5G in Belmont

Report of the IT Advisory Committee

October 4, 2019

ISSUED BY

BELMONT INFORMATION TECHNOLOGY ADVISORY COMMITTEE

REPRESENTATIVE

Paul Roberts, Chair

Glenn Wong, Vice Chair

David Goldberg, Secretary

Introduction & Background

[DESCRIPTION OF REPORT]

About 5G Technology

Prepared by Daniel Ellard, ITAC Member and Paul Roberts, ITAC Chair

This document contains three 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 list of questions and considerations raised by that proposal.

What is 5G?

Fifth generation (or "5G") is the latest evolution of wireless communications technology. 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 Gbps to 480 Gbps 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.

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.

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.

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.

Extanet Proposal

The proposal from EXTANET, 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 EXTANET.

Current Proposal's Utility to Belmont

Without additional information from EXTANET, 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 bandwidth, short frequency 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 Town-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 EXTANET proposal may represent the "nose of the camel" - an initial proposal of modest scope that precedes a much larger deployment.

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 EXTANET 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 EXTANET would like to deploy, the desired capacity, etc.

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[1] looked at 5G networks based on a range of technologies including 700MHz (2x10MHz) macrocell technology, 3.5GHz (100MHz) microcell technology (EXTANET'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 EXTANET hotspots would introduce to Belmont "can provide outdoors coverage at 100Mbps but is not adequate for indoor coverage unless the micro base (sp) stations are located within the buildings," the authors concluded. 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.

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 coverage is no greater despite the much greater cell density may actually decrease because of interference. 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.

---

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

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 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 w ork 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

Regulatory Landscape and Limitations

What other Communities are doing

Different models of 5G deployment: from exclusive relationships to independent operators, etc.
- **Boston/Verizon**
- **Sacramento/XG**

Questions to ask of Extanet

Additional Reading
Resources for Government
- State provides resources on 5G and small cell deployment (MMA.org)

- [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)

Policy and Public Planning Issues
- [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)