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Building Digital Equity in Affordable Housing in Arlington, VA

Prepared for AHC Inc. and APAH

May 2022

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1 Introduction and Report Highlights

The COVID-19 pandemic highlighted inequities that have existed for years – including that many lower-income families do not have access to reliable, affordable broadband options. The lack of affordable broadband significantly limits the ways families manage their health, finances, education, and job searches as well as their options for building and maintaining social networks.

In Arlington, VA, 16 percent of households do not have access to a fixed home broadband internet connection. Nearly three quarters (72%) of those earn less than $75,000 annually.[1]

To help quantify solutions to closing this gap, nonprofit affordable housing developers AHC Inc. (AHC) and the Arlington Partnership for Affordable Housing (APAH) teamed up to explore what it would cost to bring more broadband options to Arlington County's affordable apartment communities.

The partners commissioned CTC Technology and Energy (CTC) to conduct an engineering, market, and policy analysis to develop recommendations on how to equitably and efficiently connect residents living in AHC's and APAH's affordable, income-restricted mult-dwelling unit (MU) buildings to the internet. The project scope included 39 apartment communities owned by AHC and APAH that provide 5,119 affordable homes in Arlington. The report was made possible by a grant from Virginia Housing.

Three types of MDU buildings were surveyed in the report:

- Small MDUs – a single building with 50 units or less (five properties included in the survey)
- Large MDUs – a single building with 50 to 670 units (14 properties included in the survey)
- Garden Style MDUs – multiple small buildings in one location (20 properties included)

Two types of Broadband service implementations were considered within the buildings:

- Fiber to the individual units (FTTU) and
- Wi-Fi, which provides internet access via an antenna located on each building floor

The design and cost estimates developed in this report are based on AHC and APAH building connections to ConnectArlington, Arlington County's existing fiber network that links public buildings to the internet, although AHC and APAH could partner with any provider interested in the project.[2] The County's Digital Equity webpage emphasizes that "all individuals, including the most disadvantaged populations, have the information technology capacity required to fully participate in society," making ConnectArlington a strong candidate as a partner.[3]

[1] "American Community Survey five-year estimates (2014-2018)," U.S. Census Bureau, 2019.
[2] "ConnectArlington," Arlington County Department of Technology Services, https://departments.arlingtonva.us/dts/connectarlington/ (accessed October 11, 2021).
[3] "Digital Equity—Connecting Arlington," Arlington County Department of Technology Services, https://departments.arlingtonva.us/dts/digital-equity/ (accessed October 11, 2021).

Report Highlights

Estimated High-Level Costs

- Based on the technical models and data analysis used in the report, the total estimated capital cost for providing internet connectivity to the 5,119 apartments in the study is between $4.7 million (for fiber to each floor, with Wi-Fi service to the units) and $6.2 million (for fiber to each unit), or roughly $925 to $1,220 per unit. Adding a 20 percent contingency on material and labor would increase the total cost to between $5.5 million and $7.4 million.
- In addition to those capital costs, ongoing operating costs would include internet bandwidth, estimated at approximately $47,000 annually.

Cost Analysis Varies by Type of Apartment Community

- Garden Style MDUs and Small MDUs. The report found the per unit cost differences between fiber to individual units (FTTU) and Wi-Fi are similar enough in Garden Style and Small MDUs that the long-term benefits of fiber could outweigh the savings offered through Wi-Fi.
- Large MDUs. The report suggests providing Wi-Fi in a Large MDU is a more cost-effective solution than FTTU. The difference between FTU and Wi-Fi range from $400 to $820 per apartment in large MDUs. In addition to savings on cabling and labor, the units' proximity to one another means fewer access points are needed.

Other Highlights

- Although fiber-to-the-unit (FTTU) deployment could cost about one-third more than Wi-Fi installation, fiber is an adaptable technology that can support current and future needs – and likely require less future equipment replacement than a Wi-Fi network.
- Connecting each MDU to ConnectArlington would be the most efficient way to procure internet service, creating a unified network between all MDUs and any data center to which ConnectArlington has connectivity.
- Studies have shown free service has more potential for greater impact than a paid service. Even a relatively modest cost may suppress participation.
- Outreach and education for eligible families will be a critical part of the planning process for AHC, APAH, and the County.
- A variety of possible programs and partnerships currently exist and could be considered when developing a long-term connectivity strategy.

2 Executive Summary

Given our analysis of data and policies, CTC makes the following recommendations.

2.1 Description and analysis of policy alternatives: Recommendations for expansion or creation of new digital equity initiatives in Arlington

We recommend AHC and APAH consider linking ConnectArlington fiber (or another middle mile provider) to the 39 MDUs listed in Table 2 to provide free broadband internet service to residents in 5,119 units. The three-pronged approach described below represents an opportunity to leverage County communications infrastructure to deliver fixed broadband to some of the County's most vulnerable residents which the greatest cost-benefit that each MDU allows, based on the high-level cost estimates outlined in Section 4.3.1.

Our methodology looked at the difference in cost per unit between an FTTU implementation and a Wi-Fi implementation for each MDU. For the 14 Large MDUs, where the population density is the greatest, our analysis shows that Wi-Fi has a greater cost-benefit than FTTU. However, fiber is optimal for 12 of the Garden Style MDUs. Nestled in between are all five Small and eight Garden Style MDUs, where it is marginally cheaper to build Wi-Fi, but the difference between the two deployment options is small enough that AHC and APAH may consider fiber for its additional benefits.

We expect that AHC and APAH would be willing partners in an initiative to bring more cost-effective broadband options to its residents in their homes. Because AHC and APAH own these properties, the deployment complexity and costs would likely be reduced in relation to access to critical infrastructure required in any broadband deployment scenario, such as existing underground conduit, building rooftops, and private easements.

This recommendation is not just about seizing an opportunity to deliver cost-effective service—it is a policy-driven approach to ensuring that low-income residents have access to fixed broadband in their homes (and an important complement to the recommendation in 2.1.5 that AHC and APAH help residents participate in the federal subsidy and incumbent ISP programs for low-income residents).

This recommendation reflects an effort to ensure that low-income Arlingtonians have fixed broadband service in their homes, either as their only service or to complement their smartphones. In 2019, the Pew Research Center concluded that 26 percent of U.S. households earning less than $30,000 are "smartphone-dependent" internet users[4] that own a smartphone

[4] Monica Anderson and Madhumitha Kumar, "Digital divide persists even as lower-income Americans make gains in tech adoption," May 7, 2019, https://www.pewresearch.org/fact-tank/2019/05/07/digital-divide-persists-even-as-lower-income-americans-make-gains-in-tech-adoption/ (accessed October 14, 2021). Note, too, that the number of people who are "smartphone dependent" has increased by 14 percent since 2013.

but do not have a home broadband connection. These residents must use smartphones for tasks that typically are completed more easily with larger screens (like completing homework or applying for a job). It is no surprise, then, that Americans who can afford to purchase both fixed and mobile broadband service tend to buy both.

2.1.1 Recommendation: Install Wi-Fi in Large MDUs

The cost of building fiber-to-the-unit (FTTU) in the 14 MDUs that we've classified as Large is much greater than the cost of deploying Wi-Fi to these units. Much of the cost of FTTU in these cases stems from the number of units where CPE, which we estimate at $250 per unit, would be provided. However, our analysis shows that even when CPE costs are excluded (in the case that CPE costs would be covered by a commercial partner), the cost of FTTU is still significantly greater than the cost of Wi-Fi. Therefore, we recommend a Wi-Fi implementation for these buildings, where the difference between FTTU and Wi-Fi ranged from $400 to $820 per unit, as shown in Table 1.

Table 1: MDU Wi-Fi/Fiber Cost Differential

Property	Style	Units	Length of Conduit	Total Cost (FTTU)	Cost per Unit (FTTU)	Total Cost (Wi-Fi)	Cost per Unit (Wi-Fi)	CPU Fiber/Wi-Fi
Hunter's Park	Large	74	210 ft.	$129,300	$1,750	$68,600	$930	$820
The Shell	Large	83	170 ft.	$129,600	$1,560	$66,700	$800	$760
The Jordan	Large	90	180 ft.	$131,800	$1,470	$67,200	$750	$720
The Shelton	Large	94	280 ft.	$137,600	$1,460	$72,000	$770	$690
The Spectrum	Large	100	300 ft.	$140,100	$1,400	$73,000	$730	$670
The Springs	Large	104	80 ft.	$130,500	$1,260	$62,400	$600	$660
The Frederick	Large	108	230 ft.	$138,700	$1,280	$69,600	$650	$630
Harvey Hall	Large	116	60 ft.	$132,600	$1,140	$61,400	$530	$610
Arlington Mill	Large	122	270 ft.	$144,100	$1,180	$71,500	$590	$590
Gilliam Place	Large	173	410 ft.	$163,600	$950	$78,200	$450	$500
Parc Rosslyn	Large	238	80 ft.	$164,000	$690	$62,400	$260	$430
Columbia Hills	Large	229	180 ft.	$166,600	$730	$67,200	$300	$430
Apex	Large	256	260 ft.	$177,200	$690	$71,100	$280	$410
The Serrano	Large	280	670 ft.	$202,800	$720	$90,700	$320	$400
Historic Ballston Park	Garden	512	3,600 ft.	$184,600	$360	$69,571	$140	$220
Gates of Ballston	Garden	465	4,200 ft.	$345,700	$740	$242,400	$520	$220
Woodbury Park	Garden	364	2,300 ft.	$229,200	$630	$151,200	$420	$210
The Macedonian	Small	36	355 ft.	$33,000	$920	$25,600	$710	$210

Property	Style	Units	Length of Conduit	Total Cost (FTTU)	Cost per Unit (FTTU)	Total Cost (Wi-Fi)	Cost per Unit (Wi-Fi)	CPU Fiber/Wi-Fi
Columbia Grove	Garden	208	1,400 ft.	$147,000	$710	$108,000	$520	$190
Key Gardens	Small	22	60 ft.	$15,400	$700	$11,400	$520	$180
Calvert Manor	Small	23	150 ft.	$20,000	$870	$15,800	$690	$180
Arbor Heights	Garden	198	2,250 ft.	$185,300	$940	$151,200	$760	$180
Westover	Garden	153	4,000 ft.	$258,100	$1,690	$232,800	$1,520	$170
Cameron Commons	Small	16	240 ft.	$22,600	$1,410	$20,100	$1,250	$160
Marbella	Garden	134	1,800 ft.	$147,700	$1,100	$127,200	$950	$150
Barkalow	Small	14	60 ft.	$13,400	$960	$11,400	$820	$140
Courthouse Crossings	Garden	112	1,820 ft.	$143,200	$1,280	$128,100	$1,140	$140
Buchanan Gardens	Garden	111	1,450 ft.	$125,200	$1,130	$110,400	$1,000	$130
Arna Valley View	Garden	101	440 ft.	$74,200	$730	$61,900	$610	$120
Fort Henry Gardens	Garden	92	2,300 ft.	$161,200	$1,750	$151,200	$1,640	$110
Arlington View Terrace	Garden	77	520 ft.	$72,000	$940	$65,700	$850	$90
Virginia Gardens	Garden	76	900 ft.	$90,000	$1,180	$84,000	$1,110	$70
Fisher House II	Garden	68	1,080 ft.	$96,600	$1,420	$92,600	$1,360	$60
Colonial Village West	Garden	70	1,700 ft.	$126,900	$1,810	$122,400	$1,750	$60
Key Boulevard	Garden	46	320 ft.	$54,700	$1,190	$56,100	$1,220	($30)
Taylor Square	Garden	44	800 ft.	$77,200	$1,760	$79,200	$1,800	($40)
Leckey Gardens	Garden	40	340 ft.	$54,100	$1,350	$57,100	$1,430	($80)
Ashton/N. Ashton House	Garden	37	410 ft.	$56,700	$1,530	$60,500	$1,630	($100)
Fisher House	Garden	33	480 ft.	$59,100	$1,790	$63,800	$1,930	($140)

2.1.2 Recommendation: Install FTTU in Small and Garden Style MDUs, but consider Wi-Fi where applicable

Our analysis shows that FTTU has a greater cost-benefit than Wi-Fi in AHC and APAH's small-to-medium sized MDUs, especially if a commercial provider covers the costs of CPE.

Fiber infrastructure lasts decades, and the capabilities of a network built with fiber are scalable far into the future. By investing in fiber—both from ConnectArlington to MDUs, and inside the buildings to connect each unit—AHC and APAH would be leveraging their assets to empower their residents with high-speed, affordable broadband. Moreover, AHC and APAH would then be

able to offer additional digital equity programs for their residents and potentially incentivize incumbent ISPs to do the same.

From a technical standpoint, fiber is a future-proof technology that can support current and future residential communications needs. As our model illustrates (see Section 4), a fiber-to-the-unit deployment would cost about one-third more than a Wi-Fi deployment—approximately $6.2 million for fiber and $4.7 million for Wi-Fi—but fiber would deliver significant technical benefits and likely would require less future equipment replacement than would a Wi-Fi network.

Our cost analysis was conducted at a high-level, and actual installation costs may vary, but for the Small and Garden Style MDUs, the per unit costs between fiber and Wi-Fi are similar enough that the long-term benefits of fiber outweigh the savings offered through Wi-Fi. Should a more granular cost estimate for some MDUs prove otherwise, we suggest that AHC and APAH consider deploying Wi-Fi.

2.1.3 Recommendation: Deliver broadband service at no cost to AHC and APAH residents

By taking on the relatively modest operating cost of delivering broadband services to the 5,100 residential units analyzed in this report, AHC and APAH (or a partner entity) would be removing affordability as a constraint on residents' broadband adoption and use. We recommend that these services be offered at no cost for two reasons:

1. Given the significant cost barriers associated with low adoption of broadband, a free service has potential for far greater adoption than a paid service.
2. Offering free service entails less operating cost and complexity than a paid service with respect to sales, marketing, billing, collections, and other elements of paid broadband service. However, AHC and APAH would need to initially invest in a concerted community outreach model.

In our experience, even a relatively modest cost for internet may suppress participation. One prominent example comes from Madison, Wisconsin. In 2016, Madison led a pilot program to offer broadband to 161 buildings with 1,083 apartments for a $9.99 per month charge for customers. Although promising, the program failed for variety of reasons, connecting 86 buildings and attracting only 19 subscribers. One lesson learned from this program is that even a $9.99 monthly charge may be cost-prohibitive for many residents.

We have found that free access typically leads to greater participation. Monkeybrains in San Francisco, California, serves as another example. In partnership with the City of San Francisco, Monkeybrains offered gigabit-speed internet to over 1,000 affordable housing units for free for the first two years of use. After two years, Monkeybrains agreed to charge customers less than

$20 per month. This approach has led to the project's success, both in terms of subscriptions and business case.

We anticipate that a free service would be provided on a "best effort" basis, without particular service level guarantees, but the program would still necessitate certain operations support to deliver a reliable service and ensure the overall technical success of the initiative.

Further, additional operating costs associated with billing and marketing are required when charging a fee for service. These costs can drive up operating expenses and require the acquisition of experienced management personnel and operating infrastructure (i.e., a billing system and a sales team).

2.1.4 Recommendation: Support existing digital equity programs

As we note above, Arlington has a variety of digital equity initiatives related to broadband affordability, device access, and digital skills training. We recommend AHC, APAH, and the County consider ways to support those existing programs or conduct outreach to enable them to reach more residents in AHC and APAH buildings. Similarly, we recommend evaluating those programs and expanding as necessary to address additional barriers to broadband adoption that might be preventing AHC and APAH residents from using broadband despite these established efforts.

2.1.5 Recommendation: Help residents maximize participation in federal subsidies and incumbent ISP programs for low-income residents

Comcast's Internet Essentials, Starry's Connect program, and the federal government's Lifeline and Emergency Broadband Benefit programs offer opportunities for qualifying AHC and APAH residents to receive low-cost or discounted broadband services. But each program has its share of hurdles that make enrollment challenging, and participation rates have historically been low.

A critical effort from the AHC, APAH, and the County would include outreach and education for eligible families to provide information about the program, as well as resources to assist with the enrollment process. Ideally, support would be provided in partnership with established, trusted community organizations that are already accustomed to providing resources of this nature.

CTC recommends that AHC, APAH, and the County first collect data on the enrollment of their residents in these programs and the qualitative experience of undergoing the respective application processes and then take a series of steps to alleviate the barriers to enrollment in all four programs by launching a program that facilitates resident applications and promotes public awareness. Additionally, a partnership between AHC, APAH, and the County to undertake this effort could increase awareness about the programs and educate residents about eligibility and program benefits. Such a strategy would leverage existing County efforts to maximize the impact

of existing, long-standing programs that are available to a large number of residents that may struggle to afford the internet.

In relation to the Emergency Broadband Benefit specifically, the County could seek to maximize the participation of families in this new FCC program—and the amount of federal subsidy funds coming to residents. The program could use a similar structure employed to connect residents with ISP-initiated subsidy programs to help families understand and navigate the process. The facilitators might even connect families to ISPs to facilitate their enrollment. This will require coordination with the FCC to understand the criteria that will be used to determine the broader eligibility criteria in the federal subsidy program, and to communicate those criteria and any documentation requirements to eligible families.

A second pain point that the program might be able to alleviate is the burden on ISPs, which will have to verify families' eligibility under the FCC rules. For big ISPs, that is a relatively easy chore because they have access to the federal Lifeline verifier and their own low-income programs. But for small ISPs, that could be a potentially insurmountable task. The new federal statute suggests that, to verify a resident's participation in the National School Lunch Program (and thus eligibility for the new subsidy), an ISP can call schools, which burdens both small ISPs and schools. The program could play a role, for the benefit of its ISPs and residents, by developing materials and call center support to help ISPs and residents understand and navigate the program, ensure ISPs get qualified by FCC to participate, and then to determine that families are eligible. This approach would take some of the burden off ISPs with an eye toward benefiting smaller providers.

3 Project scope and data

AHC and APAH have long partnered with Arlington County to provide affordable housing. AHC currently offers 7,500 affordable units at more than 50 properties in Virginia, Maryland, and Washington, D.C, and APAH currently provides 2,000 affordable units across its 18 properties in Arlington County and the Washington, D.C., metro area.[5] Table 2 identifies the roughly 5,100 AHC and APAH units by property that AHC and APAH targeted for this project.

Table 2: Number of Units by Targeted MDU Property

AHC				APAH			
Property	Affordable Units	Market Rate Units	Number of Units	Property	Affordable Units	Market Rate Units	Number of Units
Apex	217	39	256	Arlington Mill	122	0	122
Arbor Heights	198	0	198	Arna Valley View	101	0	101
Arlington View Terrace	47	0	77	Barkalow	0	14	14
Ashton & North Ashton House	37	0	37	Buchanan Gardens	111	0	111
Colonial Village West	70	0	70	Calvert Manor	15	8	23
The Frederick	108	0	108	Cameron Commons	16	0	16
Fort Henry Gardens	82	0	92	Columbia Grove	130	78	208
Gates of Ballston	358	107	465	Columbia Hills	229	0	229
Harvey Hall	100	16	116	Courthouse Crossings	112	0	112
Historic Ballston Park	233	279	512	Fisher House	33	0	33
Hunter's Park	74	0	74	Fisher House II	68	0	68
The Jordan	90	0	90	Gilliam Place	173	0	173
Key Boulevard	46	0	46	Leckey Gardens	33	7	40
Key Gardens	22	0	22	Marbella	134	0	134
The Macedonian	36	0	36	Parc Rosslyn	100	138	238

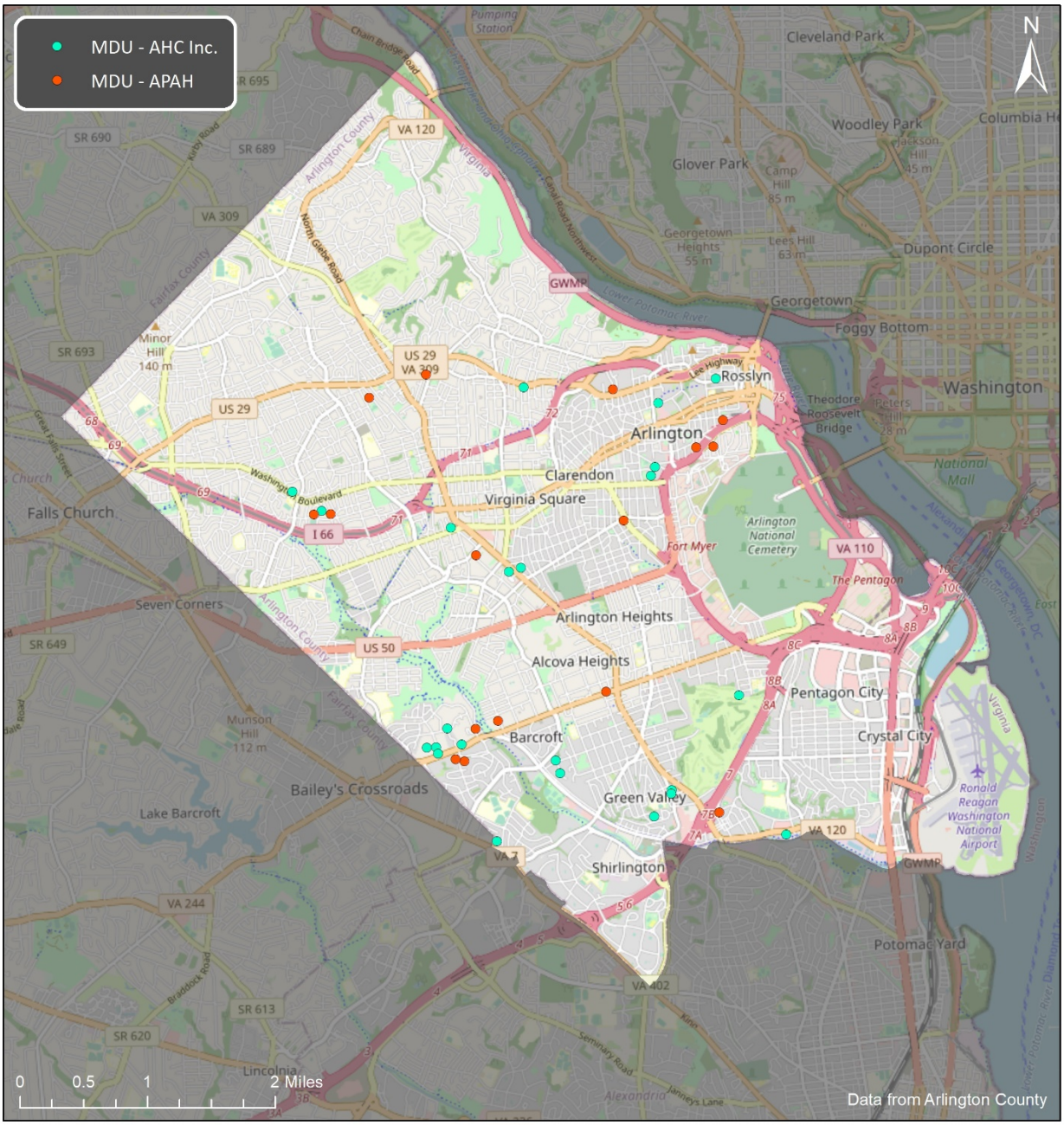
[5] "Four decades of experience, strong partnerships, community commitment and innovative development strategies," AHC, https://www.ahcinc.org/about-ahc-inc/ (accessed October 11, 2021); "Why APAH?" Arlington Partnership for Affordable Housing, (n.d.). Why APAH?, *APAH*, https://apah.org/why-apah/ (accessed October 11, 2021).

AHC				APAH			
Property	**Affordable Units**	**Market Rate Units**	**Number of Units**	**Property**	**Affordable Units**	**Market Rate Units**	**Number of Units**
The Serrano	56	224	280	**The Springs**	98	6	104
The Shell	83	0	83				
The Shelton	94	0	94				
The Spectrum	40	60	100				
Taylor Square	44	0	44				
Virginia Gardens	76	0	76				
Westover	115	38	153				
Woodbury Park	204	160	364				
Total Number of Units	**2,430**	**923**	**3,393**		**1,475**	**251**	**1,726**

In Arlington County, affordable apartment units are either Committed Affordable Units (CAF) or Market-Rate Affordable Units (MARK). CAFs offer a guaranteed rent subsidy that typically ranges between 30 and 80 percent of the area's median income, while the MARK's fluctuate with market trends, typically providing below-market rents between 50 and 80 percent of the area's median income.[6] Figure 1 illustrates where these targeted MDUs are located across the County.

[6] "What is affordable housing?" Arlington Partnership for Affordable Housing, https://apah.org/housing/what-is-affordable-housing/ (accessed October 11, 2021).

Figure 1: Location of Targeted Arlington MDUs



4 Data analysis: High-level design and cost estimate for constructing infrastructure to connect AHC and APAH MDUs to the County's ConnectArlington network

Based on the technical models and data analysis described in this section, the total estimated capital cost to connect approximately 5,100 units within AHC and APAH MDUs would be between $4.7 million (for fiber to each floor, with Wi-Fi service to the units) and $6.2 million (for fiber to each unit), or roughly $925 to $1,220 per unit. In addition to those capital costs, operating costs would include internet bandwidth, estimated at about $47,000 annually, which are discussed in Section 4.3.4.

4.1 Description and evaluation of existing information sources

4.1.1 Technical model for classifying MDUs

We began by compiling a list of all AHC and APAH MDUs and gathering relevant data on each, such as addresses, number of floors and units, and information on available floorplans. We analyzed these data to develop the parameters needed for creating a high-level network design and cost estimate. We made suitable assumptions about floorplans when the information was not available.

Due to the scope of the project and the number of MDUs, site surveys were not feasible. Instead, we created a method to categorize the MDUs into three typologies for the purpose of developing the high-level designs and cost estimates. Each typology would have an associated cost model to which we could apply attributes from a particular MDU for the high-level cost estimate.

We reviewed all available floorplans and conducted desk surveys of each building using Google Maps and Google Street View to determine representative buildings for each typology. We considered the range in the number of floors, number of units, building sizes, and other factors to determine trends across the MDUs, and to choose representative examples of three types of MDU designs. The three typologies developed were:

- Small MDU – An MDU with up to 50 units in a single building. The representative building for this model was The Macedonian.
- Large MDU – An MDU with more than 50 units in a single building. The representative building for this model was Columbia Hills.
- Garden Style MDU – An MDU with multiple buildings across a geographical area. This typology typically exhibits a large amount of underground conduit to connect multiple buildings. The representative building for this model was Buchanan Gardens.

Each MDU was categorized based on this typology.

4.1.2 Technical model for constructing fiber or Wi-Fi in MDU types

We then developed a bill of materials (BOM) and overall cost estimate for constructing a network to and in the representative building of each typology. To explore multiple options, we developed high-level models for two types of broadband service implementations within the buildings: fiber-to-the-unit (FTTU) and Wi-Fi.

In the FTTU implementation, physical fiber is run throughout the buildings to a "patch" panel inside each unit to deliver a wired fiber connection to every resident. Customer premises equipment (CPE) is provided to each unit, and residents can physically connect their computer to the CPE via a cable or a Wi-Fi signal. In the Wi-Fi implementation, physical fiber is run to a wireless access point antenna located on each floor of the building, to which residents connect in order to access the internet.

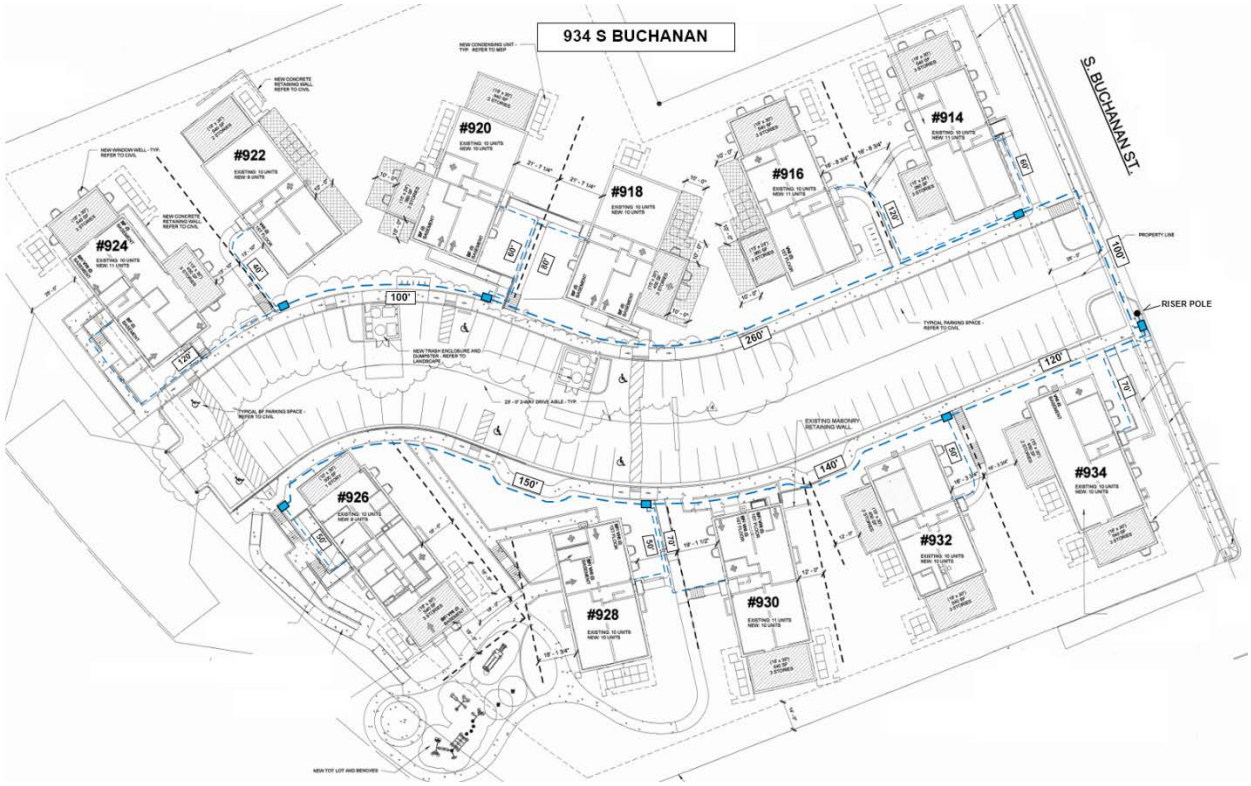
A wireless implementation can potentially cost less than a full fiber-based implementation because it does not require cabling to each individual unit. This efficiency is most noticeable in buildings with many units, where the material savings can be greater.

Using the floorplans, Google Maps, and Google Street View imagery, we first identified the utility pole, handhole, or manhole closest to the representative buildings of each typology to act as a demarcation point. This represents where the middle-mile fiber connects to the "last-mile" fiber or a "fiber drop" that connects to the MDU. We assumed this last-mile fiber would be installed underground via conduit until it reaches the entrance of the MDU. (In Section 4.1.3 below, we discuss the fiber and conduit that would need to be constructed from that demarcation point to a second demarcation point on the ConnectArlington network.)

Using map measurement tools, we measured the distance from the selected demarcation point to an entry point in the representative building to develop an estimate of the amount of underground conduit necessary to connect from the demarcation point to the MDU.

After the entrance point had been located and the outside underground conduit distance had been estimated, we then utilized the floorplans of the representative buildings to design a BOM for an FTTU implementation and a Wi-Fi implementation for each typology. Figure 2 is an example of an FTTU design.

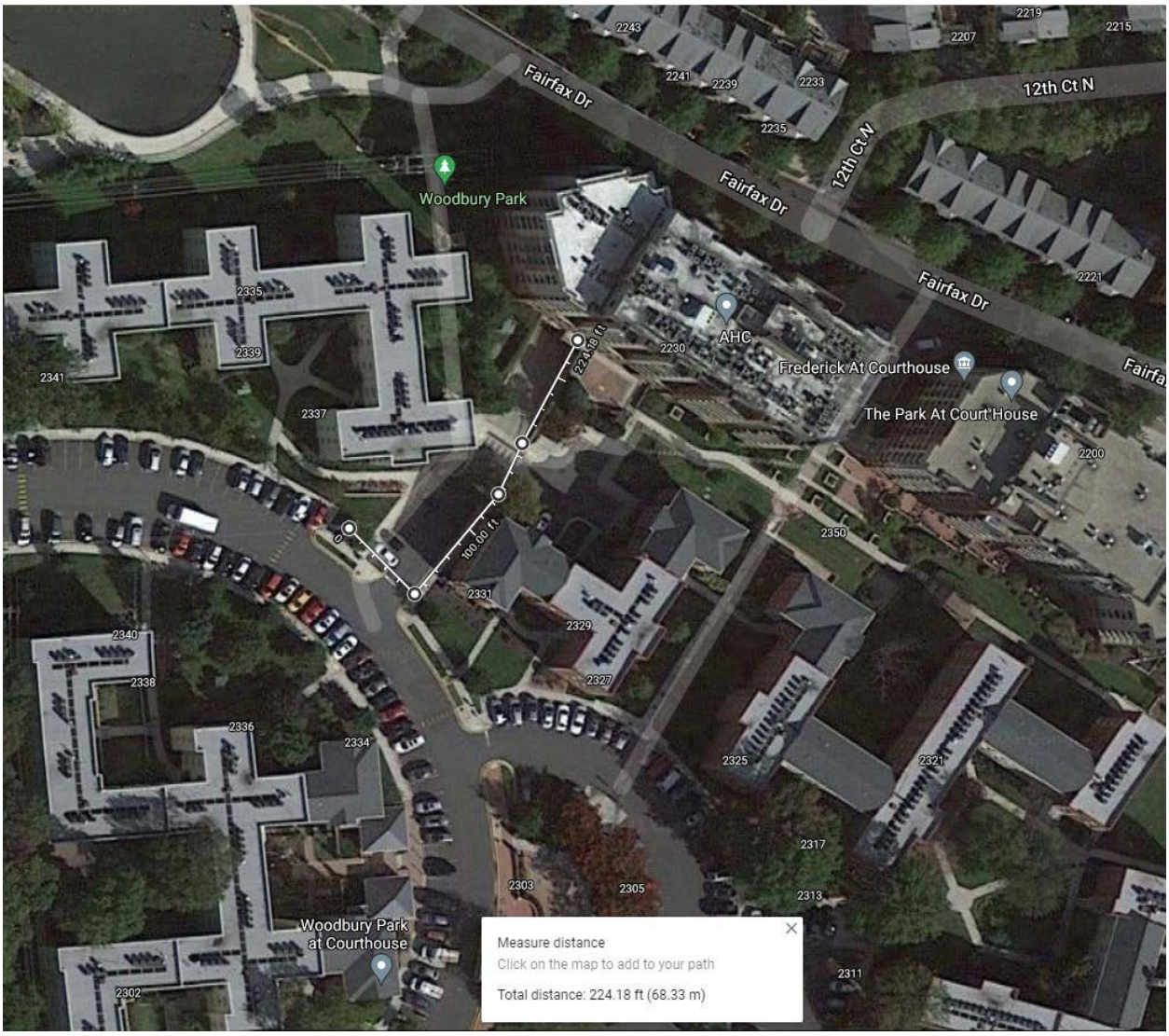
Figure 2: Example of an FTTU Design for an MDU



By analyzing the BOMs, we identified that the length of underground conduit from the nearby demarcation point into the building was the largest element of the cost for all models. We determined that, by measuring the amount of underground conduit needed for the connection from the demarcation point to each MDU and inserting it into the MDU's associated typology BOM, we could develop a high-level cost estimate for fiber deployment for each MDU while retaining each MDU's characteristics.

Applying this approach, we then used Google Maps and Google Street View to identify the manhole, handhole, or utility pole nearest to each of the target MDUs and measured the distance from that point to the MDU, or each building in a Garden Style MDU. (See Figure 3 as an example.) This distance was inserted into the BOM of the MDU's typology to calculate a high-level cost estimate for each MDU.

Figure 3: Example of Measuring Underground Conduit to an MDU

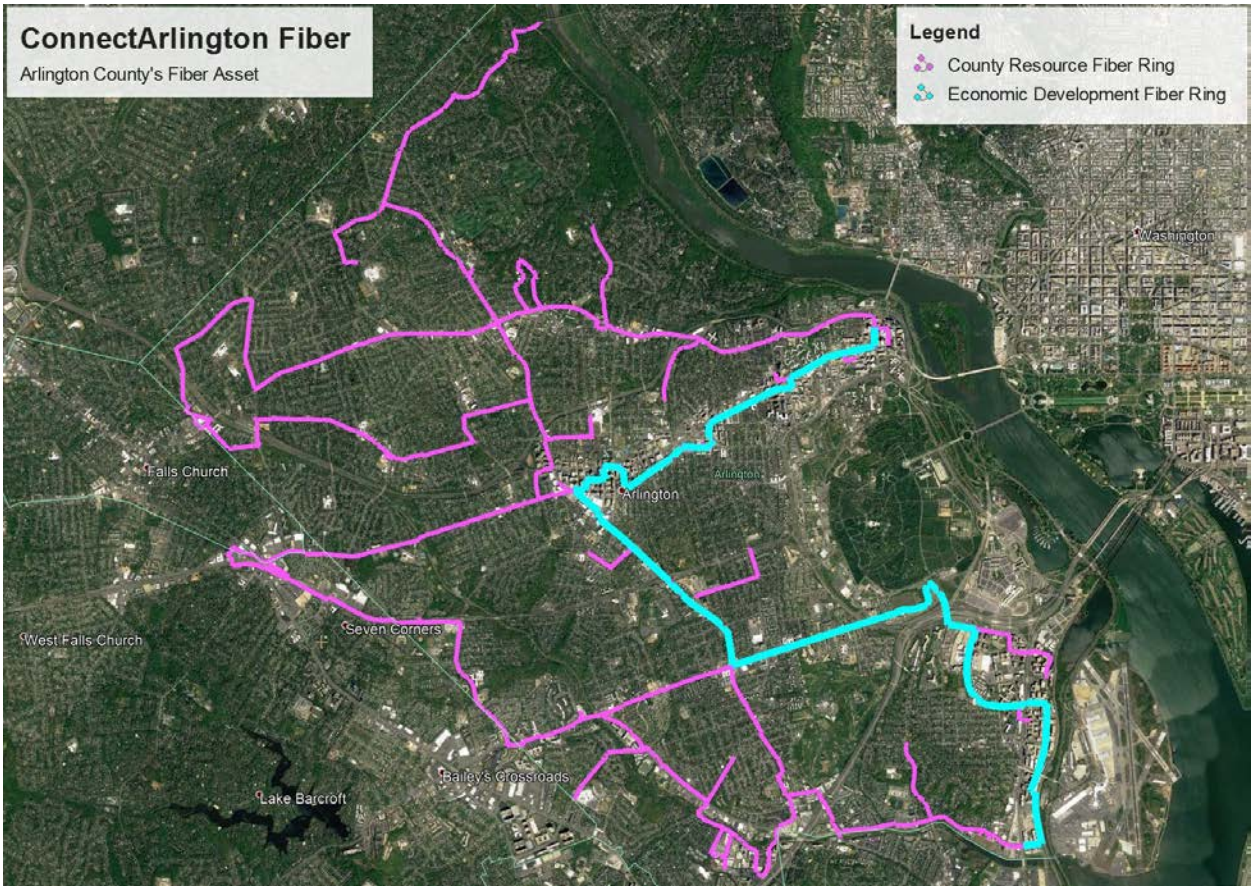


Although each of the MDU types presented a unique set of circumstances in terms of the network design, our cost estimates show that, overall, implementing a Wi-Fi network is cheaper than fiber. However, there are some Garden Style MDUs where fiber is more cost-effective.

4.1.3 Technical model for constructing fiber from MDUs to ConnectArlington

As noted above, the design and cost estimates developed in this report are based on AHC and APAH building fiber connections from demarcation points near each MDU to another demarcation point on the County's existing middle-mile fiber network, ConnectArlington. Figure 4 outlines ConnectArlington's fiber routes.

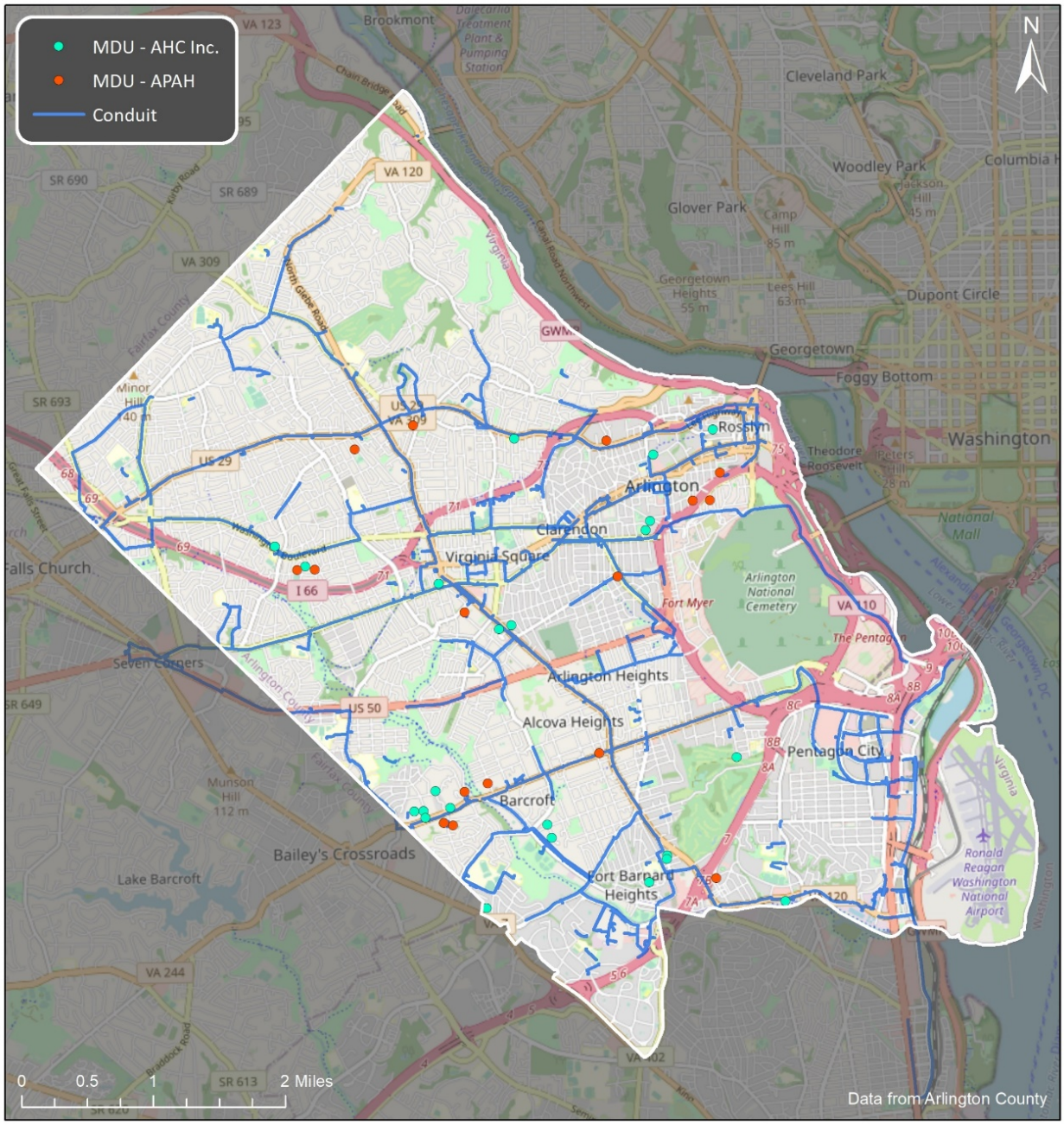
Figure 4: ConnectArlington Network Map



Arlington County provided shapefiles containing the ConnectArlington conduit routes and handhole locations. We mapped the addresses of each MDU in relation to those handholes, then used GIS software to calculate the distance of the path to connect each MDU to the nearest ConnectArlington handhole. This path followed the city streets, with the assumption it would represent underground conduit. After determining the amount of underground conduit needed to connect each MDU, we developed a BOM for installing underground conduit in Arlington from the ConnectArlington network to the demarcation point outside each MDU. By inserting the distance of the conduit required for an MDU, we calculated the required material and labor charges and created a high-level cost estimate.

Figure 5 displays ConnectArlington's conduit network as well as the location of each AHC and APAH MDU.

Figure 5: MDU Locations and ConnectArlington Conduit Routes



4.2 Analysis of data using appropriate methodology

The largest factors affecting the cost of an MDU within a typology is the number of units and the distance to the nearest handhole. When comparing MDUs against each other within a typology, MDUs with larger numbers of units will see increases in deployment costs due to a larger number of customer premise equipment, as each unit will need its own CPE. MDUs with longer distances to the nearest handhole will also see large increases in deployment costs due to the greater

amount of underground conduit that will need to be deployed to connect the MDU to the handhole.

By comparing the BOM template for each typology to each other, we have also identified several characteristics of each individual typology. We describe those in the sections below.

4.2.1 Garden Style MDU

The Garden Style, which consists of multiple buildings spread across a campus rather than a single building, makes up most of the targeted locations, with 20 of AHC and APAH's 39 MDUs. Because each building requires its own connection to the network, the costs for deploying fiber are generally greater than in the Large or Small MDUs due to the need for more conduit and the labor to install it. Although the costs will vary based on the layout of the campus, our estimates show that the five most expensive locations among AHC and APAH's MDUs for deploying fiber are Garden Style.

Each building in Garden Style MDUs is smaller and houses fewer units compared to Large and Small MDUs. This means that, although setting up a Wi-Fi network in a Garden Style MDU features greater labor costs than fiber due to the process of setting up and configuring access points, the overall need for less cable and fewer access points results in a lower cost per unit. In larger Garden Style communities, such as Gates of Ballston and Historic Ballston Park, the cost of providing each unit with CPE greatly impacts the cost of fiber deployment.

4.2.2 Large MDU

Fourteen of the locations were classified as a Large MDU, which feature a single building with between 60 and 670 units. For FTTU deployment, underground conduit still represents a considerable portion of the overall cost, and Large MDUs feature a significant amount of cable inside the buildings themselves for each unit. There are also additional costs in terms of building infrastructure across many floors and splitting it across many units, as well as the greater number of CPE required. Although Large MDUs do not have higher FTTU costs compared to Garden Style, they have the highest average cost for fiber implementation.

But as with the Garden Style, implementing Wi-Fi in a Large MDU is a much more cost-effective solution than fiber. In addition to similar savings on cabling and labor, the number of units in proximity to each other result in more residents being served with fewer access points, thereby reducing the cost per unit.

4.2.3 Small MDU

Five locations were classified as Small MDUs, whose characteristics lie somewhere in between the Garden Style and Large MDUs. These have a single building with a moderate number of units (50 or fewer), so the length of conduit is still the most expensive portion of a fiber build compared

to the costs of labor and material inside the building. Due to all units being in proximity, the Small MDUs, like the Large, feature efficient usage of Wi-Fi access. At the same time, however, there are not enough units to experience large savings on cabling costs.

4.3 Summary of data collected and compiled

4.3.1 Estimated capital cost to construct fiber or Wi-Fi in MDUs

Table 3 and Table 4 summarize the high-level cost estimates for deploying infrastructure to the MDUs for fiber-to-the-unit (FTTU) and Wi-Fi.

These estimates include the costs for material and labor of conduit necessary to connect the MDU to the nearest pole or handhole in the public right-of-way outside the building or development. They also include the fiber distribution hub (FDH), splitters, raceway, fire-rated riser cables, patch panels, and patch chords for the wiring within the MDUs.

The FTTU estimate assumes each MDU will have outside feeder fibers connected to an FDH located in a utility room (typically the telecom room), which splits the feeder fibers into enough individual fiber strands to serve each unit in the MDU. The feeder fiber is split at a 32-to-1 ratio, with each feeder fiber able to support up to 32 endpoints, whether they be residential units or W-Fi access points. The number of feeder fibers needed to serve an AHC or APAH MDU will vary based on the location, from 1 to 16 fibers.

The feeder fiber strand utilization can be adjusted by changing the size of the splitter. A 64-to-1 ratio splitter can split one strand into 64 end points, reducing the number of fiber strands needed by half, as long as the bandwidth delivered via the feeder fiber by the service provider accounts for the larger number of splits. If using their own fiber, some AHC and APAH locations may have limited availability of feeder fiber and additional evaluation would be needed as part of any implementation plan. However, there is also the option for AHC and APAH to simply allow a selected managing partner or service provider to run their own feeder fiber through the AHC and APAH conduit to the MDUs, removing the responsibility of fiber capacity from the MDUs.

The fiber from the FDH is run through each floor through a single shaft with fire-rated rise cables. The risers connect to a patch panel on each floor that serve as a demarcation point for easy access. Patch cables are run from the patch panels through raceway on the ceilings, distributing duplex fiber a junction box at every individual unit. A patch cord is then run into the unit's living room and terminated at a CPE (the CPE is estimated to be around $250 for an ONT with a battery backup).

The Wi-Fi cost estimate assumes the above, except patch cords are not run to each individual unit. Instead, a Cat 5e cable is run from each floor's patch panel to Wi-Fi access points installed in the MDUs' hallways. The Wi-Fi cost estimate includes the labor for configuring each Wi-Fi

access point. Each access point is assumed to be shared by about four units to account for capacity limits on access points and to maintain a consistent quality of service for each unit.

No active network electronics are included in the MDUs. Such electronics would be located in a head-end facility, and would be provided, installed, and maintained by the entity managing the service. These MDU network designs do include any redundancies for the network on site.

These tables do not include the cost of conduit from the nearby demarcation point to the ConnectArlington demarcation point; those costs are listed in Section 4.3.2.

These high-level cost estimates can be used to guide AHC and APAH in their exploration of broadband connectivity in their MDUs. However, actual construction costs may vary based on a range of factors, including issues identified during in-person site surveys conducted by a contracted construction company.

Table 3: High-Level Cost Estimates for Fiber and Wi-Fi Deployments in AHC MDUs

AHC Property	Style	Units	Length of Conduit	Total Cost (FTTU)	Cost per Unit (FTTU)	Total Cost (Wi-Fi)	Cost per Unit (Wi-Fi)
Apex	Large	256	260 ft.	$177,200	$690	$71,100	$280
Arbor Heights	Garden	198	2,250 ft.	$185,300	$940	$151,200	$760
Arlington View Terrace	Garden	77	520 ft.	$72,000	$940	$65,700	$850
Ashton/N. Ashton House	Garden	37	410 ft.	$56,700	$1,530	$60,500	$1,630
Colonial Village West	Garden	70	1,700 ft.	$126,900	$1,810	$122,400	$1,750
Fort Henry Gardens	Garden	92	2,300 ft.	$161,200	$1,750	$151,200	$1,640
Gates of Ballston	Garden	465	4,200 ft.	$345,700	$740	$242,400	$520
Harvey Hall	Large	116	60 ft.	$132,600	$1,140	$61,400	$530
Historic Ballston Park	Garden	512	3,600 ft.	$184,600	$360	$69,571	$140
Hunter's Park	Large	74	210 ft.	$129,300	$1,750	$68,600	$930
Key Boulevard	Garden	46	320 ft.	$54,700	$1,190	$56,100	$1,220
Key Gardens	Small	22	60 ft.	$15,400	$700	$11,400	$520
Taylor Square	Garden	44	800 ft.	$77,200	$1,760	$79,200	$1,800
The Frederick	Large	108	230 ft.	$138,700	$1,280	$69,600	$650
The Jordan	Large	90	180 ft.	$131,800	$1,470	$67,200	$750
The Macedonian	Small	36	355 ft.	$33,000	$920	$25,600	$710
The Serrano	Large	280	670 ft.	$202,800	$720	$90,700	$320
The Shell	Large	83	170 ft.	$129,600	$1,560	$66,700	$800
The Shelton	Large	94	280 ft.	$137,600	$1,460	$72,000	$770
The Spectrum	Large	100	300 ft.	$140,100	$1,400	$73,000	$730
Virginia Gardens	Garden	76	900 ft.	$90,000	$1,180	$84,000	$1,110
Westover	Garden	153	4,000 ft.	$258,100	$1,690	$232,800	$1,520
Woodbury Park	Garden	364	2,300 ft.	$229,200	$630	$151,200	$420

Table 4: High-Level Cost Estimates for Fiber and Wi-Fi Deployments in APAH MDUs

APAH Property	Style	Units	Length of Conduit	Total Cost (FTTU)	Cost per Unit (FTTU)	Total Cost (Wi-Fi)	Cost per Unit (Wi-Fi)
Arlington Mill	Large	122	270 ft.	$144,100	$1,180	$71,500	$590
Arna Valley View	Garden	101	440 ft.	$74,200	$730	$61,900	$610
Barkalow	Small	14	60 ft.	$13,400	$960	$11,400	$820
Buchanan Gardens	Garden	111	1,450 ft.	$125,200	$1,130	$110,400	$1,000
Calvert Manor	Small	23	150 ft.	$20,000	$870	$15,800	$690
Cameron Commons	Small	16	240 ft.	$22,600	$1,410	$20,100	$1,250
Columbia Grove	Garden	208	1,400 ft.	$147,000	$710	$108,000	$520
Columbia Hills	Large	229	180 ft.	$166,600	$730	$67,200	$300
Courthouse Crossings	Garden	112	1,820 ft.	$143,200	$1,280	$128,100	$1,140
Fisher House	Garden	33	480 ft.	$59,100	$1,790	$63,800	$1,930
Fisher House II	Garden	68	1,080 ft.	$96,600	$1,420	$92,600	$1,360
Gilliam Place	Large	173	410 ft.	$163,600	$950	$78,200	$450
Leckey Gardens	Garden	40	340 ft.	$54,100	$1,350	$57,100	$1,430
Marbella	Garden	134	1,800 ft.	$147,700	$1,100	$127,200	$950
Parc Rosslyn	Large	238	80 ft.	$164,000	$690	$62,400	$260
The Springs	Large	104	80 ft.	$130,500	$1,260	$62,400	$600

Table 5 summarizes the total high-level cost estimates for construction from a nearby demarcation point into and within AHC and APAH MDUs. The fiber implementation (including the CPE for each unit) would cost about $1.6 million more than Wi-Fi overall. However, fiber may also prove to be a more valuable investment since it provides a more reliable infrastructure and connectivity to each unit compared to Wi-Fi, offers higher scalability, and is futureproof.

With Wi-Fi, the signal from access points is susceptible to obstruction by environmental factors and walls. An implementation would require bespoke configuration for each MDU by the construction contractor to account for these unique environmental factors, while fiber offers a physical connection to each unit into which the residents plug CPE. Additionally, the fiber implementation does not eliminate the usage of Wi-Fi by residents, as the CPE located in each unit may also act as a Wi-Fi access point.

Table 5: Total High-Level Costs for Fiber and Wi-Fi Deployments

Item	Parameters and Cost
AHC	
Total number of units	3,393
Total length of conduit	26,100 ft.
Total cost (FTTU)	$3,200,000
Total cost (Wi-Fi)	$2,200,000
APAH	
Total number of units	1,726
Total length of conduit	10,300 ft.
Total cost (FTTU)	$1,700,000
Total cost (Wi-Fi)	$1,100,000
AHC + APAH	
Total number of units	5,119
Total length of conduit	36,400 ft.
Total cost (FTTU)	$4,900,000
Total cost (Wi-Fi)	$3,300,000

4.3.2 Estimated capital cost to construct fiber from MDUs to ConnectArlington

Table 6, Table 7, and Table 8 summarize the cost to connect each MDU to ConnectArlington via conduit. The distance is the measurement from the nearest pole or handhole at an MDU (i.e., the demarcation point outside each building) to the nearest ConnectArlington handhole (i.e., the demarcation point for connecting to the ConnectArlington network).

Table 6: Estimated Cost for Building Conduit from AHC MDUs Demarcation Point to Nearest ConnectArlington Handhole

AHC Property	Distance to Handhole	Cost of Conduit
Apex	130 ft.	$10,300
Arbor Heights	1,140 ft.	$62,800
Arlington View Terrace	1,070 ft.	$59,300
Ashton & North Ashton House	700 ft.	$39,300
Colonial Village West	210 ft.	$13,700
Fort Henry Gardens	1,120 ft.	$61,900
Gates of Ballston	260 ft.	$16,200
Harvey Hall	180 ft.	$12,500
Historic Ballston Park	250 ft.	$15,600
Hunter's Park	150 ft.	$11,300
Key Boulevard	370 ft.	$21,300
Key Gardens	230 ft.	$15,100
Taylor Square	790 ft.	$43,500
The Frederick	860 ft.	$47,100
The Jordan	200 ft.	$13,800
The Macedonian	325 ft.	$19,400
The Serrano	470 ft.	$26,100
The Shell	70 ft.	$7,300
The Shelton	400 ft.	$23,000
The Spectrum	2,220 ft.	$118,200
Virginia Gardens	1,270 ft.	$68,700
Westover	60 ft.	$6,880
Woodbury Park	450 ft.	$25,300

Table 7: High-Level Cost for Building Conduit from APAH MDUs Demarcation Point to Nearest ConnectArlington Handhole

APAH Property	Distance to Handhole	Cost of Conduit
Arlington Mill	360 ft.	$20,900
Arna Valley View	1050 ft.	$58,500
Barkalow	70 ft.	$7,100
Buchanan Gardens	640 ft.	$36,800
Calvert Manor	660 ft.	$37,700
Cameron Commons	840 ft.	$46,200
Columbia Grove	260 ft.	$16,500
Columbia Hills East	190 ft.	$13,200
Courthouse Crossings	1210 ft.	$66,100
Fisher House	890 ft.	$48,200
Fisher House II	920 ft.	$49,900
Gilliam Place	60 ft.	$6,800
Leckey Gardens	630 ft.	$36,400
Marbella	720 ft.	$40,300
Parc Rosslyn	770 ft.	$42,700
The Springs	140 ft.	$10,600

Table 8: Total High-Level Costs for Building Conduit from MDUs Demarcation Points to the Nearest ConnectArlington Handholes

Item	Parameters and Cost
AHC	
Distance to handhole	12,925 ft.
Cost of conduit	$738,580
APAH	
Distance to handhole	9,410 ft.
Cost of conduit	$537,900
AHC + APAH	
Distance to handhole	22,335 ft.
Cost of conduit	$1,276,480

4.3.3 Total construction cost estimate

Based on our technical models and data analysis, the cost for AHC and APAH to construct fiber from ConnectArlington to a demarcation point near each target MDU would be approximately $1.3 million. The estimated cost to construct fiber from that demarcation point into each target MDU, and to connect each unit within the MDU with Wi-Fi or fiber, would be $3.3 million to $4.9

million. Thus, the total estimated capital cost to connect the approximately 5,100 units within the targeted MDUs would be $4.6 million to $6.2 million, or roughly $900 to $1,220 per unit.

Material costs can increase in price due to supply chain constraints caused by the Covid-19 pandemic. An additional contingency of 20 percent can be applied to the total cost estimate to account for potential cost increase on material. We estimate a contingency of 20 percent can be added to the labor and material costs, increasing the total estimated capital cost to approximately $5.5 million to $7.4 million. These costs do not include electronics and equipment, which will be installed by the managed service provider.

4.3.4 Operating cost estimates

Delivering internet service to residents will require ongoing operating costs. If AHC and APAH were to deliver a free, best-effort internet product, the costs would largely be limited to the cost of internet bandwidth. If users are charged a fee for the service, AHC and APAH would also incur costs for account management and customer service (e.g., marketing, sales, billing, customer service staffing).

4.3.4.1 Cost of internet bandwidth

Each MDU will require a connection to an internet service provider's (ISP) network. If the ISP were to construct infrastructure to the MDUs, construction costs will likely vary greatly based on the ISP and its network footprint. The farther away an ISP's infrastructure is from an MDU, the more construction will be needed, thereby increasing the cost for connectivity.

Connecting the MDUs to ConnectArlington will lower barriers for ISPs to serve residents. In the model above, which connects all the MDUs to that one network, an ISP would need only a single connection onto ConnectArlington to deliver service to all MDUs. AHC and APAH can explore procuring service from an ISP at a data center to which ConnectArlington has access, which would eliminate the infrastructure costs for building connectivity to the ISP. Although the County is not legally allowed to support connecting to an ISP inside its own data center, this connection can be facilitated at another data center or meet-point. Alternatively, if a particular ISP is not connected to any data center on ConnectArlington's footprint, the ISP would need to only build enough infrastructure to connect to ConnectArlington at a single point to provide service to all MDUs. The cost of building infrastructure to this connection will depend on the ISP's distance from a mutually agreed upon meet-point.

Internet pricing can vary based on the amount of bandwidth needed and the agreement negotiated with the ISP. As internet usage by residents increases, whether by an increase in the size of families or an increased usage of video streaming, higher bandwidths will be needed to provide adequate capacity for the users. However, the cost for procuring service will increase as well. Although a gigabit connection to each unit would provide high capacity for every resident,

it may not be fiscally feasible, so AHC and APAH may want to target a minimum bandwidth and increase it over time as needed.

Assuming each unit requires a minimum bandwidth of 30 Mbps download, the bandwidth needed to serve the 5,119 AHC and APAH MDU units analyzed here would be roughly 154 Gbps. However, ISPs typically utilize oversubscription, a model where it is assumed that not all subscribers will be using all of their allotted bandwidth at the same time. This means that the theoretical maximum bandwidth needed is not actually required and a lower bandwidth cap can be utilized, which in turns lowers the cost of service. A common oversubscription model is to assume a 10:1 ratio on the amount of bandwidth required, which lowers the required bandwidth to only around 15.4 Gbps.

Based on sample internet service pricing in the region, we estimate internet service for around 13 Gbps of bandwidth could cost approximately $3,900 monthly. This is based on the prevailing cost for buying internet in large bulk at a data center in the region, estimated to be $0.25/Mbps/month but does not include transport or cross-connect fees. If the service is procured through a data center, there may be additional recurring costs for any cross-connects and transport fees needed to connect ConnectArlington to the ISP within the data center.

4.3.4.2 Cost of account management and customer service

With internet service procured from a data center, AHC and APAH can hire another entity to manage the service, or they can manage the service themselves. Although AHC and APAH have said they do not intend to manage the service, we provide information on how such a model would work for informational purposes.

4.3.4.2.1 Service Managed by a Partner

If AHC and APAH procure their service from an ISP, they can contract another company to manage and maintain the internet service for them. ISPs can offer managed services to entities that procure service from them for additional charges. However, the entity procuring the service can also contract another party to manage the service. This provides AHC and APAH with flexibility in choosing a partner that best fits their needs.

As AHC and APAH do not want to manage the service themselves, an agreement with the managing partner should explicitly hand over all responsibilities for managing the network over to the managing partner.

The managing partner should be responsible for the network electronics used to serve and monitor the network, located at a meet-point on or near ConnectArlington's fiber route. These electronics will distribute the service from the ISP to all MDUs via ConnectArlington. The

managing partner should bear all the responsibility for maintaining and refreshing equipment to ensure consistent and reliable internet service to residents.

The agreement should also explicitly state the managing partner have responsibility for all day-to-day monitoring of the network and providing IT support. The partner should maintain 24/7 awareness of the network's status and be able to quickly respond to network outages and initiate maintenance quickly, without the need for AHC or APAH staff to contact the partner first. The managing partner should also handle all interactions with residents regarding their internet service, handling CPE or Wi-Fi access point installation, working as customer service, providing the functionality for users to sign up for service, and allowing for the submittal and response to trouble tickets. It should also have a track record of strong security capabilities for its network and its devices.[7]

Pricing for managed service can vary greatly from company to company and based on the number of responsibilities stated in the agreement and developed through negotiations between parties. Alternatively, AHC and APAH could also opt to put this responsibility out to bid via an RFP. This could enable various companies to submit competitive proposals directly to AHC and APAH to operate their network for them.

4.3.4.2.2 Service Managed by AHC and APAH

Although AHC and APAH have expressed they do not have interest in managing their own internet service, we provide the following for informational purposes.

Maintaining and operating a broadband network serving multiple MDUs will require ongoing fiber maintenance, fiber locating, staffing, equipment maintenance, and equipment replacement.

Those costs—which are based on delivery of a free, best-effort service to residents—will differ during deployment and in the years after deployment is complete, as shown in Table 9 and Table 10 (pages 34/35). The operating and maintenance costs outlined here are based on analysis of similar deployments in other cities and reflect a network that would deliver best-in-class, carrier-grade service. Operating and maintenance costs for serving AHC's and APAH's MDUs will vary depending on the total length of the conduit and fiber required to reach each building, but we do not anticipate service to those buildings causing any increase in the networking and administrative costs.

The costs outlined below consider the staffing needed for a housing authority to run its own network across many MDU complexes. If AHC and APAH want to have the service run by a

[7] We assume a full analysis of the security capabilities and the track record of any vendor or equipment supplier would be considered as part of selecting a managing partner.

managing partner, only a subset of the staffing will be needed for administrative duties to monitor the contract. For instance, property staff can be utilized if AHC and APAH want to pursue their own marketing efforts to promote their service on top of any community outreach by the managing partner. Fiber Locating and OSP Management staffing will be needed to manage any of AHC's and APAH's own conduit builds, but all other staffing listed below is needed only in the case of entities like AHC or APAH intending to operate their own internet service.

Regular fiber maintenance includes any required changes and repairs for the fiber network. For example, if a conduit is struck by an excavator, fiber repair is required. Fiber locating includes the marking of underground utilities as part of the State's "Digger's Hotline" process. Each underground utility is responsible for locating and marking its infrastructure in the right-of-way. We estimate the cost of $30,000 annually for fiber repair and fiber locating.

We recommend establishing an equipment replacement fund, into which AHC and APAH would put a portion of the necessary funds to replace the network electronics. We recommend planning on replacing the network electronics every seven years, requiring AHC and APAH to place approximately $90,000 into the equipment fund annually.

Network electronics require yearly maintenance contracts for technical support, software updates, and equipment replacement. We estimate the cost for equipment replacement to be 15 percent of the total electronics costs annually. The FTTP deployment has an estimated annual cost of $95,000 and $88,000 for the Wi-Fi deployments.

During the project deployment, AHC and APAH will need project management stuff to run the project. We estimated project management requiring one full time equivalent during deployment at $100,000 per year. We estimate that after deployment project management staff will still need to oversee contractors and perform administrative services for the network. We see it requiring a quarter staff person moving forward.

Outside plant management will be a critical component to deploying and maintaining the broadband network. We envision that the network will need outside plant management to review fiber designs and as-builts, assist with fiber assignments, and update fiber management documentation. We predict AHC and APAH will need additional outside plant management for a quarter FTE at $150,000 for both deploying and maintaining the network.

Networking engineering staffing will help with developing the detailed network architecture of the broadband network, overseeing deployment, and maintaining the network once deployed. We envision the network manager doing more architecture design and higher layer network troubleshooting while the network technician can help connect CDA units to the network and troubleshooting. Our cost estimates include a half-time FTE for both the network manager

($150,000 annually) and network technician ($75,000 annually) for deployment while only a quarter network manager and a full-time network technician for operations and maintenance.

Based on our experience in other public housing broadband network projects, we recommend that AHC and APAH budget for the community outreach that will be needed to educate users on the service, work with nonprofit entities to get residents the devices and services they need and teaching digital literacy. During the deployment we see community outreach as a half-time FTE with it going to a quarter FTE during maintenance and operations.

The network operations center (NOC) monitors the network. The cost depends on the number of devices monitored, with the FTTP network requiring more monitoring as there is a device in each unit. We estimate NOC services at $200 per year at a cost of $100,000 and $200,000 annually for the FTTP network and $40,000 and $80,000 annually for the Wi-Fi network.

The help desk answers troubleshooting calls from residents and works with the NOC to identify potential issues. We estimated the cost of the help desk to be a half-time FTE at $75,000 annually for the maintenance and operations of the network.

Table 9: Estimated Annual Operating and Maintenance Costs During Deployment

Description	Cost	Unit	# of Units	Subtotal
Fiber Maintenance and Locating	$30,000	Per Year	0.5	$15,000
Equipment Replacement	$90,000	Per Year	0	$0
Equipment Maintenance Contracts	$95,000	Per Year	1	$95,000
Project Management	$100,000	FTE	1	$100,000
OSP Manager	$150,000	FTE	0.25	$37,500
Network Engineering	$150,000	FTE	0.5	$75,000
Network Technician	$75,000	FTE	0.5	$37,500
Community Outreach	$100,000	FTE	0.5	$50,000
NOC	$200	Per Device	500	$100,000
Help Desk	$75,000	FTE	0	$0
			FTTP Annual Operating Costs (Deployment)	**$510,000**

Table 10: Estimated Annual Estimated Annual Operating and Maintenance Costs After Deployment

Description	Cost	Measure Unit	Units	Subtotal
Fiber Maintenance and Locating	$30,000	Per Year	1	$30,000
Equipment Replacement	$90,000	Per Year	1	$90,000
Equipment Maintenance Contracts	$95,000	Per Year	1	$95,000
Project Management	$100,000	FTE	0.25	$25,000
OSP Manager	$150,000	FTE	0.25	$37,500
Network Engineering	$150,000	FTE	0.25	$37,500
Network Technician	$75,000	FTE	1	$75,000
Community Outreach	$100,000	FTE	0.25	$25,000
NOC	$200	Per Device	1000	$200,000
Help Desk	$75,000	FTE	0.5	$37,500
			FTTP Annual Operating Costs (Deployment)	**$652,500**

4.3.4.2.3 Operational Support Systems and Business Support Systems (OSS/BSS)

Adding a framework for setting up individual user accounts and billing customers for service requires additional systems and costs (which would be avoided, at least in part, if the service were provided at no cost to residents).

If AHC and APAH chooses to bill residents for internet service, Operational Support Systems (OSS) and Business Support Systems (BSS) would be required. OSS/BSS are equipment or services that allow an organization to monitor and manage a network's elements and usage, as well as allocate bandwidth to residents and charge them for access. Such a solution would be necessary for AHC and APAH to allocate internet connectivity and properly charge users for their service.

OSS/BSS solutions come in many forms. Previously, they required physical equipment on the customer's premises, but many solutions have moved toward cloud-based implementations that only require software and configuration on the customer's equipment. Eliminating physical hardware lowers the costs of deployment and ongoing maintenance while also broadening the capabilities of such services.

With these cloud-based services, residents automatically have their internet traffic routed through the OSS/BSS solutions. The operator can monitor and manage the service through a central front-end interface. These services can automate the process of residents signing up for service, choosing and changing service plans, and billing. OSS/BSS can also support monitoring of the network, such as automating the tracking assets, connections, and maintenance.

Pricing for OSS/BSS solutions can vary greatly based on the solution provider's business model and individual agreements negotiated between the customer and the solution provider.

Customers must purchase a license for the OSS/BSS system, which include a monthly fee for the service and a one-time deployment fee, to account for server hardware in the solution provider's data center as well as the process of setting up the service for the customer and training the customer in its operation.

Based on interviews we conducted with solution providers, deploying an OSS/BSS solution for a network of AHC and APAH's scale might cost $200,000 to $300,000. The monthly fees can range greatly, from around $6,000 to $20,000, depending on the solution provider's pricing model.

4.4 Implications and conclusions

As shown in our high-level cost estimates in Table 3 and Table 4, Small and some Garden Style MDUs would benefit from FTTU, which, even though it costs slightly more than Wi-Fi to construct in those specific situations, it provides more reliable connectivity, is highly scalable, and is futureproof.

However, the Large MDUs see significant savings by implementing Wi-Fi, in part because the need in a fiber implementation to provide CPE to each unit in a building with high population density considerably raises the cost. AHC and APAH can consider whether the savings provide a strong enough benefit to outweigh any additional efforts needed for maintenance and operation compared to fiber.

Wi-Fi brings with it many additional considerations due to the nature of the technology. Wi-Fi is susceptible to interference and the signal can degenerate due to building materials, natural noise levels, and the shape and distance of the building between the Wi-Fi access points and the units they serve. It can also be more difficult to manage the network due to the complexity of monitoring and troubleshooting wireless connectivity. A proper Wi-Fi implementation will be designed specifically for the building in which it is being deployed and the costs can vary based on factors identified by the construction contractor.

Connecting each MDU to ConnectArlington would be the most efficient way to procure internet service, creating a unified network between all MDUs and any data center to which ConnectArlington currently has connectivity. AHC and APAH can then procure internet service from any internet service provider (ISP) within the data center and utilize it at any MDU. Without ConnectArlington, an ISP would need to construct infrastructure to each MDU, increasing the costs substantially on top of the costs of the service itself.

Any internet solution will have ongoing operational costs for internet service and maintenance. AHC and APAH should account for these perpetual ongoing costs when planning funding. Employing an OSS/BSS solution to pass costs onto users of the service may help alleviate some of the financial burden on AHC and APAH.

5 Policy analysis: Evaluation and recommendations regarding programmatic efforts to address digital equity

The Arlington community is deeply engaged with digital equity, with a variety of entities working on the issue, including AHC, APAH, and the County. Additionally, a variety of ISP-initiated low-cost and federal subsidy programs already exist to help ease the burden of the monthly cost of broadband service for eligible households.

In the following sections, we summarize existing efforts and make programmatic recommendations around additional efforts that could address broadband gaps in the four elements of digital equity:

- **Access:** That broadband infrastructure exists, and reliable high-speed broadband plans are available for purchase
- **Affordability:** That broadband service is not only available but can be obtained at reasonable prices by all
- **Devices:** That residents own or have access to well-functioning, up-to-date computers—and have the capacity to maintain and replace these devices if needed.
- **Skills:** That residents can make full use of the often-complex functions and computers and online resources—and thus are able to use these tools to communicate, work, learn, attend medical appointments, etc.—and avoid online harms.

5.1 Description and analysis of existing programs

5.1.1 Existing low-cost and subsidy programs in the Arlington market

Qualifying low-income households in Arlington are eligible for low-cost internet subscription programs and federal subsidies for monthly broadband service.

5.1.1.1 Comcast Internet Essentials

Comcast's Internet Essentials provides 50/5 Mbps for $9.95 per month, an option to buy a computer for $150, and access to free internet training material to residents who are eligible for public assistance programs like the National School Lunch Program, Housing Assistance, Medicaid, SNAP, and SSI.[8]

5.1.1.2 Verizon Lifeline Program

The Lifeline program was created by Congress (and is administered by the FCC) with the purpose of making service more affordable by providing a federal subsidy of $9.25 per month to

[8] "Apply for internet essentials from Comcast," Xfinity, https://www.xfinity.com/support/articles/comcast-broadband-opportunity-program (accessed October 13, 2021).

telecommunications carriers for service to lower-income members of the community. Low-income residents should expect to pay $20 per month for 200 Mbps, $40 per month for 400 Mbps, and $60 per month for 940/880 Mbps service.[9]

5.1.1.3 Starry Connect

Starry Internet offers 30 Mbps symmetrical to residents of affordable housing for $15 per month. Starry installs and wires affordable housing units at no cost to the property owner. In total, Starry has connected more than 29,000 affordable housing units across the country.[10]

5.1.1.4 Emergency Broadband Benefit

The 2021 Consolidated Appropriations Act established the $3.2 billion Emergency Broadband Benefit (EBB) program. This program is to be administered by the FCC and is designed to provide a broadband subsidy for eligible households that will appear as a discount on their monthly bills. While similar to the Lifeline program, EBB offers a much more robust discount: the FCC will reimburse ISPs up to $50 per month per eligible household, or $75 per month for households on Tribal lands. Notably, this program also subsidizes the cost of a laptop, desktop computer, or tablet for each eligible household. ISPs can be reimbursed up to $100 for a connected device, as long as the recipient is charged no more than $50 for it.

The law states the program will run six months beyond the end of the public health emergency, but that is only if the funding is sufficient to cover the ISPs' charges for all participants. It is anticipated that the $3.2 billion allocated to EBB will provide approximately a year of funding. It is possible that Congress would appropriate future funds to keep the program operating, though it is not likely that the political will exists to make it permanent.

Because the benefits available through EBB are so significant for consumers, this program stands to serve as an impactful broadband adoption program. While the program will provide welcome financial relief for families that have been paying for broadband service throughout the pandemic, it will also create opportunities for many low-income families to subscribe to a home broadband service for the first time. If implemented successfully, the program stands to make headway in bridging the digital divide in Arlington County, particularly the broadband affordability gap.

However, the structure of the program's rules puts significant burden on families to prove their eligibility and ensure their subsidy is appropriately applied. AHC, APAH, and the County have an

[9] "High-speed internet at a price that works for you," Verizon, https://www.verizon.com/info/low-income-internet/ (accessed October 13, 2021).
[10] "Starry Connect," Starry, https://starry.com/starryconnect (accessed October 13, 2021).

opportunity to provide support in a number of ways that could maximize the impact of the program.

The FCC defines eligibility for the program broadly as a household in which at least one member:

- Qualifies for Lifeline (i.e., has income at or below 135 percent of the federal poverty guidelines; receives benefits from Medicaid, the Supplemental Nutrition Assistance Program, Supplemental Security Income, Federal Public Housing Assistance, or a Veterans and Survivors Pension Benefit)
- Participates in the National School Lunch Program or the School Breakfast Program
- "Experienced a substantial loss of income since February 29, 2020, that is documented by layoff or furlough notice, application for unemployment insurance benefits, or similar documentation"[11]
- Received a federal Pell grant during the current award year
- "Meets the eligibility criteria for a participating provider's existing low-income or Covid-19 program"[12]

Participating ISPs will be able to verify household eligibility in one of three ways:

1. Based on the National Verifier or the National Lifeline Accountability Database
2. Based on a school's verification of a household member's participation in the National School Lunch Program or the School Breakfast Program
3. Based on the ISP's "alternative verification process" (which must be deemed sufficient by the FCC "to avoid waste, fraud, and abuse")[13]

The program's rules raise concern that there will be significant burden on families to prove their eligibility and ensure their subsidy is appropriately applied. For instance, families will need to call their provider to ask for service and determine how to apply the subsidy. This is not an insignificant burden for the families this subsidy is intended to help, nor is the potential financial risk to those families (i.e., that they might be responsible for charges if the subsidy is not accurately applied) a minor point.

[11] "Emergency Broadband Benefit," FCC, https://www.fcc.gov/broadbandbenefit (accessed October 13, 2021).
[12] Ibid.
[13] "Public Notice: Broadband providers must apply the Emergency Broadband Benefit discount prior to claiming reimbursement and are reminded of measures to protect against waste, fraud, and abuse," p.4, FCC, https://docs.fcc.gov/public/attachments/DA-21-1018A1.pdf, (accessed October 13, 2021).

5.1.2 Existing AHC, APAH, and County digital equity initiatives

AHC, APAH, and the County have undertaken a variety of digital equity initiatives related to broadband access and affordability, device access, and digital skills training.

5.1.2.1 Capital One Digital Access program

A pilot project at 93 apartments at an AHC property in Alexandria, Virginia, in partnership with AHC, Comcast, and Capital One to provide 14 months of free internet access, Chromebooks or tablets, and digital education.[14]

5.1.2.2 Internet to Arlington Public Schools

The County leveraged $500,000 in funding from the CARES Act to provide eligible Arlington Public School students with a year of free internet access through Comcast's Internet Essentials program to support distance learning, aimed at serving more than 4,000 families.[15]

5.1.2.3 Digital inclusion initiative at Arlington Mills Residences

A partnership between APAH, the County, Connect Arlington, Wi-Fiber, and Recycle for VA yielded free internet and a free computers for 122 families living at Arlington Mills. Additionally, the program offered a free digital education course to residents.[16]

5.1.2.4 County planning initiatives

The County has led a digital equity initiative starting with data gathering and research in 2019 and community engagement in 2020, culminating thus far in their Digital Equity Action plan in 2021. Throughout this process, the County has been guided by its own digital equity goals, which include the following:[17]

- **Connectivity:** The County will invest in infrastructure to support lower cost connectivity for affordable housing residents.
- **Access:** All residents can access the internet.
- **Education and Training:** Residents have the appropriate skills necessary to be successful on the internet.

[14] "Capital One and Comcast team up to bridge the internet divide for low-income families living in affordable housing," AHC, July 22, 2020, https://www.ahcinc.org/partnership-to-bridge-internet-divide/ (accessed October 13, 2021).
[15] "Pandemic highlights the digital divide," APAH, June 29, 2020, https://apah.org/pandemic-highlights-the-digital-divide/ (accessed October 13, 2021).
[16] "Creating an opportunity for digital inclusion," APAH, February 26, 2019, https://apah.org/creating-an-opportunity-for-digital-inclusion/ (accessed October 13, 2021).
[17] "Digital equity—connecting Arlington," Arlington, Virginia, Department of Technology Services https://departments.arlingtonva.us/dts/digital-equity/ (accessed October 13, 2021).

- **Program Sustainability and Community Capacity:** Ensure our digital equity goal strategies are sustainable and the community is engaged on the issue.

The County has also developed a map for residents to identify digital resources in their area and is planning to extend the ConnectArlington fiber network.

About CTC Technology & Engineering

CTC Technology & Energy is an established, woman-owed consulting firm that offers independent strategic, technical, and financial guidance primarily to public sector and nonprofit entities such as state, county, and local governments; nonprofit consortia; universities; and municipal electric utilities. With more than 30 years of experience, we work at the highest levels on cutting-edge communications networking projects for clients throughout the U.S. For more information, visit https://www.ctcnet.us/

About AHC Inc.

Founded in 1975, AHC Inc. is a nonprofit developer of affordable housing that provides quality homes and education programs for low-and moderate-income families. Based in Arlington, VA, AHC has developed more than 7,800 apartments in 50+ properties in Virginia, Maryland, and Washington, D.C. AHC's Resident Services program reaches 3,000 children, teens, and adults and seniors each year through onsite education and social service programs and activities. Visit https://www.ahcinc.org/ for more information.

About Arlington Partnership for Affordable Housing

Founded in 1989, APAH now helps more than 2,000 households live in stable, secure, and affordable rental homes. APAH has 500 affordable apartments under construction and an additional 1,000 in its development pipeline. APAH was named one of the nation's Top 50 Affordable Housing Developers of 2019 by Affordable Housing Finance magazine. The organization was named 2021 Developer of the Year by HAND, the Housing Association of Nonprofit Developers. Learn more at https://apah.org/