

*Coverage Analysis and
Options Outline*

*In Support of Tasks 1 and 2 of the
Sudbury Wireless Planning Project*

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Broadcast Signal Lab, LLP
505 Main Street
Medfield, MA 02052
508 359 8833

Contents

Tables 3

Figures..... 3

Overview 4

Wireless Facility Classifications and Permissions 5

Current Status of Facilities in Sudbury..... 6

Capabilities of Structures 8

Multi-carrier Groupings in Several Areas..... 9

 Town Center 9

 Maynard Road Water Tank 9

 North Road Overlay District 9

 Route 20 on the Wayland Side..... 10

 Route 20 Union Avenue Area..... 10

Overlay District Utilization 10

Other Facility Sites 11

 St. John’s Evangelical Church 11

 Martha Mary Chapel 12

Pressure Points with no Facilities Presently 15

 Current Coverage 15

Analysis of Potential Options 22

 DPW Site 22

 Water District Site 22

 Lincoln-Sudbury High School Site..... 23

 North Pressure Point..... 26

 Stow Firefighter Academy Site..... 28

 Marlborough Industrial District 28

 Southwest Pressure Point 29

Composite of Potential Opportunities 31

Network Architecture Discussion 32

Summary 34

Tables

Table 1 - Classifications of Wireless Facility Placements under Sudbury Zoning Bylaw 5

Table 2 – Sudbury Wireless Sites (source: Sudbury Planning Department) 6

Table 3 – Hypothetical Sites in and around Sudbury and Existing Sites outside Sudbury that
Are Included in the Coverage Analysis 7

Figures

Figure 1 – Pressure Point Areas for Wireless Facilities in Sudbury 14

Figure 2 – Estimated T-Mobile Coverage in Sudbury (Town Boundary is Approximate) 17

Figure 3 – Estimated Coverage from Existing Sprint Facilities in Sudbury 20

Figure 4 – Estimated T-Mobile Coverage with Existing Facilities plus DPW (16) and Fairbank
Community Center Fields (19) 24

Figure 5 – Estimated Coverage of T-Mobile with Existing Facilities plus a 100-foot tower at
Lincoln-Sudbury High School (17) and a 100-foot tower at the Water District site
(18) 25

Figure 6 – Estimated Coverage from Marlborough Industrial Hypothetical 150-Foot Tower
(21), Stow Firefighting Academy Hypothetical 150-foot Tower (20) and Sierras
Restaurant Hypothetical 100-Foot Tower (22) 27

Figure 7 – Hypothetical Location of Facility to Reduce Pressure for Additional Facilities in the
Wayside Inn District 29

Figure 8 – Combination of Existing and Hypothetical Facilities to Achieve a High Degree of
Coverage 30

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Overview

Broadcast Signal Lab was engaged by the Town of Sudbury to assist with a review of wireless facility placement issues and to provide recommendations. Tasks 1 and 2 of the project are outlined as follows:

1. Review current wireless coverage.
 - Review data submitted to the record during previous facility applications
 - Evaluate permissible sites that are not presently employed by wireless facilities.
 - Identify coverage pressure points
2. Identify and evaluate options for facilitating the provision of wireless services
 - Identify prospective sites
 - Review network architecture options (camouflage, concealment, antenna height, etc)
 - Perform coverage analysis of options and provide Options Outline

We met with the Planning Director and discussed community concerns and sensitivities to wireless facility placement, tabulated the existing wireless facility locations, reviewed numerous applications for wireless facility permits in Sudbury, reviewed the wireless zoning bylaw, and

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toured portions of the town. At our office, we reviewed the Sudbury Geographic Information System (“GIS”) for details on parcel characteristics, districts, and land use; we evaluated the area with orthophotography and topographic mapping; we reviewed wireless service coverage data from permit application files; we plotted representative coverage from existing wireless facility sites in and around Sudbury; we identified wireless coverage “pressure points” in Sudbury; and we evaluated coverage from tentative sites in or near the pressure points.

Wireless Facility Classifications and Permissions

The present wireless bylaw in Sudbury classifies new wireless facilities into two broad categories: As-of-Right and Special Permit facilities.

Permit Type	Facility Type	Permissible	Limitations
As of Right	4341 Interior mounted	Any zoning district	In residential districts these are limited to steeples, bell towers, cupolas, and spires of non-residential buildings
As of Right	4342 Roof mounted	Overlay district	Limits on height above roof and setback from roof edge
As of Right	4343 Façade mounted	Overlay district	18-inch maximum protrusion
As of Right	4344 Small transceiver	Any zoning district	No equipment building, shelter, cabinet or tower. Antenna input power limited to 20 watts.
As of Right, except Sec. 6300 Site Plan Review required	4345 Changes in existing facility that has a Special Permit	Change no. of antennas, change no. of co-locators	Property owner must authorize
Special Permit	4351 Free-standing monopoles	Subset of overlay district: 4331-4335 sites only	4355 tower owner must provide reasonable access to co-locators; 4352 100 foot height limit; 4353 125 foot setback to property line; 4354 demonstrate existing structure within ½ mile cannot accommodate.
Not applicable	All of the above		Antennas must be at least 500 feet from residential lot lines;
Not applicable	All but small transceivers		All components of facility must be at least 1000 feet from schools.

Table 1 - Classifications of Wireless Facility Placements under Sudbury Zoning Bylaw

Current Status of Facilities in Sudbury

At present, there are 7 monopoles in Sudbury, each supporting the installations of one, two, or three wireless carriers. There are installations at two church steeples, on a water tank, a power line stanchion, and on one rooftop. Table 2 – Sudbury Wireless Sites (source: Sudbury Planning Department) lists the existing wireless facility locations and characteristics in Sudbury.

	Property Address	Land Owner	Tower Owner	Sub-lessee	Height	Type	Year Constructed
1	142 North Road	Cummings Properties	AT&T	Nextel	120 feet	Monopole	June 2000
2	North Road Assessors Map C12; parcel 004	Sudbury Water District	Spectrasite	Cellular One, Omnipoint, BAM	149 feet	Monopole	1995
3	North Road Assessors Map C12-100	Town of Sudbury Gravel Pit	Sprint	Voicestream (Omnipoint)	Unknown (not built)	Monopole	Not yet built
4 & 13	Maynard Road Assessors Map E07; parcel 3	Sudbury Water District	Town water tank	BAM AT&T	80.5' on top of tank	Roof mounted;	1997 2000
			Omnipoint	Omnipoint	100 feet	Monopole	2009
5	Village Green 29 Hudson Road	Private owner	Omnipoint			Roof mounted	2000
6	20 Boston Post Road (landfill)	Town of Sudbury	AT&T	Sprint Nynex	150 feet	Monopole	June 2000
7	Raymond Road Feeley Field; Assessors Map L08-12	Town of Sudbury	Voicestream	Omnipoint (T-Mobile) Sprint	100 feet	Monopole	May 2001
8	Ti-Sales, 36 Hudson Road	Ti-Sales	Nextel		100 feet	Monopole	2004
9	104 Wayside Inn Road	Wayside Inn Corporation	Verizon	Omnipoint		In steeple	2004 2009
10	163 Boston Post Road	Boston Edison	Omnipoint	Potential for 1-2	120 feet	Power Stanchion	2004
11	712 Boston Post						Abandoned Permit
12	16 Great Road	St. John's Evangelical	Omnipoint		75	In steeple	2009
14	251 Old Sudbury Rd	United Methodist Church	MetroPCS	Potential for 1	72	In steeple	2009

Table 2 – Sudbury Wireless Sites (source: Sudbury Planning Department)

The wireless carriers presently operating in the region include:

AT&T Wireless (formerly Cellular One, Cingular and AT&T)

Sprint (and Nextel)

T-Mobile (a.k.a. Omnipoint, formerly Voicestream)

Verizon Wireless (formerly Bell Atlantic Mobile- “BAM”)

MetroPCS*

Clearwire*

**new entrant to market*

Site Number	Location	Description
15	Raymond Road, Sudbury Water District	Verizon won RFP to construct facility
16	Old Lancaster Road, DPW Site	A town-owned parcel not on the overlay district.
17	Lincoln-Sudbury High School	Site has support of School Committee
18	Off Hollow Oak Drive, Water District	Large parcels
19	Hudson Road, Fairbank Center Fields	Large non-residential parcel in residential area
20	Firefighting Academy, Stow	Large, remote site; a tower is permissible
21	Marlboro Industrial Area, Rt 20	Large sites, industrial, towers permissible
22	At or near Sierras Restaurant	Commercial use in largely residential area
23	Knox Trail, Acton	Existing facility site
24	Maynard Center	Existing facility site

Table 3 – Hypothetical Sites in and around Sudbury and Existing Sites outside Sudbury that Are Included in the Coverage Analysis

Each wireless carrier has a different combination of facility locations in and around Sudbury. Each wireless carrier also has its own coverage objectives, and may or may not be planning new facilities in the area at any given time. Table 3 lists sites that we evaluated for their potential to provide additional coverage in Sudbury.

As the industry evolves, customers are growing to expect two improvements to their wireless services. First, a recent milestone was passed where there are about as many wireless households with no land line as there are land-line households with no wireless subscriptions. More and more wireless subscribers will look to rely on their wireless phones in their homes. Second, subscribers are expecting to use wireless services to provide broadband internet connections, requiring substantial wireless bandwidth for each session they are on line (e.g.

streaming video and music, or sophisticated interactive gaming). These services require more facilities to provide the capacity and the signal quality necessary to support the services and all the simultaneous users. As a case-in-point, T-Mobile has been actively developing wireless facilities in the residential areas of metropolitan Boston (and elsewhere) over the past few years. Similarly, MetroPCS and Clearwire have been moving quickly to develop new facilities throughout the market area (co-locations have been the most efficient approach, to start).

Capabilities of Structures

Monopoles in Sudbury tend to be able to support the antenna arrays of about three wireless carriers (depending on the height and structural capacity of the monopole). Steeples tend to be limited to supporting one or two carriers' antenna arrays. The number of carriers able to employ a rooftop or façade mounted installation on the same building is dependent on the characteristics of the building. If it is a concealed installation in a cupola, there may be room for only one carrier, unless a second cupola is added. In contrast, a large commercial building in a central location and with substantial height may be useful to at least three wireless carriers.

In general, the buildings in Sudbury offer limited ability to address wireless coverage needs. First, residences are not allowed to support such facilities. Second, based on a visual examination of the shadow lengths of the non-residential buildings in Sudbury (on orthophotography) compared to the shadow lengths of typical tree cover, the buildings in Sudbury are predominantly, if not entirely, no higher than the general height of the tree cover. To obtain wider area coverage from a wireless base station facility, antennas are generally placed above the dominant height of the surrounding tree cover.

Some exceptions exist regarding what are often difficulties in the use of lower height buildings for antenna installations. First, projections above buildings, such as church steeples or tall smokestacks, can achieve useful heights. Second, buildings in more densely developed areas and at busy intersections may be useful for providing the coverage and capacity necessary to support a high volume of users in a relatively small area.

Multi-carrier Groupings in Several Areas

Some areas of Town already support facilities for several wireless carriers, and appear to be able to support all wireless carriers in either of two ways – co-location on structures that are not full and the construction of new monopoles under Special Permit in these areas. All but one of the current wireless district locations in Sudbury has been developed for one or more wireless facilities. The following subsections discuss these areas of active coverage for many wireless carriers.

Town Center

T-Mobile occupies a rooftop installation at the Village Green complex, which is low in height, but is on a site of commercial activity and near a significant road intersection, the town center, and a school. Also in the same general area are a 100-foot monopole occupied by Nextel (which could be modified or replaced to support at least one additional carrier when needed), and an approved MetroPCS installation in the Methodist church steeple.

Maynard Road Water Tank

The water tank off Maynard Road is, of course, on high ground, and is at a height that clears the typical height of tree cover (about 80 feet). In the category of a “rooftop mount” the water tank supports the antennas of two wireless carriers. The third carrier on the water tank site, Omnipoint, opted to install a 100-foot monopole which is capable of supporting up to two more wireless carriers. Assuming there is space available for one additional monopole, the water tank site has the potential for being able to support all six wireless carriers.

North Road Overlay District

Another location (area) that appears to be ready and able to support all wireless carriers is the portion of the wireless overlay district on North Road near the Concord boundary. There is one 149-foot tower on Water District property presently supporting three wireless carriers, and presumably able to support at least one more. On an adjacent parcel owned by Cummings Properties, Nextel is operating from a 120-foot monopole. Typically, such poles have capacity for two or three additional carriers.

Between these two monopole towers, it is anticipated that all the present wireless carriers could provide coverage to the eastern North Road area. In the event the two towers are unable

to provide for all the carriers, the choice is to upgrade/replace a tower or to add an additional one.

Route 20 on the Wayland Side

The 150-foot tower at the Sudbury landfill site is in the overlay district and supports four wireless carriers. It is a concealed-antenna-monopole (sometimes called a *unipole*, *slick-stick*, or *flagpole-style monopole*). If the monopole were designed to conceal only the four antenna arrays, it might still be possible to support a fifth carrier (between 110 and 100 feet). To do so, the antennas would be mounted to the surface of the monopole and could be covered with a cylindrical cover; this produces a bulge in the tower 2/3 of the way up. Such an expansion is dependent on the structural capacity of the tower, the ground space available, and the demand for using the tower instead of taking another approach. This kind of expansion has been done on other such towers when the alternative is to build a new tower.

In addition to the 150-foot tower at the landfill, there is a 120-foot monopole-like attachment to an electrical transmission line stanchion $\frac{3}{4}$ mile west of the landfill. One carrier occupies this installation and there is a possibility that a second might be able to be added.

In addition to the landfill tower and the present stanchion installation, it is likely that other stanchions could be utilized for additional carriers if necessary.

Route 20 Union Avenue Area

The Raymond Road area has several parcels in the overlay district. Among them, a 100-foot tower supports two carriers on Town property at Feely Field on Raymond Road. Due to wetland constraints, it may be difficult to locate additional carriers at this site.

A third carrier is seeking permission to build a new 100-foot tower on Raymond Road at a nearby Water District parcel also in the overlay district. Presumably this new tower will be able to support at least one, and probably two, additional co-locators. It may be necessary to allow a third monopole on one of these parcels to support the remaining carriers.

Overlay District Utilization

The DPW site off Old Lancaster Road is the only remaining untapped overlay district area in Sudbury. The Sudbury wireless overlay district consists of several parcels that are individually

identified in sections 4331 through 4335 of the wireless bylaw. Some of these parcels are clustered in common areas (e.g. two parcels on North Road, also several parcels on Raymond Road). The DPW site is the one remaining area in the overlay district where a tower is permissible but none has been built.

Other Facility Sites

In addition to the areas outlined above, which have the common characteristic of being apparently suitable for all wireless carriers to occupy under special permit, there are two areas in town that can support only a limited number of carriers.

St. John's Evangelical Church

T-Mobile has approval to install antennas in the steeple of St. John's Evangelical Church at the intersection of Great Road and North Road. The antenna height is a tree-clearing 75 feet. This site represents an "interior mount" that is permissible in any district, but lacking in the 500-foot residential setback. There is limited opportunity for co-locators (presumably one additional, if practicable). This facility is in the northwestern sector of the town and is not near other facilities in Sudbury or in the adjacent towns of Maynard, Acton and Concord. The one existing facility outside Sudbury with the most potential for serving a small portion of northern Sudbury is located at 30-36 Knox Trail in Acton (Map J3 Lot 21-1) near the Acton/Concord line. However, the extent of this facility's coverage in Sudbury is extremely small, limited to the northernmost corner of Sudbury only as far south as approximately Virginia Ridge Road.

Alternatives in North – More at St. John's

There do not appear to be any obvious alternative locations for wireless facilities along or near the western half of North Road in Sudbury. One option for consideration could include a limited height monopole or faux bell tower at the St. Johns site, space permitting (certain setbacks would have to be relaxed in the bylaw or granted a variance by the ZBA).

Alternatives in North - Sierras

Another non-residential use in this area is the Sierras Restaurant at 470 North Road. The parcel is commercially developed, faces North Road (Route 117), and is backed by undeveloped land. However, the Sierras parcel is quite narrow, which makes it more difficult to integrate a tall structure on the property.

In addition, the land north and east of the Sierras parcel is significantly encumbered by wetlands. On one hand, this means the adjacent parcels, while largely undeveloped, are not themselves likely candidates for placing a wireless facility farther from Route 117. On the other hand, because these parcels are unlikely to be developed due to the wetlands, there are no residences immediately abutting the back of the Sierras parcel to be affected by the restaurant and any commercial development that might occur on the Sierras parcel, including a wireless facility.

Alternatives in North – North Fire Station

Farther east from Sierras is the North Fire Station, at the intersection of North Road and Dakin Road. It has the disadvantage of being a small parcel, surrounded by residences. It is too far east to be an effective location for addressing coverage objectives on central and western Route 117 in Sudbury.

Alternatives in North – Haynes School

The Haynes School parcel is large, relative to the residential lots in the area. The soccer fields/playground/tennis court area could support a monopole and ground facilities. Haynes School is south of North Road, but may be central enough to the northern Sudbury area to be effective. The required 1,000 foot setback to a school building will not be able to be met on this parcel.

Martha Mary Chapel

The Wayside Inn Historic Preservation Residential district is in the southwest portion of Sudbury and includes a segment of about one third of Route 20/Boston Post Road in Sudbury. The steeple of Martha Mary Chapel is in this district and is occupied by two wireless carriers. It is doubtful that even one more carrier could be accommodated in the steeple. There are no other structures of which we are aware that have similar utility for wireless antenna placement, either as a permissible “interior mount” or as rooftop of façade mounts along this portion of Route 20. North of the chapel is a substantial wooded area, north of which are parcels with agricultural use. With careful analysis it might be possible to locate a monopole of limited height, in a manner that is not visually objectionable, to provide service in the area to additional

wireless carriers. This would complement coverage from existing facilities in Marlborough that are not close enough to Sudbury to offer service of any significance in Sudbury.

Alternatively, the land use on the Marlborough side of the Sudbury/Marlborough boundary in the vicinity of Route 20 promptly becomes industrial. Within ½ mile of the Sudbury Wayside Inn Historic Residential district and within 1.2 miles of Wayside Inn one might be able to place a wireless facility (tower) on industrial property in Marlborough. Marlborough zoning allows towers up to 125 feet tall in the industrial district. Unfortunately, our analysis shows that coverage from an industrially developed site along Route 20 in Marlborough would not substitute for coverage from the Martha Mary Chapel site. Instead, such a tower would serve the segment of Route 20 that straddles the Sudbury/Marlborough boundary. Discussed further below, the Marlborough industrial area along Route 20 may be a suitable location for a tower to complement coverage from a tower that one might place in Sudbury, east of the Wayside Inn district.

We have identified several “pressure points” in Sudbury where carriers are most likely to seek additional facilities. They are summarized in Figure 1 – **Pressure Point Areas for Wireless Facilities in Sudbury** Two of these pressure points have a limited number of carriers already providing service. These carriers are utilizing the only available structures in these two regions:

- the “North” region generally along Route 117, west of the coverage from the water district parcel facilities;
- the “Southwest” region along Route 20 in the vicinity of the Wayside Inn district.

Any additional carriers seeking to improve service in the North and the Southwest are likely to try to join existing carriers as space permits. However, existing facility space is limited and new entrants to the North and Southwest areas may attempt to build new antenna structures to improve service there.

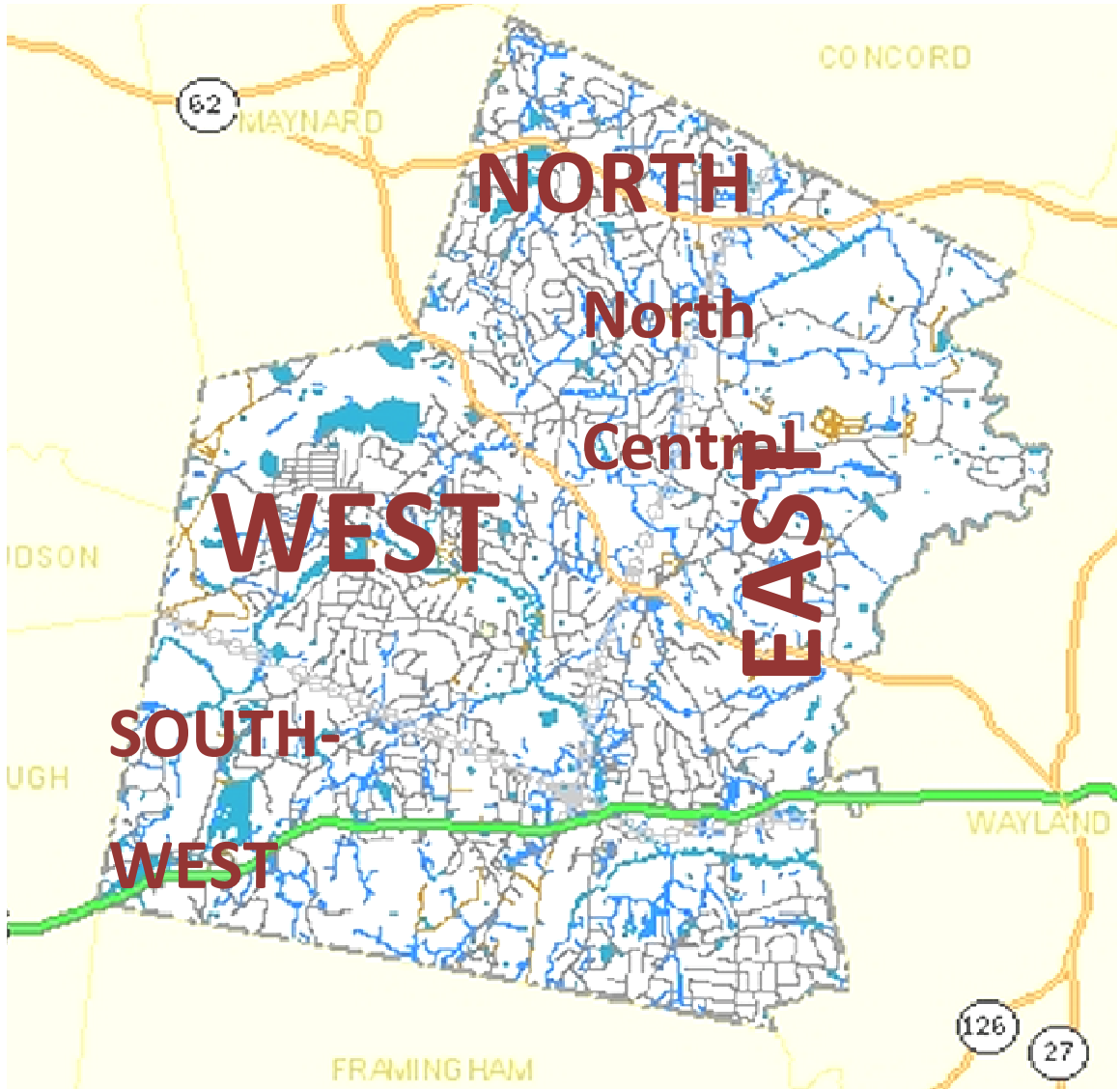


Figure 1 – Pressure Point Areas for Wireless Facilities in Sudbury

Pressure Points with no Facilities Presently

In addition to the areas discussed above where there is a shortage of options for additional wireless carriers, there are some areas in Sudbury where there are no wireless facilities and where wireless carriers may start seeking facilities in the coming years. These pressure points are distributed generally among residential areas and are also marked in Figure 1 – Pressure Point Areas for Wireless Facilities in Sudbury:

- the “West” area in the vicinity of Hudson Road west of Goodnow Road to the Stow boundary, which is roughly bounded by Maynard Road, Peakham Road and the western town boundary;
- the “East” area east of from Concord Road, north of the coverage available from Route 20 and south of the coverage available from Route 117.
- the “North Central” area bounded by the North area, the East area and the coverage from the water tower site off Maynard Road;

Current Coverage

The wireless carriers have some variations in coverage in Sudbury. However, the carrier whose service is most illustrative is T-Mobile.¹ T-Mobile has developed more facilities throughout Sudbury and is likely to be seeking more in the near future because of their on-going development program. Compared to the other carriers, T-Mobile is the one carrier that has a facility at or near each of the other carriers’ facilities in Sudbury.

T-Mobile

T-Mobile has seven active or permitted facilities in Sudbury. Figure 2 – Estimated T-Mobile Coverage in Sudbury provides an estimate of T-Mobile coverage.² The red regions depict the

¹ We have chosen to simplify the illustrations by relying on the less robust PCS coverage, which tends to have moderately less coverage than Cellular service (assuming all other factors are equal: antenna location, height and power). All wireless carriers, including the incumbent Cellular carriers in this region – AT&T and Verizon – are utilizing licensed spectrum in or near the PCS band. This just means that the Cellular carriers may be able to rely on their Cellular spectrum for the bulk of their services and wait longer until they will seek new facilities to provide more capacity and more signal strength from their PCS equipment.

² To simplify presentation we have also utilized circular antenna patterns (“omnidirectional”) rather than attempt to duplicate the individual sector-antenna configurations of most wireless facilities. Wireless carriers’ coverage plots often have shapes that have a slight cloverleaf pattern to them. As a

strongest range of received signal levels, greater than -76 dBm. This is what T-Mobile presently calls “in-building” coverage. It represents a very robust signal level that can withstand substantial degradation as it passes into the depths of buildings and basements.

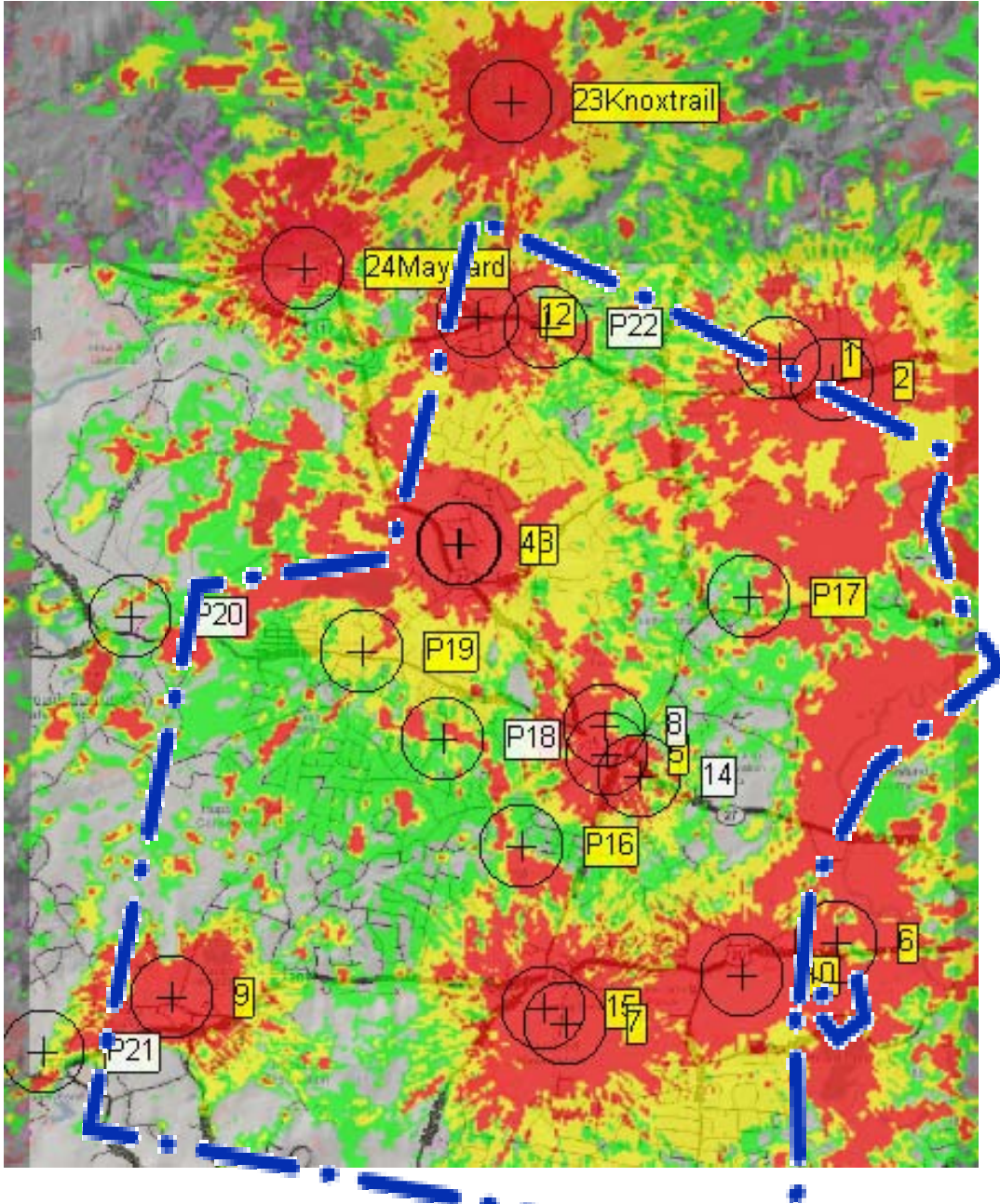
The signal level legend under Figure 2 illustrates the gradations of signal strength shown on each of the maps in this report. Sites are generally identified by site numbers in boxes to the right of each site’s crosshairs.³

The color key to signal strength starts as red in the strongest coverage area of each facility. Red represents the locations where the signal level is predicted to be greater than -76 dBm. Moving outward from any facility, the next weaker range of signal levels is yellow, spanning signal levels less than -76 dBm and greater than -84 dBm. Note that the signal levels are negative numbers, so -84 is weaker than -76.

The next range of signal strength is the green regions, which are predicted to have less than -84 dBm and more than -91. Finally, the gray areas are predicted to have signal strengths less than -91 dBm.

first-approximation, omnidirectional antenna modeling as we have performed is sufficient to glean the regions where coverage may or may not be lacking.

³ It may be a little confusing when sites are close together. The site 12 label is to the right of its crosshair, but happens to be beneath the crosshair of site 22.



Less than -91	-91dBm	-84	-76
Undesirable (typical)	Outdoor (typical)	In-vehicle and some In-building (typical)	Robust In-building (typical)
Weakest -----		----- Strongest	

Figure 2 – Estimated T-Mobile Coverage in Sudbury (Town Boundary is Approximate)⁴

⁴ Because the site labels overlap, the labels for sites 4 and 13 are stacked on the maps, obscuring the “1” in “13.” See Table 2 & Table 3 above to identify individual sites.

The caption of Figure 2 indicates that we have turned on those sites that represent T-Mobile coverage, based on the best information available to us (sites 2, 5, 7, 9, 10, 12, 13). T-Mobile typically relies on coverage that is -84 dBm or greater (both the yellow and the red areas) to provide reliable in-vehicle coverage. For the past eight years or so, signal levels in the general range of -84 dBm have been relied upon as the target signal level threshold for ideal coverage to vehicles.

As the industry matures, high capacity data services become more prevalent, and more customers “cut the cord” from their land lines at home,⁵ carriers have been tending to seek more robust signal levels and greater channel capacity in residential areas. T-Mobile utilizes a target signal level of -76 dBm or higher (the red areas) as its gold standard for in-building service.

It should be understood that while these signal level thresholds are desired targets, people will often have reliable service in their vehicles at levels less than -84 dBm and reliable service in residential homes, or parts thereof, at levels less than -76 dBm. Therefore, it is not necessary to blanket every residence with red coverage or every street with yellow and red coverage. The carriers’ objective is to serve most people/places within the target thresholds and ensure the rest are relatively close to the targets. From a planning perspective, the benefits of enabling as many people as practicable to have wireless services that evolve from tolerable to acceptable to highly robust must be balanced with careful management of the placement and community impacts of the facilities.

The last desirable signal range is the green range, representing a typical range of what is considered in many circumstances to be very reliable service outdoors. While service in the green range is often still somewhat effective in most vehicles under most circumstances, the label of “outdoor” service indicates that a caller on the sidewalk, in the woods, at a lake, or in other similar situations will have robust service in the green, yellow and red areas.

The gray areas are predicted to have signal levels below all desired thresholds. Often, some degree of wireless service can be found in these areas, but it becomes increasingly unreliable.

⁵ The Federal Communications Commission publishes an annual report on the state of the wireless industry. Within the past two years the percentage of the population with cell phones and no land line at home surpassed the percentage of the population with only a land line and no cell phones. Both are in the range of 20%. The remaining 60% have both a land line and cell phones, but the trend is toward cutting off the land line.

The farther one is from a cell site while in gray areas, the less likely a reliable call can be maintained.

We examined coverage from neighboring towns and found only two existing out-of town facilities to have any meaningful relationship to service in Sudbury. Sites 23 (Knox Trail tower) and 24 (Maynard Mill building) are depicted in Figure 2. Other facilities outside Sudbury are not close enough to Sudbury to have a substantial influence on coverage in Sudbury or near its boundary, and are not shown.⁶

T-Mobile North

T-Mobile has addressed a significant portion of the North pressure point with its installation at St John's Church on Route 117 (site 12). There is still a weakness, but some coverage exists on Route 117 between St John's and the coverage from the Water District parcel near the Concord line. This weak area appears as a green segment along Route 117.

T-Mobile North Central and East

T-Mobile has less than its desired quality of service in the vicinity of Lincoln-Sudbury High School (site 17), which is in the East pressure point. The Central pressure point is largely served with "in-vehicle" service from the water tower site off Maynard Road (site 13), except for a small region near Concord Road.

T-Mobile Southwest

Because T-Mobile has a facility on the Martha Mary Chapel (site 9) in the Wayside Inn Historic Residential district, much of the Southwest pressure point has been addressed for T-Mobile customers. In the course of performing our evaluation, we also looked at other carriers' coverage data from prior permit application documents. T-Mobile's coverage data suggests T-Mobile probably has a tolerable continuity of service along Route 20 between coverage from Martha Mary Chapel and from the Raymond Road tower (site 15). Our data are a little more

⁶ We acknowledge the presence of numerous forms of communication from the towers on the summit of Nobscot Hill. However, as was illustrated by T-Mobile in a recent application proceeding, Nobscot Hill would be a way to obtain a wide swath of the lowest level of coverage ("outdoor") in portions of Sudbury, but the wide coverage area and the low signal levels obtained from the hill combine to render the location problematic for delivering high capacity, high penetration coverage.

pessimistic than T-Mobile's, but still suggest that a borderline level of service (green) is provided along Route 20 at the center between the two sites.

The area around Dutton, French, Old Garrison, and Peakham Roads is apparently not served by more than a patchwork of minimum signal levels.

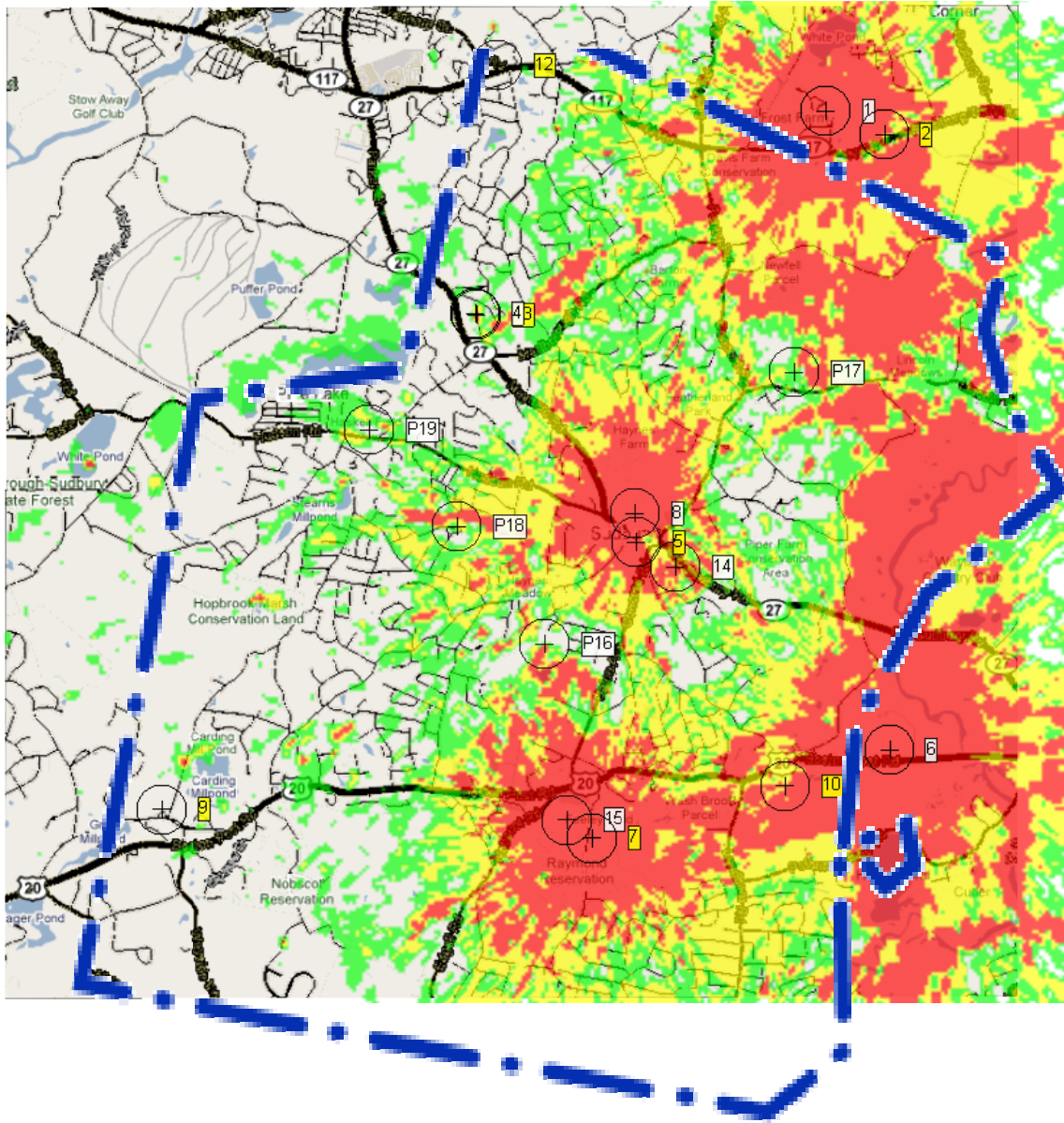


Figure 3 – Estimated Coverage from Existing Sprint Facilities in Sudbury

T-Mobile West

The West pressure point, in the vicinity of Hudson Road, is partially addressed by the facility at the Maynard road water tank site (site 4/13). However, along Hudson Road and south of it the signal levels generally diminish to green service (“outdoor”), with splotches of higher coverage (yellow and red) on the minor hilltops facing the water tank site. This area is just north of the Dutton, Old Garrison, French and Peakham Road region in the Southwest pressure point described above. Thus, there is no specific boundary between the Southwest pressure point and the West pressure point.

Sprint

To illustrate how the T-Mobile coverage plots can be utilized as the general model for this analysis,

Figure 3 – Estimated Coverage from Existing Sprint Facilities in Sudbury illustrates Sprint’s coverage in Sudbury. We have assumed Sprint PCS is operating from the Nextel tower (its sister company) at site 8. This tower is higher than the T-Mobile roof installation (site 6) and therefore obtains more coverage around the town center than T-Mobile does. This reduces the pressure for an additional Sprint facility on the Concord road area north of the center and south of the High School. However, service at the High School is still likely to be less than ideal.

Similarly, there is a moderate difference in coverage from the Sprint installation on the tower at the landfill (site 10) and the T-Mobile installation on the power line stanchion ¼ mile west (Site 7). The T-Mobile site is lower in height above ground than the Sprint site, which slightly offsets the difference in location of the two facilities. Nevertheless, the two facilities provide continuous service on Route 20 in Sudbury from the Wayland line to the coverage from the Raymond Road facilities. T-Mobile has a stronger signal along the Sudbury portion of Route 20 because its facility is set more deeply into Sudbury and away from Wayland.

The North, West, and Southwest pressure point areas of Sudbury are anticipated to have spotty to no appreciable Sprint coverage. The North Central and East pressure point areas are less disadvantaged than North, West and Southwest, but still lack the higher level of service that Sprint could seek in the future.

Analysis of Potential Options

The Town has identified municipally-owned parcels that are potential candidates for addition to the Wireless Overlay District – the Water District parcels beyond Hollow Oak Drive (site 18), and the Lincoln-Sudbury High School site (site 17). One parcel within the district, the DPW facility on Old Lancaster Road (site 16) is also not yet occupied by wireless facilities.

DPW Site

Figure 4 illustrates the coverage obtained from a 100-foot tower at the DPW site, in conjunction with existing coverage. Because it is on the eastern margin of the West pressure point, the DPW site would require an additional facility to more fully serve the West pressure point.

Taking the liberty of identifying a large non-residential parcel off Hudson Road, we chose to illustrate how coverage from a 100-foot tower at the Fairbank Community Center fields could complement coverage from the DPW site. This location was not recommended to us by anyone, and we take no position in favor or against it as a possibility. What is important to understand is that if a wireless company were to come looking for a site in the West pressure point, even after developing a facility at the now permissible DPW site, the Fairbank site could be of significant interest to a carrier because it is central to the residential area around Hudson Road as well as located at a point where there is likely to be a relatively high amount of wireless calling traffic with families and children coming and going. If this site is not desirable to the community from a planning perspective, then other options may need to be developed.

Water District Site

About halfway between the DPW site (16) and the Fairbank site (19) is the Water District site (18). Figure 5 illustrates coverage from site 18. It would be more economical in the short run to use site 18 than for a wireless carrier to develop both the other sites (16 and 19), however the coverage from site 18 alone serves fewer households with yellow and red grades of service than sites 16 and 19 together. Particularly, the Willis Lake Drive neighborhood would have outdoor grade service from site 18, but less signal level than carriers might desire to deliver robust data services into the homes (while site 19 would provide robust coverage to this neighborhood). Also, site 18 is less effective at closing a seam in coverage southeast of

Peakham Road in the vicinity of Horse Pond Road, Forest Street and Old Lancaster Road near the DPW facility.

Lincoln-Sudbury High School Site

We placed a hypothetical 100-foot tower at the Lincoln-Sudbury High School site, on the higher ground near the front of the parcel. Figure 5 and Figure 4 both illustrate the coverage that could be obtained from site 17.

In addition to providing solid coverage to the activity at the High School, a wireless facility at site 17 would provide good service to the Newbridge Road and Plympton Road neighborhoods and the Nixon School, where coverage is shown as lacking in robustness now.

The ridge to the west of the High School tends to obstruct the signal, leaving a small pocket or hole in coverage in the narrow hollow east of Hilltop road. This does not appear to have a significant effect on coverage to streets or residences.

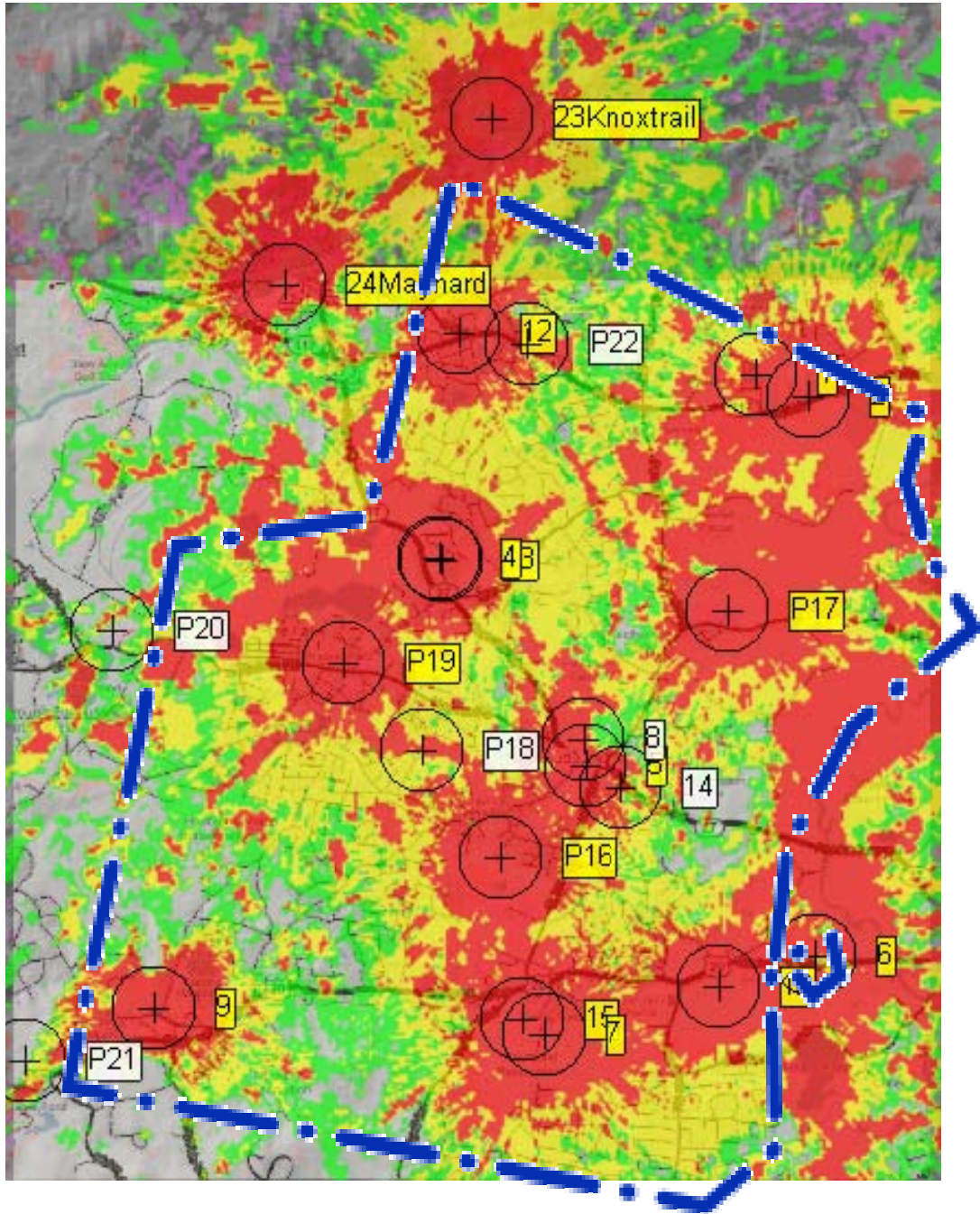


Figure 4 – Estimated T-Mobile Coverage with Existing Facilities plus DPW (16) and Fairbank Community Center Fields (19)

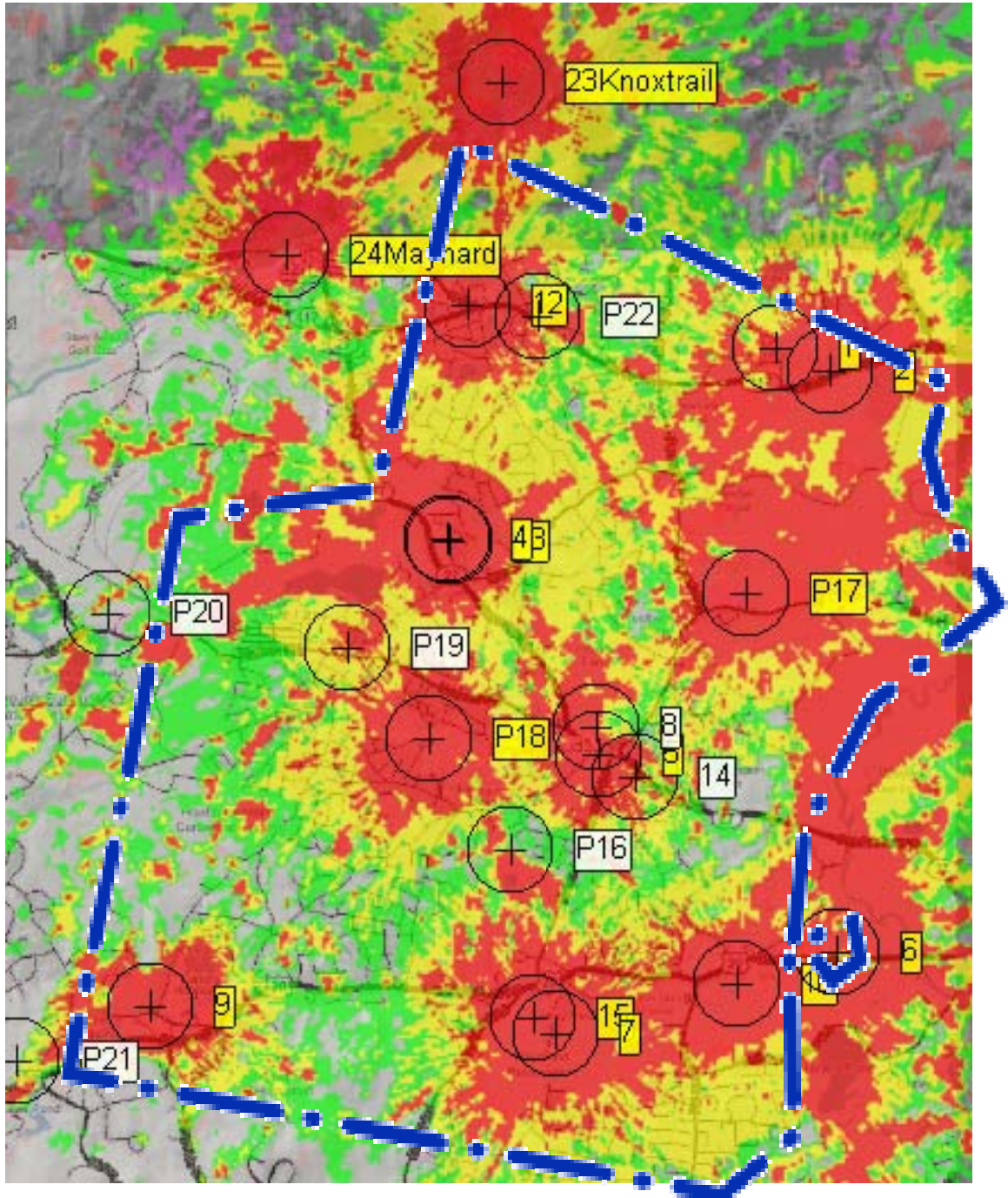


Figure 5 – Estimated Coverage of T-Mobile with Existing Facilities plus a 100-foot tower at Lincoln-Sudbury High School (17) and a 100-foot tower at the Water District site (18)

North Pressure Point

The St John's Church site has very limited capacity to support additional wireless facilities. The site is relatively small and the steeple relatively low in height. While it may be possible to accommodate one additional carrier on the building, other carriers might not be able to fit unless a tower were erected on the site. Being at the crux of a Y intersection, a tower at this location might be a dominant visual feature to traffic heading west on Route 117 toward the church. Further, the small size of the parcel may militate against trying to fit a tower and ground facilities on the site.

Taking the liberty of identifying another non-residential parcel off Route 117 in the North pressure point, we chose to illustrate how coverage from a 100-foot tower at the Sierras Restaurant site could complement coverage from the Route 117 Water District site to the east and from Acton/Maynard to the west. This location was not recommended to us by anyone, and we take no position in favor or against it as a possibility. What is important to understand is that if a wireless company were to come looking for a site in the North pressure point, assuming there is no more room at St John's, the Sierras site could be of significant interest to a carrier because it is a non-residential use central to the residential area around Route 117 as well as located at a point where there is likely to be a relatively high amount of wireless calling traffic with Route 117 and the restaurant nearby. If this site is not desirable to the community from a planning perspective, then other options may need to be developed. There are also some larger undeveloped or lightly developed parcels north of the restaurant that might be considered, unless they are restricted by wetlands, conservation or other limitations.

We evaluated coverage from a hypothetical tower at the North Fire Station, as well, but the Fire Station is too far east to serve the North pressure point and is too close to the existing facilities at the Water District Site (sites 1 and 2). Likewise, the coverage available from sites 1 and 2 near the Concord boundary do not provide coverage far enough west to address coverage objectives in the North region – particularly, west of the point where Haynes Road joins Route 117.

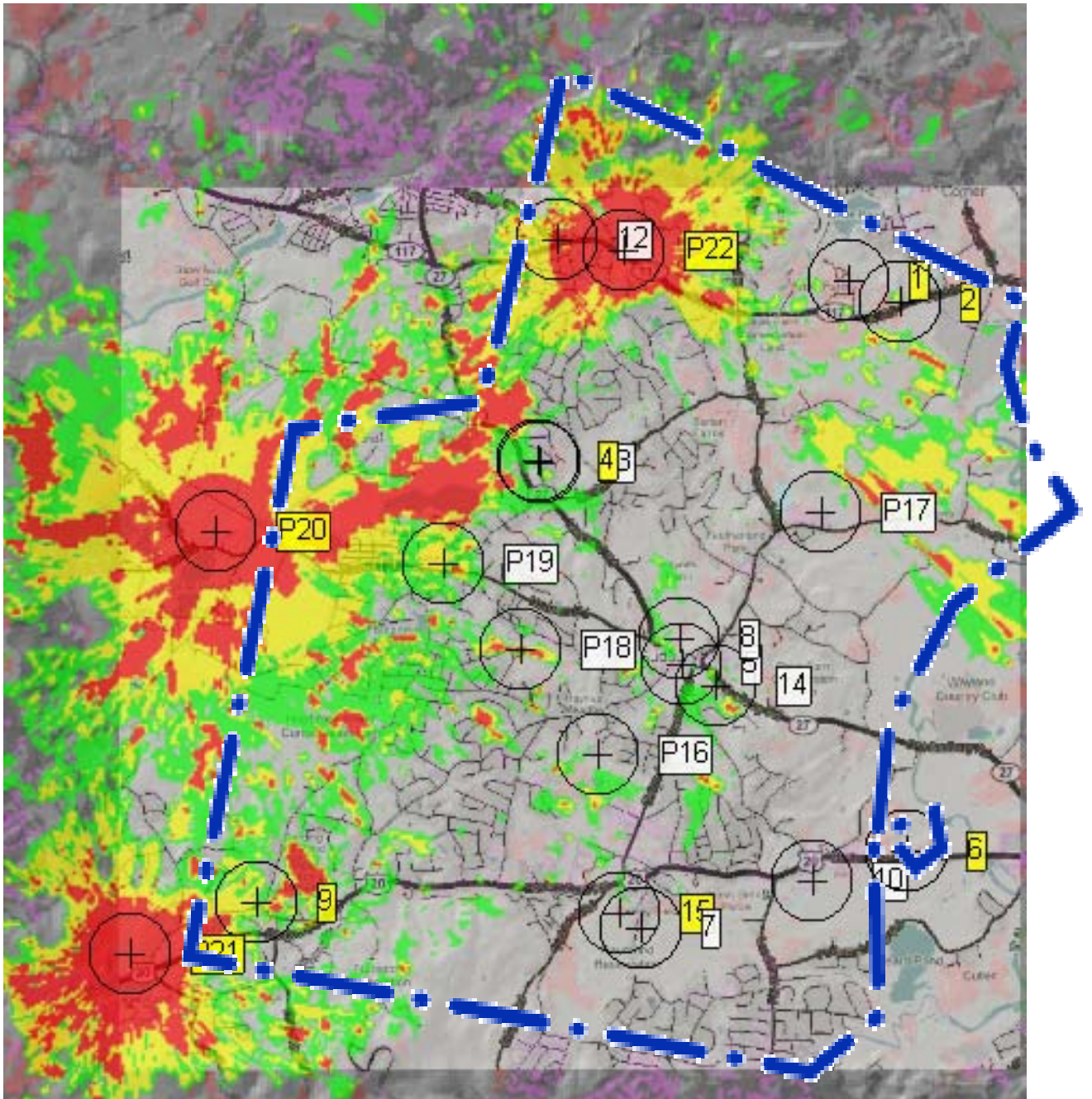


Figure 6 – Estimated Coverage from Marlborough Industrial Hypothetical 150-Foot Tower (21), Stow Firefighting Academy Hypothetical 150-foot Tower (20) and Sierras Restaurant Hypothetical 100-Foot Tower (22).

Stow Firefighter Academy Site

Anticipating the use of a 100-foot tower site 18 at the Water Treatment Plant site, we looked across the border on Hudson Road (Sudbury Road) in Stow.

The Stow wireless bylaw permits a tower on the Academy site, and excludes the site from the general height limit in other locations. Considering that the Academy is located on a through road, but in a relatively sparsely developed and populated area, a taller tower might not be objectionable for two reasons. First, in a relatively visually remote setting on Academy property, such a tower could be relatively unseen by the public. Second, while taller towers in densely populated areas are now tending to be reaching more users than the facilities on the tower can manage, the sparse population around the Academy would ensure that call traffic would not overwhelm the site in spite of its larger coverage area.

We modeled a hypothetical 150-foot tower at the Academy site (20). Figure 6 shows the estimated coverage from such a tower. Comparing Figure 6 coverage from site 20 with Figure 5 coverage from site 18, it is apparent that they are complementary. The portions of the Willis Lake Drive neighborhood and the Firecut Lane Neighborhood that would be underserved by a facility at the Water District site (18) would be well served from a tower at the Academy site.

It would be prudent to communicate with the Academy to see if it would be interested in taking referrals on interested carriers and to determine what the process is for leasing Academy property to wireless interests.

Marlborough Industrial District

In Marlborough, about 1.5 miles west of the Sudbury line, records indicate that there is a wireless facility along Route 20. Its grades of coverage do not reach Sudbury. However, immediately west of the Sudbury line there is an industrial district in Marlborough. Towers up to 125 feet tall are permitted in this district. We chose a hypothetical location to model coverage into Sudbury from a Marlborough industrial district tower. Site 21 in the lower left corner of Figure 6 illustrates this coverage. Comparing to Figure 5, it is apparent that the coverage from this location into Sudbury along Route 20 does not extend significantly east of the Wayside Inn. In contrast, the Martha Mary Chapel site provides substantially more coverage in Sudbury and easterly along Route 20.

Southwest Pressure Point

Assuming that the two existing carriers at Martha Mary Chapel are all the Chapel can support, the Town would benefit from identifying additional potential locations near Route 20 in the Southwest. For the purpose of illustration, we identified a knoll in the Nobscot Reservation behind lower Brimstone Lane and near Boston Post Road (Route 20).⁷

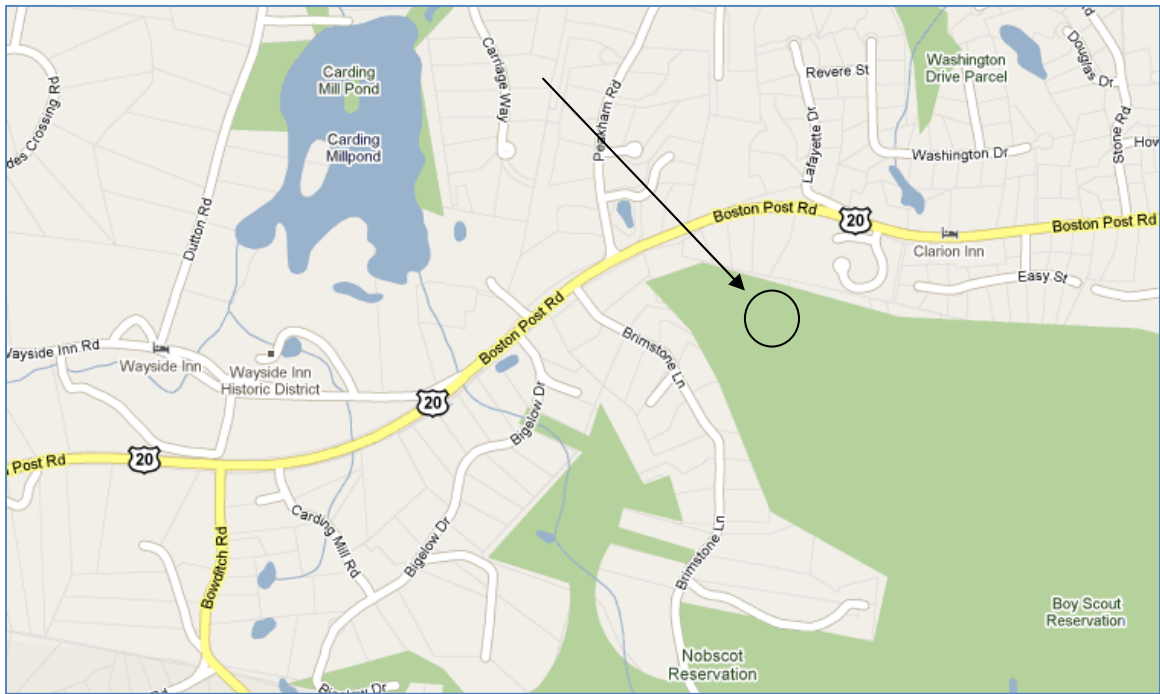


Figure 7 – Hypothetical Location of Facility to Reduce Pressure for Additional Facilities in the Wayside Inn District

Figure 8 shows estimated coverage from a number of facility locations throughout the town. In the Southwest area we have added a hypothetical 100-foot facility near Route 20, within the Nobscot Reservation (25). To complement it, we have added the coverage estimated from the Marlborough industrial district, along Route 20 across the Sudbury line (21). Considered together, these two locations complement one another and link well with coverage from

⁷ This location was not recommended to us by anyone, and we take no position in favor or against it as a possibility. What is important to understand is that if a wireless company were to come looking for a site in the Southwest pressure point, even after developing a facility in the Marlborough industrial district, the knoll could be of significant interest to a carrier because it is close to the Southwest corner where the Wayside Inn Historical residential area is while it is relatively distant from, and likely not highly visible to surrounding residences. If this site is not desirable to the community from a planning perspective or is not developable, then other options may need to be developed.

Raymond Road and from the Marlborough facility 1.5 miles from the Sudbury border (not shown).

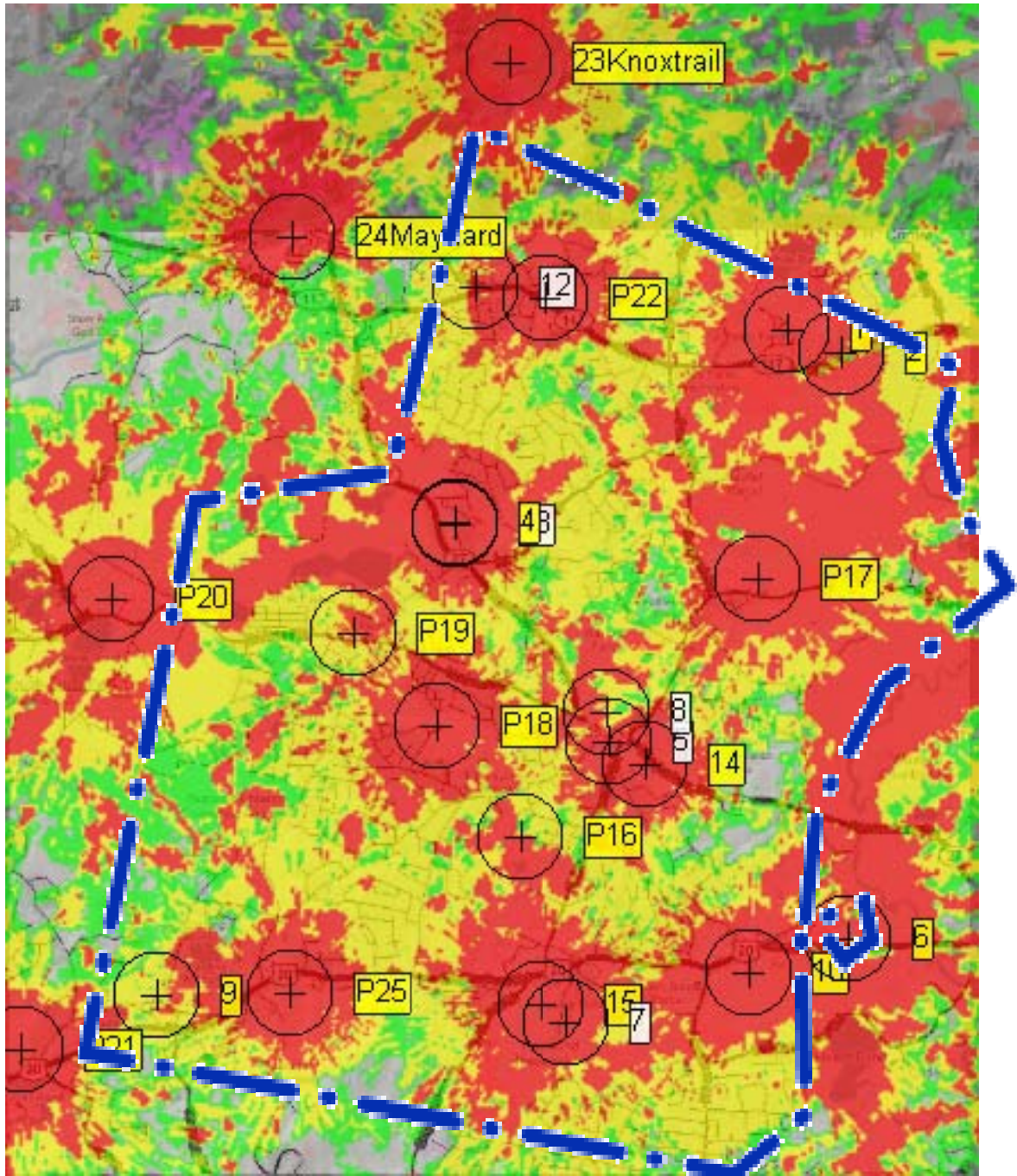


Figure 8 – Combination of Existing and Hypothetical Facilities to Achieve a High Degree of Coverage

Composite of Potential Opportunities

In addition to illustrating a way to advance coverage in the Southwest by straddling the Wayside Inn district with facilities, Figure 8 also shows some of the options mentioned in the preceding subsections in context with existing facility sites.

The Stow Firefighting Academy site (20) is turned on, reflecting the previously mentioned compatibility with the potential use of the Water District site (18).

We turned on a Raymond Road facility (15) and a utility stanchion facility (10) because we consider each of these locations to have the potential for accommodating additional wireless carriers. (In contrast, it appears that the landfill tower is “full” with three carriers, unless the tower is sturdy enough to take an additional carrier or two with antennas mounted on its surface at lower elevations; the three current occupants have their antennas concealed within the skin of the monopole.)

The combination of these facilities (21, 25, 7/15, 10/6) enables robust coverage to be delivered to the residences and businesses along all of Route 20 in Sudbury, as well as to vehicular traffic on and around Route 20.

North of Route 20, in addition to illuminating sites 20 and 18 along Hudson Road, we chose to turn on the new Metro PCS site in the steeple (14) at the town center. The combination of these facility sites provides substantial coverage in the West pressure point and easterly to the center of town. A small underserved area appears to remain straddling Old Sudbury Road near the Wayland line (gray area on Figure 8). Most of this area is undeveloped and would not be a priority for new facilities. A small number of residences might be shortchanged by this pocket of low coverage.

Moving farther north, the Maynard Road water tank site (sites 4 and 13) and the High School site offer complementary locations for handling the North Central pressure point and the East pressure point. We assume that the water tank site can accommodate additional carriers as needed. The High School site has no facility and could be developed to have either one tall tower exceeding the town height limit or potentially two 100-foot towers to accommodate potentially six carriers. The first tower could be built for interested carriers and a space could be reserved for a second tower, if and when the demand requires construction of a second tower. From a public safety perspective, having solid wireless coverage within the High School building and campus is a strong benefit from placing a tower on site. In addition, when a cell site is close

to a busy area, the cell phones do not put out as much energy in order to communicate with the cell tower, which conserves battery life, among other things.

Finally, to the north side of town, one of the existing facilities at the Water District area near the Concord line, on Route 117, is turned on, as well as a hypothetical facility near the Sierras restaurant. Together, these two sites provide reasonably substantial coverage along Route 117 across the width of Sudbury.

Network Architecture Discussion

Wireless companies have been relying on the “cellular” nature of their communications systems to provide the ever-increasing service that their subscribers demand. The cells created by each cell site form a honeycomb of small geographic areas, each served by a cell site. The advantage of a cellular network over a broadcast network is that cellular provides two-way communication and employs highly efficient re-use of the radio spectrum. This means that as new cell sites are added between existing cell sites, the new cell sites can utilize the same radio channels that other cell sites are using several miles away, without interfering with communications on the same channels at the other site.

The original architecture for cellular networks was based on the need to serve a small number of subscribers across a wide geographic area. It was a voice-only service with relatively low demand for bandwidth (i.e. channel capacity). Tall towers spaced 5-10 miles apart were installed to provide basic coverage. As the number of subscribers increased and the bandwidth of the services expanded to include data services (such as multimedia text messaging, internet browsing, video and audio streaming, and gaming), more spectrum was auctioned and more carriers entered the market. As a result, more cell sites were built and continue to be built, especially in metropolitan areas.

The height of the early antennas at a cell site typically required the use of existing tower or a new one to be constructed. As cell sites got closer together, the new tower heights diminished and the use of existing buildings and other structures became more prevalent. At the same time, there were places where the environment was so sensitive to new tower placement and there were no options to utilize existing structures. Cell sites began to be placed at utility poles in some of these locations. There are different techniques for employing utility poles for wireless communications (e.g. microcell base stations or distributed antenna configurations).

These more distributed architectures have found their place in two kinds of situations. First, in densely developed areas, these architectures can provide the vast amount of connectivity that is necessary to serve the high population density. For example, there is a distributed network in Back Bay that is installed on lamp posts. This network presently provides two carriers with the capacity and signal quality necessary to serve the residential brownstone and commercial construction that forms Back Bay land use.

Second, in areas where new towers are not viable (for a variety of reasons) these architectures are employed. Nantucket is home to a distributed network that the network developer said would avoid the construction of eight new towers on Nantucket. It is not a densely developed area, but it is highly scenic and has high-value subscribers demanding their services.

CTIA statistics indicate that the wireless subscription count in the USA is 280 million. While a small percentage of this figure represents commercial uses and dual subscribers, it is safe to compare the magnitude of this subscription count with the US population of about 310 million. Wireless device use is ubiquitous. Similarly, it is estimated that 70% of all non-voice (data) communications originate from indoors. This means wireless carriers are seeking better penetration of residences and offices.

In less densely developed areas, the efficiency of a distributed architecture on utility poles diminishes. Each single antenna/utility-pole installation in a distributed system serves fewer homes in suburban areas than in urban areas. The presence of large residential parcels and substantial tree foliage further challenges the efficiency of distributed architecture in less densely developed areas. While every situation should be evaluated on a case-by-case basis, the current state of distributed architecture deployment exploits the “low-hanging fruit” of the densely developed areas and the areas that are the most sensitive to new tower construction. As distributed architecture evolves, these systems will expand into areas of lesser density.

In large commercial, industrial and business structures, distributed architecture is sometimes employed indoors to provide better service. Malls, large office buildings, and campus environments are prime targets for indoor distributed architecture.

Another wireless architecture turns the cellular model into a multi-modal model. Carriers are beginning to offer indoor base stations that connect to subscriber phones in and around the house. These “Femtocells” are a bridge between the cell phone (the cellular mode) and the subscriber’s internet connection at the home (an internet mode). Verizon Wireless, for

instance, has offered such a device to its customers for a \$250 onetime charge. This is a stopgap method that can provide subscribers with better service at home. Femtocells do not provide coverage to streets or neighboring residences. Nor do they provide coverage to subscribers of other networks who have occasion to visit the residence.

Despite the fact that the Femtocell uses the subscriber's wired internet connection to complete the call, the evolution of wireless technology and wireless services is pushing wireless services toward being a replacement for the wired internet connection at home. Wireless services already directly compete with the residential land-line telephone. As mentioned above, there are now as many wireless subscribers in the USA without land-line phones as there are land-line subscribers who have not subscribed to wireless services. Wireless competition for home cable-internet business will follow.

There are no new techniques on the horizon that would revolutionize how wireless service is delivered to subscribers. Satellite services cannot compete with terrestrial cellular services because satellites cannot achieve the intensive frequency reuse patterns of the cellular services (satellite "cells" are geographically very large compared to terrestrial cells).

Summary

At present, three carriers are most aggressively seeking new facilities in the region. T-Mobile is expanding its service into residential and underserved areas. Clearwire and MetroPCS are new entrants in the market seeking to rapidly deploy new facilities to obtain substantial starting coverage. MetroPCS is seeking a basic level of coverage to establish service, and does not appear to be seeking the degree of signal penetration in Sudbury that T-Mobile is seeking – at least for now. Clearwire utilizes a different technology (WiMAX) than the others and appears to have plans to utilize more facilities from the outset in order to support the high bandwidth capacity of its services. At this time, we are seeing Clearwire and Metro-PCS reaching for the "low-hanging fruit" by seeking to co-locate at existing facilities as much as possible. Both companies have an interest in obtaining as much coverage in the market as quickly as possible to be competitive with incumbent services. Co-location with existing wireless facilities is the fastest and least expensive way (usually) to get new coverage.

Verizon and AT&T, as the longest-standing incumbents in the market, are not as aggressively pursuing new facilities in the region at this time. However, the continuing market pressure to

provide more capacity and higher levels of service will eventually prompt them to deploy new facilities where needed.

The North Central pressure point should be able to be served primarily from the Maynard Road water tank site. It appears that there is enough room for the Town to continue to offer this site to additional carriers who express interest.

The Southwest pressure point area may have no existing structures that will be useful to additional carriers (two are in the Martha Mary Chapel). A strategy of straddling the Wayside Inn area with facilities in Marlborough industrial space (to the west) and in Sudbury (east of the Wayside Inn district) near Route 20 might suffice for any other carriers seeking to improve Southwest service. Alternatively, the proposed expansion at the Wayside Inn might be coupled with a locally sensitive design to accommodate additional wireless service facilities in this Southwest corridor.

The area in the southeast, near the power lines and the landfill, appears to have the capacity to support additional carriers, either by utilizing additional power line stanchions, or by adding antennas to the surface of the landfill tower, or by adding a tower at the landfill if one becomes necessary.

The town center area has limited options. It is often possible to co-locate at least two carriers at a church steeple (MetroPCS is already approved for a steeple installation). T-Mobile has the least antenna height on a building rooftop. Nextel (and we assume Sprint) are on a tower near the center. This tower provides the best coverage of the three locations in the center. Other carriers may be interested in improving service in the center in the near future, so a preferred strategy should be developed.

To the West pressure point, it appears that the Water District parcels (around site 18) has beneficial characteristics (large parcel, municipally-owned, nearly central to a significant coverage objective) that are more enticing than utilizing the DPW site. In the future, if carriers seek better coverage closer to the Stow boundary, a tower is permissible on the Firefighting Academy property and could complement coverage from the Water District (site 18).

To serve the East pressure point, a tower at the High School would be satisfactory. Broader coverage might be achieved by installing facilities on the high ground west of Concord Road at the Lincoln Road intersection, but the land use is such that it may be most desirable to utilize the large developed parcel that hosts the High School campus. The highest ground at the front of the parcel should be utilized if a tower were to be installed on the site.

To the North pressure point, there continue to be options for additional wireless carriers to site facilities on existing or new structures in the overlay district along Route 117 near the Concord line. However, the remainder of Route 117 and surrounding area lacks obvious locations for facilities, other than the present use of the steeple of St John's Evangelical Church by one carrier. It might be possible to add a second carrier to the site, but the parcel is small and is on the point of an intersection, rendering it questionable for a tower or other structure in addition to the steeple. The North Fire Station is too far east to be effective in serving the North pressure point area. This region around Route 117 will require some planning to anticipate possible wireless coverage needs.

David Maxson
Managing Partner
Broadcast Signal Lab, LLP
505 Main Street
Medfield, MA 02052
508 359 8833

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