Wireless Internet Coverage for Harrisville (Phase I report)

Fred Goldstein, Interisle Consulting Group, December 2017

Harrisville’s current broadband Internet coverage is spotty at best, and the fastest and most economical way to make high-speed (25 Mbps) service available is via fixed wireless. To that end a study is providing showing how a fixed wireless system can reach virtually all of the Town’s homes. This makes use of 11 base station locations, a mix of towers and (new) utility poles, strategically placed at high locations, to overcome the challenges of the terrain.

This wireless network is not intended to displace, or prevent, the development of a fiber optic network in parts of the Town. Instead, it is meant to become part of a hybrid fiber-wireless network, wherein optical fiber reaches, at least initially, the most densely populated areas, while wireless coverage reaches everyone else. Wireless service also takes less time to provision, so service can begin sooner, and everyone who wants service quickly can order it while waiting for fiber. A phased design for deploying fiber will be provided in Interisle’s Phase II report.

Zoning issues

The existing zoning law confines antenna towers to a small overlay district near the Dublin border. The terrain limits its coverage into Harrisville. In the fixed wireless study, a pole was modeled at one of the highest roadside points in that district, on Morse Road (a public road) at the corner of Morse Lane (not a public road). While it did project potential coverage to about a fifth of the Town’s homes, it was the first choice for only about a dozen, and filled no significant gaps. It was thus omitted from the working mix. There is no obvious site for a tall cell tower nearby. Clearly, the overlay zone is preventing coverage.

A rewrite of the tower rules has been submitted. It defines four types of antenna support:

- Wireless Communications Facility, a full-sized tower
- Limited Height Structure, a tower not more than 20 feet above the treeline or 50 feet above a clearing
- Small Wireless Support Structure, a utility pole, lamp post, or other structure that supports a limited antenna load
- Attached Antenna Array, one or more antennas attached to a building.

Different degrees of regulation apply to each type of antenna support, with the Wireless Communications Facility having the strictest approval requirements. Where they can be located is summarized in this table:

<table>
<thead>
<tr>
<th></th>
<th>WCF</th>
<th>LHS</th>
<th>SWSS</th>
<th>AAA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential/agricultural district</td>
<td>SE</td>
<td>SE</td>
<td>BP</td>
<td>BP</td>
</tr>
<tr>
<td>Village/lake district</td>
<td>No</td>
<td>No</td>
<td>BP</td>
<td>BP</td>
</tr>
<tr>
<td>Historic district</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>SE</td>
</tr>
</tbody>
</table>
The design proposed herein meets those requirements. It is a mix of Limited Height Structures and Small Wireless Support Structures. None are believed to be in a Historic district. The towers should qualify for a Special Exception. If the Town decides to own the structures, even if it makes them available to a private operator, then it may also exempt itself from the zoning requirements.

**Geographic Network Design**

Several potential tower locations were provided by Brian Foucher, a member of Harrisville’s committee who is also the President of WiValley, a wireless ISP. The geographic design thus begins with these sites, and adds additional poles to fill in gaps.

The preciseness of these locations varies from place to place. In many cases the pole can be moved tens of feet in in order to find a more suitable locations; in some spots where hill tops or trees may block critical links. Thus actual visual sighting may be useful before installation siting. We did physically examine potential locations at Cobb Hill and Aldworth Manor; the Jaquith tower exists and is owned by Brian Foucher. He identified the availability of the Marienfeld and Wellscroft tower sites. The others are roadside utility poles, intended to be deployed within Town rights of way, without land acquisition.

<table>
<thead>
<tr>
<th>Site name</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Height</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jaquith</td>
<td>42.93722</td>
<td>-72.038056</td>
<td>90</td>
<td>Tower</td>
</tr>
<tr>
<td>Cobb Hill</td>
<td>42.95722</td>
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<td>80</td>
<td>Tower</td>
</tr>
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<td>Aldworth</td>
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<td>Tower</td>
</tr>
<tr>
<td>Marienfeld</td>
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<td>-72.156111</td>
<td>80</td>
<td>Tower</td>
</tr>
<tr>
<td>Old Chesham Rd</td>
<td>42.92389</td>
<td>-72.154167</td>
<td>57</td>
<td>Pole</td>
</tr>
<tr>
<td>MtView Lane</td>
<td>42.93222</td>
<td>-72.138333</td>
<td>57</td>
<td>Pole</td>
</tr>
<tr>
<td>Breed</td>
<td>42.94111</td>
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<tr>
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</tr>
<tr>
<td>Wellscroft</td>
<td>42.94778</td>
<td>-72.150833</td>
<td>80</td>
<td>Tower</td>
</tr>
<tr>
<td>Recycling Ctr</td>
<td>42.93389</td>
<td>-72.095556</td>
<td>47</td>
<td>Pole</td>
</tr>
<tr>
<td>Dublin Rd</td>
<td>42.93556</td>
<td>-72.086389</td>
<td>57</td>
<td>Pole</td>
</tr>
</tbody>
</table>

It should be noted that coverage from these sites is anything but circles on a map. Due to the terrain, it is almost unpredictable, with base stations sited on one hill often serving homes on an adjacent hill, and vice-versa, as the foliage often blocks coverage to the nearby homes. Some homes are covered from a site several miles away that happens to have a view through the mountains, while not covered by several closer sites. Coverage patterns for each site (viewsheds) are thus highly irregular.

Of the actual tower sites, Jaquith is on Brian Foucher’s property, north of Houghton Road and east of Jaquith Rd. The tower exists. It does not clear the trees to the north and thus its coverage is primarily southward.

The Cobb Hill site is behind the parking lot to the site’s north, minimizing its visual impact. It covers a large share of the town, and into the adjacent towns. This is a potential site for a cellular tower, in which
case the structure must be somewhat taller in order to accommodate a cellular carrier or two as well as the fixed-wireless network.

The Aldworth site is in the woods to the east of Aldworth Manor, on its property. It is near the top of the one-time ski tow. It has the largest viewshed of any of the proposed sites, and will support the largest potential number of subscribers, the first choice of about 200, of any one site.

The Wellscroft site is on private land overlooking Sunset Lake Road from the west, and is the choice for reaching much of Chesham Road, South Road, and Eastside Road. Marienfeld is also an older tower location on the hill north of Marienfeld Lane, near Nelson and Roxbury. It is not actually vital for coverage (it largely overlaps Wellscroft) but improves coverage in the Silver Lake area.

Of the pole sites, all are sited along public roads. Old Chesham Road is near the Dublin line, overlooking much of Chesham. Mt. View Lane reaches much of South Road and Brown Road, and fills some other gaps in Chesham. Breed shoots across Chesham Pond to serve the area near Seaver Road.

The Sargent Camp Road pole is at the corner of Rt. 137. It serves the eastern panhandle. The Recycling Center site serves a mix of places around the town center, where it fills in various “shadows” where hills block service from other sites. The Dublin Road site serves much of the center, and also much of Hancock Road across Skatutakee Lake. A site on Morse Road, in the existing overlay district was considered, but does not appear to be necessary for full-town coverage.

Figure 1 Band and Base Station coverage predictions. Color represents predicted band; shape represents base station site.
Tower and pole construction issues

The current design contemplates the construction of three new antenna towers, in addition to a set of poles. While a pole and tower are functionally similar and mainly differ in height, the process of installing them differs dramatically. Which type of tower should be used at each site thus remains to be determined.

A utility pole is processed from a single tree, and is delivered in one piece. It is set into the ground by a truck, after a hole is drilled. (Dig Safe, of course, must always precede any underground work.) The process is relatively quick. The 55 to 70 foot poles noted herein have a suggested underground depth of 8 to 13 feet, resulting in a net height of 47 to 67 feet, though this may vary slightly based on soil conditions. Poles of up to 80 feet have been used locally; it is less likely that taller ones can be delivered to some locations because they may not fit around all of the turns in some roads. Thus taller poles are not considered. When a site is itself forested, however, a pole may not suffice, as the local trees are taller than 67 feet. Poles are thus ideally sited near hillside clearings.

The working coverage modeling tool is set to use 22 meters (72 feet) for deciduous and 23 meters (75 feet) for evergreen trees, though of course actual heights do vary. As an example of what height can do, the Aldworth site’s 5 GHz coverage area is estimated as 41 square kilometers from a 27-meter elevation but only 26 square kilometers, some of that water, from a 20-meter elevation. For Cobb Hill the difference between 26 and 20 meters height is even more dramatic, falling from 44 to 23 sq. km, and losing coverage of much of the historic center. Mobile carriers also must have several feet of clearance over nearby treetops, and tree growth needs to be taken into account. Hence a design without towers would require significantly more poles, and would not provide a new site for mobile carriers to improve their coverage. It is, however, probably possible.

Tower erection is far more elaborate than setting a pole, though it varies somewhat depending on the type of tower. There are three broad categories of tower:

- Guyed lattice towers.
- Free-standing lattice towers
- Monopoles

Guyed lattice towers are generally the least expensive. They typically are constructed from uniform 10’ or 20’ sections. Most are galvanized steel: While aluminum towers exist, they are brittle and more prone to failure. The tower base is typically a fairly small concrete base, as small as 1-2 cubic yards for a small tower. The tower is supported by a triad of guy wires attached near the top. These are anchored at strategic positions, in buried concrete blocks or cemented rock anchors, to support the tower against winds from any direction. Often two or more triads of guy wires are required, especially when the tower is more than 60’ high. The most popular guyed tower is probably the Rohn 45G, based on a 16 ¾ inch equilateral triangle design. Guyed towers work well in open fields, but the guy wires may pose a problem in wooded areas; trees may need to be cleared along the guy paths. (The suitability of this option may thus depend on how one views logging.) The cost of a guyed tower rises slightly faster than linearly with height.

Free-standing lattice towers do away with the requirement for guy wires. In exchange, most have much less wind-load capacity than guyed towers, and a much larger base, though they can be engineered to any
requirement. They typically take a pyramidal form, wider at the bottom than the top. When they are engineered to be taller, the incremental sections are added at the bottom, meaning wider, and thus the cost rises much faster than linearly with height.

Monopoles are free-standing towers that essentially take the form of a hollow metal (or fiberglass) pole. The diameter is constant or narrows slightly towards the top. The structural support for the tower is in the underground tower base. One form of monopole base, direct embed, also called a caisson base, is somewhat like a utility pole – a base section is embedded in a deep, round hole backfilled with concrete. For a steel monopole this is typically about 20% of the above-ground height. (Fiberglass, being lighter, requires a somewhat smaller hole.) It is easy to install these in soil, but more difficult in ledge rock. The other type, the mat base, uses a large volume of reinforced concrete, typically 4’ deep and 10 to 30 feet square, to anchor the tower. Monopoles are generally more expensive than alternatives, but are also seen as less obtrusive, and are more easily disguised with “stealth” decorations (fake tree parts). Most cell towers are monopoles. However, they are slightly less rigid than lattice towers and thus less suitable for highly-directional microwave point-to-point antennas. That is unlikely to be a problem for Harrisville’s fixed wireless network, whose unlicensed microwave backhaul links can tolerate 3 degrees of movement, but licensed microwave links, with more focused antennas, may have problems on some monopoles. (The backbone connection to an Internet provider outside of Harrisville may require a licensed link.)

Tower installation must be carefully engineered. Typically this begins with a geotechnical survey, in which the ground is drilled to determine its composition. A Professional Engineer then prepares a report, for the tower manufacturer’s use. The tower base is then engineered to suit the ground. The ground can then be excavated to support the base, and the base is built with concrete. The tower is then erected over the base. A monopole is typically installed, section by section, by a crane. Guyed towers and fiberglass monopoles can, however, be installed by hoisting one section on top of the next using a gin pole or similar rigging. Hence a tower site does require a small clearing for the trucks, as well as a truck road (or better) to provide access.

Power, of course, is also required. It is likely to be easier to bring in power aerially, perhaps via short poles along or across the road, than to trench under the typically hard, rocky ground. Off-grid power via wind chargers and solar is possible, but requires additional types of engineering. None of the proposed sites in Harrisville are believed to be off grid.

**Site switching hardware**

A cabinet will be installed at each tower or pole, housing an outdoor-rated Ethernet switch and a power subsystem. All of the equipment is DC powered, using Power over Ethernet (PoE). The site cabinet will include a rectifier to produce DC power and batteries needed to provide reserve power for some period of time (tentative design goal: 8 hours, but critical sites may warrant more). The leading candidate for a switch in most sites is the Netonix WS-12-250-DC (under $400), which provides programmable, remotely controllable PoE insertion, minimizing the required space and allowing devices to be remotely rebooted. It also monitors and conditions battery voltage. Category 5E or 6 shielded twisted pair outdoor-grade Ethernet cable is then run up the pole or tower.
Core hardware

The network will converge at a central location where it will meet the Internet backbone uplink (to be determined). A small router is installed there to act as the hub of its network. That router also manages the rate caps assigned to each subscriber account. An uninterruptible power supply is also required. Other services are provided by the ISP at its own locations. If a hybrid fiber-wireless design is adopted, additional hardware will light the fiber, and fiber patch panels will likely be required. However, all of the hub equipment is still likely to fit into a single rack.

Budgetary cost

A wireless ISP system in a rural area typically costs ¼ to 1/3 as much as a fiber optic system, but fiber’s cost is highly dependent upon subscriber density per mile. Wireless can also be built much more rapidly, as there are no utility pole attachments, pole make-ready, or rights of way to deal with. A hybrid fiber-wireless system typically begins by building wireless coverage of the entire area, which can be done in one construction season, while fiber generally takes more than a year before construction can even begin, with “first light” typically taking 18+ months or longer. Thus the wireless network cost is a baseline for a hybrid network.

While the exact cost depends upon many factors to be determined in conjunction with the actual network owner or operator (depending on the business model), the design proposed herein has the following key approximate budgetary costs, assuming a 400 subscriber take rate (about 55%):

| Vertical assets (poles, towers)       | $300,000 |
| Network electronics (base stations)  | $130,000 |
| Subscriber electronics               | $150,000 |
| Network core equipment               | $10,000  |
| Administrative and engineering cost  | $50,000  |
| Spare parts inventory                | $10,000  |
| **Total, without startup capital**   | **$650,000** |

The largest cost is in the towers, whose actual cost is very hard to predict, as it depends upon whether lower-cost guyed or higher-cost freestanding towers such as monopoles are used. The cost of freestanding towers is itself highly dependent upon the ground composition (e.g., depth of ledgerock) at the selected sites. Thus the estimated cost of $65,000 per tower is simply a mid-range estimate for 80-90 foot towers. (These would be “Limited Height Structures” under the proposed zoning rules, based on the tree canopy.)

In a hybrid fiber-wireless network, there would probably be fewer subscribers and thus less expense for subscriber electronics, but the rest of the costs would be about the same.

Radio spectrum options

(This section is provided for informational background purposes.)

A wireless network design has to deal with issues of available radio spectrum. Broadband access networks need relatively wide swaths of spectrum in order to operate. Radio spectrum in the United States can be divided into three basic categories: licensed, unlicensed, and federal. The latter – spectrum
controlled by the federal government – is not even regulated by the Federal Communications Commission, but by the Department of Commerce (NTIA), except to the extent that it is shared with civilian use. Recent acts of Congress have, however, forced the federal government to give up or share increasing amounts of its spectrum, which is largely used for radar.

Licensed spectrum is, for the most part, unavailable for this type of project. Major blocks of spectrum have been auctioned off to the Commercial Mobile Radio Service (CMRS) providers, such as AT&T, Verizon Wireless, and T-Mobile. And while they are not making extensive use of it in or near Harrisville, they are allowed to “bank” it and keep others from using it. Thus we are focusing on unlicensed or, at most, “lightly licensed” (nonexclusive) or “licensed by right” spectrum, and one special case, TV White Space, wherein a licensed frequency band has vacant channels that can be used, with some restrictions, on an unlicensed basis.

WISP operation has largely used three unlicensed bands, 902 MHz, 2.4 GHz, and 5 GHz. The 902 MHz band is narrow (26 MHz wide) and crowded in many areas by utility meter reading devices. It has seen little new usage in recent years, even though it has decent non-line-of-sight properties and foliage penetration, and it remains a viable option in some locations. The 2.4 GHz band is widely used for Wi-Fi and Bluetooth, as well as microwave ovens, baby monitors, and many other devices. As such it is usually too congested for widespread WISP use except in very rural areas, where the combination of low density and woods reduces the noise level. It has modest foliage penetration, and thus the 2.4 GHz band is an option for rural subscriber access. However, it does not appear to be necessary in Harrisville.

The 5 GHz band actually consists of multiple sub-bands with different regulations. The middle of the band is shared federal spectrum and thus requires radios to have radar detection, and to change frequency when radar is detected. The allowed power level there is relatively low. Two other sub-bands have higher power limits and do not require radar detection. This band has been the focus of most WISP development over the past decade. It has a wide selection of radio equipment, at low cost, and radios are now available that can carry about a gigabit per second on a point-to-point link. Even shared point-to-multipoint access channels can operate at 300 Mbps, and thus support individual users at 25 Mbps or higher. However, it is easily blocked by hills and foliage, and thus is not sufficient as the sole choice.

The best foliage penetration is available on the lowest-frequency available spectrum, TV White Space (TVWS). The base station must connect at least daily with a database in order to verify which channels are currently available at its location, following a complex set of rules. The number of available UHF TVWS channels varies widely across Harrisville, based upon several factors. (No equipment is available to make use of vacant VHF TV channels, which are also technically available.) TVWS is not permitted within 2.4 km of a VLBA radiotelescope site, one of which is just east of Harrisville on the Hancock-Peterborough line. More channels are available on the western than eastern side of the Town, and it is more widely available at lower elevations.

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1 This is not the case, however, for two future bands. The 3550-3700 MHz Citizens Broadband Radio Service will auction off priority access to about half of its channels, but unlicensed use will be allowed where priority licensees aren’t using it.

2 Contracts with the white space database are entered into by equipment vendors, not WISPs or users. Google, Spectrum Bridge, and Ericsson iConnectiv (f/k/a Telcordia) are among the operators.
TVWS gear is relatively expensive, compared to other frequencies, and its narrower channels limit total capacity. Thus it is used as a last choice, but given the dense foliage cover, this nonetheless appears to be best choice for about some potential customers. Whether 25 Mbps speeds can be achieved on TVWS remains to be seen, but 12-18 Mbps speeds should be no problem.

Another band, at 3650-3700 GHz, has been available on a “lightly licensed” basis. This behaves somewhat like 2.4 GHz, and some equipment is inexpensive. However, licensing was frozen as of April, 2015, and only existing licensees can use it at present. (WiValley is one such licensee.) This is because it is being subsumed into a new 3550-3700 MHz Citizens Broadband Radio Service (CBRS). The new 3550-3650 range is shared federal spectrum, used by naval radar. While CBRS rules are in effect, they require a Spectrum Authorization System (SAS) to assign frequencies to all base stations and high-power clients, based on a three-tier priority system. It is considerably more complex than the database system used for TVWS. It is likely that this band will open up in 2018. CBRS rules also require that a Certified Professional Installer digitally sign each device installation; certification training is expected to begin in 2018.

Existing licensees may install new equipment on the 3650-3700 MHz band, but it operates at a lower priority than equipment registered before April, 2015, and in any case these licenses expire in 2020. Thus investment in this band is only recommended when the equipment vendor has committed to upgrading to CBRS. For the most part, this is LTE equipment. This is likely to be less costly than TVWS gear, at least on the subscriber end, but carries the recurring SAS fee.

Higher frequency bands are available, but do not appear to be needed in Harrisville. Considerable interest has been shown in the 60 GHz (millimeter wave) band, and both point to point and point-to-multipoint equipment is now available on that frequency. (This is being touted by some carriers for “5G” use.) This is capable of carrying signals at fiber-like speeds, over 1 Gbps. However, its practical range is generally much less than one kilometer, and it requires true line of sight – it does not penetrate any trees or walls, and suffers considerably from rainfall. Hence it is most useful in urban areas.

The backhaul links between sites will primarily use 5 GHz point-to-point systems.

Radio transmitter power levels

It is not uncommon for some individuals to fear radio transmission systems. All of the planned radio systems will be either unlicensed or, in the case of CBRS, limited to similar power levels. The maximum transmitter power (“conducted power”) allowed on any of these unlicensed frequencies is 1 watt. That power is sometimes seen in enterprise Wi-Fi systems, but is more than used in these applications. All of the antennas used for a WISP network are directional. They focus the signal in the desired direction, thereby providing gain which, multiplied by the conducted power, creates the effective isotropic radiated power (EIRP). While the EIRP is higher in the focus of the antenna, it is lower in every other direction. A 5 GHz subscriber unit is likely to use a parabolic dish antenna of about 18 inches diameter that provides 25 dB of forward gain, while its conducted power will be no more than 200 milliwatts, usually much less. The amount of power radiated more than 10 degrees off-center is very low. These radios will be mounted

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3 Device owners must subscribe to SAS services, which will be provided competitively, the charges for which have not yet been determined.

4 The author represents the Wireless ISP Association on the standards committee for CBRS, WinnForum.
on the outside of homes, pointed away, and thus put negligible signal (typically only barely detectable) indoors, since that is outside of the main beam. Signal strength declines to the square of the distance. FCC approvals define safe distances from these radios in operation, typically under two meters, and that is in the main beam. Professional installation of the outdoor radios is also legally required to ensure safety.

In contrast, a cell phone is allowed to put out the same 200 milliwatts of transmitter power into its nearly-isotropic antenna, and thus a rather large share of the power is absorbed by the user’s head. This is still deemed safe by the federal government. If the cell phone is closer to a base station, it will lower its power to the exact level needed; adding base stations thus reduces the risk of cell phones to their users. Home Wi-Fi devices typically generate about 20-50 milliwatts, a safe level.

A base station will use sector antennas, which typically focus the signal across 90 degrees of azimuth and only 5-10 degrees of elevation. Thus an antenna 40 feet up a pole will put very little signal near ground level. The maximum EIRP allowed of a base station (4 watts) is likely to again keep its conducted power below the full watt level (to about 100 milliwatts).

Stated simply, the power levels used in the proposed system are literally several orders of magnitude lower than those that could potentially cause any harm, not to mention far below federal safety guidelines.

**Path prediction methodology**

The radio network design was prepared with the help of Radio Mobile, a widely-used mature program for predicting coverage. It predicts point-to-point paths between two sites in a network using a model that takes into account both terrain and ground cover. The terrain data comes from SRTM, the Shuttle Radio Topography Mission, a worldwide digital topography model based on radar taken by the Space Shuttle Endeavor in 2000. Its precision is between 1/3 and 1 arc-second. Ground cover data is taken from the US Geological Survey. For this study, deciduous and mixed forests were assumed to have a tree height of 22 meters; evergreen needleleaf forest 23 meters. These predominate in New England. Old-growth trees do get taller, and recently-logged forests are shorter, so reality may vary from coverage predictions based on the imprecision of these estimates.

A list of home locations was provided (under nondisclosure) by the public safety communications authorities. This was used to generate path loss predictions from each base station location to each home on each band. In some cases the home locations are imprecise, and thus actual path loss may vary. Manual corrections were made in a few cases.

Paths between each base station location (pole or tower) and each potential subscriber were computed on five bands of interest using Radio Mobile. Because the cost and performance of higher frequency bands is superior when the path is usable, the budgetary network design uses a “waterfall” method (in Excel) to assign homes to bands: If a 5 GHz signal is predicted to be strong, use it, if not use CBRS, if not use 2.4 GHz, if not use TVWS or 900 MHz, and if none are strong signals, repeat comparing the bands in the same order with lower signal strength thresholds, which are likely to either provide slower service or require larger antennas. (This determined that there is no need for 2.4 GHz or 900 MHz if CBRS is used.) The final determination of which band to use at a given location must be verified at time of installation. It should be noted that the path quality prediction software is configured with a 70-75% probability factor:
The signal is that likely to be \textit{at least} as strong as predicted. Thus in most cases it will be stronger than that.

\textbf{Remaining issues}

Several issues are to be resolved in Phase II of this study and thus are not answered herein. They include:

- Phase design of a fiber optic network to serve areas where it may be practical
- Means of connecting to a backbone ISP
- Business models
- Mobile tower siting
Improved communications services for Harrisville (Phase II Report)

Fred Goldstein, Interisle Consulting Group, February 2018

This report is a follow on to Wireless Internet Coverage for Harrisville (Phase I report), and provides the remaining subjects in our consulting engagement. A redraft of the Town’s tower zoning rules had previously been provided. The Phase I report provided a general design for a fixed wireless network that can reach essentially all homes in Harrisville, the vast majority with 25 Mbps service.

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Mobile coverage

Mobile (cellular) coverage in Harrisville is currently very spotty. There are no cellular towers in the town, whether by choice or because of the existing zoning ordinance that only permits them in a small area near the Dublin line where they would not reach most of Harrisville anyway. What service does exist primarily comes from towers in other towns, including Marlborough and Nelson.

The suggested rewrite of the zoning ordinance provided in Phase I prevents towers from being erected in lakeside or historic districts, but allows towers, by Special Exception, in the Residential/Agricultural district. Two sites in particular have been identified and studied as potential mobile tower sites, Cobb Hill and a hill behind Aldworth Manor. Both are reasonably accessible and not far from power lines, and both would be able to provide service to most of Harrisville. Neither one has a particularly clear advantage over the other, though their service contours differ. Neither site currently has or is near fiber, which is pretty much the case throughout the town, so initial service may require microwave backhaul, unless new fiber reaches the site first. Both towers are proposed for the town-wide fixed wireless broadband network, so mobile carriers could potentially have access to both; the main question is which site to promote as superior and build accordingly.

The Aldworth site is located to the north of the main buildings, near what had once been the top of a ski slope. It should not be visible from the main house. Its coordinates are 42.95278N 72.11278W (WGS84) and ground elevation is approximately 1643 feet above sea level. (Harrisville Pond is at 1317 feet.) It overlooks Harrisville Pond from the west and has a very good radio shot into Harrisville Center. The tower needs only to be tall enough to clear the trees with a reasonable margin. A Limited Height Structure (only 20 feet above the tree line) is likely to be adequate for one mobile and one fixed provider, but since it is likely to be shared by a fixed wireless network as well as potentially two mobile carriers, 25+ feet of clearance may make the proposition more sustainable. This would constitute a full-scale Wireless Communications Facility and would thus have to permit multi-carrier collocation. A 100 to 110-foot tower may thus suffice depending on tree height and whether collocation is planned.

Overall coverage from this location is likely to be good in most areas, and also in to parts of Nelson and western Dublin. It should cover most of Chesham, and the Chesham Road corridor, as well as the Skatutakee Lake area. It would not, however, cover the Route 137 area. It does have a usable microwave shot at the SBA Tower site in Marlborough. Its view of Dublin Center is blocked by Beech Hill, but it reaches part of the Rt. 9 corridor west of Dublin Center and the Dublin Lake area.
The proposed Cobb Hill site is positioned inconspicuously near the parking lot, north of the site’s buildings, though the precise location has not been identified. If a guyed tower is used, it will need to be positioned carefully to keep its guy wires away from the parking lot. Approximate coordinates are 42.9571N 72.0795W and its ground elevation is approximately 1820 feet above sea level. This site overlooks Harrisville Pond from the east and also has a good shot into Harrisville Center, though the Historic Harrisville itself building is largely shadowed.

Overall coverage from the Cobb Hill site is also likely to be good in most areas, and well into eastern Nelson, though not that town’s center. While it reaches much of the Rt. 137 area, it does not cover much of the Silver Lake area, and has a few gaps around Chesham and around Nelson Road. It has a usable microwave path to the SBA Tower, an existing mobile carrier site, in Marlborough. It also reaches much of the Rt. 101 corridor from Dublin Center to the east, but not to the Dublin Lake area.
Either of these two sites would substantially improve service to Harrisville, if a major carrier could be persuaded to build a cell there. There is however no guarantee of this; carriers are often willing to have gaps in coverage in rural areas. It may be worth contacting Verizon and AT&T, and possibly T-Mobile, to see if they would be interested in using the site. If the Town owns the tower, it still may want to have a tower company (e.g., Blue Sky Tower, American Tower, Crown Castle) act as its leasing agent. A tower company may also help estimate demand.

It should also be noted that a mobile tower site requires a small building at the base, to house both the equipment and its backup generators. This is typically about 10 by 20 feet, fenced off along with the tower itself, plus an area for trucks to drive up to it. Fixed wireless gear is smaller and would only require a pedestal at the base of the tower.

**Design revision impacts on fixed wireless**

The Phase I report posited a fixed wireless design that reached essentially all buildings in Harrisville. It presumed that towers would be built at the Aldworth, Cobb Hill, Wellscroft and Jaquith sites, with wooden poles added at six additional sites. No base station in the Harrisville Center historic district is posited. The entire network, with approximately 400 subscribers, would have a capital cost on the order of $650,000.

While no substantial changes to that design are recommended, the impact of some potential changes can be noted. The towers in particular are most expensive and potentially most contentious. An estimate is made of $65,000 per tower. This is typical of a guyed tower (e.g., Rohn 45) in the 100’ range. Mobile-
grade towers are typically costlier, but could be justified by the rent levels paid by mobile carriers (typically over $1000/month per carrier).

If the Aldworth tower (which picks up the largest load in the fixed design) were not built, its users would be mostly distributed across other sites, mainly Cobb Hill, but about 8 homes could lose service. These are concentrated along the northeast of Harrisville Pond (Tuttle Lane) and could probably be served by a small pole elsewhere, but that may have to be in a lakeside area, which has otherwise been avoided.

If the Cobb Hill tower were not built, its users would largely move to Aldworth, but 14 could lose service. These are in various parts of town (including Bancroft Rd., Wilderness Trail, and a stretch of Nelson Road).

While Cobb and Aldworth would form the core of the wireless network and serve the largest number of users, their coverage does substantially overlap. Other sites are more isolated. The Wellscroft site is more critical to many users. Without it, 29 homes would lose service, almost all on Eastside Road. An alternative site, or a smaller tower or pole, could probably replace it, though a lower tower would have somewhat inferior coverage to some locations.

The Jaquith site, if not built, would lose 8 homes, mostly in the Houghton-Jaquith area. A smaller tower or alternative pole could potentially replace most of them, but the site has an existing tower so its cost is likely to be less.

The other sites are poles, and thus less costly. The one on Dublin Road is most critical, as it serves parts of the center as well as Hancock Road north of Skatutakee Lake.

Because both Cobb and Aldworth are potentially heavily loaded, and many potential users are in the historic district, if fiber is not built at all, it may be advisable to improve the wireless capacity in the center by putting a small concealed sector antenna in the center. A good potential location might be the roof of the store, set well back from the street. This could reach dozens of sites in the vicinity.

**Staged fiber deployment**

While fixed wireless coverage is frankly adequate for most purposes and a dramatic improvement over slow DSL or (especially) satellite, fiber optic service is the “gold standard”. The problem with fiber, of course, is cost. Especially in rural areas where the number of potential subscribers per mile is low, it requires a large capital investment that may not generate sufficient return to be warranted.

We thus suggest that a *hybrid fiber-wireless* (HFW) approach be viewed as most realistic. This begins with town-wide wireless coverage but adds fiber in areas where the density is high enough to warrant it. Harrisville turns out to be a *textbook case* of where HFW is a good option. Its density varies widely, and the Harrisville Center area’s density is far more than adequate to support fiber, and antennas are not particularly welcome there. At the same time, the most remote homes would be very costly to reach via fiber.

A six-stage fiber design is thus postulated in order to allow the Town or its service provider to roll out fiber to the extent desired, with each stage building upon the previous one, and each one becoming less
economically viable. Stage 1 passes more buildings than stage 6, even though the latter has about ten times the mileage. Thus the unit cost of stage 1 is proportionately lower.

The following table summarizes the six stages and their cost. It uses an estimated fiber cost of $40,000/mile. This number is at present highly speculative, as will be noted below. Note that “buildings” is based on the E911 unit count, and some multi-dwelling units may be counted more than once. (The business buildings on Main St. are only counted once per address.) The fiber cost per taker is based on a 60% take rate.

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**Cost of aerial fiber construction**

At this stage the cost of fiber construction can only be estimated at a high level. Aerial and underground construction are both possible, but aerial is more common in this area. The cost has multiple components. The fiber itself is not costly; most will cost on the order of $1/foot. The biggest cost is hanging it on the poles. Per-pole engineering and licensing are required. Fiber is typically installed in the communications area of the pole, which is at least 40 inches below the bottom of any electrical lines or transformers, which are on the top of the pole, the power area. The fiber must also be mounted at least 16 feet above ground. Many poles are quite old and were installed when there was only electricity and “the phone company”. But poles today are often more crowded. New England Telephone and its successors (now Consolidated) have some optical fiber on the poles, interconnecting the central office (a small building on Main St.) with the rest of the network. Other Consolidated fiber may feed remote line terminals that provide service to outlying neighborhoods. Poles may be owned by Consolidated, the electric utility, or jointly by both.

There is no cable service in Harrisville, but there is actually a cable plant in place, passing a majority of the town’s homes. While installed by a now-defunct operator (Pine Tree), it is now owned and maintained by Fibercast, a Manchester-based company whose operating cable systems are in Coos County and the adjacent corner of Vermont. Fibercast has not upgraded it to hybrid fiber-coax (HFC), the near-universal architecture of modern cable plant, which is required for offering high-speed data service. Because it does
have existing pole attachments, though, fiber could be overlashed (i.e., hung from the existing network in its attachment space) at far lower cost than fresh fiber construction. This would be likely to cost less than $20,000 per mile.

Fibercast may also be able to operate the fiber on a wholesale basis for use by an ISP. (Fibercast, whose owner also has part interest in Argent Communications, has similar inactive facilities in Nelson and Stoddard.) Theoretically, the coaxial cable plant itself could be activated, but coax has a much higher maintenance cost, especially in New Hampshire’s climate and given the age of this coax. Fibercast has been replacing its Coos County coax systems with GPON fiber. (Another advantage of this approach is that it may be able to also support cable TV service, though that would require either fiber backhaul to a head end or a local head end, which would cost several hundred thousand dollars.) Fibercast will consider this plan if enough customers can commit to taking service.

Absent the use of Fibercast’s attachments, the cost of building fiber is likely to be far higher. Much of the cost of fiber installation is for make ready, the process of creating a vacant 1-foot gain on the utility poles. If there were sufficient vacant space on the poles, then construction could be in the $20,000/mile range. But in practice, given the age of most poles, make-ready typically adds $20,000 or more per mile to the cost of fiber installation. Thus a $40,000/mile figure is typical and reasonable if not overlashing; some vendors estimate over $50,000 for rural installation, though this seems unlikely in Harrisville.

Poles must also be rented from their owner. The typical regulated rate for a fiber attachment is on the order of $1/month/pole. Some variation exists, though, depending on relevant state and federal regulation. (A 2012 PSNH rate case set telecom attachments per pole at $22.98/year and cable at 10.07/year, but this may not be current.) Historically, cable has paid a lower rate than telecom providers. But with the functional distinction between the two disappearing, federal policy is for rates to become unified. Fibercast is paying the cable rate; this should remain even if fiber is overlashed.

**Cost of underground construction**

Underground construction does not require pole attachment. But it is very rare in most of New England for a good reason: The ground here is very hard, and the cost of burying fiber is several times the cost of hanging it on poles. This is especially true in mountainous regions, where topsoil is rare and ledgerock frequently protrudes. A first estimate of cost is $200,000/mile. The exception is in flat areas, typically along river banks, where topsoil abounds.

Underground construction in much of the United States is very inexpensive. West of the Appalachians, typical costs for rural underground construction are in the $20,000/mile range. A cable plow can simply dig up the ground with its front and lay cable from its rear as it is driven across a field or soft shoulder. There are spots in New Hampshire where this is possible, or where undergrounding is not especially difficult. Hanover, for example, has plans to lay fiber to most of the town’s buildings. But these are in the immediate Connecticut River valley, a relatively flat area along the river, where the ground is soft. Like most of New Hampshire, Harrisville has far more forest than farmland for a reason.

Standard underground construction requires conduit to be laid below the frost line. That may be as deep as 3 feet in the Monadnock region. Once conduit is in place, with regular manholes and hand-holes for access, fiber is pulled through it. Direct burial of fiber is also possible, using an armored fiber sheath.
designed for the purpose. But this still needs to be buried in a stable place. And any underground construction is particularly sensitive to environmental issues such as wetlands.

A pole build may, however, require occasional underground construction, where there is no aerial route. This sometimes involves road crossings. If there is existing telephone company conduit (not power conduit), it can sometimes be rented. Otherwise, a small amount of underground construction may be needed. In these cases a typical approach is to use horizontal directional drilling, rather than opening the roadbed. A drill rig at one side of the road can bore underground to meet a target location some distance away.

**Microtrench**

An alternative to traditional underground construction, *microtrench* is considerably less costly. This involves using a saw to cut a narrow trench, about an inch wide and around a foot deep, in the pavement. A thin plastic conduit is then laid into the trench. Fiber can then be pulled or, in the case of thin fiber, blown through the conduit. (The relatively small sheath count of PON can be acquired in blown fiber, not the heavy backbone fiber needed for Active Ethernet.) It is also possible to directly bury armored cable in a shallow microtrench, with cover material placed over it. A special compound can be used to backfill the microtrench, as it is too narrow for ordinary asphalt to flow reliably to the bottom. A bottom layer of sand topped with asphalt works in some areas but appears to be unstable in cold climates.

Microtrenching is typically limited to short-distance applications, such as parking lots. After Sandy, Verizon was allowed to use microtrenching in some sidewalks in New York City in order to replace lost copper with fiber. Sidewalks are more stable than roads, as they lack heavy vehicle traffic, but are obviously scarce in Harrisville. Even roadway microtrench is usually positioned out of the main traffic lanes, which is obviously difficult on narrow country roads. It is seeing some such use in Connecticut, where it is being placed in the gravel alongside the road. Microtrench is likely to be sensitive to frost heaves and other disturbances, and may be damaged by routine road-repaving activities that would not impact deep-buried conduit. While it is not possible to rule out all microtrenching in Harrisville – it may well be suitable for use on some side streets and driveways, and around the center, for instance – it is not a panacea, and is not well proven for longer-haul applications. Microtrench technology is improving and it may become more useful over the next few years, but aerial remains the most economical method of fiber construction in New England.

**Staged deployment maps**

The following maps illustrate the extent of each suggested stage of a staged fiber deployment that allows construction to stop after any stage and resume, if desired, where the previous one left off. The stages are color coded on the map, which is most visible in the Stage 1 diagram. (The color order is spectral: Red, orange, yellow, green, blue, violet.) These stages are likely to be applicable whether or not Fibercast’s coax is overlashed or not, though the economics of overlashing could support more stages than a fresh build. Fibercast’s known coverage roughly seems to cover almost all of stages 1-2, much of stage 3, part of stage 4 (near Silver Lake and around Lampman Road), and essentially none of stages 5 and 6.

On these maps, a 1/10-mile buffer is drawn around each fiber route as its stage is activated, with the assumption that houses within that buffer can be connected at standard rates. Of course a longer drop (street to premise) fiber can be provided, and may be needed for some homes that have a large setback,
but it is common practice to charge the subscriber for extra distance, as the fiber may need to be buried or private poles may be needed.

Note that the costs here are for the fiber itself, in a Passive Optical Network (PON) configuration, similar to Verizon FiOS (but not carrying linear TV). Fibronics (electronics that light the fiber) are an additional cost, noted below. A common guideline is that fiber is self-sustaining at a density of about 20 subscribers per mile.

The subscriber count is based on the location information provided, under nondisclosure, by the Cheshire County E911 office. Not all units are necessarily occupied, and units may be seasonal.

**Stage 1**

The first stage of the fiber rollout would be Harrisville Center. With 109 buildings reached by 1.54 miles of fiber (+/- 10%), there are 70 potential subscribers per mile. This is a dense urban value, and with a 60% take rate and $40,000/mile cost, the cost of fiber is still under $1000/customer. This is cost-competitive with wireless and construction of this stage is highly recommended even if no more fiber is pulled, and even if some undergrounding is required. The short distances on some streets may well be amenable to microtrench or horizontal drilling, if necessary.
Stage 2

The second stage adds 5.2 miles, passing an additional 141 buildings. This stage has a density of 27 per mile, still urban. Its incremental cost is close to $2500/subscriber, still very good.

As can be seen, Stage 2 extends the network around both Harrisville Pond and Skatatukee Lake, both high-density areas at either end of the Stage 1 build.

Stage 3

The Stage 3 build extends to Chesham and its more densely built-up areas. It also builds up to the Aldworth Manor site. If a tower is built there, this section could be added to Stage 2.
Stage 3 adds 6.7 miles of fiber and 151 buildings. More than half of the homes are now reached with a total of 13.5 miles of fiber. Stage 3 has a density of 22.5 homes/mile, still a reasonable suburban value, and a per-subscriber cost just under $3000. Note that Aldworth and Brown Road are in this stage but are not part of the existing Fibercast coverage.

**Stage 4**

The Stage 4 design extends to the east and northwest. The denser areas along Silver Lake are built out, along with stretches of Lampman Road and Hancock Road.

Stage 4 adds another 150 buildings with 7 miles of fiber. This is very close in density to Stage 3 and has an estimated incremental cost of $3136/subscriber. Economically, this stage is likely to be coupled to Stage 3, but would be built afterwards as it is farther out. This is the last stage with favorable economics for an unsubsidized build.

**Stage 5**

The Stage 5 design adds in the southern and eastern ends of the town. Route 137 and Venable Road are primary targets.
Stage 5 adds 54 buildings with 5.1 mile of incremental fiber. With 10.6 homes passed per mile, the estimated cost per actual subscriber is around $6300. This is not economical per se. Essentially these subscribers would be cross-subsidized by the high margins from the first stage. In an HFW design, this would likely be left unbuilt. But they can conceivably be built if the earlier stages prove successful.

**Stage 6**

In Stage 6, the rest of the houses are reached by as many extensions of earlier stages as required. A handful are not counted because they are not near roads, but the stage itself adds 86 to its home-passed count with 15 more miles of fiber. This is 5.7 homes passed/mile and a cost estimate of over $11,600 per home added. Stated differently, 37% of the total mileage (and thus approximately that cost) would be spent to reach only 12% of the homes, in a 100% fiber buildout. The average cost of a town-wide buildout rises from $3775 to $6992 when this stage is included. A 4-stage build averages only $1881.

The only streets not built out in Stage 6 are those that have no buildings on them. Some houses, however, do not appear to be along public streets, so they may need additional fiber along private roads or driveways.
Architectural options for lighting fiber

There are two widely-used architectural options for residential fiber networks. The more common one, used by FiOS and many other providers, is a passive optical network (PON), in which a set of passive splitters distributed in the field multiplexes many users onto a single strand of feeder fiber. The most common form of PON today is GPON (gigabit PON), which has a downstream (towards the subscriber) capacity of 2.4 Gbps, and half that much in the upstream. This is shared capacity, not simply divided, so in a typical configuration that typically allows up to 32 users to share the link (i.e., both an 8-way and 4-way passive splitter are used), all subscribers can have nominal “gigabit” speeds. A PON splitter might be located at a major junction, and then further down to feed several nearby houses.

The advantages of a PON are twofold. One is that it lowers the strand count on the main feeder routes, compared to alternatives. The second is that it reduces the amount of active equipment needed. One Optical Line Terminal (OLT) shelf feeding 8 strands can potentially serve over 200 customers. (64-way and even 128-way splits are possible but not as commonplace as 32 ways.) OLTs can typically be up to 20 kilometers from the subscribers, so a single active hub could serve all of Harrisville. The price of OLTs has fallen such that a basic 8-line OLT can be purchased new for under $2000, though support for cable TV service adds to that, and some full-featured models are costlier. Thus the per-subscriber rate is quite minimal. The splitters themselves only cost a few dollars per subscriber. The terminal at the subscriber’s home can be had for under $100, but a full-featured one with Wi-Fi and high-quality phone jacks is over $200.

Using PON architecture, no fiber sheath would need to have more than 120 strands, which would include both the local distribution strands and the feeder strands reaching more distant splitters. Sheath size would decline with distance, from 120 strands on Main St. and 96 on Chesham Road down to a minimum of 24 strands near the periphery. The fiber itself can be ordered pre-engineered with its splitter and drop connections factory-installed, so that the installers do not have to open up the sheath (a fairly costly
procedure) for each cluster of drops. This of course requires precise measurement of the distances of each section of fiber.

A disadvantage of PON is that it does not allow for much customization between users. Different subscribers on a PON can be assigned different rate-limiting classes, and certain services such as telephone (reserved capacity) can be provisioned for customers, but there is less flexibility than in an Active architecture. Upgrades and adjustments also impact more users at once.

The other major option is Active Ethernet. This uses separate strands from the OLT to each subscriber, more like a traditional telephone model but all-optical. Each strand can then be provisioned as either 100 or 1000 Mbps, with rate limiting as well, and can have different quality of service classes assigned. Active configurations are more standard for business services. If fiber is provisioned to serve cell towers, those strands would need to be Active or simply provisioned dark to the carriers, who would light them themselves. That however presumes that some dedicated backhaul service for their use could be provisioned on the fiber network, as cell companies do not use public Internet service for backhaul.

While Active requires more ports on the OLT, they are inexpensive (budgetary $100/port), so the major additional cost component is the fiber itself. One approach to control this is to put separate Active switches in the field, in pedestals, so the feeder going back to the center does not have to support every subscriber on a “home run”. But this requires the pedestals to have power and batteries. Wireless sites already do, so this is not a major burden, but it does slightly complicate maintenance compared to a PON. Hence a home run design was used to estimate the required fiber sheath sizes in an Active arrangement. This ranges from 432 strands on Main St. and parts of Chesham Road down to 24 on the periphery (i.e., beyond where any PON splitters would be located anyway). In between it typically requires two to three times as many strands as PON. This is not a huge expense for the fiber but does require more costly splicing and installation. Hence an Active system overall tends to cost, all told, about 10-20% more than a PON; a larger percentage probably applies when using low-cost overlash to install the fiber.

GPON is also able to carry linear streaming video (i.e., cable TV) in either of two ways. One is to convert it all to IP streams at the head end (IPTV) and treat it as digital multicast traffic. A second is to use a third lambda (wavelength of light) on the fiber, in addition to the digital upstream and downstream lambdas, which carries TV channels in standard channelized cable format, superimposed over light. This RF over Glass (RFoG) approach is used by Verizon FiOS and thus the equipment is readily available. The choice depends on the head end design and total network capacity.

It thus appears that the most cost-effective broadband approach for Harrisville, then, is a hybrid fiber-wireless system with most of the homes on GPON, a few strands of fiber for Active use to businesses and towers, and fixed wireless coverage across all corners of the Town.

Time to install

If the network were a fully-funded project belonging to a single provider (which is not necessarily the case here), then the wireless network could be completed in less than one year, assuming no unforeseen permitting delays. Fiber is a much more time-consuming process. Given the requirements for pole surveys, pole licensing, make-ready (which is done by the other attachers upon request, and which may take months), and other problems that may come up (environmentally-sensitive areas, pole replacement, etc.), a fiber project typically takes about 18 months from funding to “first light”, and often over three
years to complete. Overlashing, however, takes less time, perhaps by a year or so, as the attachments already exist.

Hence the wireless network could be used to provide service very rapidly, while customers are migrated to fiber as fiber stages are built, if and where they are built. The electronics used for the wireless network are relatively cheap, especially on the subscriber sites, and the poles and towers will still be needed to reach the outlying homes. Some users might pay a small fee to keep the wireless link as a backup facility in case the fiber breaks. It is noted that fiber, while very reliable, has a relatively long time to repair, so a catastrophic failure (from an ice storm, car accident, etc.) could take more than a day to repair. Wireless service tends to be much faster to restore, though it is more prone to brief outages.

**Provision of telephone service**

Many ISP networks also now provide telephone service. This is both incremental revenue to the provider and a service to the community, especially in areas where the incumbent local telephone company (i.e., FairPoint) does not provide top-quality service.

Legacy analog telephone service is provided over twisted pair copper wire. This is also used to provide DSL, but absolute speed limit of DSL is a function of distance. While the telephone line and set are still usually analog, the rest of the telephone network is digital; voice is carried as a 64,000 bit per second stream. Compared to modern broadband speeds that is not very much. Thus telephone traffic is often carried over IP streams. However, the sound quality of a telephone call depends on having low loss and jitter (delay variance), while ordinary Internet service has problems in both regards. Hence the quality of Voice over IP (VoIP) services varies widely; a call that sounds good one minute can sound bad the next.

There are thus two ways to carry voice in IP networks. One is “over the top” (or parasitic) VoIP, wherein the IP network has no knowledge of the phone call itself, and provides no assistance to maintain its quality. This works when it works… Examples are Vonage and Ooma. A broadband provider can also resell these under its own brand, or as part of its service bundle, but if it is still touching the public Internet, quality will be erratic. (This is still considered acceptable by the FCC to meet Connect America Fund voice service requirements.) The second way is to integrate the telephone service into the IP network, using prioritization and queue management to ensure a smooth flow of packets carrying telephone calls, regardless of what happens with the lower-priority Internet traffic. While sometimes called VoIP, this is better referred to as Voice using IP, or VuIP. Cable company telephone service using the PacketCable standard is an example. Unlike over-the-top VoIP, VuIP services can support fax machines, modems, TDD, and other sensitive applications.

A network provider in Harrisville thus could configure the network either way. It is not hard to set up voice priority in a network. It would still, however, need a high-quality connection to a wholesale CLEC who would in turn provide the dial tone services. Thus the backhaul provider may also need to sell voice Quality of Service (QoS) capacity, usually for a fee, and the local network provider will have to provision it accordingly. Exactly which company has the legal responsibility for the telephone service, with its state and federal reporting and tax obligations, must be worked out.
Business models

Broadband service can conceivably be provided to Harrisville under several different possible models. But give the relatively high cost and the limited market size, the primary challenge is to find a model that is economically viable. If its density were higher, then an existing cable operator would have edged out into the town, but the previous cable operation never finished building out and shut down.

Fortunately, better tools exist today than in the past. Wireless technology has improved markedly over the past 15 years since the introduction of the first generation of radios designed for the wireless ISP market. Fiber optic material costs have come down, though labor/installation costs have not. Network core equipment for routing and switching has come down in cost and is a trivial share of the total. Upstream ISP per-megabit rates have come down, but the connection to the backbone remains very situational. These factors play into each of the following business models.

The all-wireless design posited in the Phase I report has an estimated cost of about $600,000. This assumes $188,000 for the construction of four towers, and almost $300,000 for electronic equipment, about a third of which is the installation cost. This is a budgetary estimate that needs some validation, especially for the cost of towers, one of which would be offered to mobile carriers. (The incremental cost of mobile-carrier capacity on that tower is not included.)

Pure municipal ISP

An approach that has found support in a few communities, though not in New Hampshire, is for the municipality itself to own the ISP. Examples exist in Massachusetts, where Warwick, bordering Cheshire County, has a town-owned wireless network, and Leverett has a town-owned fiber network. Town-owned fiber is also being installed in Alford and Mount Washington, two very small towns. Several cities and towns with municipal electric companies have ISP service through them (they are referred to as Municipal Light Plants, MLPs, in Massachusetts). These include (among others) Westfield, Shrewsbury, Norwood and Braintree.

While the larger MLPs have fully-staffed ISP operations of their own, and some, like Westfield’s Whip City Fiber, provide contract services to other towns, smaller MLPs generally contract out their operations to a network operator. Thus the town maintains ownership and supervision, and retains profit and loss responsibility, but does not need to bring operational skills in house. The network operator handles installation, maintenance, customer service, and billing.

In this model, the town finances the construction of the network. This is easier in Massachusetts where bonding for this purpose is allowed, and where subsidies have been made available to about 40 towns. New Hampshire municipalities are (to our knowledge) not allowed to borrow beyond the current fiscal year for this purpose, and thus is unlikely to be able to finance a municipal ISP, though the legislature may be considering a change in that law.

Privately-owned and financed

The traditional business model is for private financing to build the network. The local government has no involvement other than permitting. This has obvious advantages to the town. But a privately-financed network must operate at a profit, and only invests in profitable builds. Thus a private operator may well be encouraged to reach most of Harrisville’s residents, but will be unlikely to build the lower-use higher-
cost facilities needed to reach the last 10-25%. This has been the problem with private systems all along, including FairPoint, whose DSL was built to some but not all of the town.

**Direct subsidization**

One widely used approach (notably by the federal Universal Service Fund, but also in several places by the Massachusetts Broadband Institute, a state agency) is for public money to be given to a private provider in exchange for their promise to serve a given area that would not have not been served by the use of private capital. This is intended to tilt the playing field in a manner that attracts private capital. Charter (Spectrum) cable, for instance, has received subsidy money to edge out into several towns. The provider retains full ownership of the network, and the government retains some oversight ability for some period of time to ensure that the funds are spent as intended. Long term, however, it remains a purely private venture.

Key to efficient use of this mechanism is to determine just how much subsidy is needed, vs. what a business-as-usual approach would be to the private provider. It also requires willing private providers, generally nearby, who are willing to take the risk. Typically these are cable companies in adjacent towns, but could also be fiber providers or other ISPs.

**Wait for FairPoint**

One option that must be acknowledged is to do nothing on a Town basis and simply wait for FairPoint (which is rebranding under the name of its new owner Consolidated) to build out the network upgrades that it committed to in exchange for the Connect America Fund subsidies it receives from the federal government. CAF requires them to provide 10/1 Mbps service to at least 95% of homes in their service area, but they have six years to complete it from the time they accepted funding (2016). Milestones begin at year 3, but construction has already begun in some parts of their Northern New England area. This upgrade will be accomplished by reducing the maximum length of their copper local loops to 7000 feet, by adding remote fiber terminals in various locations. The speed of DSL is (roughly) inversely proportionate to its length, so shorter copper loops allow higher speeds. AT&T, for comparison, uses 4000 feet as the maximum copper length in its U-Verse service, which operates at a minimum of 20 Mbps and provides video as well as Internet and voice. It should be noted that in a recent Comment to an FCC Docket which was cosigned by Consolidated, they expressed interest in using fixed wireless technology to fulfill parts of their CAF obligation.

While this will theoretically bring “adequate” residential broadband service to all of Harrisville, 10/1 speed is rather backwards-looking, slower than most new fixed wireless connections are capable of. The copper wire that they will be maintaining is in fairly poor shape, and will continue to deteriorate. And FairPoint’s service quality in general has not received rave reviews, though Consolidated seems to be making some improvements. Hence this option is not necessarily recommended, but it must be noted as an option, especially for patient people whose requirements are minimal.

**Public-private partnership**

A variation on the municipal and private themes is to combine them. In this model, the service is provided by a private operator, who owns the network, but the Town owns certain assets. In a wireless network, this would normally have the Town owning the vertical assets (towers and poles), which have a long
depreciation lifetime, while the ISP would own the electronics, which have a shorter economic lifetime (5 years is recommended for budgeting). In a hybrid or fiber network, the Town might own the fiber itself, if it contributes to its cost. An advantage of this approach is that the poles are located on town rights-of-way anyway (or in some cases state rights-of-way, which the Town would be more able to negotiate). And if the ISP fails to provide adequate service, or goes out of business, the Town can easily bring in a new operator, or can even buy out the network for a contractually-agreed-upon price.

This approach depends on the Town’s ability to make at least some contribution to the capital cost. Its rights of way are valuable and do not cost anything, but towers are costlier. In some cases (depending on applicable public procurement laws) a private player may be able to construct a tower more cheaply than a government, so a partnership might involve a transfer of the tower from the private company who would act as the builder using town subsidy money. Other approaches can be explored that provide mutual benefit.

An advantage of the partnership approach is that the Town also gains assets that it may use for municipal purposes. Towers, for example, can be used as remote receiver sites for public safety and public works communications, which can be securely backhauled over the network independent of the Internet itself.

The private half of this partnership could also be divided between two companies. For example, Fibercast might operate the fiber network on a wholesale basis and an ISP would provide the wireless service and act as the retail ISP on the fiber. This may be ideal for Harrisville.

**Backhaul (middle mile)**

One of the more daunting challenges facing Harrisville is access to the Internet backbone itself. While wholesale capacity is very inexpensive nowadays at major data centers on national backbone fiber, “middle mile” access from the cities to rural areas can be very costly.

The amount of backhaul required is generally a function of customer count. At minimum, backhaul should generally be at least twice the highest rate subscriber’s nominal speed; thus if 1 Gbps fiber service is sold, then 2 Gbps backhaul should ideally be available. Beyond that, average use dictates requirements. Ten years ago, average broadband usage was around 0.1 megabit/second. Today, thanks to Netflix and other video services, it is in the range of 1-2 Mbps. It is likely to level off at some point, though, as video demand, like telephone call demand, is limited by the number of human users. So if the network is to have 300 customers, with a peak service plan of 100 Mbps, backhaul should be at least 400 Mbps, and probably higher.

**Telephone company fiber**

Three potential approaches can be used for the middle mile. One is to go via the incumbent telephone company, Consolidated, whose fiber runs through Harrisville serving its central office and remote terminals. While this fiber exists, there is no guarantee that a broadband network operator would have any access to it. The FCC has completely deregulated so-called Business Data Services, the high-capacity links often used by ISPs. The incumbent carrier no longer has an obligation to provide it to anyone it does not want to. Since Consolidated plans to upgrade its DSL in Harrisville, anyone else would be seen as a competitor, and Consolidated could simply refuse to offer service, or not offer it at a reasonable price. Hence Consolidated’s high-capacity Carrier Ethernet service, which is technically well suited, cannot be
relied upon. Nor are they marketing it very actively. Harrisville or its operator could of course request a quote anyway to see what they come back with. Consolidated is more professional than its predecessor company FairPoint and if it sees that Harrisville is gung-ho on building its network anyway, they might choose to take something rather than nothing.

One narrow exception to this rule applies only to certificated Competitive Local Exchange Carriers (CLECs). If a CLEC has collocation in two telephone company wire center buildings (i.e., Harrisville and Keene), then it may request to rent “spare” strands of dark fiber between them. The price is very reasonable, as it is strictly regulated, and its capacity is virtually unlimited, for runs of up to about 40-50 miles. However, telephone companies go to great lengths to claim that there are no spare strands. They are all dedicated to some already planned use, or some other excuse is found. Verizon, who of course owned that network until 2007, put in place a dark fiber ordering process that began with a query to a database to determine if strands were available. That database did not maintain the inventory of fiber strands at all. Hence it rejected all requests within minutes. Getting a human to even check typically took months and considerable lawyer expense. So this approach is not recommended.

**Build fiber to reach existing competitive fiber**

A second approach is to build fiber to a place that already has it. Harrisville is not on the Fast Roads fiber (now owned by FirstLight), which runs across the southern end of Cheshire County through Keene on route to the Upper Valley. Nor do cable providers (who often sell high-speed wholesale services across fiber) extend very nearby, though Peterborough is on Comcast’s network and Argent serves several non-adjacent towns in Cheshire. (Peterborough is technically adjacent but has no direct road crossings.) Hence connecting Harrisville to a major Internet backbone is a challenge. FirstLight appears to have recently built fiber along Route 101 to a school in Dublin Center. FirstLight also reaches the intersection of Routes 101 and 202 Peterborough. Crown Castle Fiber, formerly Lightower, has fiber passing through Stoddard, accessible at Rt. 123 near Rt. 9.

A path can be built down Dublin Road to the FirstLight fiber in Dublin, or to the new fiber that the Town of Dublin is planning to build. Much of that route would be part of an eventual Harrisville fiber build anyway, but Route 101 is about 1.8 miles from the nearest point on Stage 4 fiber, and another mile to proposed Stage 1 fiber. If a large-scale fiber build is planned, then only fiber will provide the gigabit backhaul needed to support even half-gigabit user speeds, so this would be desirable. But any other location than Dublin would be much farther. And any fiber build takes considerable time. Thus it would delay the lighting of a wireless network.

The FastRoads network reaches Marlow, and connects with the dormant Fibercast coax there, so that route could be overlashed about 18 miles to Harrisville. But that is a fairly large expense and would make more sense as part of an eventual fiber build, and perhaps best shared with neighboring towns.

**Microwave**

A third approach is to build a microwave radio path to a spot that is on fiber. WiValley has three such locations that would reach proposed base station sites in Harrisville. One or two (for redundancy and possibly capacity) could be lit at relatively low cost. Microwave backhaul links require line of sight (even more so than the fixed-wireless subscriber access links). Medium-haul (4-15 mile) microwave links typically have a capacity in the 300 Mbps range, adequate to support about 250 wireless subscribers.
Higher capacity may be possible; 500 Mbps should not be particularly difficult to engineer. Short-haul links within Harrisville could probably be engineered into the gigabit range.

The three locations each have their advantages:

- **Pumpelly** is just south of Dublin Center, and has line-of-sight to several proposed Harrisville towers, including Aldworth, Wellscroft, and Jaquith. It does not see Cobb Hill. The 7km path to Aldworth is the shortest of the paths to one of the two Harrisville core sites (Aldworth and Cobb), which may allow for a higher-speed link. Pumpelly has a microwave link to fiber in Rindge, which would however also need to be upgraded.

- **Hyland Hill** is in Westmoreland, just outside Keene. It has 14 and 16 mile paths respectively to Aldworth and Cobb Hill. The tower there is solid and could accommodate the type of dish required to feed high speeds for that distance. It has a direct microwave connection to WiValley’s office in Keene, which has fiber, without going through third-party fiber.

- **Pack Monadnock** in Peterborough has a commercial tower (Crown Castle) that WiValley is using for a link to fiber in Fitzwilliam. While this site has higher rent, it has line of sight to Aldworth and Cobb Hill. Interestingly, it also appears to have a 12 mile line of sight path right into parts of Harrisville Center, including 69 Main and 29 Church, so if an antenna could be placed (or concealed adequately) on a structure near there, it could feed the core of the network at that location without using one of the other towers as a relay.

One or more of these can probably be lit fairly expeditiously with low capital cost, even if fiber is planned for the long haul. Unlicensed backhaul radios are under $1000, and can perform very well in uncongested rural areas (like Cheshire County). Licensed radios, which are protected against interference, tend to cost considerably more, and require a coordination process. If microwave is the best solution for Harrisville, then, the ideal answer may be to have both one licensed and one unlicensed link, to provide redundancy.

For a hybrid fiber-wireless system, though, the best option may well be to light a microwave link initially, to provide service to the wireless customers, and then to build fiber to Dublin. This would provide redundancy even after the bulk of traffic moves to the fiber link.