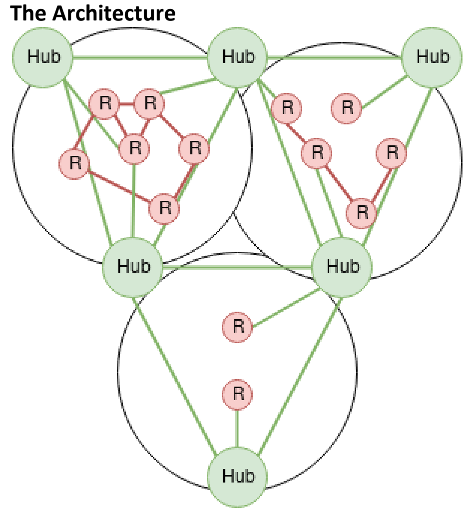
At A Glance: NYC Mesh

- **Location:** New York / Brooklyn
- **Technology:** Wireless Mesh
- **Size:** Over 470 Nodes
- **One Time Install Cost:** $290
- **Monthly Fee:** $20 donation

The Coverage:



The Architecture



Resources on Community Networks hosted by NYC Mesh:

How to Start a Community Network: https://www.nycmesh.net/blog/how/

Case Study in Community Wi-Fi: https://www.nycmesh.net/blog/700jefferson/

Precedent: Chicago's Smart Communities Initiative

For the past seven years, the city of Chicago has embarked on a broad set of strategies to address not only gaps in broadband access but also the need for education and adoption of technologies to improve the workforce. Among 28 initiatives outlined under the plan, increased computer literacy, partnerships with community leaders and industry, and investment in technology centers is the focus of this multi-year plan. The plan includes numerous strategies to ensure that Chicago innovates and advocates for an end goal of a technologically-savvy population with few barriers to success.

https://techplan.cityofchicago.org/executive-summary/initiatives-by-strategy/

9. Glossary of Terms

Access Network - The method, circuit, or facilities used to enter a communications network. The service provided by local exchange carriers or internet access providers, which connect subscribers to voice, video, or internet services. The Access Network today is typically a mix of copper telephone wire, coaxial cable, and fiber optic cable.

ARPU – Average revenue per user/unit. A metric used by service providers to broadly quantify revenues in a broadband access market. It is defined as the total revenue in a service area divided by the number of subscribers.

CO (Central Office) - The Central Office is where communications service providers terminate subscriber access lines and locate switching and routing equipment that interconnects those lines. The CO may support different types of service such as twisted pair copper telephone services or fiber optic-based services.

Backbone - The part of a service provider network used as the primary path for transporting traffic between central office (CO) connections and higher speed connections which serve long distance voice networks and internet services.

Bandwidth - The throughput, or ability to move information through or from a communication device, system or subsystem, and is usually measured in quantities of data per second such as kilobit, megabit, or gigabit. A measure of the information-carrying capacity of a communications channel; range of usable frequencies that can be carried by a system, corresponding to the difference between the lowest and highest frequency signal that can be carried by the channel.

Core Network
See backbone

Dark Fiber - Fiber-optic cable which is not currently connected to active communications equipment. Service providers, municipalities, and private companies may deploy fiber optic cable with an overbuild (i.e., spare capacity) to avoid downstream capital expenditures for expansion or repair. Often the dark strands of fiber are monetized by leasing to individuals or companies who need to expand or install new connectivity.

Ethernet - A communications protocol for connecting computer systems to form a network. These networks can be architected to support a single location or campus as in a local area network (LAN) or serve either metropolitan area networks (MAN) or a wide area network (WAN). Ethernet is the most prevalent networking protocol in use today.

FTTB - Fiber to the Business is a fiber optic access network architecture serving businesses only and differs from consumer fiber to the home offerings in terms of pricing, service level agreements, and maximum speeds.

FTTC - Fiber to the Curb/Cabinet is a fiber optic access network architecture where the service provider extends fiber optic cables to pedestal or in-ground fiber cabinets and converts the optical signals to electrical circuits which can readily connect to homes or businesses using legacy twisted pair telephone cable or coaxial cable.

FTTN - Fiber to the Node is a fiber optic access network architecture where the service provider extends fiber optic cable to an existing broadband platform such as a VDSL cabinet located in a neighborhood or business park. This allows for higher speeds as the subscriber's connections are aggregated to the provider's backbone network.

FTTP - Fiber to the Premises is a fiber optic access network architecture where the service provider extends fiber to a single location within the premises of a business. It is then the responsibility of the business to connect their networks to that service provider equipment.

FTTX - Fiber to the "x" is a generic term for a fiber optic network architecture which can extend from a service provider to any number of service offerings such as fiber to the home, business, curb, or node.

GPON – Gigabit Passive Optical Network is an ITU standardized PON technology characterized by a 2.5 Gbps downstream throughput and 1.25 Gbps upstream throughput. See PON.

Headend – a telecommunications facility where an MSO (Multiple Service Operator or CATV provider) extends cable TV and internet services to subscriber locations.

Internet Protocol (IP) – IP is a networking protocol for transmitting information from one network to another. It is the primary protocol used for the internet.

ISP - Internet Service Provider

Last Mile - The last mile is the local access network that extends from the Central Office (CO) to the end-user subscriber. Also called the local loop network, it is traditionally copper-based however, fiber-based networks are rapidly replacing aging copper infrastructures.

Metro Fiber - The portion of a service provider's telecommunications network which extends from the central office to other internet peering or wholesale internet provider network.

Middle Mile – See Metro Fiber.

MDU/MTU - Multiple Dwelling Unit/Multiple Tenant Unit - a building with more than one residence or business.

MSO - Multiple Systems Operator is a company that provides cable or direct-broadcast satellite television systems. (i.e., CATV company)

OLT – Optical Line Terminal is an aggregation device associated with a Passive Optical Network (See PON). The OLT is typically deployed in the central office of a broadband service provider's optical network. It communicates with ONTs (See ONT) at the subscriber location and can serve thousands of subscribers from one location.

ONT - Optical Network Terminal is a network device associated with a Passive Optical Network (See PON). It typically resides at a broadband subscriber's home or business and converts the optical signals from the broadband service provider's network (See OLT) into various service protocols including Ethernet, Wi-Fi, RF-Video, and plain-old-telephone-service (POTS)

PON - A Passive Optical Network (PON) is a type of broadband access system that distributes a single fiber optic cable to subscriber homes or businesses. The term "passive" refers to the use of optical splitters in the midspan of the network (between the central office and the subscriber) which combine the subscribers signals in the upstream direction and split the aggregate signals from the service provider in the downstream direction. This forms a point-to-multi-point topology that reduces operational expenses and troubleshooting complexity. Typically, the optical splitters in a PON will split a single fiber into 32 individual fibers which are each used by the subscriber's device called an optical network terminal (ONT). In the central office, the fiber from the splitter connects to an optical line terminal (OLT) which connects to the provider's backbone network. A PON system utilizes a specific wavelength for downstream traffic and yet another separate wavelength for upstream traffic.

Single Mode Fiber – (SMF) is a type of fiber optic cable that utilizes a single mode of light to transmit data rather than sending light at predetermined time intervals to separate signals as is the case with multi-mode fiber.

SONET -Synchronous Optical Network – is a protocol for transmitting data over optical networks using time and wave division multiplexing. It provides multiple optical line rates known as Optical Carrier (OC) signals which can range from an OC-1 at 51.84 Mbps to an OC768 at 39.813 Gbps.

Wavelength - A measure of the color of the light which is a function of the length between waves of light. These lengths are typically measured in nanometers (nm) or micrometers (um).

Wavelength Division Multiplexing (WDM) - A type of telecommunications transmission where each of several data streams are coordinated by two or more wavelengths of light.

XGS PON – 10G PON (the "X" is the Roman Numeral 10) is an ITU standardized PON technology characterized by a 10 Gbps downstream throughput and either a 2.5 Gbps or 10 Gbps upstream throughput. See PON.

Appendix A Metro Fiber Networks

Century Link

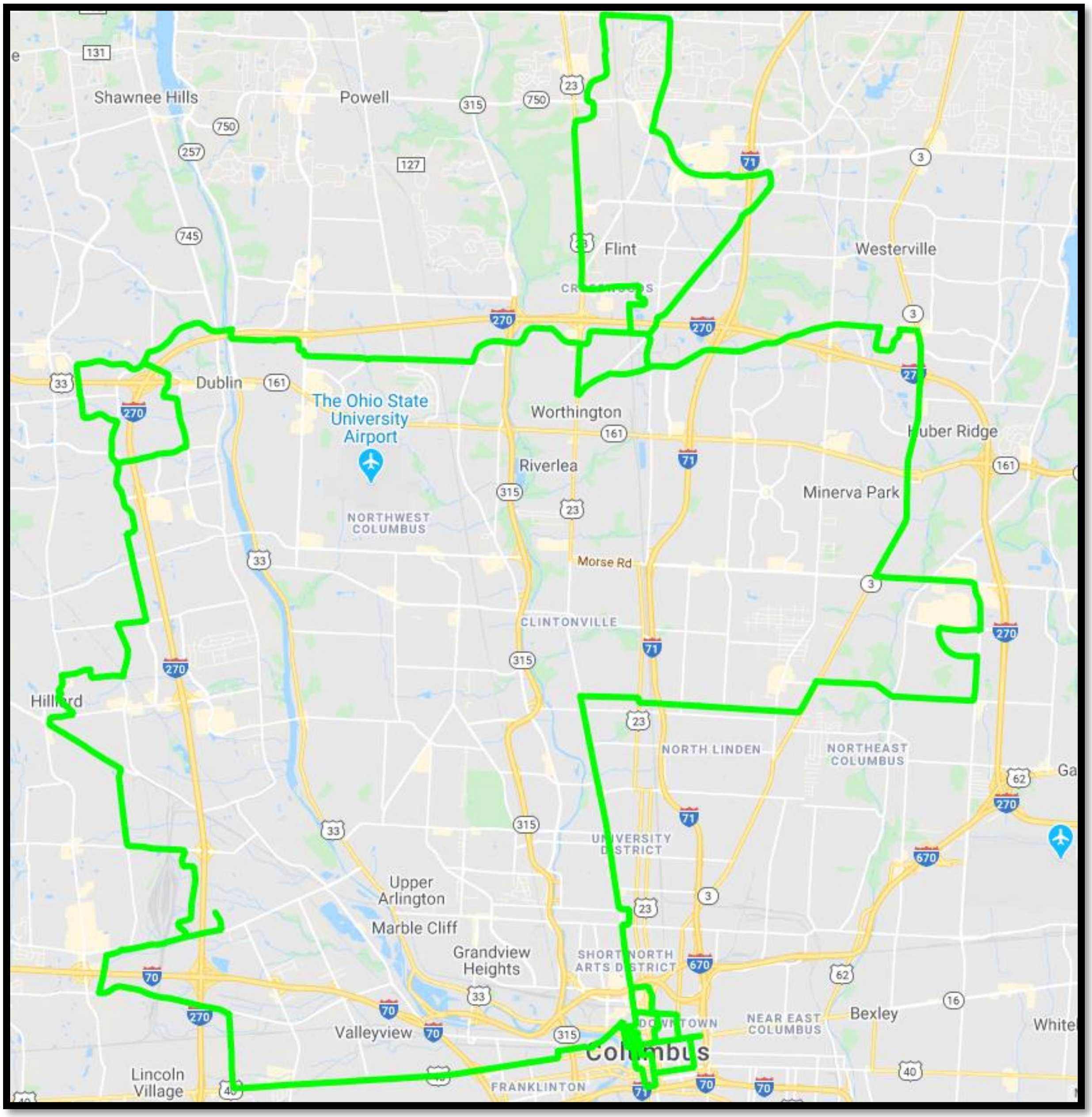


Figure 22: Century Link Metro Fiber

CityNet

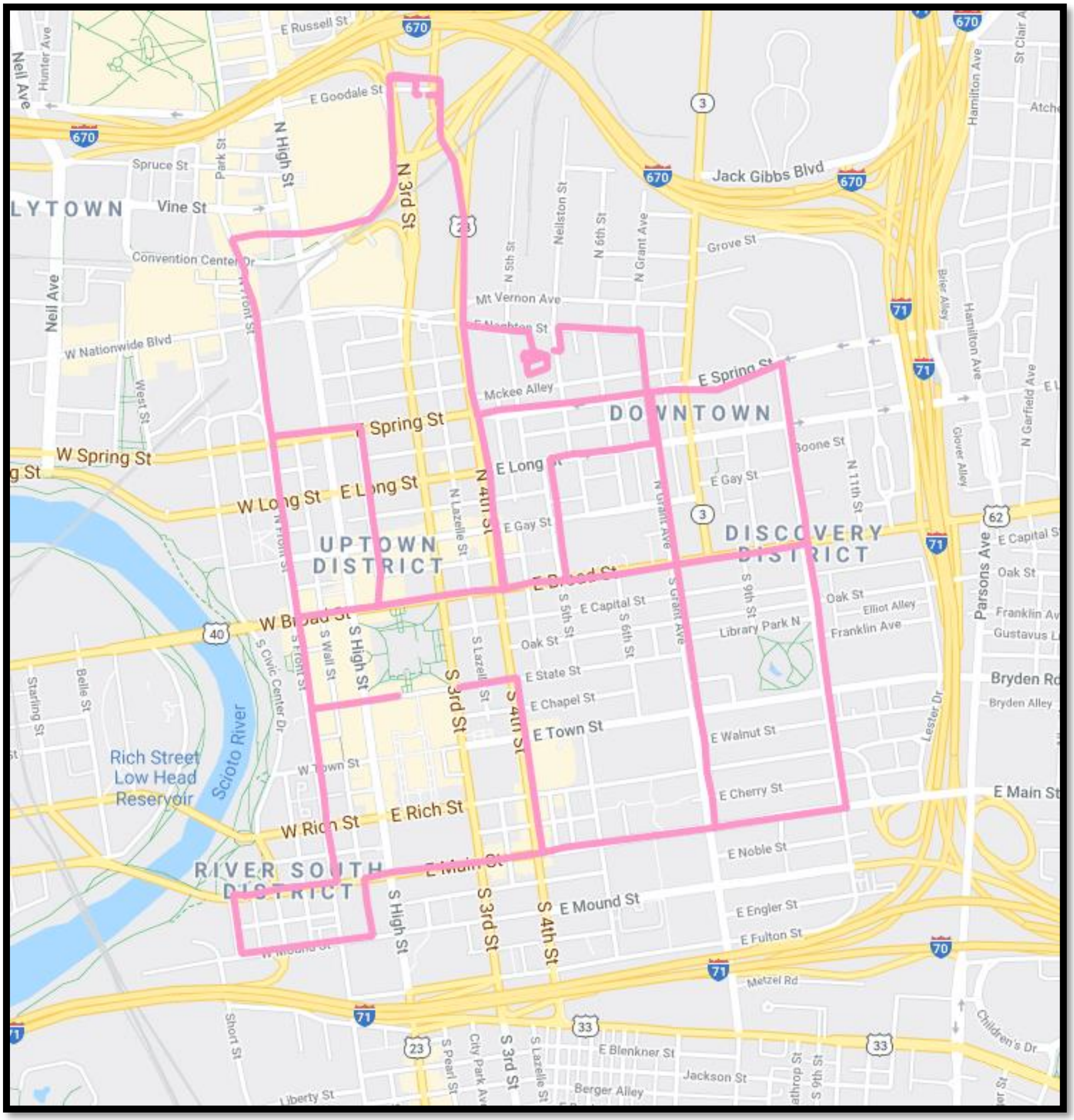


Figure 23: CityNet Metro Fiber

Cologix, Columbus Fibernet, Dublink

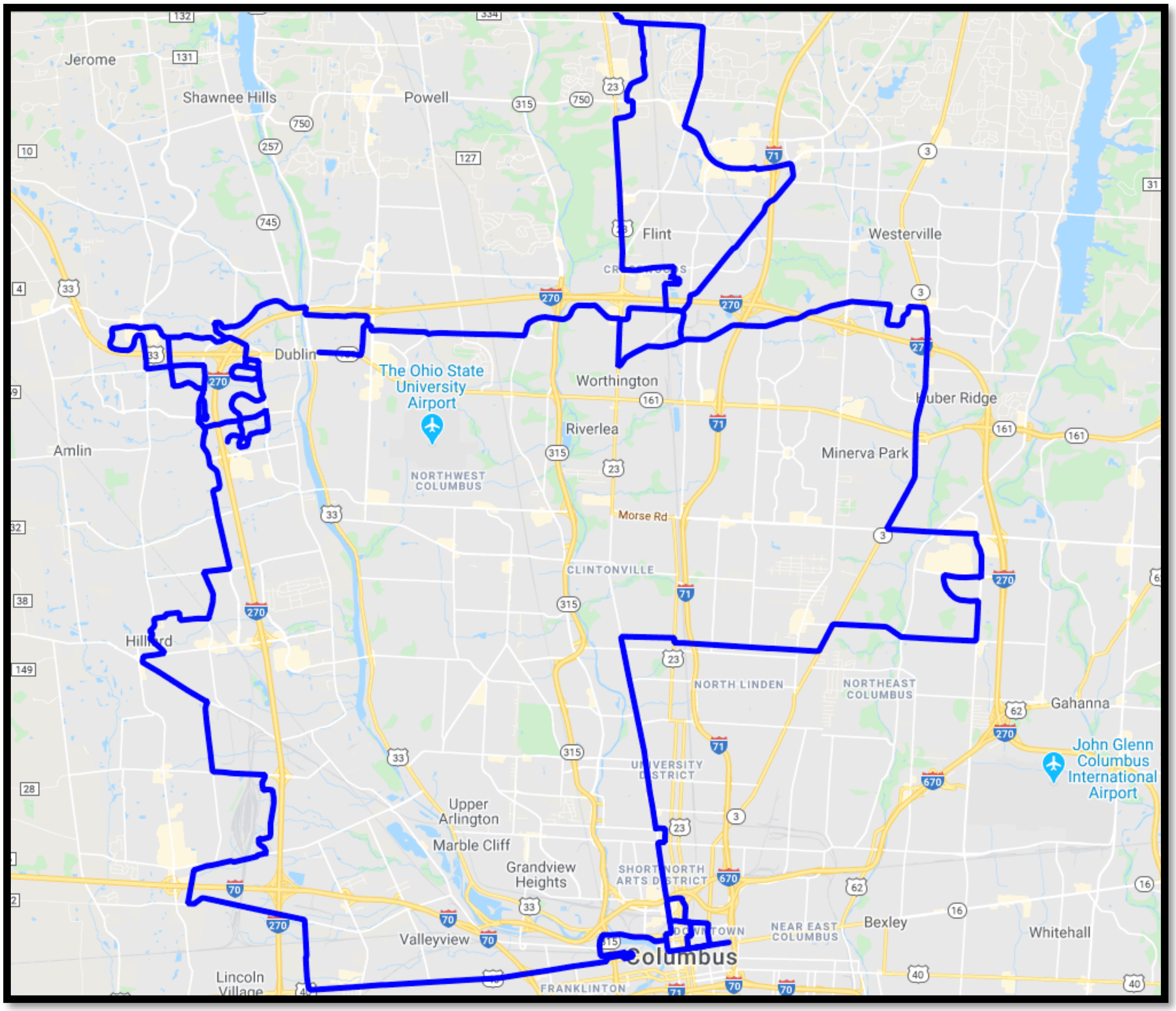


Figure 24: Cologix, Columbus Fibernet, Dublink metro fiber

Crown Castle

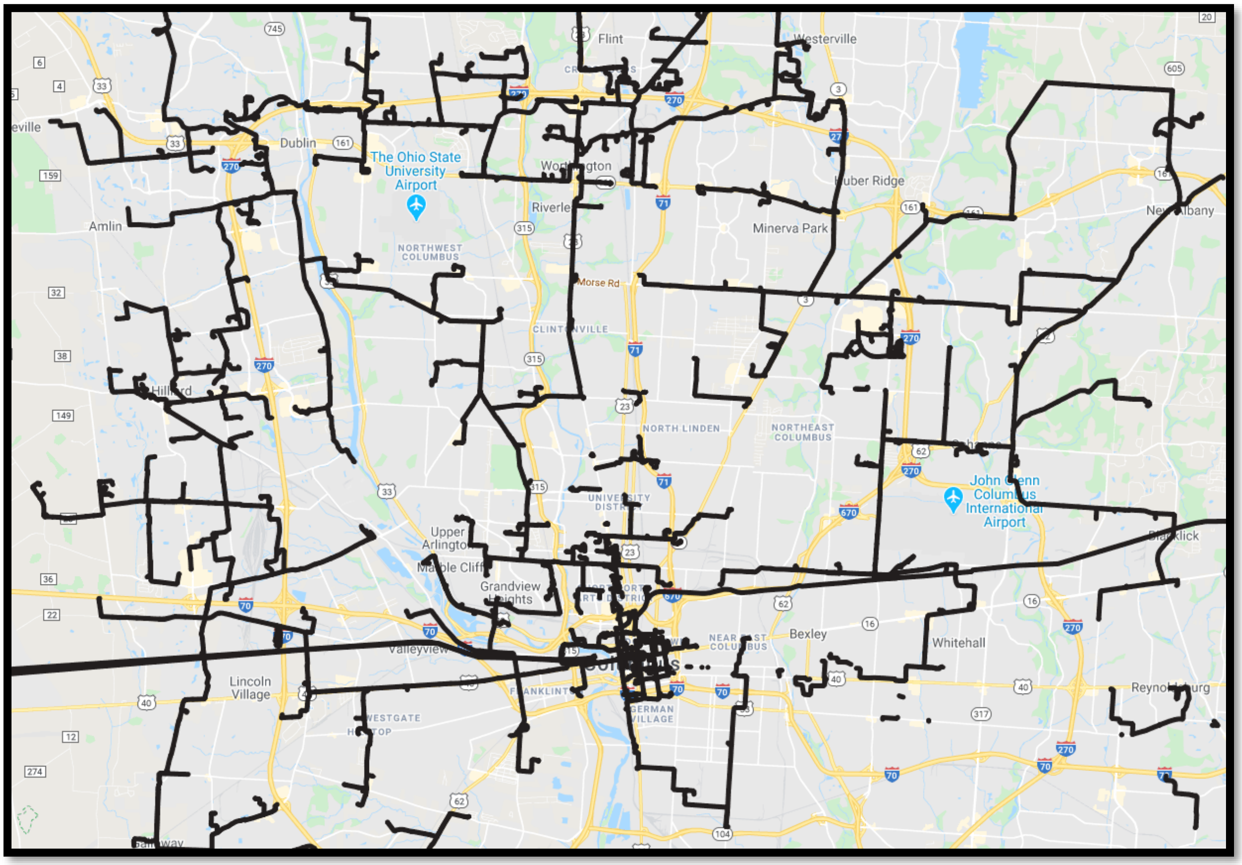


Figure 25: Crown Castle Metro Fiber

Enlite by CEC

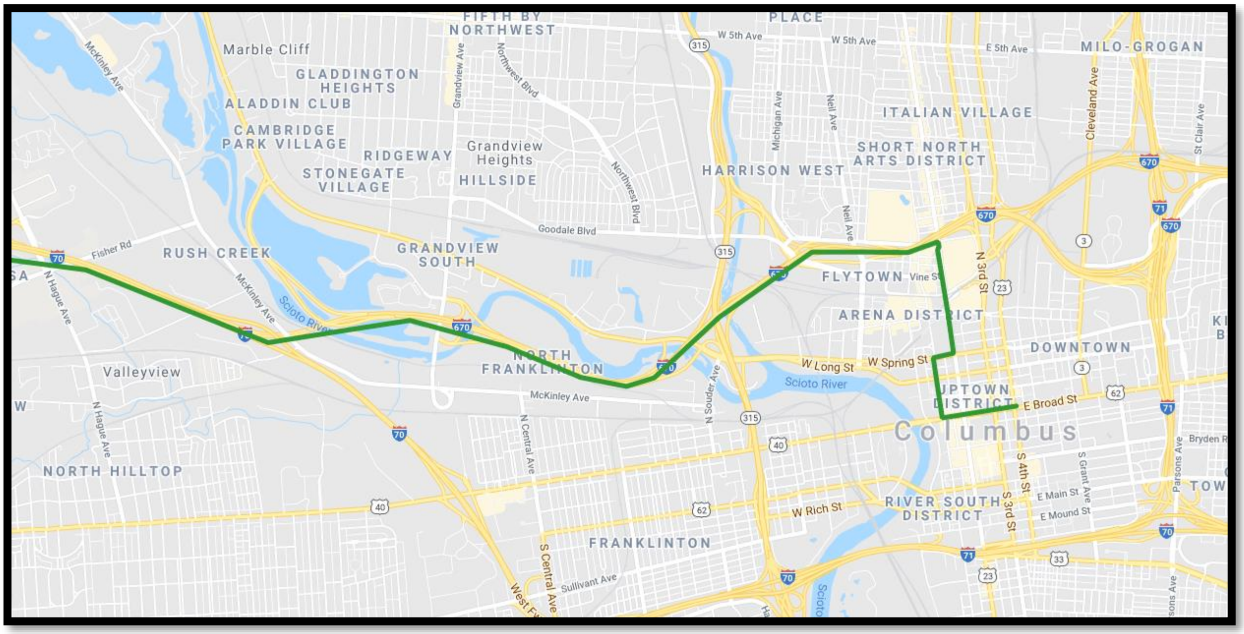


Figure 26: Enlite by CEC metro fiber

Everstream

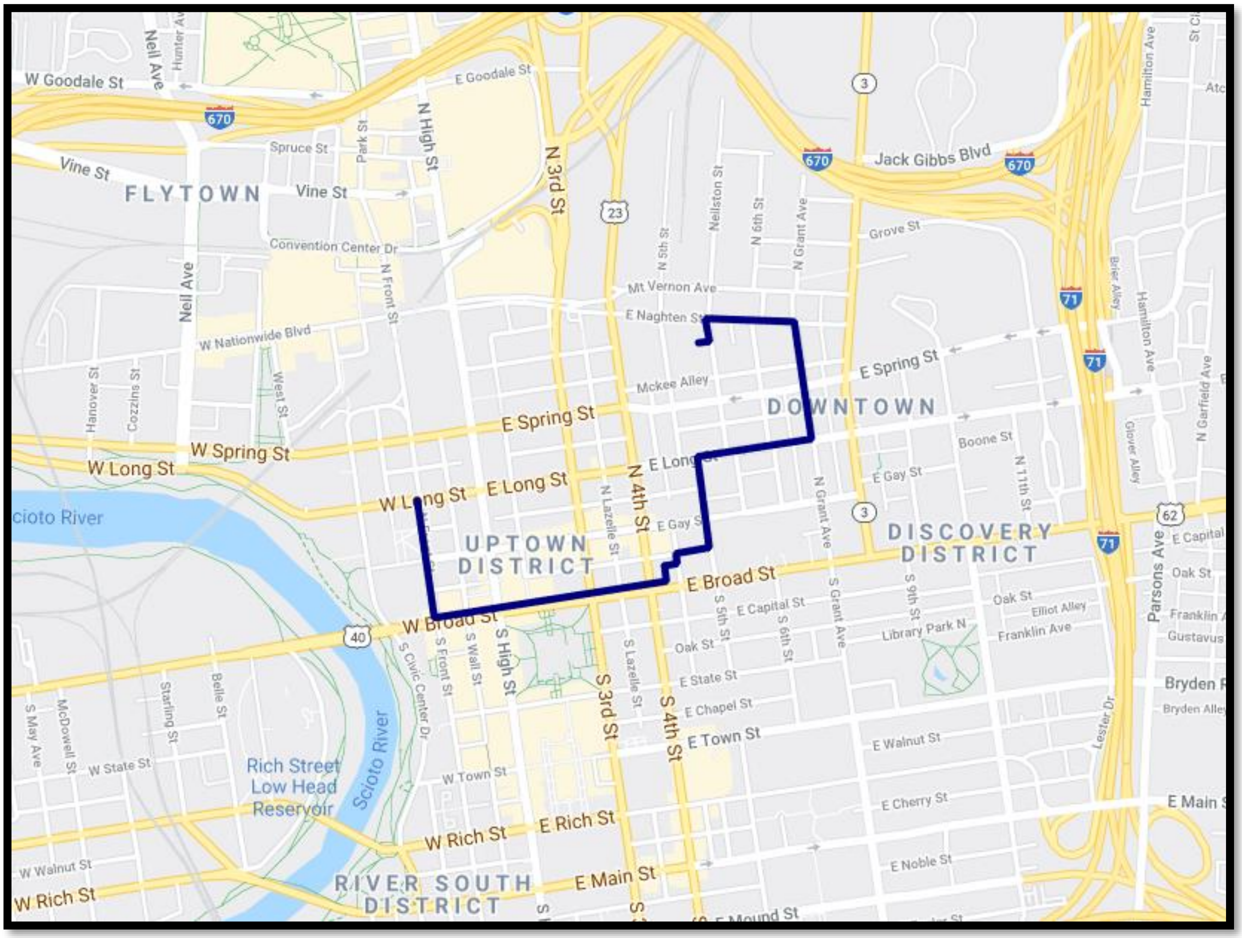


Figure 27: Everstream metro fiber

Horizon Telecom

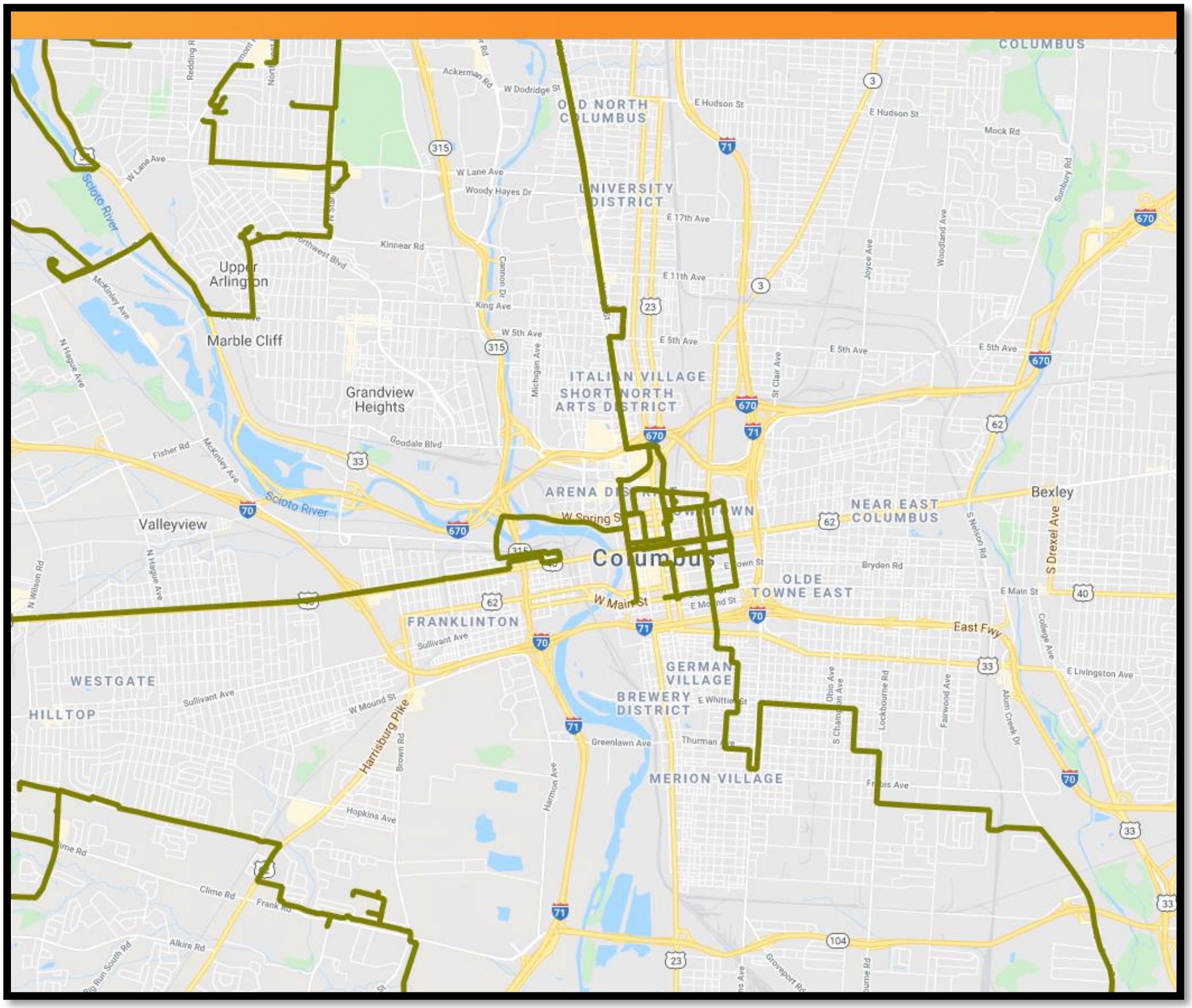


Figure 28: Horizon Telecom metro fiber

Independents Fiber Network

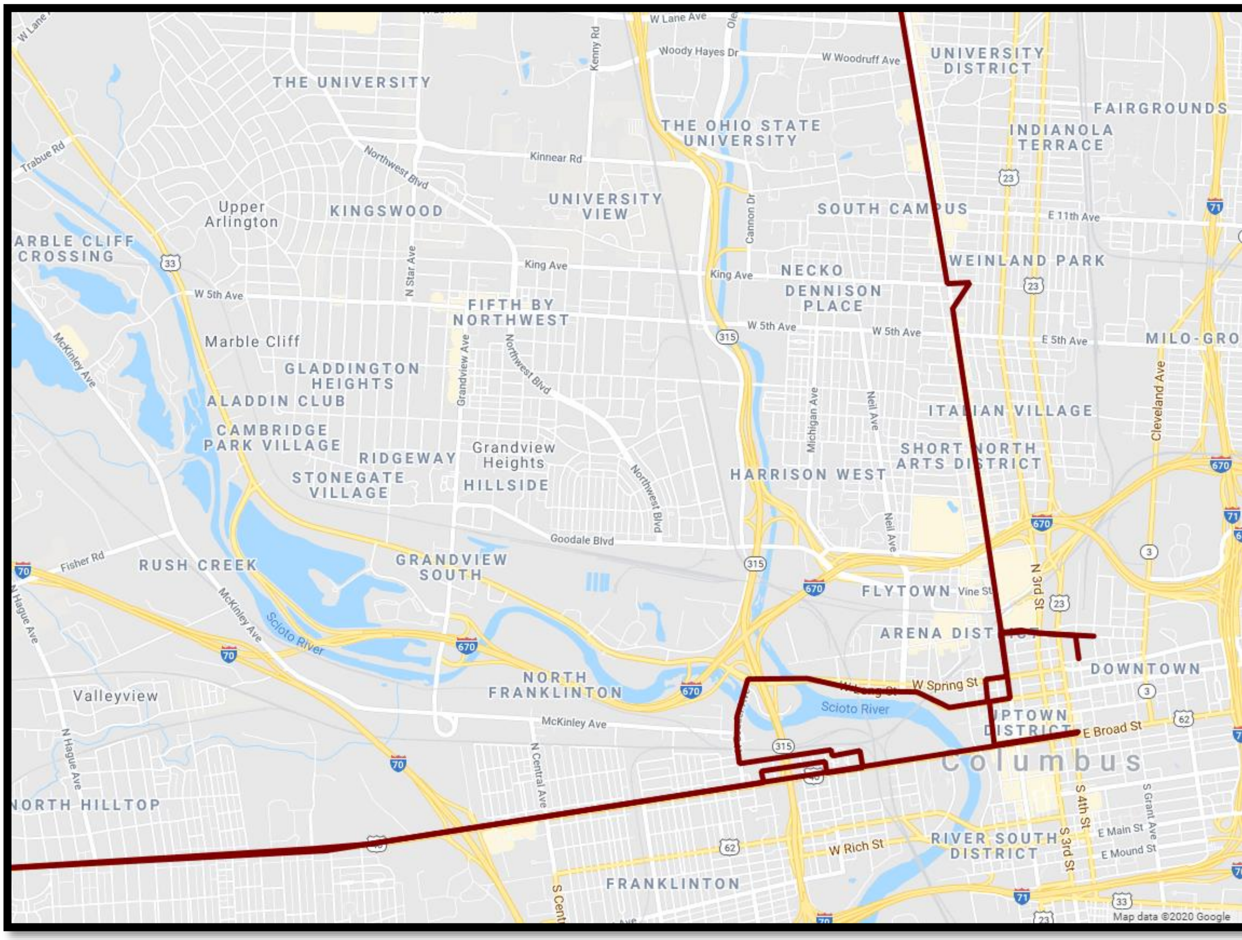


Figure 29: Independents Fiber Network metro fiber

Level 3

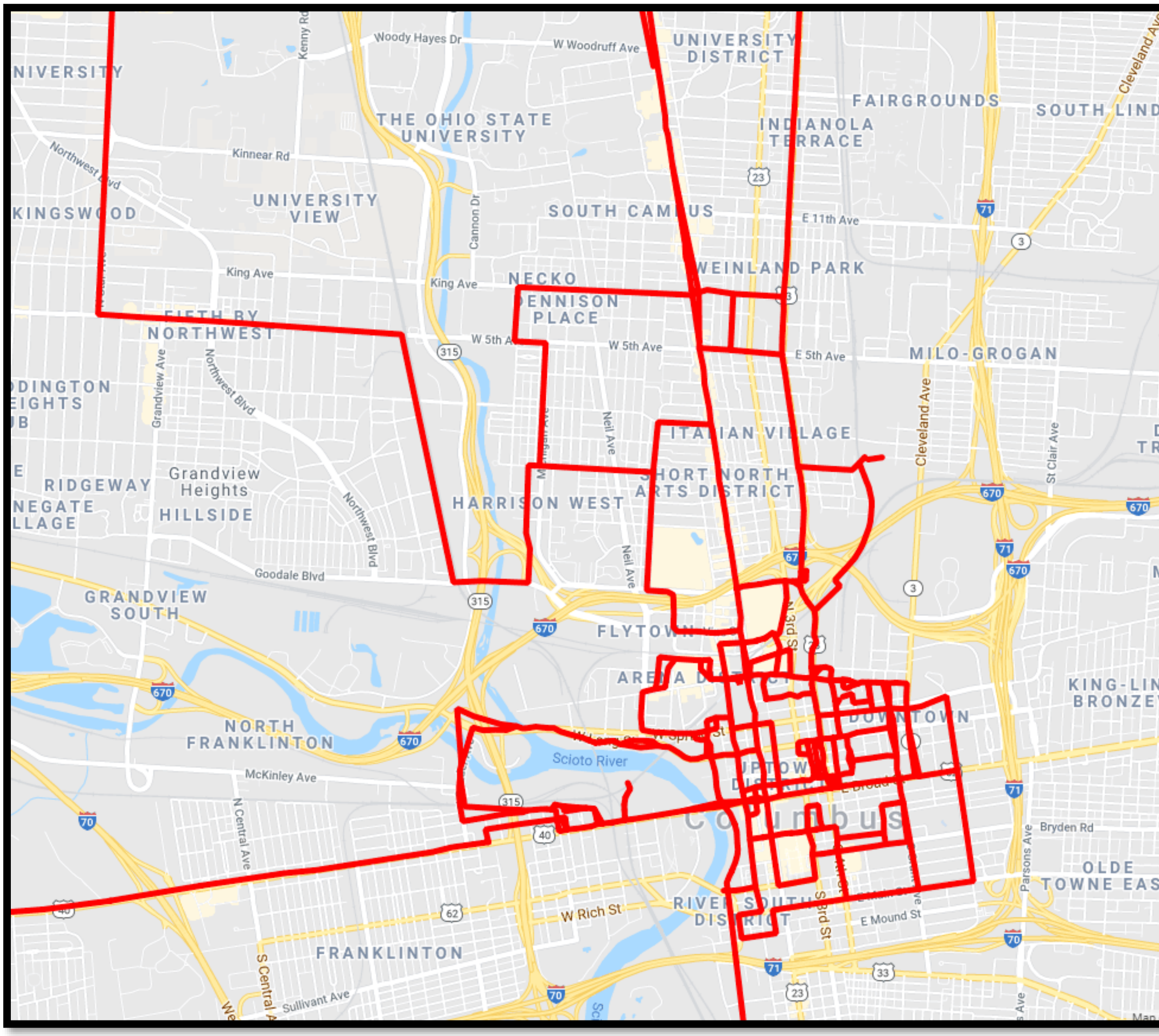


Figure 30: Level 3 metro fiber

Metro Data Center

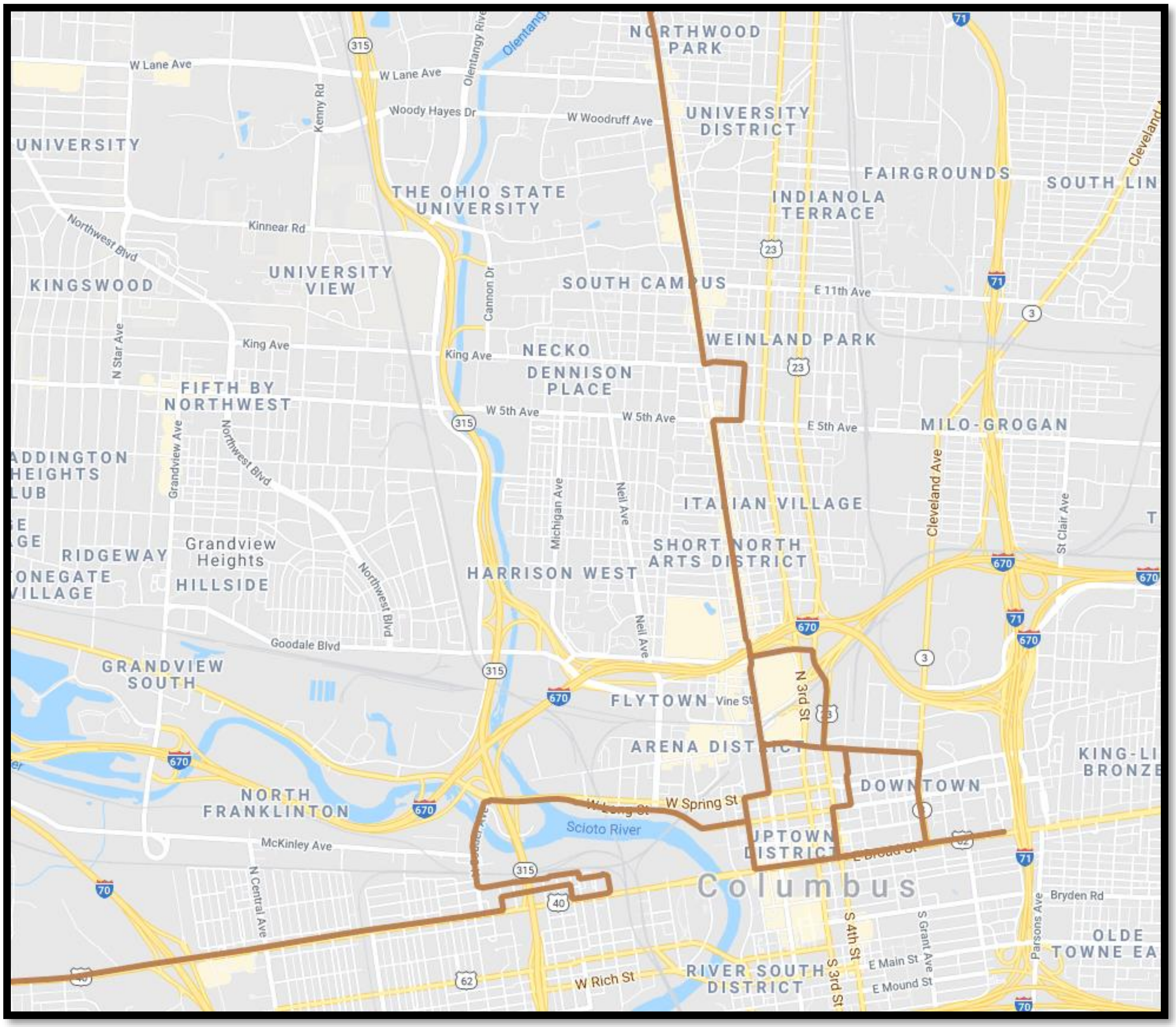


Figure 31: Metro Data Center metro fiber

Rail America (ROW)

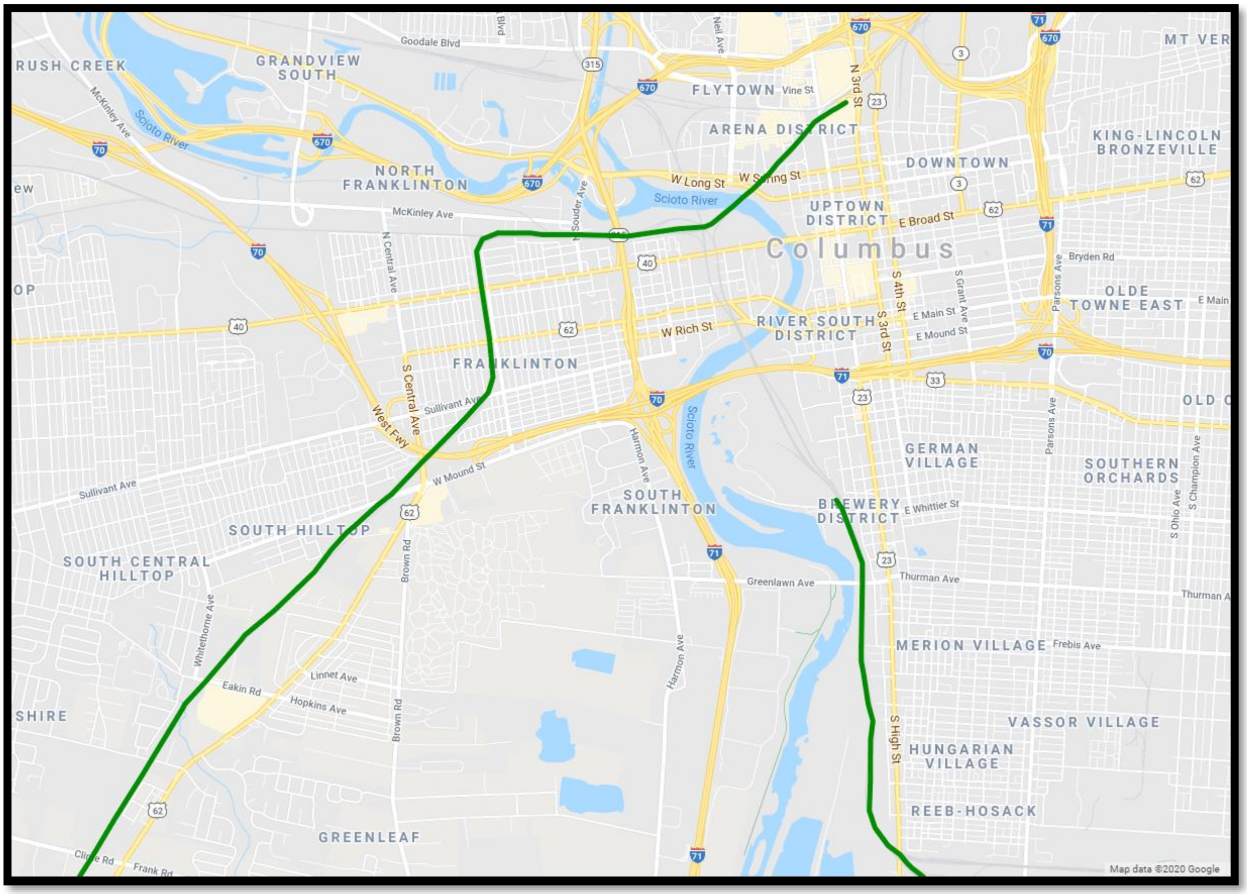


Figure 32: Rail America (ROW) metro fiber

Segra

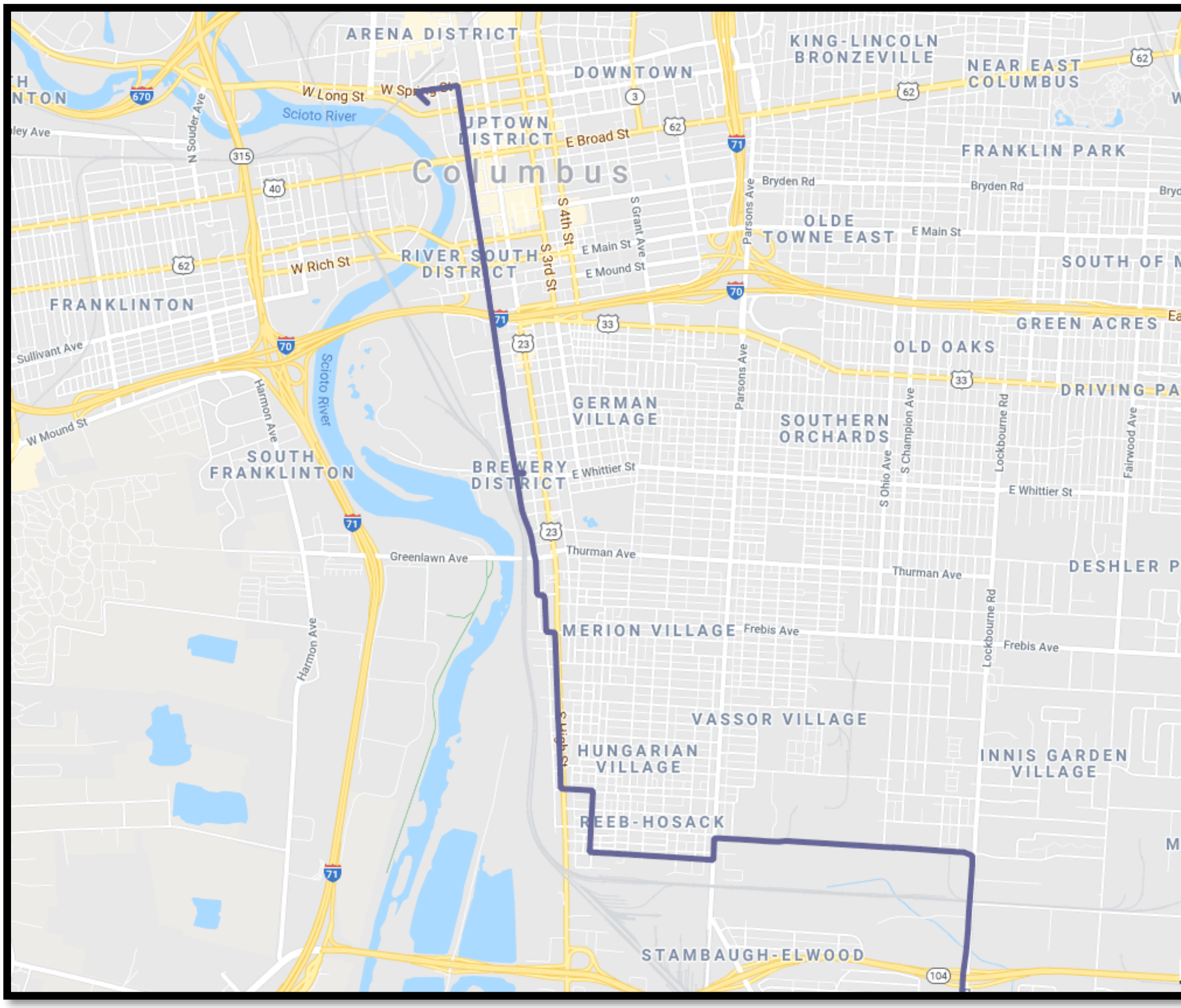


Figure 33: Segra metro fiber

Windstream

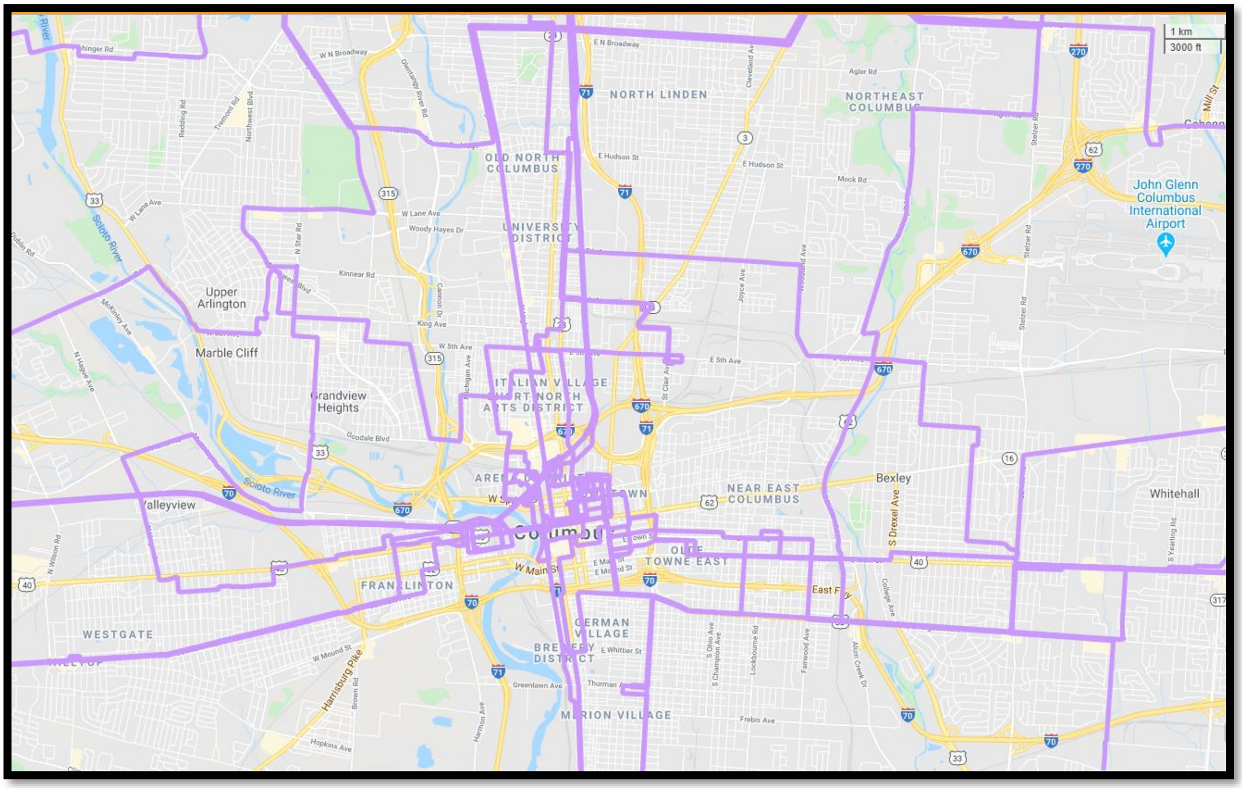


Figure 34: Windstream metro fiber

Wow! Business and Wow! Bluemile

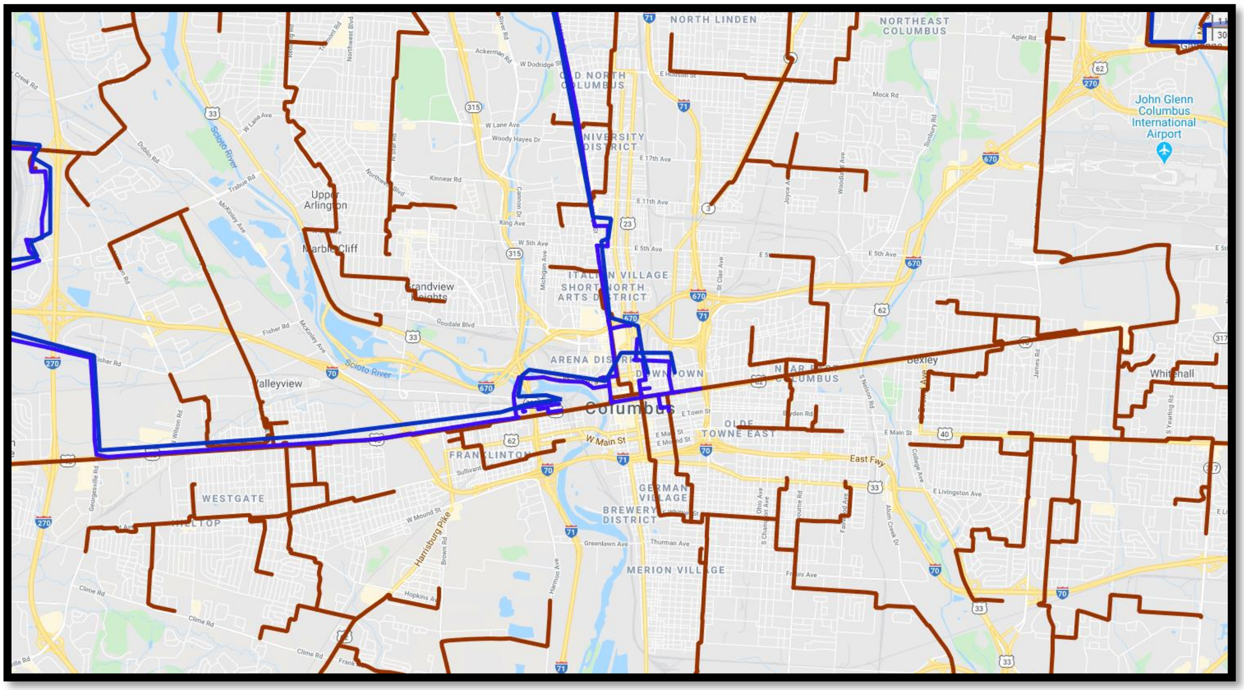


Figure 35: Wow! Business and Wow! Bluemile (colored blue)

Zayo Metro and Zayo Leased

Figure 36: Zayo Metro and Zayo Leased (in green)

aecom.com