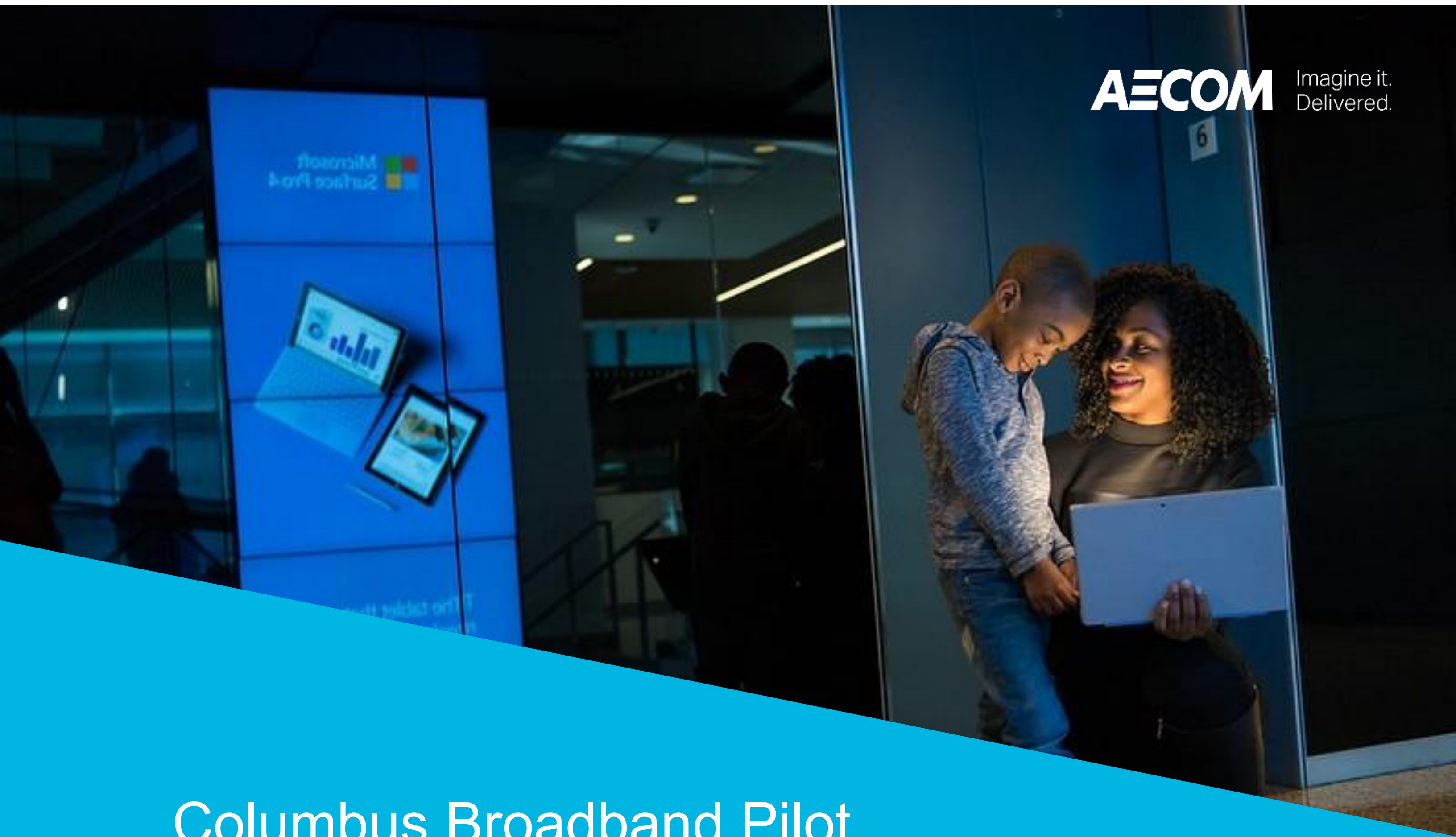

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Columbus Broadband Pilot PACT Neighborhood

Feasibility and Guidance

The Columbus Foundation

September 08, 2020

Quality information

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Introduction

This report represents a follow-on study to the Columbus Foundation's previously commissioned report on Broadband Access in the City of Columbus, Ohio. Having identified several data sets representing the problems associated with access to broadband as well as detailing some broadband platforms for addressing the digital divide, AECOM was commissioned to work with stake holders, planners, and community leaders to identify the feasibility and any challenges associated with near-term solutions.

The goal of this report is to provide the broadband committee with enough information to begin deployment on an effective and cost-reduced broadband access solution for a small community. Beyond the pilot program however, the process used and technologies chosen should provide a framework to expand the exercise to pilot projects in other areas of concern. One of the facets of this resulting pilot program is that it should be designed and planned to resolve the broadband concerns as expeditiously as possible to minimize further educational disruption and encourage technical literacy within the target households.

Summary of Recommendations

This report presents analysis of several solutions for a focus area in Columbus known as the Near East Side. However, following on from the survey work, the technical evaluation, and discussions of implementation models by the working group, our recommendation is that the most feasible solution to deliver the goals of this project as defined below is to:

> Engage an incumbent wireless internet service (WISP) provider in a public-private-partnership. Upon successful negotiation of fees and subsidies between the two parties, a low-cost broadband offering for qualifying households can be achieved very quickly and with no additional operational overhead. There are several advantages of a WISP including their existing engineering, administrative, and professional services. Additionally, the technical advantages of a WISP are both the time to deploy and the internet speeds. The build-out time is minimized by leveraging existing core network and metropolitan fiber deployments and the last mile connection to the subscriber is wireless which makes for an expedited deployment. At the same time, the internet speeds or throughput is higher than a cellular Wi-Fi hotspot and the service is better suited to serving households with multiple concurrent users participating in remote work and remote learning.
>
> Alternatively, it would be feasible to install a new wireless point-to-multipoint solution within the neighborhood. This solution is relatively quick to deploy and would require a fraction of the cost of a longer-term solution such as a fiber to the home (FTTH) system. The technical advantages of a new wireless point-to-multipoint solution are the same as a WISP model described above except that a third party operator would need to be identified to take on the engineering, administrative and professional services components.
>
> Further details on the new infrastructure recommendation and an example of the framework for how the public-private-partnership would work is detailed in the section titled Findings & Recommendations. Note that references to rough-order-of-magnitude pricing are not for public distribution and are therefore provided in a separate Appendix A.

Goal and Definitions

The working group consisting of the Columbus Foundation, PACT, and AECOM agreed to the following language as a way of defining the terms of the pilot study and identifying success.

We view success as **increased community adoption** of **fixed broadband** that is **affordable**, **accessible**, and **effective**.

Further defining each of these terms, we agreed that…

- **Increased community adoption** means that the pilot study and proposed solution should increase the number of residents with internet access, not drive residents with existing internet access to switch. Put another way, the goal is to increase the percentage of residents in the Near East Side with fixed internet access. It is recommended that the service deployment be offered for qualifying households only. Examples of qualifications associated with existing service provider assistance programs include:
  - Households with school-age children
  - Eligibility for public assistance programs such as SNAP, National School Lunch Program, and Head Start.
  - Eligibility for public housing
- **Fixed Broadband** means that the solutions should focus on technologies that provide a stable internet connection to a household, not one that is dependent on mobile device type hotspots or single-device type data-plans. The working group felt that traditional cellular hotspots utilizing a traditional Sim-card data-plan and subject to current carrier rates, data caps, and focused on mobility are a good stop-gap but not an ideal medium or long-term solution. Examples of existing fixed broadband solutions include fiber-to-the-home, cable internet or DSL modems, and satellite solutions. Other fixed broadband solutions can include wireless internet service providers, or WISPs where the connection to the home is wireless, not a hard-wired signal, but the device in the house is a fixed device providing multi-user fixed coverage within the residence.
- **Affordable** was difficult to define but based on similar studies of the digital divide literature and the initial results of pre-pilot survey work the team agreed that a target cost to the subscriber of $25.00 was appropriate. This provides for a service provider fee that, depending on the cost model assumptions and terms, can still provide an acceptable payback period. It is understood that this may still be too expensive for some households and that additional subsidies may be required in order to activate these homes.
- **Accessible** was defined as a complementary term to affordable and meant to address some of the harder to define barriers to accessing broadband services including personal preferences and service provider terms and conditions. The pre-pilot survey results indicate that personal choice and literacy factors pose as much of a barrier to adoption of internet access as affordability.
- **Effective** was an important distinction for the working group. The goal was a solution that would allow households with multiple working-age and school-age users to utilize the most common internet applications simultaneously. The benchmark model consists of (2) users actively using tele-working applications and (2) users actively using distance-education applications. Specifically, the minimum throughput levels were targeted based upon (4) simultaneous video calls with room for additional services and future expansion. The goal for the chosen system architecture is 100 Mbps download and 50 Mbps upload speeds combined with a latency of less than 40 ms. The goal for day one of the Pilot solution is to ensure all subscribers have reliable access to a minimum internet speed of 50 Mbps download and 25 Mbps upload speeds. More information on the topic of broadband internet speeds and existing baselines is provided in the Columbus Broadband Access Report commissioned by The Columbus Foundation and published by AECOM in June 2020.

Focus Areas

A working group was established in early August 2020 and composed of members from the Columbus Foundation, PACT, and AECOM. Among the goals for the working group was the identification of a focus area(s) for the initial pilot program. The criteria for selection of the focus area was based on average household income as reported by the American Community Survey (ACS), a geographical footprint free of substantial transportation infrastructure such as bridges, interstates, or significant waterways, and the presence of metro (dark) fiber assets in the general area.

Based on the knowledge of the Near East Side that PACT and the Columbus Foundation provided, four areas were initially identified as likely areas to focus on for survey work and solution analysis. These areas were **Bronzeville Pilot Area, Scholar House Pilot, Woodland Park Pilot Area, and Saunders Park Pilot Area.**

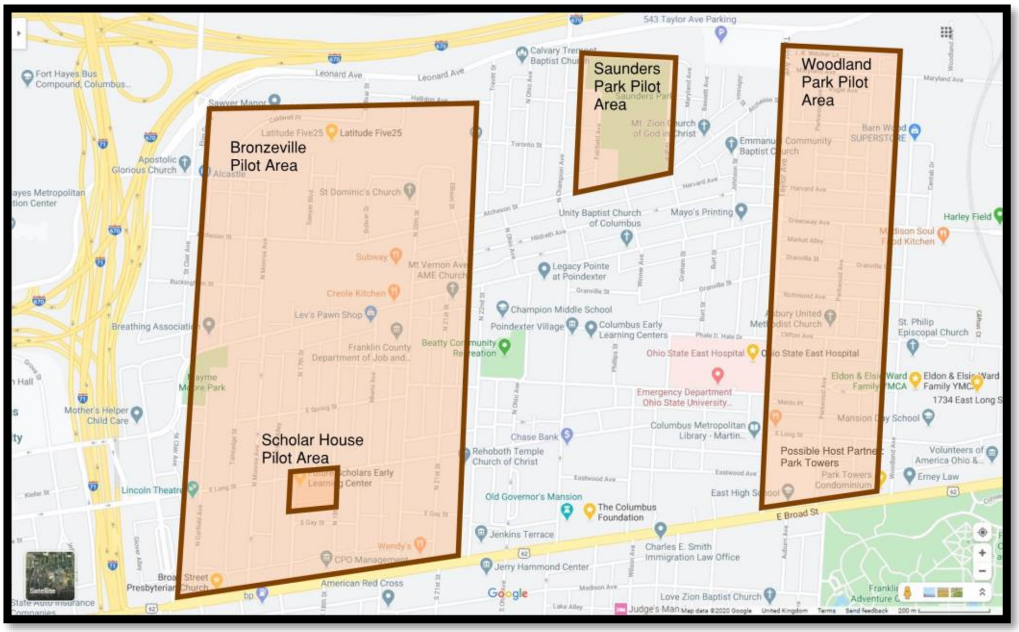

Figure 1: Proposed Broadband Feasibility Pilot Areas

- **Bronzeville Pilot Area:** ACS data and initial demographics research by PACT indicated this region as likely to have an especially high percentage of people without internet service and therefore a good target for affecting change to the number of people with internet access. Additionally, this area represents good diversity of income, residential building types and households with children attending schools.
- **Scholar House Pilot:** This area was identified as a possible self-contained project involving several housing types with a tight tie to the Future Scholars Early Learning Center which could prove to be a partner in a pilot project.
- **Woodland Park Pilot Area**: The northern end of this pilot project overlaps with the area indicated in the ACS data to be the second highest area for no internet access response. Moving from North to South along this pilot area represents a wide range of economic and household types as well as diversity in resident age.
- **Saunders Park Pilot Area**: This area was identified as representing a likely geography for a different type of pilot, specifically outdoor public Wi-Fi. The surrounding residents represent many families with school age children, and they are part of an ACS tract with higher than average ACS no-internet-access responses for Columbus. The Saunders Park space is close to a charter school set to open soon.

Pre-Pilot Survey Work

The starting point for understanding the internet connectivity of the area was the ACS data as presented in the overall Columbus Broadband Access study. The ACS survey data for the Near East Side tracts is presented below.

Figure 2: Central Columbus ACS Data Overview

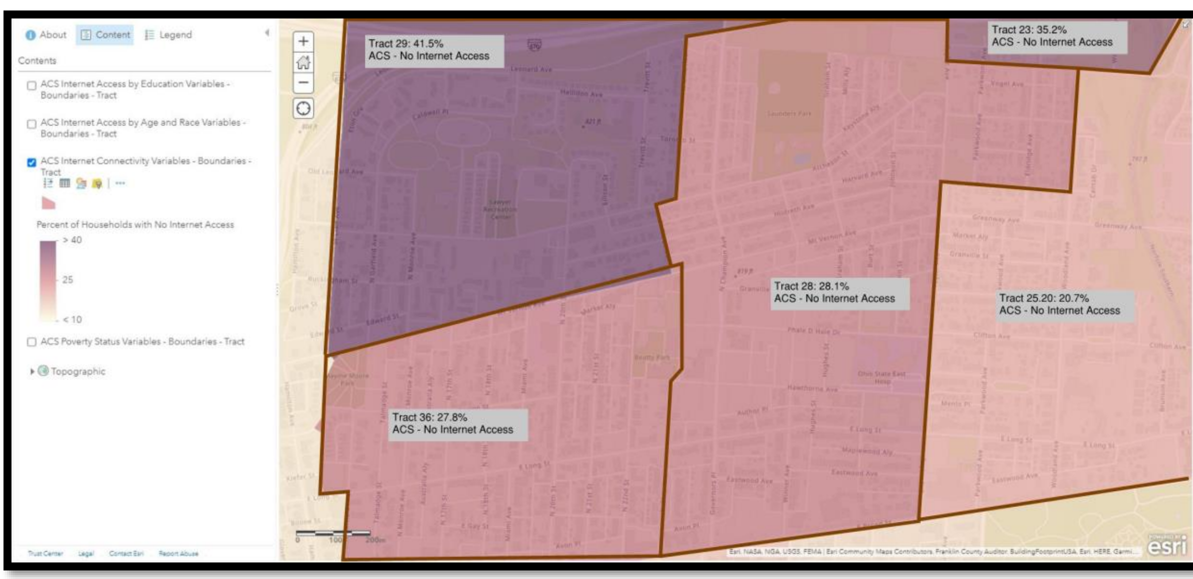

Figure 3: Near East Side ACS by Tract

PACT recognized the limitations of ACS data and designed a community engagement strategy to include neighborhood surveys to be conducted door to door. In support of this pilot study, PACT adopted feedback from AECOM and The Columbus Foundation to survey a specific section of the study area (Bronzeville) and was able to complete 325 surveys in that section of the neighborhood. This is an ongoing survey and engagement effort by PACT, however a list of the key findings from the initial survey work is below. At a very high level the survey results paint a picture of a community that would benefit from educational efforts to address literacy, questions of importance or trust issues, awareness of existing income qualified discount programs, an ongoing need for device access and a general need for lower cost options that are less costly than the incumbent ISP standard pricing tiers over $30.00.

- Based on the survey results in the proposed Bronzeville Pilot **area we estimate that approximately 39% of the residents do not have a reliable fixed internet offering**. This is in line with the ACS data as the Bronzeville pilot area is split between census tracts 29 and 36 which have 41.5% and 27.8% "No Internet Access" responses in the ACS data respectively (see Figure 3: Near East Side ACS by Tract)
  - **61.7% of respondents said they have Fixed Internet**, defined on the survey as "Internet access through an internet router, hub, or Wi-Fi device with a service such as a fiber, cable, DSL, or Satellite connected to a Modem, Router, or WiFi device. This includes broadband services from AT&T, Spectrum, Frontier, Centurylink, WOW!, Bresco, HughesNet, Viasat, Earthlink, or other fixed provider."
  - **11.57% of respondents said they had no internet access**, defined on the survey as *"access to the internet via any of the above at my household"*. This response very explicitly meant the respondent did not have fixed internet, cellular Wi-Fi Hotspot device, or a mobile internet connection on a smartphone or tablet. This response means the residents have no internet access at all at their house.
  - 7.46% of respondents had a cellular Wi-Fi Hotspot in their household
  - 19.28% of respondents said they had a device with a dataplan such as a smartphone or a tablet.
- There is a **strong opportunity to increase internet connectivity via an educational push** to raise awareness of existing income qualified discount internet plans through existing internet service providers.
  - 61.08% of the respondents said they **were not familiar with the existing broadband discount** and subsidy programs
  - 70.65% of the respondents said **they would likely benefit from knowing more about these programs**
- The survey data points to a concern for device availability within the households. **AECOM recommends a continued focus on ensuring that households have access to updated and affordable devices**. The primary devices used within the households are laptops and smartphones with each representing approximately 24% and 28% adoption respectively among respondents. It should be noted that these numbers are still very low for the sake of driving internet adoption. Of particular note, in a best-case scenario, combining desktops, laptops, and tablets still only results in approximately 46% of households with a device that could conceivably be used for remote work or learning. This is optimistic as this data is likely combined with some households having more than one type of those devices and others not having any suitable device, which would result in fewer than 46% of households having a device. This information should be further explored.
  - 24.13% of the respondents said they had a laptop in their household
  - 9.82% of the respondents said they had a desktop in their household
  - 12.24 of the respondents said they had a tablet in their household
  - 28.06% of the respondents said they had a smartphone in their household
- As expected from the Columbus Broadband Access study**, fixed internet costs were almost exclusively over $30 with the highest grouping between $31 and $60.** A significant percentage is paying over $60 currently. Very few residents appear to be benefiting from subsidized or income qualified programs with only 10% of the households reporting an internet bill $30 or under. AECOM

recommends a focused effort to share details of existing service provider subsidies and discounts via direct mail or other community outreach events.

- 32.70% of the respondents paid $31 to $60 per month
- 25.40% of the respondents paid $61 to $100 per month
- 14.29% of the respondents paid over $100

- **The average cost per month that would prompt residents to adopt internet appears to be $25 per month.**
  - 75% of the respondents cited they would feel comfortable paying up to $25 per month for internet access; the responses ranged from as low as $12 to $25
  - 13.7% of the respondents cited that $40- 50 per month was affordable for their household
  - 16% of the respondents cited that adding internet at any cost was not achievable for their household
- As expected from the Columbus Broadband Access study, cost was cited as the largest reason for not having internet access by households without internet access at approximately 33%. However, interestingly personal preference and digital literacy related options combined to come in a very close second at 30%, indicating that additional education and awareness campaigns may have as much impact on internet adoption as reduced price programs.
  - 32.70% of the **respondents cited cost** as the primary reason for not having internet access
  - 15.32% of the **respondents cited a lack of perceived importance** as the primary reason for not having internet access
  - 14.41% of the **respondents cited a lack of trust of internet service providers** as the primary reason for not having internet access
  - 6.31% of **the respondents cited digital literacy** as the primary reason for not having internet access
  - 6.31% of the respondents cited service denial by service providers as the primary reason for not having internet access
  - 6.31% of the respondents cited lack of a device with which to use the internet as the primary reason for not having internet access
- From a broadband throughput or speed perspective AECOM recommends **designing the solution around 4 people utilizing the internet simultaneously** within a single household as the appropriate metric. The survey data seems to back this up.
  - 52.59% of the respondents said they would often **have 2 to 3 people utilizing the internet at the same time**
  - 35.93% of the respondents said they would often have **more than 3 people utilizing the internet at the same time**.
- The **most common concerns for technology regarding the upcoming school year were no internet access or slow internet access**.
  - 13.97% of the respondents responded no internet access as a concern
  - 32.96% of the respondents responded slow or insufficient access as a concern
  - 20.11% of the respondents cited the cost of internet access required for remote learning

Broadband Technology Options

The following sections will detail the primary technologies which AECOM recommends be considered for this broadband access solution. These technologies **include Wi-Fi, Point-to-Multipoint Wireless, Wireless Mesh, and Private LTE (pLTE)**. These technologies were chosen due to a number of factors revealed throughout the initial broadband study. These include subscriber density, proximity to metro (dark) fiber, and the speed of a potential deployment serving 500 to 1000 households. Note that fiber to the home would be the ideal technology choice for long-term deployment offering speeds in the range 1Gbps today and even higher future speeds and is what incumbent ISPs are deploying in their newest build-outs, however **the time to deploy the fiber and the cost which must be captured via higher subscriber payments mean that fiber to the home is not practical for a fast-track pilot project targeting hundreds of subscribers in less than a year.**

A brief detail on the architecture of the technology is provided and, for those technologies deemed viable for the pilot, a rough-order-of-magnitude (ROM) CAPEX requirement is detailed as well.

Wi-Fi

Wi-Fi is among the world's most popular wireless connectivity technologies. It represents one of the most compelling solutions for engaging citizens and enhancing the urban experience for both convenience and commerce. Wi-Fi can also represent a platform for connecting sensors and devices as part of Internet of Things (IoT) services. The technology has become ubiquitous and therefore provides this value at a minimized cost relative to other wireless technologies.

When considering the application of Wi-Fi for a broadband access application, it is easy to imagine how the subscribers would interact with the service. After all, most households with broadband access do indeed use Wi-Fi for a majority of their device connections. But a common misconception about Wi-Fi is that it actually "is" the broadband connection itself when in fact, it only represents the medium by which some household devices connect within the home. For the vast majority of broadband access solutions, the internet connection exists upstream of the Wi-Fi router and is typically delivered by a cable modem, xDSL modem, or an optical network terminal (ONT).

The main reason for why Wi-Fi itself is not a prevalent broadband access methodology is the lack of scalability and range of the technology. Wi-Fi typically utilizes the 2.4 GHz and 5 GHz wireless spectrum which, although capable of transmitting hundreds of megabits per second within a home, it is vulnerable to interference from metallic or glass objects and the signal can even be affected by the presence of a working microwave oven. Signals from a Wi-Fi router are not likely to travel much farther than an adjacent house in a suburban neighborhood. For Wi-Fi to be deployed as a broadband architecture, a separate fiber or cable connection to the home must therefore be deployed to provide the backhaul to the core network. This is why Wi-Fi therefore exists as a mechanism for in-home connectivity, not a regional or even neighborhood-wide connection.

For the purposes of the focus area's broadband improvement goals, AECOM recommends that Wi-Fi be considered an enhancement to public services and to add value to the amenities of a neighborhood. As part of a greater broadband deployment, Wi-Fi could be deployed in designated public areas that would only require a single broadband connection and minor cabled infrastructure within the area to connect the individual Wi-Fi antennas.

Such an area under consideration by the working group is Saunders Park in the Northwest section of the focus area known as Mt. Vernon.

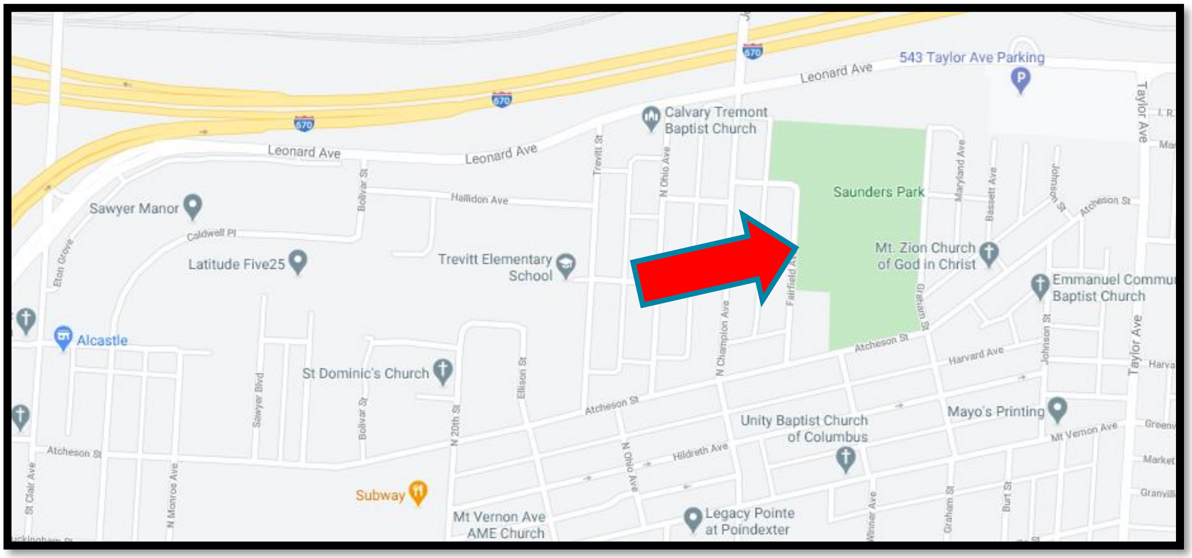

Figure 4: Saunders Park Wi-Fi Candidate

Wi-Fi Architecture

A deployment of an estimated eight (8) outdoor wireless access points (WAPs) should provide sufficient coverage for the entirety of the Saunders Park. The southern end would be served by two WAPs to contend with what is likely a higher density of end users around the pool area. The other larger open areas with athletic fields could be served by pole-mounted WAPs on the periphery of the park aimed towards the center of the fields.

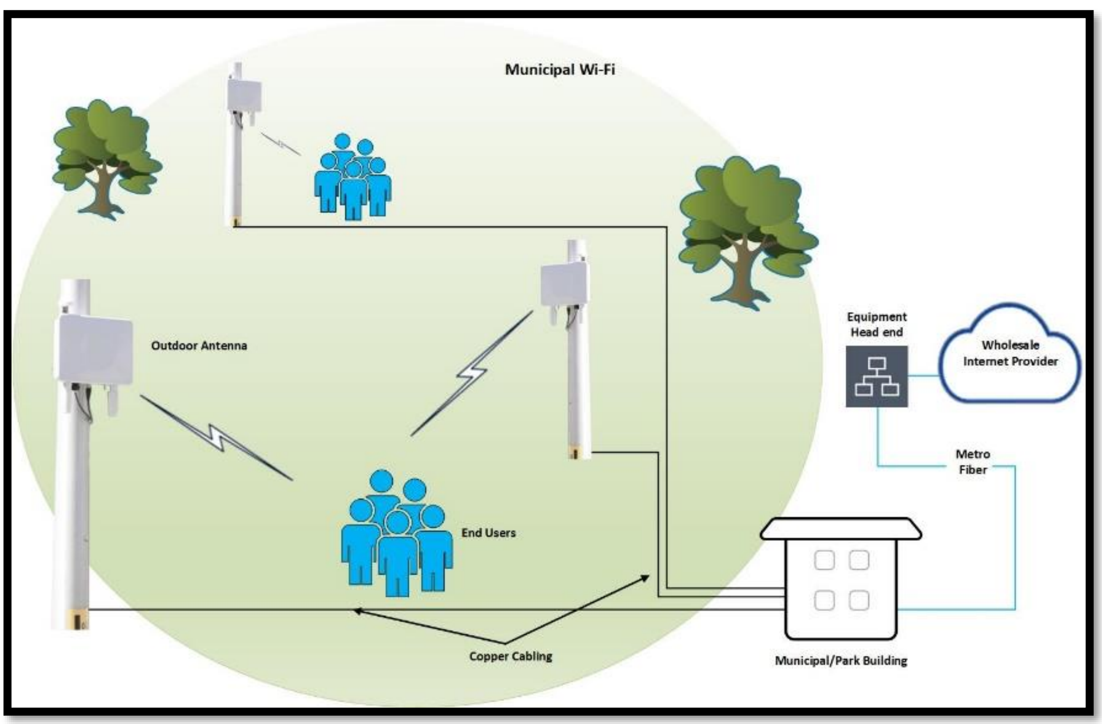

Figure 5: Notional Wi-Fi Architecture

Wi-Fi Capital Requirements

Because of the proliferation of Wi-Fi for both residential and commercial applications, the cost of wireless chipsets and the efficiencies in the supply chain around these products present a very attractive price point versus other wireless technologies. An outdoor Wi-Fi solution at Saunders Park would therefore represent a minor investment compared to the larger broadband deployment.

Initial analysis of the park infrastructure reveals that outdoor lighting or other vertical mounting poles are not currently available which impacts the cost for serving the northern area of the park. AECOM took into consideration a design which would represent a starting point for other community Wi-Fi deployments. The system pricing is therefore representative of a highly scalable enterprise-class solution which provides a robust wireless controller system. This controller will allow for multiple sites to be efficiently served with high-bandwidth, intelligent monitoring, and a secure service delivery. A rough order of magnitude for that infrastructure and the Wi-Fi equipment is included in Appendix A.

If there are budgetary constraints or the long-term expansion of the Wi-Fi service is not deemed a necessary component of the project, the above Wi-Fi pricing could be dramatically reduced with a smaller-scale, stand-alone solution that would effectively serves the park itself but with no capability to expand service to other areas.

Wireless Point-to-Multipoint

Wireless point-to-multi-point (PtMP) broadband networks have been deployed for over 25 years and there have been successful deployments in both urban and rural environments. The model requires that end users have a relatively high-altitude (40 feet or more) macro antenna serving their neighborhood. This typically can only be accomplished with radio towers, water towers, or multi-story buildings as the interference between adjacent homes, buildings, and even trees can cause significant reception problems. Wireless PtMP technologies offer excellent throughput and low latency which is good news for gamers and video streaming. Wireless PtMP networks can be more costly as a per-subscriber model as the wireless equipment typically is a stand-alone technology intended to be connected to a broadband router for Wi-Fi services within the home. The technology, as is the case with many wireless broadband services, is susceptible to rain fade during severe storms.

Wireless Point-to-Multipoint Architecture

Wireless PtMP broadband networks represent a low complexity architecture for broadband internet access. AECOM has included it the consideration of technologies for this very reason. Not having to build out a large fiber network throughout a network reduces the overall broadband deployment costs by several orders of magnitude. The macro antenna locations that serve the subscribers must be in a line-of-sight however. This requires careful consideration of the geography and placement of larger structures and even the presence of tall trees. Fortunately, there are options for addressing subscriber home installation challenges such as the placement of outdoor antennas at a higher altitude (roof top) or the selection of a different radio transceiver.

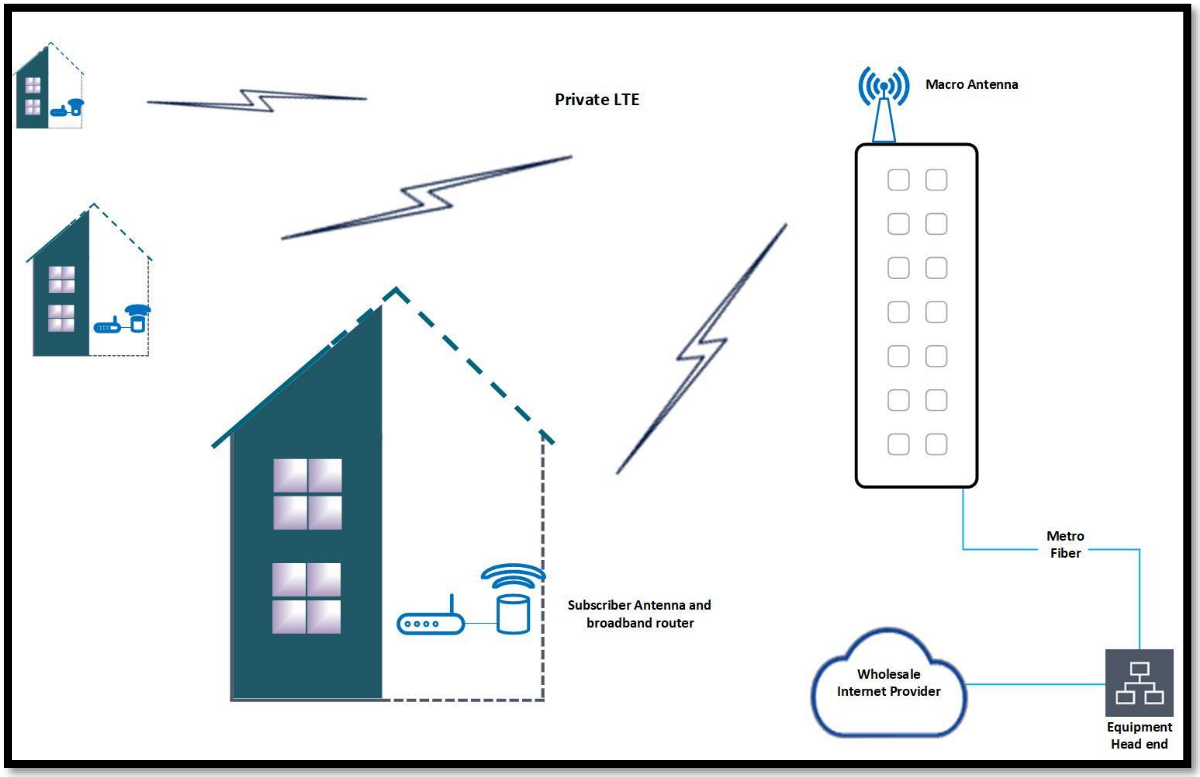

Figure 6: Wireless Point-to-Multipoint Architecture

AECOM has analyzed the geography of the focus area to determine if there are significant impediments to the proposed antenna sites. As a result, any line-of-sight issues, would likely be able to be addressed by elevating subscriber antennas to a roof-top deployment. Otherwise, it is expected that most subscriber installations could be done with a small antenna deployed on the eaves of a roofline, rather than the roof surface itself. These locations will obviously require the approval and coordination with the property owner. While there is likely a backbone fiber within each of the two buildings, we have included the capital requirements for that fiber in our CAPEX ROM figures.

The first location is the Latitude Five25 building in the Northwestern area known as Mt. Vernon. This building is estimated to be approximately 160 feet high. It represents one of the most effective vantage points in the focus area due to the resulting angles for line-of-sight to the residences in the western areas. The building is not currently served with municipal-owned fiber. This represents a significant cost factor and is detailed in the CAPEX requirements in **Error! Reference source not found.**.

Figure 7: Proposed Western Antenna Site

The second proposed antenna location is atop the Park Tower condominium building in the southeastern portion of the focus area. AECOM estimates the altitude of this building at approximately 150 feet. It is currently served with municipal-owned fiber as well as having a couple of options for other wholesale fiber providers in the vicinity.

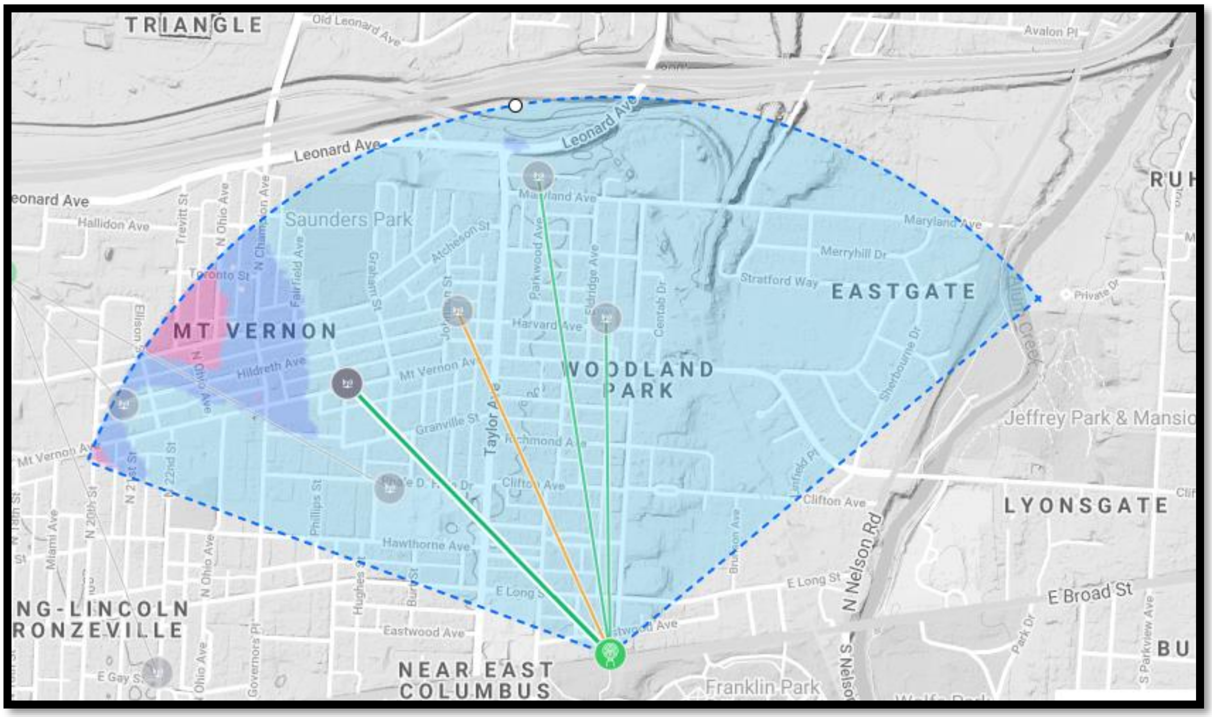

Figure 8: Proposed Eastern Antenna Site

Wireless Point-to-Multipoint Capital Requirements

The focus area for the pilot deployment presents some advantages with respect to antenna siting. There are several options for deploying a macro antenna on a relatively high roof top elevation. This results in better coverage for the subscribers and more flexibility in addressing RF interference concerns.

The capital requirements for the focus area consist of the macro antennas themselves which will connect via fiber back to the core network. It is unknown at this time if the City of Columbus' fiber network can be leveraged however at least one of the proposed antenna locations is served by the municipal-owned fiber network. This proposed location is the Park Tower condominium complex and should provide excellent coverage for the eastern portion of the focus area.

The other proposed antenna site provides an even more effective vantage point for addressing the remainder of the neighborhoods. This site is the Latitude Five25 apartment tower in the northwest section of the focus area. While strategically located for the antennas, it does not have municipal fiber deployed to the building. AECOM has therefore included a rough order of magnitude for deployment of a 2500-foot fiber buildout from the closest municipal fiber landing up to the apartment building. There are other options for metro fiber access however they would be available through conventional wholesale fiber providers in the area at a recurring lease cost. The ROM pricing is provided in Appendix A.

Wireless Mesh

As explained in the report, wireless mesh networks have been around for decades and there have been successful deployments in larger urban environments. The model requires that end users either have a macro antenna serving their home nearby or one or more subscribers providing the mesh connection points to span the distance between the furthest subscriber home and the antenna.

While the throughput of a wireless mesh network provides ample room for growth as a broadband technology, AECOM has determined that the most significant risk to a mesh deployment is the potential for a lack of sufficient participation (i.e. subscriptions) for a given span of subscriber homes. This "hole" in the subscriber service area would therefore require a new antenna connection with a dedicated broadband connection (fiber or other high speed fixed broadband connection) at a municipal facility or perhaps a subscriber's home.

This could have unexpected impacts on the operational expenses of a mesh network as subscribers move or cancel service which in turn impacts the network efficacy for nearby subscribers. Therefore, the adjacency of subscribers or "nodes" in the network is the key to a successful mesh deployment.

Wireless Mesh Architecture

As with wireless PtMP networks decribed later, wireless mesh networks represent a low complexity architecture for broadband internet access. AECOM has included it in the consideration of technologies for the same reasons which include a lower dark fiber requirement with no need for a "last mile" infrastructure buildout. Not having to build out a large fiber network throughout a network reduces the overall broadband deployment costs dramatically. The peer-to-peer nature of mesh architectures is a proven technology and can deliver hundreds of megabits of throughput without a large capital investment.

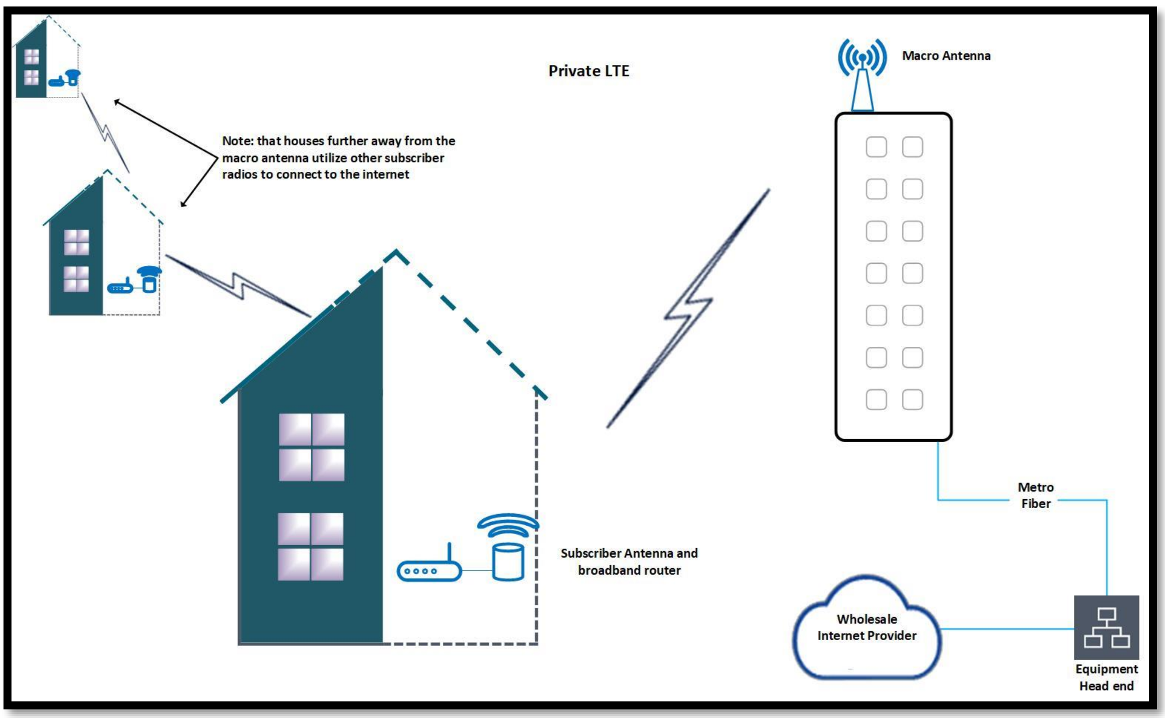

Figure 9: Wireless Mesh Architecture

Wireless Mesh Applicability

Having a very similar architecture to the Wireless Point-to-Multipoint technologies described above, AECOM finds that the CAPEX requirements would likely fall into the same order of magnitude. However, as projections for subscriber take rates and density of homes were considered, it became clear that the propensity for gaps in the service area would be high. Existing wireless mesh networks are almost entirely deployed within multi-dwelling units such as public housing and apartment buildings. While some anecdotal mesh networks exist for single-family dwellings, the deployments are usually the result of a lack of broadband alternatives. In this case however there are multiple service provider choices and the neighborhood surveys depict a range of consumer price sensitivities. Wireless mesh requires a dense collection of subscribers close enough to provide the mesh connection that the technology takes its name from. The distributed nature and limited number of connections are likely to cause significant gaps in the wireless mesh resulting in poor performance and the need to install more macro antennas to fill in the wireless mesh gaps**. It is for this reason that AECOM does not recommend the deployment of a wireless mesh architecture as a pilot technology**.

Private LTE

Private LTE (pLTE) is a wireless technology that is relatively new networking application however, the underlying technology behind pLTE is the same 4G LTE technology cell phone subscribers have been using for years. The difference is in the target user application and the fact that it makes use of a recently accessible radio spectrum called CBRS. CBRS stands for Citizens Broadband Radio Systems and is the result of the FCC's efforts since 2012 to allow a new spectrum to be set aside for commercial applications with adjacent spectrum restricted to US government and military applications. This change in how the spectrum is used also allows for unlicensed use of the spectrum which can translate to lower operating costs.

pLTE network provide the same advantages of the cellular carrier networks including heightened security, mobility and the ability to be deployed on various network devices including handsets, touch pads, and fixed wireless hotspots. The application of pLTE is largely seen as a large commercial solution for connecting many devices on a private and secure network such as a hospital, higher education campus, or even a manufacturing environment.

Although the components of a pLTE network resemble those deployed for enterprise Wi-Fi networks, the most significant advantages over legacy Wi-Fi networks is the ability to provide higher throughput (up to a gigabit), longer range, and higher end-user density.

PLTE Architecture

The simplicity of the private LTE infrastructure is one of its many advantages. Subscriber devices consist of a handheld compatible phone or tablet but in the case of this requirement, a single LTE transceiver would be used to convert the wireless LTE protocols to standard Ethernet. The Ethernet connection is then cabled to a conventional broadband home router which can provide additional wired Ethernet connections plus Wi-Fi connectivity that the subscriber can control themselves. This approach minimizes cable clutter for the home owner and provides a rapid installation for the service provider with no need for fiber or copper cabling to be installed from the roadside right-of-way to the home.

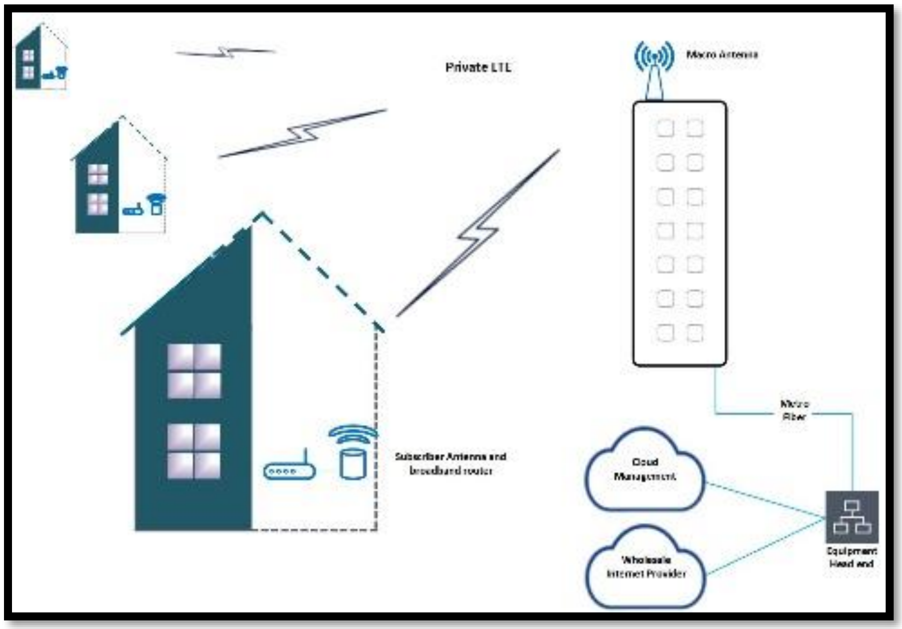

Figure 10: Private LTE Architecture

PLTE Findings

While **private LTE is an excellent fit for many large campus environments, industrial automation, and a variety of IoT applications**, AECOM's analysis found that the density of the homes in the neighborhoods coupled with the distances from antenna sitings was cost-prohibitive for the purposes of this pilot. Private LTE can provide high-speed coverage for a high density of users but if those users are then spread out over thousands of feet, the resulting device throughput falls far below the parameters AECOM has recommended for effective broadband service. Nominally speaking, using pLTE in this pilot deployment we would expect to see a 7 to 10 Mbps service delivery in some homes with even lower throughput (2-5 Mbps) for homes on the fringe of an antenna signal. This is far lower than the broadband throughput recommended in the solution definition agreed at the start of the study. While more antennas could improve this situation, **the quantity of antennae required to achieve the desired broadband throughput across the required geography coupled with the cost of fiber required to serve those antennae, renders pLTE unsuitable for the selected pilot areas of this residential broadband application**.

Low-Latency Satellite

As an update to the information provided in AECOM's Broadband Access report from June 2020, the SpaceX Starlink satellite broadband delivery system is being brought to market more rapidly than previously reported. While the system is still in beta testing, the number of satellites in the Starlink constellation are now over 400 with an eventual plan of nearly 12,000. The expected low latency (below 20 ms) and throughput (at least 45 Mbps) may satisfy the broadband requirements for most individuals.

Figure 11: Early image of a Starlink ground terminal transceiver

The ease of deployment will also be an attractive feature for subscribers needing an alternative to legacy satellite services such as HughesNet which tops out at 25 Mbps. SpaceX has yet to detail the service offering enough to determine if it will be a viable option for those who have more traditional broadband access providers to choose from. At this stage of the deployment the subscription rate is expected to be around $80 per month which certainly does not meet the affordability definition for this pilot project. However, as time goes on and more subscribers are added, it would be prudent to track the service options for a potential low-income subsidized offering.

Operational Models

The operation of a broadband network can be a complex and costly endeavor. For most broadband operators, there must be a return on investment within perhaps 5 or 7 years depending on the cost of capital and funding sources. For this reason, the operational model represents the second most important consideration in a broadband network, behind the initial infrastructure buildout. Considerations for the operation of a broadband network are complex and include:

- Staff for support, billing, and subscriber installation
- Warranty and maintenance support for network equipment
- Recurring wholesale internet costs
- 3rd party content/peering costs
- Modifications and maintenance for backend billing systems
- Ongoing maintenance and repair of fiber and copper networks
- Pole attachment fees
- Rental of antenna/equipment spaces
- Managed services (for build, operate, and transfer models)
- Insurance

AECOM is proposing three operational models for consideration in the broadband pilot program. These models may change significantly beyond the pilot deployment due to the need for expanded staff or equipment.

Public-Private-Partnership

In terms of speed to execution, no solution can present a more expeditious path than a public-private-partnership (PPP). By leveraging existing infrastructure or at the very least, an existing operational support model, a PPP can reduce the risk for both parties in deploying a broadband offering. This approach has been successful in lowering risk for both capital and operational costs.

Expansion of Existing Staff

There are a number of organizations participating in the broadband committee. Organizations like the City of Columbus's utility and IT departments, the public library system, and Columbus public schools all have existing staff to support their respective technical infrastructure. Other non-profit organizations also provide some level, albeit much smaller, of technical support for their operational needs. At this point AECOM cannot recommend which organization can provide an initial or ongoing expansion of support and operations for the network, however the concept of leveraging existing staff in one or more of the Columbus broadband committee organizations should be considered as a cursory approach.

3rd Party Outsourcing

There are a number of firms which provide broadband technical support, monitoring, cable plant maintenance, installation and repair, as well as administrative billing system support. AECOM has reached out to existing business entities to solicit interest in supporting a potential broadband pilot with the potential to subsequently expand service. The feedback thus far is positive and should be considered as a potential operational model after the initial deployment is completed.

Hybrid Operational Models

A pilot deployment such as this may benefit from a hybrid of the options outlined above. For example, an organization could be internally staffed to provide the configuration and communication with subscribers for the initial deployment. The installation and turn-up at the subscriber home however could be conducted by contracting a 3rd party. The expected number of subscribers in this phase of the network may not represent an onerous workload for operational elements such as capacity planning or billing systems; particularly if some functions are integrated into existing operations (e.g., the subscriber costs are incorporated into ongoing water meter billing functions).

Findings & Recommendations

Based on an analysis of the four pilot areas, the various technologies, and the possible operational models, the working group landed on the following options as the most effective approach for the pilot project.

The efficiencies associated with a public-private-partnership are substantial. There is no faster method of addressing the affordability and accessibility of broadband internet than engaging an incumbent service provider to offer a subsidized service. The following is an example framework for a broadband offering to qualifying households for $25 per month:

- $25 per month for a symmetrical 50 Mbps service delivery
- One-year contract term
- No subscriber installation fees
- Subscriber must be eligible for SNAP or other state and federal assistance programs
- Subscriber must have school-age children living in the home

In exchange for this service offering, the wireless internet provider would be compensated by the funding organization on a recurring basis. Details for the proposed framework are as follows:

- Funding organization provides a one-time reimbursement to the service provider of $250 for labor, electronics, and materials resulting from each initial subscriber installation
- Funding organization provides the service provider with a monthly $25 subsidy per subscriber
- Funding organization provides a one-time $25 subsidy to the service provider for any subsidized subscriber account this is closed for non-payment

An example of the annual costs for this approach serving 500 households is included in Appendix A.

This framework is representative of options for negotiation with a service provider. It would be prudent to discuss further terms and conditions to identify opportunities for improving pricing and/or subsidy requirements.

Should the negotiations for a public-private-partnership prove unsuccessful, AECOM considers the alternative of deploying a new broadband infrastructure quite feasible. The technology AECOM feels is most appropriate for the project goals is the point-to-multipoint wireless solution detailed in this report.

The focus area is well-suited for the initial pilot deployment. It provides the elements for a smooth technological deployment and statistically the area meets the criteria of households needing improved accessibility and affordability of broadband internet. This is the finding based on analysis of technical constraints, surveys, discussion, geography, and proximity of fiber infrastructure to suitable antenna locations.

Based on discussions within the working group, the most effective operational model would be to fund the installation and materials detailed in the ROM estimate and issue a request for proposal for the operational labor to administer, monitor, and support the infrastructure on an ongoing basis. The offeror would then be expected to assume ownership of the system and continue to provide the subsidized service while offering a higher-priced service to the general market.

Additional engineering and construction details are required to complete the design of this system and should be provided by the entity selected to build out the pilot solution. However, the high-level infrastructure and coordination requirements for this solution are presented below.

- Peering/Core Network Requirements
- Antenna Mounting/Hosting Requirements
- Technical Efficacy Targets
- Cost Model Assumptions

Suggested Next Steps

The following are AECOM's recommended next-steps for proceeding with the broadband pilot deployment.

RF Survey

In preparation for a deployment of any of the wireless technologies, it is recommended to have a radio frequency (RF) spectrum survey conducted in the area of focus. An RF survey typically entails one or two technicians walking and/or driving the target area with specialized spectrum analyzers and associated software. This survey will identify the existing RF spectrum that is in use in a service area and provide insight on the signal levels (i.e., the power level) and how a new deployment should be configured to co-exist and provide effective service.

Request for Proposal

AECOM recommends an RFP be prepared to solicit interest from existing service providers, broadband consultants and engineering firms, and 3rd party technology support firms.

Fiber and Antenna Site Negotiation

Coordination with either the City of Columbus or other wholesale fiber providers would be necessary to secure access for the connection to the internet. Consideration will need to be given to the location of the head-end equipment which will connect the wireless system to the internet. It is expected that the head-end equipment for the initial pilot deployment would fit into a single 19" equipment rack. Coordination will also be required with building owners for the antenna locations. These negotiations may result in additional recurring fees for rental of space at the top of the towers and/or access of fiber within the building.

Legal Review

Like many businesses, there is an existing ecosystem of attorney firms which focus on specific commercial verticals. There are competent firms that specialize in legal services for the service provider market. In addition to the general concern of litigation vis a vis competing broadband services and existing service provider markets, there are many considerations for seeking legal counsel in the deployment of a broadband network. These include:

- Assisting with the drafting of Requests for Proposals and Requests for Information
- Negotiation of broadband network deployment contracts for 3rd party and subscriber services
- Advising on strategies for effective market penetration and cost control
- Assisting with financial vehicles such as bonds and grants
- Consultation on telecommunications regulations
- Equipment and antenna lease negotiations
- Negotiation and mediation of utility pole attachments
- Wholesale carrier interconnection agreement litigation
- Navigation of right-of-way and eminent domain disputes
- Subscriber dispute resolution

End of Report

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