Example Approaches to Connecting the Unserved and Underserved

Potentially inspirational examples for those thinking about OVERCOME project innovation. Be inspired by, improve on, and/or combine these with your own ideas in creative ways.

This document can be found at https://www.us-ignite.org/program/overcome/

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Example A: Lay/String Your Own Fiber

1. Problem being addressed: Generate a long-term sustainable infrastructure to provide digital services into currently unconnected areas. Fiber has an expandable capacity far higher than wireless technology can provide.

2. Organization(s) involved might include
    a. Municipalities - Municipal Internet - c.f. See Next Century Cities, muninetworks.org
    b. Transportation Departments (State, Country, City) are often already laying fiber; microtrenching fiber across a road is a lot like adding traffic loop sensors
    c. Electric Utilities - perhaps using a utility lease model
    d. Electric Co-ops, Agricultural Co-ops, or other Co-ops providing Internet services
    e. Municipal buildings of all kinds (fire stations, courthouses, park buildings, maintenance depots, homeless shelters, etc.) from which fiber could be extended

3. Technologies employed include
    a. Metro-range fiber optics
    b. Use existing municipal underground conduit or rights-of-way to lay fiber
    c. Install new underground conduit and blow fiber through it (preferred since it allows for more fibers of possibly newer types to be added later)
    d. Micro-trenching or slot cutting; direct burial; boring under surface obstacles
    e. String fiber optics through storm drains or sewers
    f. String fiber optics on top of road / sidewalk surfaces but secured and protected by a hardened weight-bearing adhesive
    g. Overhead on utility poles - can be put between power and communications since fiber doesn't conduct electricity
    h. Existing utility and light poles provide powered, easy-to-access junction points

4. Affordability and sustainability: Viewed independently, upfront installation costs are significant ($1.00-$1.35 per foot), but when financed, fiber provides a stable long-term payback through leases to commercial organizations of all kinds and through property liens for residential construction. Useful for open access capabilities.

5. Financing options include:
    a. Treating as a capital expense; can go in the capital budget instead of the expense budget
    b. Cost-share with utility or multiple open-access users
    c. Add pro-rata cost as a property lien to be paid off as part of property taxes over 15-20 years (shifts part of the financing burden to landlords and keeps initial costs low)
    d. Also, use fiber for another purpose (e.g., upgrading traffic control; adding DSRC; etc.)

6. Safety, speed, and ease of deployment: your public utilities or roads departments know about safety, can schedule priorities for speed, and may already be familiar with fiber.

7. Risk in technical approach: Minimal since fiber is proven and provides long-term benefits. Fiber feeds wireless, and short-distance small-cell and WiFi needs fiber feeds for best performance.

8. Scalability: Highly scalable if conduits are used; scalable to hundreds of gigabits with single-mode metro fiber.

9. Quality, reliability, and maintainability: Treat as a capital asset.

Example B: **Rooftop WiFi**

(Extend WiFi from buildings to nearby parks, parking lots, MDUs, and residences)

1. Problem being addressed: Quickly connect parking lots and dwelling units near existing buildings (often public buildings) using WiFi. (Also see Mesh Networks Example F.)

2. Organization(s) involved might include
   a. Anchor institutions such as schools, colleges, libraries, museums, healthcare organizations, universities, etc.
   b. Municipal buildings of all kinds (fire stations, courthouses, park buildings, maintenance depots, homeless shelters, etc.)
   c. Volunteer businesses willing to extend their own WiFi to nearby homes and MDUs.
   d. Startups that might provide these services.

3. Technologies Employed include
   a. Adding multiple WiFi base station units with extended range thanks to directional antennas to volunteer building rooftops pointed at parks, parking lots, MDUs, and homes
   b. Further away homes can increase their capacity by adding WiFi repeaters with optional directional antennas in windows facing the rooftop base station or with outside antennas.

4. Affordability and sustainability:
   a. Ask the Internet provider to waive any restrictions in the use agreement for the Internet service provided to the building; a for-profit building owner or leaseholder may be able to take a tax deduction for donating services to a nonprofit serving the underserved.
   b. Train both building IT personnel and selected volunteer residents of the served area to provide troubleshooting and support. (For example, a windstorm re-orients a directional antenna and it needs to be reoriented.)

5. Financing options include:
   a. If the rooftop WiFi base stations are owned by a nonprofit, a for-profit rooftop owner can take a tax deduction for the value of its rooftop space, providing power, providing Internet access, and the capital cost of the equipment donated to the nonprofit.
   b. Municipalities may have some leverage if there is a franchise agreement with the Internet provider.

6. Safety, speed, and ease of deployment:
   a. This deployment can be done quickly by volunteer IT personnel familiar with WiFi but directional antennas are in short supply right now.

   b. More distant locations may require outdoor directional antennas pointed at the rooftop.

7. Risk in technical approach:
   a. A clear line-of-sight will help this kind of deployment be successful. A little foliage may not be a problem, but metal fences can act as Faraday cages.
   b. Roof penetrations can allow water ingress, especially on flat roofs; professional roof installers may be required in some cases; in other cases, cables can be routed out of windows and antennas weighted down with sandbags to avoid roof penetrations. Check local building codes.
   c. Total bandwidth available per rooftop sector is limited to WiFi speeds (a theoretical maximum of 1.3Gbps per rooftop sector) which will depend on distance and interference and antenna gain and pointing accuracy.

8. Scalability: Any single WiFi link has a maximum capacity shared among all users who are on that link at any given time. Each project can be formulated and get underway quickly with no municipal permits or engineering required.

9. Quality, reliability, and maintainability: Reliability is subject to WiFi interference. In some cases, a high degree of in-MDU WiFi can create a WiFi noise floor so high that the relatively weak signal from the rooftop has trouble being consistently heard (and vice versa).

Example C: U-NII Wireless Line-of-Sight to a Single Point <25 Miles

1. Problem being addressed: A rural home or cluster of homes is currently unconnected but there is unobstructed line-of-sight from a nearby building, hill, tower, etc. to a location willing to provide Internet service. (We'd expect that several such connections would be proposed to different clusters.)

2. Organization(s) involved could include
   a. Homeowners and small business owners
   b. Co-ops including electric co-ops and agricultural co-ops
   c. Amateur radio operators
   d. Counties and small cities
   e. Anchor institutions such as schools, colleges, libraries, museums, healthcare organizations, universities, etc.
   f. Municipal buildings of all kinds (fire stations, courthouses, park buildings, maintenance depots, homeless shelters, etc.)
   g. Volunteer businesses willing to extend their own WiFi to nearby homes and MDUs.
   h. Members of The Quilt (usually primarily serving academic institutions)
   i. Startups with an interest in providing these services

3. Technologies Employed include
   a. FCC Part 15 U-NII point-to-point wireless over clear line-of-sight to the other antenna (perhaps on an MDU or farm building). At that point, it can be converted to WiFI to serve the immediately surrounding area.
   b. Buried or strung fiber/Ethernet to the location where line-of-sight is available.
   c. Locate a powered repeater at the location where line-of-sight is available if it is infeasible to bury or string fiber/Ethernet to the location where line-of-sight is available. Sometimes amateur radio operators have already located repeaters for their own line-of-sight use in such locations. Sometimes solar power and batteries are used for power.
   d. Typical aggregated speeds (total of all customers operating at the same time on the same radio link) are typically up to 150Mbps depending on distance, foliage, and accuracy of antenna pointing.

4. Affordability and sustainability:
   a. If the rooftop WiFi base stations are owned by a nonprofit, a for-profit rooftop owner can take a tax deduction for the value of its rooftop space, providing power, providing Internet access, and the capital cost of the equipment donated to the nonprofit.

5. Financing options: The costs are mainly in equipment acquisition, installation, and maintenance. Financing can be secured by the equipment.

6. Safety, speed, and ease of deployment: Someone familiar with amateur or 2-way radios should set up the equipment. It should be properly grounded, for example.

7. Risk in technical approach: These devices are commonly used by commercial WISPs--wireless Internet Service Providers. You probably have this expertise in your community and can leverage your local WISP's expertise.

8. Scalability: Any single link has a maximum capacity shared among all users who are on that link at any given time.

9. Quality, reliability, and maintainability: Treat as a capital asset.

Example D: CBRS GAA or PAL

1. Problem being addressed: U-NII (see the previous example) is point-to-point (1:1). CBRS can be used in an LTE-like fashion to serve multiple homes/MDUs/WiFi community access points. It's like a privately-owned (or publicly-owned) cellular data provider. In addition, U-NII is generally limited by FCC Part 15 rules to a maximum Effective Isotropic Radiated Power (EIRP) of 36 dBm (4 watt). Somewhat greater power (and therefore additional distance) is available in the CBRS band (3.5 GHz) with so-called Category B CBRS access points which are permitted to operate up to 47 dBm/10 Mhz. Access can be either with a Priority Access License (PAL) or under an automatic license with a General Authorized Access priority. GAA users can operate throughout the 3550-3700 MHz band. GAA users must not cause harmful interference to Incumbent Access users or Priority Access Licensees and must accept interference from these users. GAA users also have no expectation of interference protection from other GAA users. Technical rules for GAA users can be found in Subpart E of Part 96 of the FCC rules. PAL licenses have been issued in an auction during the summer of 2020 and using PAL will require partnering with someone holding a PAL for the county you propose to serve. GAA is available in nearly all US locations and may be particularly safe to use in rural areas. (The extent to which GAA in urban areas will be crowded is unknown.).

2. Organization(s) involved could include
   a. Homeowners and small business owners
   b. Co-ops including electric co-ops and agricultural co-ops among others
   c. Amateur radio operators
   d. Counties and cities
   e. Anchor institutions such as schools, colleges, libraries, museums, healthcare organizations, universities, etc.
   f. Municipal buildings of all kinds (fire stations, courthouses, park buildings, maintenance depots, homeless shelters, etc.)
   g. Volunteer businesses willing to extend their own Internet to nearby homes and MDUs.

3. Technologies Employed include
   a. Wireless point to point or point to multiple housing units using the CBRS band and commercial equipment
   b. CBRS radios per MDU or single-family home, mounted (like U-NII) on the sides of buildings in locations with line-of-sight to the CBRS base station (often located atop a tall building).
   c. CBRS backhaul from light poles or other community WiFi access points
   d. Aggregated speeds (to all users operating simultaneously) are up to 200 Mbps.

4. Affordability and sustainability: The electronics and dishes can be very affordable (<$500) and no license is required to operate. The location providing the Internet service may need to be paid. If the rooftop CBRS or CBRS-to-WiFi base stations are owned by a nonprofit, a for-profit rooftop owner can take a tax deduction for the value of its rooftop space, providing power, providing Internet access, and the capital cost of the equipment donated to the nonprofit.

5. Financing options: This option is so affordable that costs will tend to run < $1000 in total per cluster connected and hence capital costs can be fully financed locally or via a grant.

6. Safety, speed, and ease of deployment: Someone familiar with 2-way radios (e.g., amateur radio operators) should set up the equipment. It should be properly grounded, for example. Existing cellular carriers and cable companies have bought lots of PAL CBRS licenses in the recent auction. They may provide deployment and installation as well as the use of their license.

7. Risk in technical approach: Line of sight distances are subject to reduction during heavy rainstorms and snowstorms. Windstorms can move carefully-aligned antennas. Devices must be professionally installed. You may want to partner with a commercial CBRS provider due to the complications of automatic licensing and newer equipment with which few people have experienced. CBRS GAA must not cause interference to CBRS PAL licensees which might become an issue in some urban areas with high demand for the wireless spectrum.

8. Scalability: Each CBRS base station has a maximum range of about 10 miles with unobstructed line-of-sight. That base station should be elevated (e.g., on a rooftop) to enhance the chances of unobstructed line-of-sight. Some coverage may be available through light foliage. The base station needs to be powered and have its own Internet connection. This model can be scaled as often as desired although base stations close to each other may need to use different CBRS frequencies and will need different “license-by-rule” CBRS GAA licenses if GAA is being used.

9. Quality, reliability, and maintainability: Line of sight distances are subject to reduction during heavy rainstorms and snowstorms. Windstorms can move carefully-aligned antennas.

10. Other information sources:
    a. A good FAQ on CBRS.
    b. FCC Overview of the 3.5 GHz band hosting CBRS
    c. CBRS Alliance is making equipment and partnerships available to communities in need as a COVID-19 response. (OnGo Together.)

Example E: Low-Earth Orbit (LEO) Satellite

1. Problem being addressed: Remote and rural areas may be best served from above.

2. Organization(s) involved could include
   a. Satellite Internet providers
   b. Counties and cities
   c. Anchor institutions such as schools, colleges, libraries, museums, healthcare organizations, universities, etc.
   d. Municipal buildings of all kinds (fire stations, courthouses, park buildings, maintenance depots, homeless shelters, etc.)
   e. Volunteer businesses willing to extend their own Internet to nearby homes and MDUs

3. Technologies Employed include
   a. Satellite-delivered Internet LEO (Low-earth orbit) or MEO (Medium-earth orbit)

4. Affordability and sustainability: Early partnerships with satellite-providing organizations may provide early-mover advantages.

5. Financing options: The main investment is being made by LEO satellite Internet providers

6. Safety, speed, and ease of deployment: Equipment and directions are provided by the satellite provider.

7. Risk in technical approach: This is a new and unproven technology. Speeds available may be limited; constellations of satellites are just now being deployed. High bandwidth and low latency may be difficult to achieve. However, it also offers great promise for being able to reach even the most remote locations. Most worthy of consideration for very rural areas.

8. Scalability: The satellite provider provides the scalability.

9. Quality, reliability, and maintainability: A community trying this approach can provide information to all the rest of us on quality, reliability, and maintainability.

Example F: **Community Mesh Networking**

1. Problem being addressed: In an urban area, a mesh network connecting rooftops and terraces with line-of-sight radios (e.g., U-NII or WiFi or CBRS) carries Internet signals from one building to another. One or more of the buildings has their own existing Internet connection(s) (or Internet Exchange Point or Digital Town Square) which connect the mesh to the greater Internet. Mesh networks are often developed by community volunteers seeking donations to finance equipment and services. A mesh network can also make sense in suburban or rural areas where a number of dwellings are close enough to each other to create a mesh. WiFi meshes are the easiest; U-NII meshes require a bit more knowledge); CBRS meshes are fairly new.

2. Organization(s) involved could include
   a. Community volunteer groups
   b. Neighborhood associations
   c. Parents of elementary school children giving them online learning access
   d. Churches, community centers, local libraries
   e. Youth groups
   f. Anchor institutions such as schools, colleges, libraries, museums, healthcare organizations, universities, etc.
   g. Municipal buildings of all kinds (fire stations, courthouses, park buildings, maintenance depots, homeless shelters, etc.)
   h. Volunteer businesses willing to extend their own Internet to nearby homes and MDUs
   i. Startups interested in serving community meshes

3. Technologies Employed include
   a. A network of point-to-point radios interconnect sites on the mesh
   b. Directional WiFi is popular due to the low cost of equipment, availability of donated equipment, and no license needed
   c. Aggregate speeds depend upon the speed of interconnections to commercial Internet or Internet exchange points or Digital Town Squares; since many users are using the same mesh links, the speed of the slowest mesh link between the end-user and the Internet connection they're using determines the aggregate bandwidth available to all similarly situated users compared to that ink.

4. Affordability and sustainability: The electronics and antennas can be very affordable (<$200) and no license is required to operate. The location providing the Internet service may need to be paid. If the rooftop WiFi base stations are owned by a nonprofit, a for-profit rooftop owner can take a tax deduction for the value of its rooftop space, providing power, providing Internet access, and the capital cost of the equipment donated to the nonprofit.

5. Financing options: This option is so affordable that people being connected often are asked to donate to the cost of their equipment plus some additional money for people who can't afford to pay.

6. Safety, speed, and ease of deployment: Volunteers trained in finding line-of-sight WiFi connections can work with building owners to use safe rooftop or terrace locations. Within the building, traditional Ethernet cabling and WiFi access points are used to distribute the Internet signals.

7. Risk in technical approach: Line of sight distances are subject to reduction during heavy rainstorms and snowstorms. Windstorms can move carefully-aligned antennas.

8. Scalability: The denser the mesh, the more reliable the network and the greater overall capacity.

9. Quality, reliability, and maintainability: Line of sight distances are subject to reduction during heavy rainstorms and snowstorms. Windstorms can move carefully-aligned antennas.

10. More information:
    a. How Stuff Works Overview of the technology
    b. PCWorld recent Overview of the technology

Example G: TV White Space Wireless (aka TVWS and Super-WiFi)

1. Problem being addressed: Most 100+ Mbps wireless technologies work on line-of-sight connections. TV White space, so named because its spectrum is in the “white space” between TV channels, uses frequencies under 1 GHz which penetrate through walls and buildings to transmit data. Special transmitters and receivers are used which avoids interference by registering frequency uses with a master database. The trade-off is that lower data rates are available at these lower frequencies. Data rates of 10-50 Mbps download are achievable over up to 25 miles. Usually, a base station on a tall building (often a public building) will communicate with a TVWS device in a home or MDU. TVWS has been marketed under the name “Super Wi-Fi” without permission and without any real connection to WiFi. (The TVWS node in a building may connect to a traditional WiFi access point to provide the connectivity in the building to laptops, PCs, phones, etc.) TVWS is especially applicable in rural areas without line-of-sight connectivity available. An innovative use of TVWS is Microsoft’s Airband Initiative using aerostats.

2. Organization(s) involved might include
    a. Anchor institutions such as schools, colleges, libraries, museums, healthcare organizations, universities, etc.
    b. Civic organizations
    c. Startups interested in serving this option
    d. ISPs

3. Technologies Employed include
    a. Sending Internet signals over somewhat obstructed paths which wouldn’t be useful for WiFi, U-NII, or CBRS.
    b. Data rates are limited due to the use of lower frequencies with penetrating power.
    c. Indoor equipment often can be used at MDUs and homes because of the penetrating power of lower frequencies.

4. Affordability and sustainability:
    a. TV white space is more resilient because it doesn’t need precisely-aimed outdoor antennas and can be used with indoor equipment
    b. If the rooftop WiFi base stations are owned by a nonprofit, a for-profit rooftop owner can take a tax deduction for the value of its rooftop space, providing power, providing Internet access, and the capital cost of the equipment donated to the nonprofit.

5. Financing options include:
    a. Equipment cost and its maintenance are the primary cost components.

6. Safety, speed, and ease of deployment:
    a. This deployment can be done quickly by volunteer IT personnel familiar with white space radio requirements.

   b. More distant locations may require directional antennas pointed at the rooftop.

7. Risk in technical approach:
   a. Bandwidth is limited by the TVWS frequencies and cannot grow to meet increasing demand.
   b. There is some compatibility risk due to some vendors using 802.22 standards and others using 802.11af standards to implement TVWS.

8. Scalability: Bandwidth is limited by the TVWS frequencies and cannot grow to meet increasing demand.

9. Quality, reliability, and maintainability: Signals are less affected by weather compared to other wireless choices. Antenna alignment is less crucial than in other wireless choices.

10. More information: Good overview.

Example H: Unlicensed 60 GHz and 90 GHz rooftop-to-rooftop at gigabit data rates

1. Problem being addressed: Get gigabit-class Internet service to the unconnected using rooftop to rooftop high-frequency, high-datarate, high-power point-to-point beams. There are unlicensed bands at 60 GHz and 90 GHz which are friendly to multigigabit data rates from building to building. Unlike the choice of merely providing "adequate" connectivity (often defined by the FCC as 25 Mbps down and 3 Mbps up), these high-frequency wireless connections can carry gigabits per second of information.

2. Organization(s) involved might include
    a. Anchor institutions such as schools, colleges, libraries, museums, healthcare organizations, universities, etc.
    b. Municipal buildings of all kinds (fire stations, courthouses, park buildings, maintenance depots, homeless shelters, etc.)
    c. Volunteer businesses willing to extend their own Internet to nearby homes and MDUs
    d. Digital empowerment organizations
    e. Cities and counties
    f. Startups interested in building out this technology in their communities

3. Technologies Employed include
    a. Point-to-point completely unobstructed view high data rate focused beams at 60 GHz and 90 GHz in unlicensed bands.
    b. These frequencies are so directional that one can use the same frequency multiple times from the same building when pointed in different directions.
    c. The rooftop at the edge will re-distribute the signal using other technologies such as WiFi to other nearby homes or MDUs.

4. Affordability and sustainability:
    a. If the rooftop WiFi base stations are owned by a nonprofit, a for-profit rooftop owner can take a tax deduction for the value of its rooftop space, providing power, providing Internet access, and the capital cost of the equipment donated to the nonprofit.
    b. This only makes sense if there is a multi-gigabit Internet source to be distributed.

5. Financing options include:
    a. If the rooftop Super-WiFi base stations are owned by a nonprofit, a for-profit rooftop owner can take a tax deduction for the value of its rooftop space, providing power, providing Internet access, and the capital cost of the equipment donated to the nonprofit.
    b. Municipalities may have some leverage if there is a franchise agreement with the Internet provider.

6. Safety, speed, and ease of deployment:
    a. This deployment can be done quickly by volunteer IT personnel familiar with WiFi but directional antennas are in short supply right now.
    b. More distant locations may require directional antennas pointed at the rooftop.
    c. Because of the high data rate, the network should connect multiple homes and/or dwelling units to a single beam using other technologies such as locally-strung or laid fiber optics (capable of handling these data rates) or multiple WiFi base stations.

7. Risk in technical approach:
    a. A clear line-of-sight is required.
    b. Roof penetrations can allow water ingress, especially on flat roofs; professional roof installers may be required in some cases; in other cases, cables can be routed out of windows and antennas weighted down with sandbags to avoid roof penetrations.
    c. The Internet provider should have fiber optics to feed the high data rates to and from the originating rooftop.

8. Scalability: This wireless option brings in a firehose of data, so there must be commensurately fast equipment or large numbers of devices at the edges. Wireless at these frequencies is relatively future-proof in the sense that the data capacity is extremely high and will accommodate growth in many installations.

9. Quality, reliability, and maintainability: Reliability is subject to attenuation (and reductions in data rates) during very heavy storms.

Example J: Free-Space Optical rooftop-to-rooftop at gigabit data rates

1. Problem being addressed: Get gigabit-class Internet service to the unconnected using rooftop to rooftop point-to-point optical beams. Like the 60 GHz and 90 GHz radio beams, optical beams carry massive amounts of data quickly and can supply dozens to hundreds of dwelling units with top-notch Internet speeds. They need to be fed from the main fiber feed of an Internet service provider or directly connected to an Internet Exchange or Digital Town Square. Distances can go 5+ miles between devices and operate at 100s of gigabits per second. However, the further the distance and the higher the data rate, the more difficult the beam management is - and the more turbulence and air pollution degrade the signal. Commercial units typically go up to about 1 mile.

2. Organization(s) involved might include
    a. Anchor institutions such as schools, colleges, libraries, museums, healthcare organizations, universities, etc.
    b. Municipal buildings of all kinds (fire stations, courthouses, park buildings, maintenance depots, homeless shelters, etc.)
    c. Volunteer businesses willing to extend their own Internet to nearby homes and MDUs
    d. Cities and counties
    e. Startups interested in providing this service

3. Technologies Employed include
    a. Point-to-point completely unobstructed view high data rate focused optical beams; no licenses are required in most cases (check local requirements).
    b. These frequencies are super-directional so that one can use the same optical frequency multiple times from the same building when pointed in different directions.
    c. The rooftop at the edge will re-distribute the signal using other technologies such as fiber or WiFi to other nearby homes or MDUs.

4. Affordability and sustainability:
    a. Costs are in equipment, fiber connections, and Internet feed fees (or Internet peering fees).

5. Financing options include:
    a. Leasing equipment.
    b. Securing financing with the surety of the equipment value.

6. Safety, speed, and ease of deployment:
    a. To date, the professional installation has been used due to the high optical power and possibility for blinding someone.
    b. Directional optics are always pointed at each other.

c. Because of the high data rate, the network should connect multiple homes and/or dwelling units to a single beam using other technologies such as locally-strung or laid fiber optics (capable of handling these data rates) or multiple WiFi base stations.

7. Risk in technical approach:
    a. A clear line-of-sight is required. Fog and heavy precipitation can interrupt the optical beam. A wide beam is often used so that bird flights don't cause interruptions.
    b. Atmospheric turbulence can make link quality unreliable.
    c. Pointing, acquisition, and tracking is difficult because of the unguided narrow beam propagation through free space. Since an optical beam is highly directional, the divergence of a few milliradians or less is used in order to concentrate the optical energy at a receiver. Each "optical transceiver" must be simultaneously pointed at each other for communication to take place. Because of its narrow beam property, precise alignment of the beams is required and PAT is non-trivial even for stationary nodes.
    d. Roof penetrations can allow water ingress, especially on flat roofs; professional roof installers may be required in some cases; in other cases, cables can be routed out of windows and antennas weighted down with sandbags to avoid roof penetrations.
    e. The Internet provider should have fiber optics to feed the high data rates to and from the originating rooftop.

8. Scalability: This wireless option brings in a firehose of data, so there must be commensurately fast equipment or large numbers of devices at the edges. Data rates at optical frequencies are relatively future-proof in the sense that the data capacity is extremely high and will accommodate growth.

9. Quality, reliability, and maintainability: Reliability is subject to attenuation (and reductions in data rates) during very heavy storms or in fog or smoke.

10. More information:
    a. An excellent technical primer
    b. Another Technical Primer on Free-space optics

Example K: Education Broadband Service (EBS); Private LTE Waivers

1. Problem being addressed: Obtaining spectrum for wireless educational and other connecting the unconnected purposes in the 2-3 GHz Education Broadband Service and Broadband Radio Service bands which are friendly to longer-distance rural communications. Note: Any proposal in this band will need to propose an FCC Waiver to obtain a frequency (as if they were an incumbent) as the frequencies are otherwise to be auctioned. (This was successful in the upper Michigan Peninsula for a school district requested waiver in 2019.)

2. Organization(s) involved:
    a. Schools (K-12 through higher education) to provide educational services
    b. Healthcare organizations (making a similar public service argument)
    c. Nonprofit organizations providing coverage for otherwise unconnected citizens

3. Technologies Employed include
    a. EBS-compatible private LTE

4. Affordability and sustainability:
    a. Requires line-of-sight; mostly capital expenses

5. Financing options include:
    a. School district bonding; CARES Act-like funding if another stimulus bill is passed

6. Safety, speed, and ease of deployment:
    a. Requires system design
    b. Antennas need to mostly see each other
    c. Commercial cellular data-capable phones or similar stand-alone equipment can be used in homes

7. Risk in technical approach:
    a. FCC Licensing is not guaranteed, and would need to be requested.

8. Scalability: Depends on the priority of connecting the unconnected compared to 5G deployment.

9. Quality, reliability, and maintainability: Lifeline-like speeds are easily obtained

Example L: Hybrid and Edge Solutions

1. Problem being addressed: Much of the traffic moving over today's Internet is duplicative. For students watching a teacher, each student is getting an independent feed of the teacher's video, even if Zoom or another video conferencing application is being used. Hybrid and edge solutions are intended to use Internet bandwidth more wisely by eliminating duplication and caching commonly accessed data and video nearer the edge. See "Technologies Employed" for example hybrid and edge solution possibilities.

2. Organization(s) involved:
    a. Anchor institutions such as schools, colleges, libraries, museums, healthcare organizations, universities, etc.
    b. Volunteer businesses willing to extend their own Internet to nearby homes and MDUs
    c. Local Google and Apple Developer Groups
    d. Local professional meetups
    e. Cities and counties
    f. Startups

3. Technologies that might be employed:
    a. Using a digital television subchannel to broadcast high definition classes (without using the Internet) and mesh networking to return per-student video, audio, and homework.
    b. Distributing electronic library books and pre-recorded instructional materials at night when contention for bandwidth is lower and storing it on local laptops/tablets/phones until it's viewed the next day.
    c. Use "data mules" to carry one-way data such as pre-recorded instructional materials.
    d. Using better image compression to send video.
    e. Using edge caches at schools, libraries, fire stations, and other WiFi / U-NII / CBRS distribution points.
    f. Using edge caches in MDUs to avoid sending the same information to multiple students in the same MDU independently (one copy for all instead of one copy per student)
    g. Using multicast technologies to avoid sending multiple video streams to students in the same classes.

4. Affordability and sustainability: Depends on specifics of the technologies to be employed

5. Financing options: Depends on specifics of the technologies to be employed

6. Safety, speed, and ease of deployment: Depends on specifics of the technologies to be employed

7. Risk in technical approach: This option breaks new ground which is always risky but sometimes very rewarding. Details would depend on specifics of the technologies to be employed and the applications to which they are being put.

8. Scalability: Depends on the specifics of the technologies to be deployed

9. Quality, reliability, and maintainability: Depends on the specifics of the technologies to be deployed.

Connecting to Multiple Dwelling Units (MDUs) for all examples

If the Internet connectivity is coming in via fiber, it will probably be to a utility room in the basement. Generally, MDUs have vertical chases through which you can run Ethernet cables or twisted pair copper or fiber to the access points in each unit, or perhaps you'll have several on each floor. Ethernet cables can't be longer than 100 meters (328 feet) and should be Cat 6 cables for up to gigabit service delivery using standard 802.3ab (1000BaseT). In a large building, you'll want intermediate distribution frames every second or third floor to keep the runs less than 100 meters each.

If the connectivity is coming in from roof-mounted antennas wirelessly, you'll need to find a way to provide power, stability, and data cabling from the antenna and radio unit inside the building. That may involve a roof penetration that should be done professionally to avoid leaks. In some cases, an antenna can be inside a window or hung outside a window on a high floor. Often, providing the distribution of the Internet within the building is the most difficult job of the whole project.

Dealing with the building owner's expectations is often a barrier.

Potential Community Resources that may apply to all examples

Successful "connect the unconnected" efforts often draw on multiple resources from governments, schools, colleges and universities, libraries, healthcare organizations, philanthropies, and community-based neighborhood groups and churches. Many anchor institutions are already organized through the SHLB Coalition to be local experts. Indigenous communities usually have their own leadership and support resources.

Governments and schools may have some degree of cash and in-kind resources that can be used to support efforts. They may have buildings with power and existing Internet which can be extended to the immediate neighborhoods. They may have access to grants at the state, federal, or local levels.

Sometimes there is a tech-oriented community group already doing work in connecting the unconnected.

Technical expertise can come from university faculty and students in engineering and computer science, IT staffs from academia, industry, and government, Google and Apple developer groups, local tech incubators and startup support groups (like 1 Million Cups), civically-minded ISPs, and amateur radio operators skilled in wireless technologies no doubt have a meetup in your area.

Anchor Institutions

Consider community anchor institutions that have community-serving roles. The SHLB Coalition may be particularly valuable in including in your partnerships because of their existing commitment to connecting the unconnected.

Tribal Community Partnerships

Tribal communities traditionally rank highest among the unserved and underserved. Proposed projects involving them and serving them in creative ways are welcomed.

There are any number of anchor institutions in native communities such as BIA schools, Tribal Community Colleges, Indian Health Service clinics, HUD housing or tribal businesses that may have a similar interest in expanding broadband services to their communities.

Other organizations with an expressed interest in helping connect the unconnected

NDIA - National Digital Inclusion Alliance
ILSR - Institute for Local Self-Reliance
Next Century Cities
Schools, Health, and Libraries Broadband Coalition (SHLB)
Internet Society and their online resources (including) courses for community networking