5G in Belmont

Report of the IT Advisory Committee

November 25, 2019

ISSUED BY
BELMONT INFORMATION TECHNOLOGY ADVISORY COMMITTEE

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Executive Summary

Research conducted by the IT Advisory Committee for the Select Board finds that so-called fifth generation or “5G” wireless technology of the kind proposed by ExteNet and other providers holds great promise for our community.

Lots of promise

5G wireless technology -if it works as promised - would increase wireless Internet upload and download speeds dramatically, enabling much faster data exchanges to smart phones, automobiles, connected infrastructure, digital signage and more. The potential uses and applications of this wireless data bonanza are difficult to imagine, but would be considerable and transformative. Consider that 4G technology birthed disruptive services like ride hailing (Uber and Lyft), social media (Instagram) or electronic commerce (Venmo). These were simply unimaginable prior to the introduction of 4G wireless technology and the advent of devices like iPhones - just ask your next cab driver!   Likewise, 5G will make possible the creation of entirely new products and services; we just don’t know what they look like yet.

A more humble reality

That said, the reality of 5G today is a far cry from what has been promised by firms including Verizon, AT&T and ExteNet. In the few cities where substantial small cell deployments have been realized, 5G service is limited to a handful of blocks. Most users of those wireless networks enjoy something more like 4G or 4G+ service - akin to what many Belmont residents already receive via relatively unobtrusive cell towers. Even when deployed in ideal settings like sports stadiums and concert halls, 5G mesh networks like that proposed by ExteNet often fail to deliver 5G service to everyone in the hall.

5G town-wide: thousands of cells

Our study of high bandwidth 5G “millimeter wave” technology and our review of proposals and studies of 5G deployments suggests that delivering true 5G speeds of 30 Gbps to Belmont will require as many as *200 to 250* microcells per square kilometer, or 2,400 to 3,000 cells town-wide. Belmont has 3,148 wooden electric poles in the town, so a town-wide deployment serving both residential and commercial areas would require a small cell antenna to stand where every one of those poles stands, more or less. It is worth noting, as well, that these speeds are for outdoor users and will not benefit residents inside their homes, given the poor ability of mmWave technology to penetrate walls and other hard surfaces.

Of course, 5G providers like ExteNet may have no interest in serving residential areas with 5G, or have other deployments in mind to do so. Still, it would be good to understand what their vision is for our Town of Homes: commercial and residential? Commercial only? Small cell only or a range of devices for indoor and outdoor use? What *is clear* is that a one or two cell deployment like the one proposed by ExteNet is of little use to the community or its residents. A clearer understanding of what providers imagine for a town wide deployment would be of great use to the Select Board.

Peer communities: setting rules and filing suit

A survey of our peer communities finds a wide range of approaches to 5G deployments. Communities like Boston are in the forefront: providing a streamlined, standardized online application and approval process that has led to a city-wide deployment of hundreds of cells.

Other communities including Cambridge, Burlington and Watertown have taken a more cautious approach: approving small scale deployments and creating permitting processes that look similar to permitting for any other kind of city or town service. Burlington, Cambridge and other communities have published standard applications for 5G petitioners to use and have created design guides for the benefit of wireless petitioners that codify town policy on issues like sighting, aesthetics and fees. Other communities have resisted 5G petitions, filing suit and seeking to push back on providers in the name of local control and community standards. Many of those suits continue to work their way through the courts, though nationally local jurisdictions have won suits over issues like their right to regulate the aesthetics of small cells.

A need for facts...and a vision

What does this mean for Belmont? Given the strong hand federal officials have given to telecommunications firms, the fact that 5G technology fails to live up to the hype associated with it does little to change the options before our town in considering petitions to deploy 5G antennas.

There is every reason to assume - and expect - that an astute and prepared community like Belmont will leverage 5G technology to better serve its residents: engendering new services for elderly residents and families, connecting residents more closely with the government that serves them and giving key decision makers better data to work with, on everything from traffic patterns to air quality to service consumption.

However, it is important for Town leaders to inform themselves about the hype vs. the reality of 5G from vendors like Verizon, AT&T and others and to come prepared to ask petitioners what our Town can expect in return for access to our rights of way. Having a clear vision for what we want as a community and how 5G or even 4G+ might be leveraged by our government and residents will be critical in our negotiations with 5G providers like ExteNet.

Introduction & Background

In response to a request by the Town Administrator, the IT Advisory Committee has assembled this technology brief on 5G "fifth generation" wireless technology. The objective of this report is to inform the Select Board about 5G wireless technology, including so-called "millimeter wave" wireless technology proposed for deployment, on a limited scale, in Belmont. This report also seeks to inform the Select Board about how Belmont's peer communities have responded to petitions for 5G "small cell" wireless infrastructure including permitting, fees and other policies applying to applicants.

This document contains four parts: first, a brief overview of 5G technology and its differences from LTE, then a description of the proposed installation of 5G technology in Belmont, and then a look at what some of Belmont's peer communities are doing and finally a description of some legal cases related to proposed 5G deployments that may be relevant to Belmont.

About 5G Technology

Fifth generation (or "5G") is the latest evolution of wireless communications technology for the mobile phone industry. It continues a trend of development in broadband wireless technology that stretches back more than two decades and that has commercialized technologies like text messaging (2G), mobile web browsing (3G) and mobile apps, music and video streaming (4G). Like earlier generations of wireless technologies, 5G improves on previous generations in three key areas: **speed, reduced latency** and **scale**.

Faster speeds

On the issue of speed, 5G is promised to be 2x to 10x faster than the existing 4G wireless technology, initially, and maybe 100x as fast eventually. Speed tests conducted by the news and review site CNET put the fastest 5G deployments in Los Angeles (1.8 Gbps) and Chicago (1.3 Gbps) and Chicago. In other cities like New York or Dallas, however, 5G sports speeds that are far lower: in the 580 Mbps to 480 Mbps range. Still, even those are a big jump over 4G which - in the US - currently supports mobile download speeds in the 30-40 Mbps range and upload speeds averaging around 10 Mbps.

Low latency

On the issue of latency - or the delays in wireless signals that results when they traverse long distances. Latency can result in interruptions in services and 5G will also mark an improvement over 4G technology. The higher frequency signals used by 5G will reduce latency to almost nothing, allowing video to stream seamlessly (to use just one use case). That in turn will enable a wide range of new use cases, from vehicle-to-vehicle communications to virtual reality applications, remote medicine and so on.

Greater scale

Finally, 5G will offer much greater scale than 4G wireless: allowing many more wireless devices to share a network. This will enable much larger deployments of connected devices without overloading the capacity of the network. In turn, 5G will power the development of the Internet of Things, smart cities, connected infrastructure and so on in ways that 4G technology cannot.

Millimeter wavelength radio (mmWave)

5G isn't one wireless signal but a mix of low-, mid- and high-band spectrum. Each band plays a part, with low-band spectrum providing foundational wireless coverage, mid-band spectrum boosting the wireless network's capacity and high-band spectrum -so called mmWave technology— enhancing wireless network capacity above what is currently available.

“Millimeter wavelength” radio, or “mmWave” is the critical technology in 5G deployments. The wavelength used as the basis of this signal is measured in millimeters, which is considerably shorter than current LTE signals. The frequency of these signals (which is inversely proportional to the wavelength) is therefore considerably higher, in the microwave band. The high frequency of this signal is one of the reasons that 5G can, in some situations, be more than an order of magnitude faster than LTE.

The high frequency also means that it is possible to build small, efficient phased-array antennas that allow the signal to be “steered,” using a technique known as “beam forming” in specific direction. This means that instead of transmitting a signal in every direction, a message intended for only one recipient (i.e. a specific cell phone) can be focused in the direction of that recipient. This means that the power required by the signal can be significantly less than earlier technologies, and more information can be transmitted and received at the same time from different directions. The shorter wavelength also permits the antenna to be smaller than contemporary cell antennas.

The drawback of mmWave frequencies is that they are attenuated more quickly than lower frequencies. As a rule of thumb, the shorter the radio wavelength, the more quickly it is attenuated, particularly when it encounters any sort of solid material. For example, an ordinary house is nearly transparent to the radio frequencies used by television and FM radio, but higher frequency radio waves, such as visible light (which are physically identical to radio waves, but at a much higher frequency) are blocked by a thick curtain or a few layers of paint.

What this means in practical terms is that mmWave radios work best when they have a “line of sight” between the sender and receiver. Anything that blocks this line of sight will degrade the signal. For mmWave, the signal can be severely degraded by tree branches and foliage, for example. Solid walls and other obstacles will also degrade the strength of the signal. In general, the effective range of mmWave transmitters is much shorter than a similar transmitter at a lower frequency. This is why a LTE single cell tower is able to cover many square miles, while a mmWave tower can usually cover only a fraction of a single square mile. In practice, mmWave stations are typically placed within 300 meters of each other.

Mesh networking

5G networks do not depend entirely on mmWave signals, however. The 5G protocols can also make use of lower-frequency signals, with correspondingly longer ranges, in order to communicate with stations that are too far away, or blocked by too many obstacles, to reach via mmWave signals. Because these signals are at a lower frequency, however, they are not able to provide the large improvements in bandwidth and latency that mmWave provides.

5G stations may be arranged to form a *mesh network*. A wireless mesh network is, conceptually, very similar in structure to a network of routers that use dynamic route-discovery protocols to determine how communication should flow through the network. In a nutshell, each station in a wireless mesh sends a beacon signal that tells any recipients that can detect the beacon signal its identity. As each station learns who its neighbors are, and the strength of the signal from those neighbors, it can begin to construct a map of the local network and the capabilities of its neighbors.

Mesh bootstrapping larger cell networks

This information is used to bootstrap larger maps of the network. For example, imagine that there was a station in Cushing Square, another in Waverly, and a third in the Town Center. The station in Cushing Square might be able to exchange messages with both Waverly and Town Center, even though the Town Center and Waverly might not be able to detect each other's signals at all. The Cushing Square station, however, would be able to tell the Town Center "if you need to send a signal to Waverly, you can send it to me and I can forward it for you and send a corresponding message to the Waverly station." As the size of the network increases, the decisions become more complicated, but this problem has been studied at length and good solutions are known.

No wired link between towers

Typical contemporary cell towers do not form a wireless mesh. Instead, each cell tower is a wireless endpoint (similar, conceptually, to the wifi router in your home, which communicates with wireless devices in your home, but does not communicate with other wifi routers belonging to your neighbors). The cell towers are connected by a “wired” network (which is actually often glass fiber, rather than literal wires). These wired networks are usually able to carry much more traffic than the cell towers themselves, and communications over the wired network do not interfere or take bandwidth away from the wireless network. In contrast, wireless mesh networks do not need to have any physical connection between the cell towers—all of the tower-to-tower communication can be done wirelessly. In order for this to be effective, however, the number of stations in the mesh needs to be higher than in a contemporary network (to achieve the same efficiency).

Wireless mesh networks are appealing because of the simplicity of their installation: no cables need to be run, and the protocols permit dynamic changes to the network configuration (i.e. they are able to continue to work even if some of the nodes are unavailable or degraded, and they can grow in capacity by adding new nodes in a somewhat ad hoc manner). For this reason, wireless mesh networks have been proposed for applications such as tactical networks and disaster relief, where wired networks do not exist or have been disrupted, and radio is the only practical way to quickly deploy communication networks.

A difficult task to build

Building a wireless mesh network that delivers on the marketing promises of 5G is a difficult challenge. As described earlier, the fast links in a 5G network are short-range, so in order to achieve fast speeds across the network requires a large number of stations, each within a few hundred meters of several other stations.

From a performance and efficiency point of view, a wireless mesh network does not provide as much performance as wireless stations that are connected by a “wired” network, simply because of the underlying physics of the signals. In the general case, it is beneficial to have many wired connections to the underlying network, and use the wired connections for multi-hop routes, instead of relying on multi-hop wireless routing.

Applications of 5G

For Belmont, 5G technology might be considered an enabler of a new generation of “smart city” (or in our case “smart town”) services. While 5G is not a requirement of “smart city” applications and many have been realized using existing, 4G networks, 5G’s promise of faster connections, more reliability and greater capacity at lower costs are widely seen as a "smart city/smart town" accelerant. 5G - or some technology like it - will be a prerequisite for any high-bandwidth and low-latency smart city applications. For example: vehicle-to-infrastructure applications that connect automobiles with traffic signals to reduce traffic. Next generation smart-infrastructure including water, electricity, building management and transportation may also demand a functioning 5G network.

Singapore: smart transportation and government services

Consider Singapore, which is among the most technologically advanced cities in the world. There, a government-wide initiative called "Smart Nation" is behind projects in a range of areas including transportation, government, urban living, health and small business that encourages the use of digital innovation and technology to drive sustainability and liveability.

Some of the Smart Nation initiatives include a common mobile application for accessing government services and reporting problems (OneService App), an on-demand and (soon) autonomous public bus and shuttle system that allows visitors to use their smartphones to hail shuttles. Among other things, dynamic routing and matching algorithms are being tested to optimise limited resources.

Chicago's Array of Things

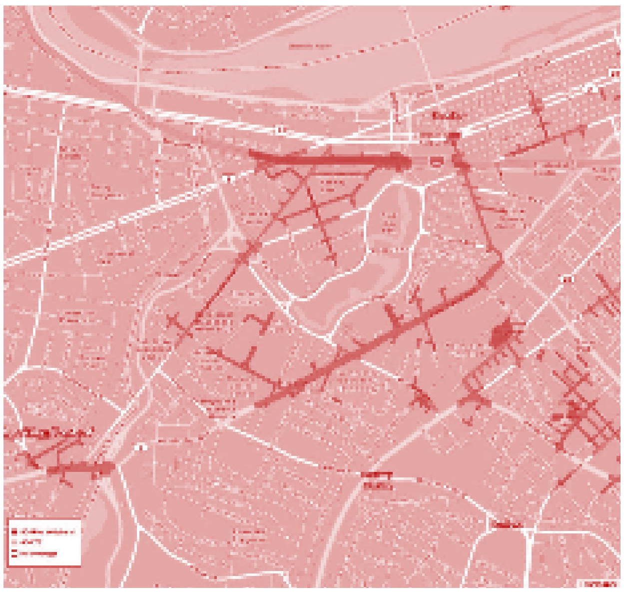
In the United States, the city of Chicago is generally considered one of the farthest along in implementing smart city initiatives. An example of that is the city's "Array of Things": a city-wide deployment of light post and building-mounted sensors. AoT sensors collect a wide range of data: on light, air and surface temperature, vibration, carbon monoxide, nitrogen dioxide, sulfur dioxide, ozone, barometric pressure, sound intensity, pedestrian and vehicle traffic, and surface temperature. That data is then made available to city planners, the public, academics and researchers via portals like the Chicago Data Portal, which fronts data on everything from food inspections to crime.

With continued development, AoT may soon be able to collect data on flooding and standing water, precipitation, and wind.

Similar deployments, with the added capacity that 5G brings could engender a wide range of powerful applications for local and city governments in areas like crime fighting, public health, transportation, and the provisioning of public services.

5G Hype vs. Reality

The technology and telecommunications industries have aggressively hyped 5G technology. However it is important to realize that, as of the writing of this report, many of the promises about 5G's potential are just that.



For one thing, as we noted above, limitations in millimeter wave technology and the small size of current deployments mean that 5G small cells operate at 4G speeds for most users in most locations.

That is one reason that true 5G deployments in the U.S. have mostly focused on sports arenas and concert venues, where 5G cells can serve the needs of a large population concentrated in a relatively small area.

In Boston, for example, Verizon in November announced that the city was one of a handful of cities that now offer "Verizon 5G Ultra Wideband service." But as a recent article at Ars Technica[1] noted: despite its 300+ cell deployment in Boston, Verizon can offer 5G service on a small number of streets covering just a small fraction of the city. (See image.)

Similar scenarios are playing out in other cities as well, the article notes. "It's clear that 5G isn't the revolutionary technology promised by carriers and government officials like Federal Communications Commission Chairman Ajit Pai, who has stoked 5G hype while attempting to preempt regulation by local governments," Ars notes.

1 https://arstechnica.com/information-technology/2019/11/verizons-new-5g-coverage-maps-show-just-how-sparse-the-network-is/

In fact, even 5G deployments in sports arenas have been shown to have coverage gaps where physical obstacles or other conditions dictate that attendees are forced to accept sub 5G speeds.

What does this mean for Belmont? Given the strong hand federal regulators have given to telecommunications firms, the fact that 5G technology fails to live up to the hype associated with it does little to change the options before our town in considering petitions to deploy 5G antennas.

However, it is important for Town leaders to inform themselves about the hype vs. the reality of 5G from vendors like Verizon, AT&T and others. Using existing technology, 5G antennas deployed in Belmont and other towns will offer high bandwidth service to very limited areas in immediate proximity to small cell antennas. More service will be available at lower frequencies but won't offer anything like the speeds promised from millimeter-wave bands. As Ars Technica notes: the lower frequencies "will be more like 'good 4G,' so consumers won't even notice much of a difference if they already have strong 4G coverage."

ExteNet Proposal

The proposal from ExteNet, as it was described to ITAC, is to place two 5G stations near Town Center. One of these will be near the intersection of Leonard Street at 19 Moore Street, adjacent to Town Hall. The other will be at 223 Channing Road by the juncture with Statler Road. The two stations are approximately 1,000 meters (3,000 feet) apart, which is well beyond the practical limit of mmWave signals.

As described to ITAC, these stations would be mounted on light poles, which would provide power to the stations. The stations would be connected to a wired network via connections to the town's existing fiber network using conduits installed by ExteNet.

Current Proposal's Utility to Belmont

Without additional information from ExteNet, these sites will provide limited value to the community beyond a "proof of concept" or model deployment that gives the community an idea of what 5G infrastructure will look like deployed in business districts and residential neighborhoods.

Located in downtown Belmont and connected (“backhauled”) to a fiber optic network, the Moore Street 5G hotspot could offer high speed wireless cellular service to much of the Leonard Street shopping district. However, the difficulty of mmWave technology penetrating building exteriors would mean that the highest bandwidth would be limited to out-of-doors users, while dropping off precipitously inside Leonard Street establishments.

In short: *high-speed coverage will be limited to a small radius, and might not be of use to patrons or employees of shops in the Town Center, due to the limited range and ability of mmWave signals to penetrate the brick walls used in many of the buildings.*

At more than 1,000 meters apart, the two stations will not be able to communicate with each other using the high frequency, short wavelength mmWave signals, but will rely on longer range, lower bandwidth wireless signals similar to how current cell stations communicate with the rest of the Internet. Even if both of these 5G stations has a wired connection to the network, their benefit to the Town will still be limited to the residents who live within a small radius of these stations - in the range of 150 - 200 meters and pedestrians and commuters who happen to be nearby (for example: at the Belmont Center train station or waiting for the 74/75 bus in Belmont center).

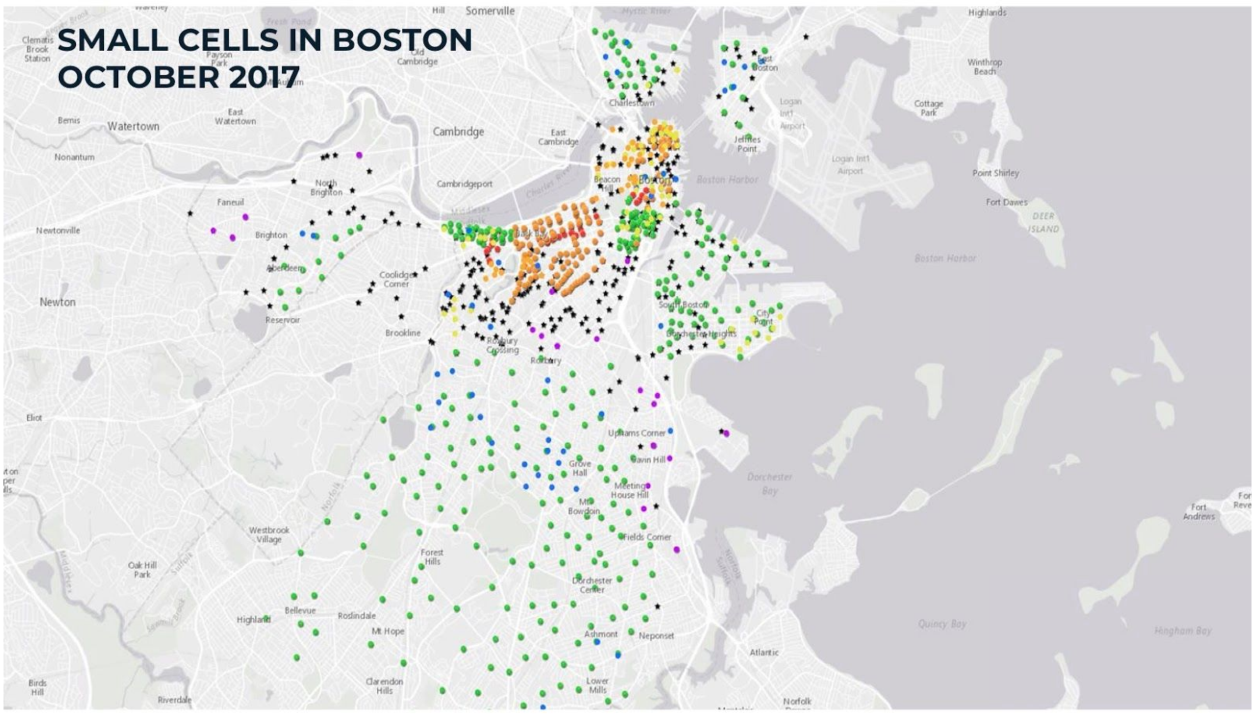
It is possible that there are, or will be, other 5G stations nearby which we do not know about, and these two stations will merely be part of a larger mesh. It seems unlikely, however, that there is a robust design for a wireless mesh that covers Belmont except for the small area covered by these two nodes. The information known to ITAC is not enough to reach any deeper conclusions.

Imagining a Belmont-wide 5G Deployment

Given the limited size and utility of the proposed “small cell” 5G deployment in Belmont, ITAC undertook to understand what a town-wide 5G deployment might look like. Our thinking was that the ExteNet proposal may represent the “nose of the camel” - an initial proposal of modest scope that precedes a much larger deployment.

A matter of conjecture

The exact shape and size of a town-wide 5G deployment in Belmont is a matter of conjecture. For one thing, the density of 5G cells depends on the kind of wireless technology used. Still, there has been some research done on the best density of small cell deployments to enable 5G. Given what we know about the kind of equipment ExteNet is planning to deploy on Moore and Channing Roads, we can make some 'back of the envelope' calculations about what it would take to serve Belmont's residential and business districts with millimeter wave (mmWave) 5G service.



Because there are few - if any - city-wide 5G deployments in North America to use as a comparison, much of the work of estimating what a deployment in a community like Belmont would look like involves backing into an estimate based on what we know about the capabilities of the technology ExteNet would like to deploy, the desired capacity, etc.

Little data on optimal cell density for 5G

Wisely, Wang and Tafazolli of the Institute of Communication Systems at the University of Surrey in the UK conducted an analysis of the capacity and costs of 5G networks in dense urban areas, using a 1 Square Kilometer of downtown London to model different 5G deployments.

Their paper[2] looked at 5G networks based on a range of technologies including 700MHz (2x10MHz) macrocell technology, 3.5GHz (100MHz) microcell technology (ExteNet's offering), as well as 24.5- 27GHz GHz (1GHz) hot spot deployments and a 802.11 ac metro wireless LAN.

Their key conclusions on coverage are that 5G with speeds in the range of 64- 100Mbps can be provided across a significant (90%+) part of a dense urban environment using a combination of mmWave outdoors and WLAN technology indoors.

The 3.5GHz technology – with 100MHz of bandwidth – that the two ExteNet hotspots would introduce to Belmont "can provide outdoor coverage at 100Mbps but is not adequate for indoor coverage unless the micro base (sp) stations are located within the buildings," the authors concluded.

30 cells per kilometer² - or 10 times that?

Data from this research suggests that at densities of 30-40 base stations/km2, the 3.5GHz mmWave technology can achieve speeds of 100 Mbps with around 40% - 50% coverage in a dense urban area - an improvement on current wireless speeds, but more akin to 4G+ than what has been promised as 5G . At densities of *250* 3.5GHz microcells per square kilometer, speeds of up to *30 Gbps* are achievable - matching the "100 times increase in speed" promises of the telecommunications companies. However, actual wireless coverage in such a large deployment may be no greater despite the greater cell density - and could actually *decrease* because of wireless interference between the deployed cells.

Finally, it is worth noting, as well, that these speeds are for outdoor users and will not benefit residents inside their homes, given the poor ability of mmWave technology to penetrate walls and other hard surfaces.

This is Belmont, not London!

Of course, Belmont is not downtown London. The built environment of our town - even in its busy shopping districts - is far less dense than London, with lower building heights and

[2] Capacity and Costs for 5G Networks in Dense Urban Areas

more clear lines of sight. That means that the University of Surrey estimates about cell density could likely be revised downward considerably for a Belmont 5G deployment.

What fraction of a square kilometer of busy downtown London is Leonard Street or Cushing Square in Belmont? That's a matter for conjecture. Based on population density, Belmont is about 1/5th as dense as London, overall. During working hours, Belmont is far less dense than downtown London, where millions of people go to work each day. The lower buildings create easier lines of sight that enable 5G "mesh" networking.

However, the final shape of 5G deployments are determined as much by physics as by demographics and topography, meaning that the scale of a Belmont 5G deployment, compared to a 5G deployment in a far more dense urban environment, will not shrink in proportion to the population density.

The key for Belmont, as with any proposal, is to figure out how 5G can benefit Belmont residents and have a firm idea of what the Town wants as an "end state" or "win" in its negotiations. Belmont then needs to be informed and prepared to ask tough questions of our would-be business partners to ensure that our goals and objectives are met and that the community's priorities are respected in the 5G deployment.

What other Communities are doing

As part of its research on behalf of the Select Board, ITAC conducted open source and in person research of 5G deployments in neighboring communities and nationally. Our research revealed that many of Belmont's peer communities are in a similar situation: having been approached by ExteNet or other 5G providers with requests for small scale 5G antenna deployments, often proximal to dense commercial centers.
Here is a round-up of developments of note to the Board:

Boston, Massachusetts
Boston is a national leader in deploying 5G "small cell" antennas. As of October of 2017, the City had approved 656 small cell deployments from six different providers. As of 2017, around half of those sites were in the process of being installed. Ninety percent of those were approved by the City within 10 business days and 100% within 28 business days

Clearly Articulated Priorities

As part of its approval process, the City first established clear goals for its small cell deployments. Boston sought to both encourage investment in current and future (5G) wireless infrastructure, while also protecting residents and the public interest and protecting public rights of way.

The Boston licensing application process was designed to:

- Minimize aesthetic impacts
- Encourage competition in the wireless market
- Engage the community and fostered awareness and comfort about wireless deployments
- Collect fair compensation for the use of a public asset (the right of way).
- Create conditions for fast and predictable approvals
- Handle a large volume of installations
- Create a manageable community input/feedback process
- Establish appropriate pricing models for carriers

Permitting & licensing

The result was a program that featured a standardized license agreement and multiple pricing models via a simple, online application system. Boston was keen to have a licensing program that supported multiple vendors, encouraging competition and discouraging wireless "land grabs." The city also established a cooperative design process that formalizes community communication and engagement.

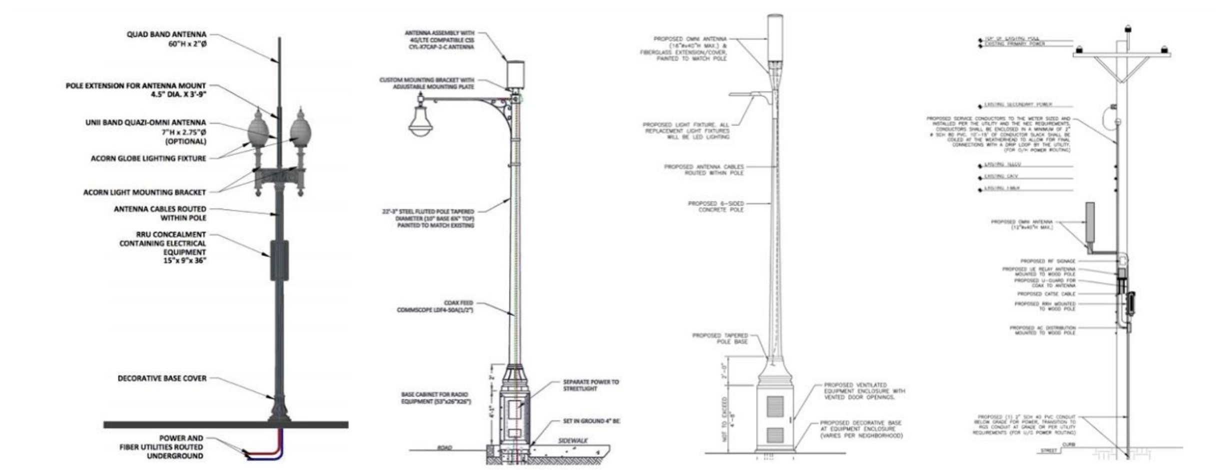
The City's licensing program includes a:

- Easy to use online application website
- 10 year term with 10 year renewal option
- Quick negotiation for new licensees
- Covers access to all structures in the right-of-way
- Fair, defined process when two companies want same location

Boston gives licensees 12 months to complete installation following approval of a sighting request, however the Commissioner of Public Works has discretion to extend that deadline.

Design

Boston established a cooperative process for the design of replacement posts that would be used to host small cell antennas. The City's process sees licensees and the city jointly develop designs for replacement lights together with a heavy focus on aesthetics, concealment, and historic character. Any approved design can be used by any license.



Sample Light Post Designs, City of Boston

Siting requirements

Boston grants small cell licensees the right to install and maintain small cell equipment on City Poles or on City Property Poles, on City-owned infrastructure (such as bridge abutments, retaining walls, overpasses, arcades, buildings), in the Public Rights-of-Way or on City-owned Property and on Non-City Poles. Program, safety, location, and design information is standardized and available online via the City's website.

Licensees are asked to submit the location of their proposed small cell site using Boston's online application website. Licensees hold notification meeting in each neighborhood where they build and n o community signoff is required for individual locations. Should sighting issues arise from a proposal, the City works with licensees to address any community concerns.

In the cases of a Wireless Facility on a Non-City Pole in the Public Rights-of-Way or on City-owned Property, Boston asks licensees to obtain approval from the owner of the pole and provide the Commissioner of Public Works with written evidence of such approval.

The Commissioner of Public Works is expected to not unreasonably deny such applications but can disallow a proposed location or installation based on “material potential Interference with other pre-existing City communications facilities, or future City communications facilities that have already been designed and planned for a specific location or that have been reserved for future public safety communications Facilities,” among other reasons.

Fees

Boston’s licensing model offers a choice, with the licensee choosing the pricing model that best fits their business model. Pricing models are based on assessment of fair market value in comparable cities and analysis of City costs. Prices are renegotiated at 4 years and 7 years.

Boston Licensing Models	
Fixed Fee plus % of Revenue	Fixed Fee Only
$500 per site per year + 5% of gross revenue	$2,500 per site per year
Designed for neutral hosts (Crown Castle, ExteNet, etc.)	Designed for carriers (Verizon, Sprint, AT&T, etc.)
% of revenue allows licensee costs to scale as their revenue grows	Predictable costs
Simplified accounting	Reduces financial risk to licensee if location doesn’t generate full potential revenue

Cambridge, Massachusetts

Cambridge has taken a more traditional approach to 5G small cell applications. The City’s Pole and Conduit Commission’s [Policy Regarding Small Cell Wireless Installations on Public Ways], published in June, 2019, lays out a variety of fees and conditions for applications, but no standardized applications, online portal or other amenities.

Permitting and licensing

Cambridge's permitting process requires applications to a minimum of three City departments: the Pole and Conduit Commission, the Community Development Department and the Historical Commission, as well as "any other department that the Commission determines should receive a copy." Applications follow a "shot clock" for completeness (30 days) after which they are dismissed. Complete applications are granted hearings within 60 days (existing poles) or 90 days (new locations).

Design

Cambridge provides a lengthy and proscriptive list of requirements for the design and location of small cell wireless antennas. Among the design goals and requirements the City puts forward are:

- Minimizing visual as well as physical clutter to the maximum extent possible including by collocating Installations onto existing infrastructure
- Maintaining public open spaces and parks clear of visual clutter of communication and signage elements
- Discouraging placement of Installations on decorative pedestrian municipal street lights
- Standardizing components of Installations, e.g., size, scale, color, location to be consistent with the" character of existing public infrastructure in the public right of way."
- Avoiding siting of Installations in front of designated historic structures, landmarks, parks or impacting view corridor to major natural, cultural, or historic resources.

Siting requirements

In terms of siting, Cambridge takes a prescriptive approach. The City limits installations to a minimum 150' radius from other installations and limits them to "existing non-decorative light poles."

The City further limits deployments in commercial districts and major city squares such as Harvard Square, Central Square, Inman Square, Porter Square and Kendall Square. In those locations, small cell installation cannot be located directly adjacent to a preexisting pole with a previously approved Installation.

Cambridge asks that all antennas, equipment, wiring and cabling be built within the pole itself, allowing for multiple carriers in one pole, similar in design to the "Smart Fusion Pole."

The City further mandates setbacks from existing building walls, curbs, driveways and intersections. Cambridge prohibits equipment associated with the Installation from being installed in pedestrian walking area or parts of the sidewalk where seating or bike racks are located.

Cambridge prohibits small cell installations in any location that the City determines might hinder its ability to install any city infrastructure, transportation elements or facilities including bike lanes, bike racks or other street furniture and the like based upon existing City plans for installation of such facilities.

If the City redevelops or changes a street, sidewalk, square, or other area, small cell applications are expected to remove their Installation at their own cost within 60 days of notice by the City. They may apply to re-install their Installation in a different location upon the City's redevelopment or change to such area.

Fees

Cambridge's policy imposes a variety of fees on would-be applications. These include:

- An application fee of $500 per Application to cover up to five installations. Applications for more than five installations is subject to a separate fee of $100 per Installation.
- A $270 "Annual Recurring Fee" for each Installation, to be submitted with each Application.
- If the Application relates to a request for installation of a new non- City owned pole or other structure on or within the public right of way, a one-time $1,000.00 fee is required for each such new pole or other structure in addition to said Annual Recurring Fee.

Watertown, Massachusetts

Watertown was the recipient of similar proposals as Belmont in late 2018/early 2019. Those requests include requests for two ExteNet Systems small cellular antennas in the public right-of-way at 141 Palfrey St and 550 Arsenal St, and one AT&T/New Cingular Wireless petition for a small cellular antenna in the public right-of-way at 5 Coolidge Ave. Town issued a report dated February 12 to Watertown Town Council. The report includes guidelines addressing requests for small cell deployments on existing town light poles in the right of way.

In response to these requests, Watertown has initiated a preliminary process for accepting and approving petitions to place small cell wireless antennas on public rights of way. Watertown's Committee on Public Works report to Town Council provides an excellent overview of the Town's process of considering these requests, its interpretation of State and Federal laws and consideration of needs for future rule-making is must-read material for Belmont's Select Board.

For the time being, Watertown Town Council has approved the three small cell applications by Verizon and ExteNet. It has also asked its Public Works and Rules & Ordinances Committees to develop an ordinance and regulations for Small Wireless Facilities in a public right-of-way to address future applications including those involving colocation on existing light poles and traffic light poles and the installation of new, free-standing poles for small cell antennas.

Permitting and licensing

Watertown has developed a preliminary Grant of Location Form which can be viewed as an Appendix in the Committee on Public Works report to Town Council. That form generally binds petitioners to "the requirements of existing Watertown Ordinances and/or Regulations, as may be applicable and as may be adopted in the future, governing the construction, operation, and maintenance of Small Wireless Facilities, insofar as they are not inconsistent with the laws of the United States or of the Commonwealth of Massachusetts." It specifies that "no sidewalk or road surface may be disturbed under this Grant of Location by the Applicant or its agents." Discussion by the Public Works Committee included suggestions to create an online portal for petitioners. It is unclear what progress has been made towards those goals.

Design

Watertown's Committee on Public Works has only addressed applications for small wireless antennas on existing poles. For now, the Committee is recommending that antennas use "a cylindrical design mounted at the top of the pole, with a central axis of the antenna and pole aligned." Antennas mounted to the side of a pole are not currently allowed in Watertown.

The Committee required the minimum pole height to be 30 feet. It further ruled that antennas can not be located where the RF field calculation in an existing habitable building space is greater than 0.5% of the Maximum Permissible Exposure over 30 minutes as defined in 47 CFR § 1.1310.

Siting requirements

The Committee recommended that the condition of poles being considered for small cellular antennas should also be taken into account prior to approval of a petition. It also recommended that an antenna and its associated equipment cabinet not be mounted on a utility pole if it is a double pole or if existing equipment is already deployed including:

- Another Small Wireless Facility installation
- An electrical power system transformer
- A remotely-operated primary electrical power system switching equipment
- An amplifier or power-supply cabinet for a cable/broadband system
- Non-wireless telephone system equipment cabinet
- Traffic control equipment
- An electric meter for other existing use.

Fees

At the recommendation of the Watertown Public Works Committee, Watertown Town Council in February 2019 adopted a "Safe Harbor" fee schedule, which includes a one-time application fee of $500 for up to five locations and annual recurring fees of $270, or a "reasonable approximation of cost" fee consisting of the objectively reasonable, actual costs incurred by the municipality.

Burlington, Massachusetts

Burlington has created a Small Cell Wireless Committee. The Town has developed both a standard form[3] for 5G providers to petition the Town to deploy a small cell wireless transmitter. Burlington has also produced a Design Rules and Regulations Document[4] governing small wireless cell deployments.

Among other things, the town set up a policy to require annual recertification of small cells with a fee. That caused Verizon to withdraw an application[5] for a deployment of wireless "booster" cells pending clear answers to Burlington's siting and design questions.

Permitting and licensing

Burlington requires each application to follow the same process:

- Applications are submitted to the Board of Selectmen through the Office of theTown Administrator, with 10 hard copies and 1 electronic copy of the application submitted.
- The Town Engineer or his designee makes a determination as to the completeness of the application and notifies the Applicant, in writing, within 10 days, if the application is incomplete. If the Applicant is notified that the application is incomplete, the application is deemed rejected and must be resubmitted.
- The Office of the Town Administrator circulates a copy of the application to a list of Town departments for comment. Among them: Building; Engineering; Planning; Health; Police; Fire; Conservation Commission; and, any other department the Town Administrator considers relevant.
- Written comments from the departments are submitted back to the Office of the Town Administrator within 20 days of circulation of the application.
- Once the application is deemed complete, and all comments have been received, the Board of Selectmen will schedule and hold a public hearing to consider the

3 http://www.burlington.org/1%20BU%20STM%205.20.2019%20SWF%20Cell%20Application-Cover%20Sheet.pdf

4 http://www.burlington.org/3%20BU%20STM%205.20.2019%20SWF%20Design%20Rules%20and%20Regs_Approved%20PB_4_4_19%20BOS_4_8_19.pdf

5 http://www.bcattv.org/bnews/top-stories/verizon-drops-small-cell-wireless-booster-application-in-face-of-fees/

application, such that a determination may be made on any application for an installation on an existing structure within the time period required by law.

- Upon completion of the hearing, the Board of Selectmen may grant, grant with conditions, or deny the application, based on inadequate capacity of the pole or 2 mounting structure, safety concerns, reliability concerns, or failure to meet applicable engineering or design standards.
- Any approval granted to an applicant shall be only for the specific applicant and application.

Design

Burlington provides considerable design guidance in its Design Rules and Regulations document covering cells, poles, enclosures, wiring and other components. It is worth referring to. Among the design requirements for small cell deployments:

- Poles and all equipment must be the same color and finish as surrounding streetlight poles or third-party poles.
- Exposed wires are not permitted.
- Corporate or company names are not permitted on poles, equipment or enclosures (boxes, cabinets, etc.),
- The height of any standalone pole (including its antenna(e)) is capped at 32 feet or no more than 10 % taller than other adjacent poles, whichever is greater

Siting requirements

Burlington's siting requirements seek to promote "cleanly organized and streamlined facilities" using the "smallest and least intrusive means available to provide wireless services to the community."

The City's design document outlines preferred and less preferred locations. Burlington strongly prefers cells co-located with existing infrastructure. In terms of surroundings, Burlington names industrial districts and public rights of way unless they are adjacent to parks or residential districts. Residential districts and parks are less desired locations.

The city asks that small wireless facility and/or wireless support structures "match and be consistent with the materials and finish of the wireless support structure, adjacent poles and structures, and of the surrounding area adjacent to their location."

As with other communities, Burlington asks that small wireless facilities and wireless support structures do not impede, obstruct, or hinder usual public pedestrian or vehicular travel or public safety on a right of way. Small cells are expected to be located in alignment with existing trees, utility poles, streetlights, and buildings. In addition, the City mandates that small wireless facilities and wireless support structures are located no closer than 150 feet away, radially, from another facility.

Deployments in Burlington are limited to locations where “an existing pole can be removed and replaced, or at a new location where it has been identified that a streetlight is necessary.” Burlington requires small cells to be placed equidistant between trees with a minimum of 15 feet separation so that “no proposed disturbance shall occur within the critical root zone of any tree.”

Similarly, Burlington bars wireless facilities and wireless support structures along the frontage of any building deemed to be of historic significance on a federal, state, or local level, bars them from “sight triangles at street intersections” and from the front of any existing residential, commercial or industrial structure.

Fees

Burlington charges a fee of $500 per application for up to 5 locations. Application for more than 5 installations must attach a separate fee of $100 per additional installation. For approved small cells, the party responsible for the equipment maintenance pays an annual recertification fee of $100 per installation which remains in use.

Lawsuits involving 5G Deployments

Our research has uncovered numerous examples of litigation involving 5G deployments. These suits make it clear that a pattern has emerged in which ExteNet applies for permits in various municipalities for very small scale deployments that are insufficient to provide the service beyond a very limited geography. Typical are requests for fewer than a handful of poles per municipality. There are many possible explanations for this approach. One may be that ExteNet is experimenting both with its technology and with its business model: feeling out a wide range of communities for their willingness to allow 5G deployments rather than investing in larger, more expensive deployments in a small number of communities.

Here are some communities we identified who are engaged in litigation with ExteNet and other would-be 5G providers:

ExteNet v. Somerville

This lawsuit was initiated by ExteNet on June 24th 2019 and centers on Somerville's 'failure to act' on ExteNet's applications within the 60 period mandated by the FCC.

ExteNet is asking the court for immediate approval to access Somerville's public rights-of-way for its installations. ExteNet's original applications were for installation of 'personal wireless' facilities on 3 existing Eversource-owned poles. The ExteNet complaint states that the company had an agreement with Eversource for this. Although the lawsuit was filed by ExteNet on June 24th, it was voluntarily dismissed by ExteNet on July 30, 2019. We have not been able to determine the reason the suit was withdrawn. We note that on October 10, 2019 the City of Somerville held a public hearing concerning a petition by ExteNet to replace 4, city-owned street poles with new poles that would include 'wireless small cell antenna and related equipment.'

ExteNet v. Cambridge

This lawsuit was filed August 28, 2019 over Cambridge's denial of ExteNet applications for 5 installations on 'replacement city lights.' ExteNet is asking the court for immediate approval to access Cambridge's public rights-of-way for these installations.

This ExteNet lawsuit references the FCCs 'Third Report and Order' in which municipalities are urged to adopt aesthetics standards. The lawsuit seems to indicate that municipalities may consider aesthetics when allowing applications, as long as any aesthetic guidelines are clearly in place prior to the application filing date.

This lawsuit also referred to Cambridge's Pole and Conduit Commission that published "Policy Regarding Small Cell Wireless Installations on Public Ways". This Cambridge Policy is a worthwhile read, as it might offer the Town of Belmont valuable suggestions for its own policy decisions.

Finally, it appears that Cambridge originally denied ExteNet's applications, in part, because these applications did not address how data (fiber cables) and power were going to be attached to the ExteNet installations. We consider this an important detail, as it does not make sense for ExteNet to propose a personal wireless installation minus the ability to provide the services promised. Any successful deployment of 5G antennas will require both data and power to the poles, otherwise the 5G deployment will not succeed..

ExteNet v. Village of Pelham, NY

This suit relates to a 2018 ExteNet application that was denied by Pelham for upgrading some existing installations to add capacity for AT&T to supplement the original installation's T-Mobile capacity.

In a decision handed down on March 27, 2019 the Village of Pelham was ordered to allow ExteNet to upgrade its installation because it was deemed a 'collocation' and did not substantially alter the dimensions of the original installation.

Appendix A: Additional Reading

Resources for Government

- State provides resources on 5G and small cell deployment (MMA.org)
- Massachusetts guidance and model agreements for small cells
- Massachusetts Department of Telecommunications and Cable: Department Notice on Mobile Broadband Deployment April 2019 (Mass.gov)
- DCR Small Cell License Agreement (MMA.org)

Technical and Implementation Issues

- What is 5G: An Explainer (CTIA - note: telco industry group!)
- Capacity Costs for 5G Networks in Dense Urban Environments (ICS)
- 5GS Waveform is a Battery Vampire (IEEE)
- 3Q: Muriel Médard on the world-altering rise of 5G (MIT News)
- The Cost, Coverage and Rollout Implications of 5G Infrastructure in Britain (sciencedirect.com)
- Ericsson Invisible Wireless Sites (less intrusive wireless antennas)

- Different models of 5G deployment: from exclusive relationships to independent operators, etc. (City of Worcester)

Policy and Public Planning Issues

- Policy Regarding Small Cell Wireless Installations on Public Ways (Cambridge, MA)
- Town of Burlington Small Wireless Facility Design Rules and Regulations (Burlington, MA)
- Watertown Committee on Public Works Report Feb 12, 2019 (Watertown, MA)
- Modernizing FCC Siting Rules would Jumpstart 5G Investment & Deployment (CTIA)
- 5G is a Policy Minefield for Cities (CityLab)
- How Sacramento got to 5G and what it means for the rest of the U.S. (FireceWireless)
- Mill Valley Joins Effort to Fight 5G Proliferation (Marin Independent Journal)
- Cities Saying 'No' to 5G citing Health, Aesthetics, FCC Bullying (WSJ)
- Super Speedy And A Little Scary: 5G Is Coming To Boston (WBUR)