5 New wireless infrastructure could be a partial solution to broadband gaps in Dallas: Evaluation and recommendations regarding wireless pilots and expansion

In this section, we provide an introduction to wireless connectivity, an overview of the wireless broadband pilot projects DISD launched at one high school, and that the City of Dallas launched in several neighborhoods, an exploration of the feasibility of using wireless infrastructure to close the broadband gaps in Dallas, and a recommendation that the City continue to explore its options for funding and building its own backbone fiber network. On the latter point, CTC's engineers developed a candidate design and cost estimates for a full-scale network, based around neighborhood characteristics and prioritization.

5.1 Introduction to fixed wireless network connectivity

Broadband speeds in compliance with the FCC's definition (i.e., 25 Mbps download, 3 Mbps upload) are now more technically feasible using fixed wireless networks than in the past, due to increased available spectrum and new wireless technologies.

A fixed wireless connection may be a desirable solution if cable or fiber is not available or cost-effective. If adequate care is taken in the design such that the network is not overloaded and uses spectrum capable of broadband speed, subscribers will enjoy high-quality performance, sufficient for applications such as Zoom.

5.1.1 Fixed wireless spectrum and architecture

Fixed wireless networks typically use the following spectrum and associated frequencies:

Table 23: Fixed Wireless Spectrum

Spectrum	Frequency Band
TV White Space (TVWS)	500 MHz
Unlicensed (including Wi-Fi)	900 MHz, 2.4 GHz, and 5 GHz
Educational Broadband Service (EBS)	2.5 GHz
Citizens Broadband Radio Service (CBRS)	3.5 GHz

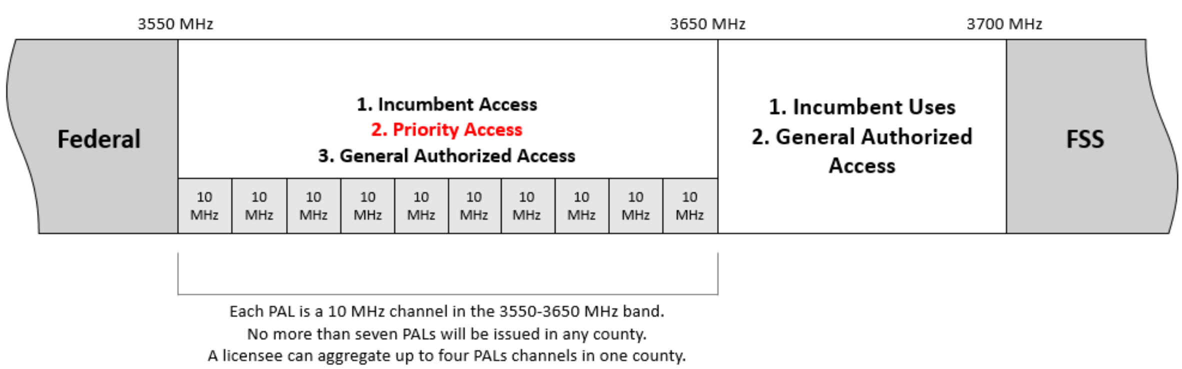
Fixed wireless broadband is delivered via access point antennas mounted on towers, rooftops, or poles to a subscriber antenna. Subscriber antennas can be located indoors or outdoors depending on the distance to the access point and the amount of "clutter" between the subscriber antenna and the access point. Outdoor antennas may be attached to a building or a mast on the premises (Figure 97).

Figure 97: Sample Indoor and Outdoor Customer Antenna Configurations for a Fixed Wireless Network

As one example of fixed wireless technology,[21] Citizens Broadband Radio Service (CBRS) is a band of spectrum in the 3.5 GHz range that was authorized for both licensed and unlicensed use by the FCC in 2015. Extending between 3550 MHz to 3700 MHz, CBRS provides spectrum to a broad audience of potential users, from government entities to small businesses. The FCC has divided access to the CBRS band into three tiers with different levels of interference protection. Access to the CBRS band is managed by a cloud-based dynamic frequency coordination system called a Spectrum Access System (SAS).

Access is divided into three tiers: Incumbent Access, Priority Access [Licenses] (PAL), and General Authorized Access (GAA) and is managed by the SAS. Each Tier spans the ten 10 MHz channels; the remaining spectrum is available for incumbent uses and GAA (Figure 98).

Figure 98: CBRS Tiers (Source: FCC)



[21] We have focused on CBRS because it is the band DISD used for the Lincoln High School pilot.

- Tier 1 – Incumbent Access grants access to the 3550 MHz to 3650 MHz band to existing license holders, primarily U.S. Navy radar systems and commercial fixed satellite stations.[22] Users in Tier 1 have the highest priority for their licensed frequencies and have a GSA of 35 miles. The SAS continuously monitors the channels and will prioritize a Tier 1 transmission over a Tier 2 or Tier 3 transmission on the Tier 1 incumbent's frequency.[23]

- Tier 2 – Priority Access channels were auctioned off as through competitive bidding. PAL licenses were granted for 10 MHz channels in the 3550 to 3650 MHz band in individual counties (as opposed to the 35-mile GSA that incumbents have) and must be renewed every 10 years. A total of 70 MHz, and thus seven PALs, are available in each county; however, no single licensee may operate more than 40 MHz (four PALs) in a single county. The SAS will prioritize a Tier 2 transmission over a Tier 3 transmission on the Tier 2 frequency licensed to that provider.

- Tier 3 – General Authorized Access (GAA) allows open, unlicensed access to the full CBRS band. This spectrum is available for use by anyone using certified equipment and who has registered with the SAS. However, Tier 3 users have the lowest priority of the three Tiers and are granted access on a first-come, first-served basis.

As noted, the SAS coordinates use of the band, ensuring Tier 2 and Tier 3 users do not interfere with incumbents. The SAS is responsible for databasing spectrum users and prioritizing and granting access requests based on users' access Tiers and the spectrum load of a given area. As CBRS usage grows, the SAS will be responsible for efficiently managing the user load to ensure access rules are enforced and interference is minimized.

In late January 2020, the FCC authorized full commercial deployment of OnGo[24] service in the 3.5 GHz CBRS band. This allows OnGo-certified antennas and devices to use the band as General Authorized Access (GAA) by unlicensed users. As PAL holders build out their networks, the SAS will give PAL licensees priority on the spectrum they have been allocated. In areas where all of the PAL holders make use of their channels, GAA users will only be able to share 80 MHz of the band. In Dallas, the PAL licensees are AT&T, Charter, and Dish Network.

The SAS monitors the spectrum through the internet and provides a temporary license to that spectrum in its area to a user. This temporary license must be renewed at regular intervals. The

[22] "What is CBRS?" *Fierce Wireless*, June 23, 2020, https://www.fiercewireless.com/private-wireless/what-cbrs#:~:text=The%20incumbent%20tier%20is%20reserved,as%20commercial%20fixed%20satellite%20stations. In Georgia, Navy radar systems may potentially be activated from time to time at Kings Bay Naval Submarine Base inland of the eastern coast, and the Naval Reserve training center on the western border with Alabama.

[23] There also exist grandfathered users who had been using this band before CBRS was created, but these users were supposed to have migrated to GAA in 2020.

[24] OnGo is a brand name that represents the networks and devices in the CBRS band.

SAS checks its national database and verifies the user's access priority (Tier). In an extremely congested situation where spectrum channels may not be available, the SAS will reduce or revoke access to existing users to accommodate a new request from a higher Tier user, with the Tier 1 users having the highest priority. Because the CBRS band is in the early days of use, there is no public record of congestion or spectrum availability, but anecdotal reports in urban and rural areas are reporting the ability to access GAA spectrum.

Wi-Fi uses the 2.4 and 5 GHz bands. It is an unlicensed service and is subject to the FCC's rules on unlicensed spectrum, which require that users use equipment that complies with limits on power levels and other parameters, use equipment that is type-certified by the FCC, and accept all interference from other permitted users of the spectrum. Wi-Fi originated as a technology to eliminate the use of cables in indoor local-area networks, and this initial vision of indoor use still imposes limits to its use over wide outdoor areas. Though the technology has improved in performance and has expanded to more spectrum as authorized by the FCC (including emerging "Wi-Fi 6" expanding beyond the prior upper bounds of the 5 GHz band), the power limits keep the range at hundreds of feet, and the combination of power limits and the propagation of the spectrum bands make it challenging for outdoor signals to effectively provide high-quality service indoors, and vice versa.

5.1.2 Fixed wireless network characteristics and considerations

Most fixed wireless network solutions require the antenna at the subscriber location to be in or near the line-of-sight of the base station antenna. Line-of-sight can be especially challenging in in areas where multiple tall buildings or trees can interfere with the signal. Moreover, the quality of line of sight can vary seasonally, with the variations in density of foliage.

As a result, wireless internet service providers (WISP) and other network operators often need to lease space on rooftops, or at or near the top of radio towers; even then, some customers may be unreachable without the use of additional repeaters. Climate conditions like rain and fog can also impact the quality of service.

When designing and deploying a fixed wireless network, there is a tradeoff in spectrum between capacity and the ability to penetrate obstructions such as clutter and terrain. Higher frequencies have wider channels and are therefore able to provide more capacity. However, higher frequencies are those most easily blocked by obstructions.

Wireless equipment vendors offer a variety of point-to-multipoint and point-to-point solutions. Point-to-multipoint is more suited to a residential or small business network while large or medium-sized business connections and backbone connectivity between wireless sites would use a point-to-point solution. Point-to-point connectivity enables dedicated bandwidth needed for these applications, but at a higher cost per user than a point-to-multipoint design. Both Dallas pilot networks were designed for residential and small business use and thus use point-to-multipoint technology.

5.2 DISD educational network pilot at Lincoln High School

With the move to distance learning due to the Covid-19 pandemic, the accessibility of broadband connectivity in students' homes has become a paramount element to the quality of their education. Students who are unable to receive broadband connectivity due to lack of service or high costs are at a disadvantage in their education.

To explore options for meeting students' broadband needs, DISD developed a pilot concept using CBRS GAA tier spectrum (which is open access and has a low cost of deployment), radios located at DISD buildings (to avoid facility lease fees), and fiber connectivity to DISD's network.

In late 2020 and early 2021 DISD began to pilot an educational network to provide broadband service to student households located near Lincoln High School. BearCom, in partnership with Motorola, installed an antenna and related radio equipment near the school and, in the first months, about 40 participating student households living about a half-mile from the school were provided indoor Wi-Fi routers (also called customer premises equipment, or CPE) to deliver service within their homes. The first phase included indoor CPE equipment with Wi-Fi and USB interfaces, capable of connecting to DISD-provided Chromebooks and other Wi-Fi-based devices.

The pilot user devices are all provided to users by DISD. Therefore, at this stage, all makes and models of devices are provided by DISD according to their selection, and only DISD families authorized by DISD receive equipment or are allowed to use the network. Because the equipment is uniquely identifiable through serial number, DISD is able to identify particular user devices on the network and their usage. DISD is also able to monitor and limit network usage by user. While in the future, smart phones and other wireless devices may have standard CBRS technology interfaces, these still will require SIM cards or digital certificates to access the DISD network and will be uniquely identifiable.

Backhaul was provided through the DISD fiber optic network and out to the DISD internet connection. The network core in the first stage was a Motorola hosted LTE evolved packet core. As DISD moved to expand the network to additional schools, it found performance problems in the cloud-based core and worked with BearCom to move to a core located at the DISD data center.

DISD is planning to test different CPE equipment to expand the range of the network and improve performance to homes with more challenging lines of sight. One option is a window-mounted CPE radio that can be installed by the DISD family at a location with the best connection to the network, which then acts as a Wi-Fi hotspot connecting to student devices.

DISD is targeting connecting 5,000 student households at five schools by the end of June 2021 from five schools—Lincoln, Roosevelt and South Oak Cliff High Schools, Dunbar Learning Center, and Rice Learning Center.

5.3 City of Dallas Wi-Fi pilot in priority zones

At approximately the same time as the DISD pilot, the City of Dallas also began a pilot, using Wi-Fi technology from Neo Networks. Locations were selected in 10 priority zones consistent with proximity to City facilities, DISD and City collaborative projects, and areas of limited household connectivity to the internet.

Initial locations are listed below, identified by Council District (CD), and illustrated in Figure 99 below:

1. Martin Weiss Recreation Center: Thibet St. from Martindale to Westmoreland (CD 1)
2. Fire Station #52: Bridlewood from Cockrell Hill to Western Park (CD 3)
3. Beckley Saner Recreation Center: Seevers from Hobson to Elmore (CD 4)
4. Fire Station #23: Iowa from Corinth to Bruck (CD 4)
5. Pleasant Oaks Recreation Center: Greenmound from McCutcheon to McKim (CD 5)
6. Fire Station #32: Toland from Jim Miller to Elva (CD 5)
7. Arcadia Branch Library: N. Justin Ave. from Library to Goodman (CD 6)
8. Fire Station #50: Bluegrass from Keeneland to Furlong (CD 6)
9. Singing Hills Recreation Center: Gillarel Springs from Old Ox to Cul-de-Sac (CD 8)
10. Polk Wisdom Library: Deerwood from Library to S. Polk (CD 8)

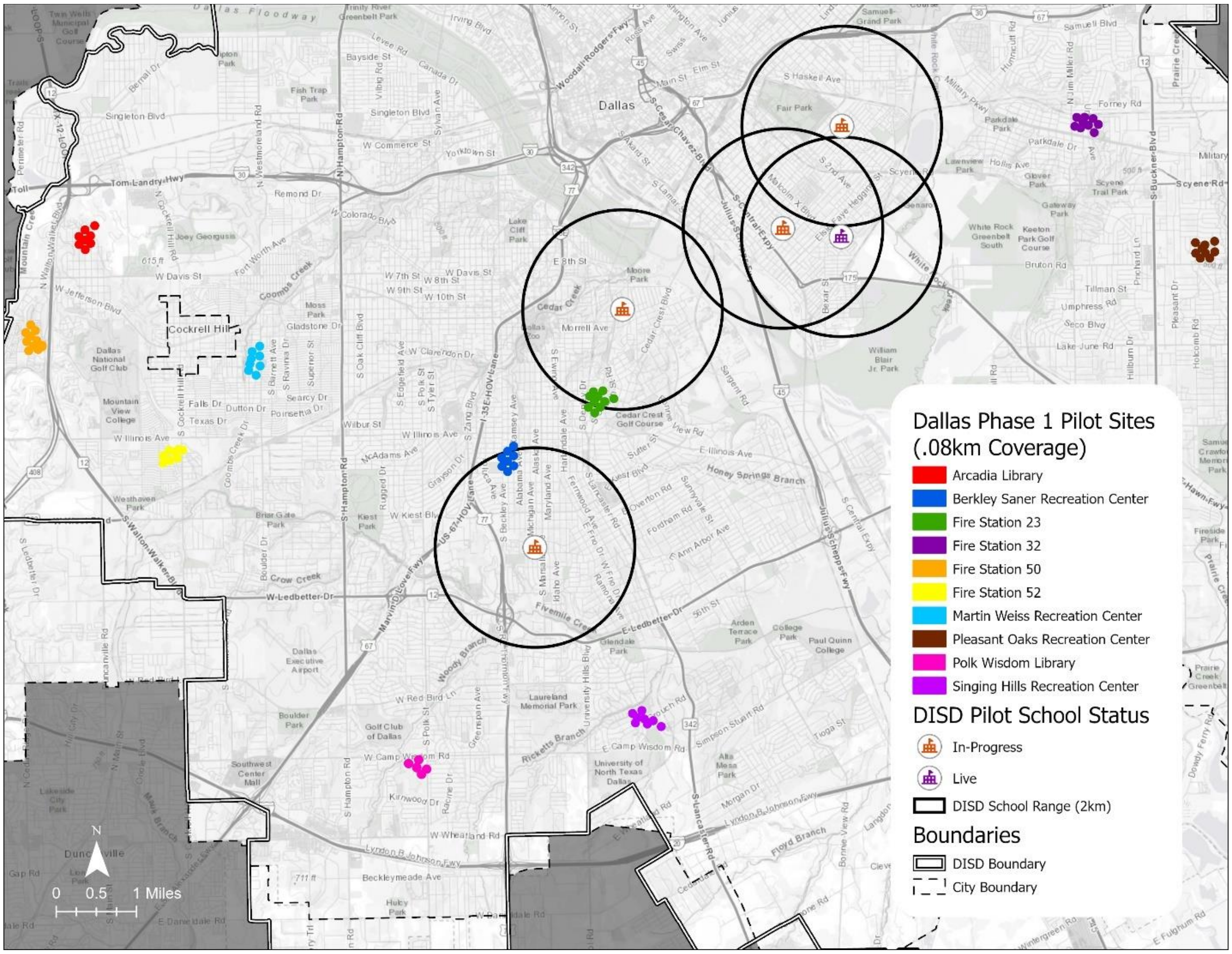
The network is a Wi-Fi wireless mesh network with five to 10 outdoor access points in each of the areas. Access points are mesh routers manufactured by ARRA. Wi-Fi access points are installed on City-owned poles, installed for this purpose. Poles are metal poles built by CommScope , as well as wooden poles in neighborhoods where there are wooden utility poles, and fully integrated solar powered ClearWorld smart poles.

The mesh network is operating on a 5 GHz band using 60-degree directional antennas between the points, with signals from access points to public at 2.4 GHz.

Backhaul to the areas is either with Charter cable modem circuits operating at best effort, usually 600 to 700 Mbps, or mobile broadband connections using Cradlepoint routers. The intent is to upgrade the backhaul to fiber, as the pilot continues. As of the date of this report, all but the Singing Hills location have been moved to the Charter cable modem services.

Devices on the poles are solar-powered, with battery backup. The devices appear to be working with low power draw at the moment, but if equipment is added at the pole, such as other City equipment or additional radios, the backup time may be reduced.

Figure 99: City of Dallas Pilot Locations



Backhaul and pole installation were done to provide a rapid proof of concept; different choices may be made if time permits—such as fiber backhaul and use of Oncor utility poles instead of purpose-built poles.

In this proof-of-concept phase, residents in the area would connect using their own Wi-Fi-enabled devices. Neo conducted an analysis to determine where a minimum level of -70 dBm signal strength would be available, in order to estimate a margin to take into account building penetration.

Speed currently is capped at 50 Mbps downstream, 5 Mbps upstream, for the pilot service. The pilot has not tested network authentication, with the network currently appearing as an open network to any Wi-Fi device in range, and the same login and password used for all users. It also has not yet tested the ability to have different rate limits and parental controls for different users, this functionality relies on separate services not budgeted in the initial implementation.

Neo has not tracked the number of users to connect to the network—the common login and password makes this impossible at the moment. Drive testing or in-home testing have not taken place yet.

According to Neo, availability of the Wi-Fi access points and the backhaul connections has been approximately 98 percent. Issues found in the network so far include susceptibility to the backhaul circuits "locking up" in the event of power failure, requiring the pilot team to manually visit the sites and restart all of the access point devices. The City is addressing this issue by placing uninterruptible power systems (UPS) at the sites with mobile wireless connections, to keep power up and reboot the devices remotely if necessary.

The second pilot was completed by City contractors. Locations were selected in 10 priority zones consistent with the findings of the Mayor's Task Force on Safe Communities, as well as in strategic lighting zones which take into account factors such as the Market Value Analysis, and areas of racial and ethnically concentrated poverty.

Initial locations are listed below, identified by Council District (CD):

1. Thurgood Marshall Recreation Center: Ariel from Mark Trail to Dove Creek (CD 3, LIA and SLZ),
2. Fire Station #38: Cicero from Wilhurt to Ann Arbor (CD4, LIA, MTF, and SLZ),
3. Eloise Lundy Recreation Center: Denley from Hutchins to Reverend CBT Smith (CD 4, MTF and SLZ),
4. Fire Station #5: Corvette from Bruton to Limestone (CD 5, LIA, MTF, and SLZ),
5. Janie C. Turner Recreation Center: Ezekial from Elam to Hoode (CD 5, LIA, MTF, and SLZ),
6. Mattle Nash Myrtle Davis Recreation Center: Bayside from Hampton to Puget (CD 6, LIA and SLZ),
7. Juanita J. Craft Senior Center: Frazier from Spring to Marshall (CD 7, LIA, MTF, and SLZ),
8. Skyline Library: Symphony from Everglade to Snowbird (CD 7, LIA, partially in MTF, and SLZ),
9. Fire Station #40: Kirnwood from Cul-de-Sac to Cul-de-Sac (CD 8, LIA, MTF, and SLZ),
10. Fire Station #54: Pinebrook from Bonnie View to Strawberry Trail (CD 8, LIA and SLZ).

This pilot included the installation of streetlights with fiber optic installation from adjacent City facilities to wireless access points (WAP) on the streetlights installed on the selected blocks.

5.4 Recommendations for data evaluation and tracking

Both the DISD and City pilots are in process. It is important to continue to use these pilots as an opportunity for evaluating technical and business processes, including:

- Technical performance in actual user situation—with the applications (software) that will actually be used, with a range of likely user hardware (user devices, hotspots, access points, extenders, indoor and window mounted), in the actual environment of use (indoor, in different places in the house), and with the full, envisioned loading of the network
- Business and operational processes, with actual users, connection to network, customer help desk, repair and maintenance processes, installation processes, and interactions with other entities involved (e.g., pole owner, backhaul provider)—both to evaluate feasibility and to estimate the cost to scale and operate a potential full-size network

5.4.1 Technical evaluation

Technical evaluation may start with initial connection and demonstrations but should include development and fulfillment of a detailed test plan that will identify strengths and weaknesses that will enable the City to develop specifications and cost estimates for a network at scale.

A comprehensive technical evaluation test plan includes:

- Numerical performance parameters measured with user equipment—speeds, latency, and jitter
- Range of end-user equipment—laptops, smart phones, tablets, internet of things machines
- Range of environments—in-house, outdoors, in rooms where public and users will be
- Qualitative assessment using actual applications—Zoom, video streaming
- Stress testing to determine scalability—with individual wireless network segments fully loaded, and/or use of traffic generation equipment
- Backhaul configurations—including the use of leased circuits, incorporation of connection through intermediate locations such as City sites, use of routing and switching configuration
- Network management—determining how to best monitor and manage performance, how to provision new users, how to troubleshoot, and how to assign different levels of service and access to different users—verifying operation of network management, provisioning, and authentication tools

- Security—ascertaining the vulnerability of the network to external attempts to shut it down or damage it, physical security of devices, degree of security of information of individual users and warnings and safeguards that need to be provided to users

Tests can be done in a wide range of ways, including using customized versions of the speed test used in Section 3.3. In equipment provided by DISD or the City, scripts can be installed to automatically test the connections at regular intervals.

Wireless technology has great advantages, such as (in many settings) speed to deploy, and great flexibility. However, the flip side is that wireless is significantly less predictable than a wired network because performance changes radically with line of sight and loading. Additionally, technologies like Wi-Fi that are widely available and work off the shelf, need to be adequately equipped with the necessary management and security functions when they are providing a mission critical service or when individuals rely on them as their main internet service—while in carrier network technologies like CBRS these may be included, in Wi-Fi they are often add-ons that need to be added explicitly.

A citywide Wi-Fi model for ubiquitous service is untested and thus represents unknown risks to the City in such areas as execution and operations, until these are demonstrated in the pilot. In particular, we are concerned that Wi-Fi antennas mounted outdoors may not provide consistent service to Dallas residents inside their homes and are concerned that large Wi-Fi mesh networks may not deliver consistent performance if a user is more than a few "hops" from the connection to the internet.

5.4.2 Business evaluation

Operating and sustaining a network can be complex. To the extent the network is operated by internal City and DISD staff, operations will require a standardized procedure to install or activate a user, customer support help desk, and a maintenance team. It will require education of users and an ongoing outreach to the users. It will require staff to access equipment on poles, towers, or rooftops, it will require an ongoing relationship and agreements with pole or facility owners, as well as the operators of backhaul networks. It will require training of staff who handle all of these areas.

There will need to be an evaluation of the likely lifetime of components and the need to replace or upgrade them.

All of the various operational components will need to be specified and assigned either to the appropriate part of the City/DISD or to a contractor or partner. If a responsibility is assigned to a contractor or partner, it needs to be spelled out in a sufficiently detailed way that the work can be bid out competitively.

One of the key parts of the business evaluation should be a complete analysis of the costs of all labor and materials in order to define a business model.

5.5 Candidate wireless design and cost estimates

Starting with the equipment specifications of the DISD pilot at Lincoln High School, we developed five models to estimate the effectiveness and costs of expanding the pilot concept to other parts of the City by adding antennas to the rooftops of additional DISD buildings. In our modeling we used the rooftops of all 282 DISD schools as potential radio locations and determined the maximum number of potential subscribers that could be served under different parameters. (The addition of other publicly owned rooftops and other infrastructure, including that of the city of Dallas and the county, would further extend the potential of the network and improve coverage.)

The first two models are for DISD families. The third, fourth and fifth models are for all City residents. In all models we use DISD rooftops, both because the model is proven in the DISD pilot and because DISD buildings have fiber connections that are necessary to connect the antennas to the internet.

We used the DISD Community Resource Index (CRI), a tool created by the Child Poverty Action Lab, as one tool to help establish prioritization for Model 2; CRI was designed to inform investment decisions and resource allocations because it measures various characteristics of Dallas neighborhoods, such as education, economics, and health.[25] We considered the areas where broadband-level speeds are not available everywhere, and that have seen less investment in fiber by the incumbent providers, for Model 3. We also considered the City of Dallas Office of Equity and Inclusion's Covid-19 risk score data in Model 4; within that framework, Risk 5 areas have the highest risk, followed by Risk 4 and so on.[26] In Model 5 we considered reaching all residents reachable from DISD rooftops in areas with a Community Resource Index (CRI) score under 40.

The five wireless infrastructure models we developed are:

- Model 1: All DISD families are potential subscribers
- Model 2: Only DISD families who can be connected from schools with a Community Resource Index (CRI) score under 40 are potential subscribers

[25] "DISD Community Resource Index," Child Poverty Action Lab, https://childpovertyactionlab.org/disd-cri (accessed May 2021).

[26] Covid-19 risk score description and methodology, Office of Equity and Inclusion, City of Dallas, https://dallasgis.maps.arcgis.com/home/item.html?id=186b98f0fab940118dbd9a4422db7eaa&view=table&sortOrder=desc&sortField=defaultFSOrder#overview (accessed April 29, 2021).

- Model 3: All City residents (DISD families and others) in areas that have seen less existing broadband infrastructure are potential subscribers
- Model 4: All City residents (DISD families and others) in City-designated Covid Risk 5 areas are potential subscribers
- Model 5: All residents (DISD families and others) in Dallas using DISD rooftops in areas with a Community Resource Index (CRI) score under 40

These models were used to estimate the greatest number of eligible households that could be reached using different target areas and selection parameters. These data are intended to help DISD and the City compare options for deploying a wireless network for student households and/or other residents.

5.5.1 RF coverage modeling methodology and assumptions

For the purpose of our analysis, we modeled radio frequency (RF) coverage using CloudRF propagation software. The software was chosen because of its ability to output accurate coverage maps in a GIS layer than can be overlaid on the unserved address points, and therefore identify which of the addresses would be covered by the wireless model. CloudRF uses a sophisticated model that considers terrain and ground clutter such as trees, vegetation, and buildings.

The industry uses a wide range of propagation models used RF analysis. Widely used models include the line of sight (LOS) model, cost 231 model, Okumura Hata model, and Longley-Rice model (also called the Irregular Terrain Model, or ITM).

For our analysis we used ITM, which is the most conservative model and takes into consideration the atmospheric conditions, the ground elevation, the deployment environment, the obstacles between the base and mobile stations, and the ground clutter.

Additional modeling assumptions:

- Channel bandwidths used are 40 MHz for the CBRS GAA band.
- The CBRS band equipment operates at the maximum allowed power.
- 10 dB of fade margin was included. Fade margin is defined as the difference between receiver signal strength and receiver sensitivity. Fade margin accommodates additional miscellaneous losses which might occur.
- 13 dB of loss was assumed due to building material absorption.
- Assumed receiver antenna gain of 8 dB.

- Access point antennas were placed at 60 feet height. We assumed each DISD school rooftop would accommodate a small mounting structure on the main roof level allowing antenna heights to be 60 feet.

- Ground elevation and clutter resolution were 30 meters—therefore this model takes into consideration any obstacles or clutter of up to 30 meters in size.

5GHz modeling assumptions (Model 5 only):

- We assumed that the 5 GHz band can reach the same distance as CBRS, providing greater capacity but within the same coverage area.
- We assumed 80 GHz of bandwidth in the 5 GHz band to provide the additional capacity.
- From a technical perspective, this deployment (5 GHz plus CBRS) can theoretically serve three times the number of addresses as CBRS alone. But to be conservative, we assumed that this deployment would serve only two times the number as CBRS alone.

We based our analysis on the following assumptions:

- We considered all DISD school rooftop locations in our analysis.

- We eliminated those DISD rooftop locations that could not reach 33 or more addresses, because we defined those locations as reaching too few addresses to be cost-effective.

- Assuming a three-sector site, a 40 MHz CBRS channel has the capability to serve 768 addresses with 25/3 Mbps capacity. With 60 percent market penetration, the maximum number of addresses in the service area is 1,280 addresses. A 60 percent penetration was chosen for the model because it is assumed that some number may not be eligible or may have service from other sources (e.g., AT&T or Charter). In Model 5, as noted above we add 5 GHz wireless antennas to serve additional addresses from each rooftop.

- Assumed 64 QAM and 2x2 MIMO for DL and 16QAM and 1x1 MIMO for UL.

- Assumed that for any DISD school rooftop that covers more than 768 addresses the additional number of addresses can be offloaded to neighboring DISD school rooftops, and there is sufficient overlap between all DISD rooftop locations.

- Unit pricing is based on industry pricing from various suppliers.

We note that these are high-level models based on scaling the networks built during the pilot. Because the CBRS technology is new and its use is just beginning—and it is open to other service providers and the public—it is possible that interference with other providers in the future will reduce the performance of the network and/or the number of DISD families and City residents who can effectively be served. We also note that CBRS has not yet been operated in a network that seeks to serve the majority of a large city, and caution that an actual deployment take into account the possible need to place more antennas and/or use other spectrum options in the event of interference or network overload.

5.5.2 High-level coverage and cost estimates by model

The following tables illustrate the estimated capital and operating costs for the models, as well as key parameters for each.

Table 24 summarizes the estimated capital costs for each model.

Table 24: Estimated Fixed Wireless Capital Costs

Model	Number of DISD Rooftops	Homes Served	Capital Cost	Average Cost per Home Served[27]
1: DISD families – All schools	210	74,500	$38,173,800	$854
2: DISD families – schools with CRI < 40	107	44,800	$20,993,280	$781
3: All City residents in areas with less existing broadband infrastructure	148	28,235	$21,870,831	$1,291
4: All City residents in Covid Risk 5 areas	5	774	$893,664	$1,924
5: All residents who can be served from schools with CRI<40	107	106,721	$56,156,064	$877

Note: The capital cost model assumes a 60 percent penetration rate, which is likely in an area with no other broadband option.

[27] Assumes60 percent penetration. Includes $350 per household served for installation and customer premises equipment.